

14 Cardiovascular System

The goal of this topic is to examine and understand the structure of the heart, blood vessels and the lymphatic vessels. You should aim to understand how the structure of blood vessels change from large arteries to the level of capillaries and back to large veins. At each level, the composition of component layers are closely related and adapted to the function at that level. The same principle of relationship between the layer structure and function is seen in the respiratory and digestive systems. The cells in blood are covered in Topic 7 Blood. You should also review contractile cells.

Objectives

Study each of the given types of vessel using the following points:

- Structure and size of lumen.
- Presence or absence of the three luminal layers.
- The thickness of the layers in the vessel.
- The thickness of the tissue between the different layers.
- The different types of tissue found in each layer.
- The presence or absence of vasa vasorum.

You should be able to:

1. Describe the general anatomy of the cardiovascular system.
2. Describe how the histological morphology facilitate the functioning of the cardiovascular system.
3. Describe the structure and function of each of the parts of the cardiovascular system.
4. Describe the generic structure seen in blood and lymph vessels.
5. Describe the specific structure seen in each part of the cardiovascular system.
6. Correlate the structural specialisations in each part of the cardiovascular system with the function of that part.
7. Identify and describe the various types of arteries, veins, arterioles, capillaries and venules.
8. Compare arteries, veins, arterioles, capillaries and venules.
9. Compare blood and lymphatic vessels.
10. Explain the structure, function and distribution of valves in the cardiovascular system.
11. Give examples of each of the types of vessels found in the cardiovascular system.
12. Describe the various portal systems and their relevant histology.
13. Identify, describe and compare the various contractile elements found in the cardiovascular system and the rest of the body.

Slides

Slide name	Slide number	Stain
Vessels		
Muscular artery and vein	69	H/E

Muscular artery and vein	70	R/F
Elastic artery	67	H/E
Elastic artery	49	R/F
Large vein	92	H/E
Large vein	109	R/F
Ductus thoracicus	75	H/E
Ductus thoracicus	65	R/F
Accessory structure		
Valve	47	Masson's trichrome
Cardiac muscle		
Heart muscle (longitudinal section)	20	H/E
Heart muscle (cross section)	77	H/E
Heart muscle	86	Y/H

Tasks

Study each of the slides, using the guidelines below. Select and compare different types of staining (H/E and R/F) where available and as appropriate. Use the following points and compile a table for each type of vessel. Do this, while studying the specific items for each slide listed below:

1. Structure and size of the lumen.
2. Presence or absence of the three luminal layers.
3. The thickness of the layers in the vessel.
4. The thickness of the subdivision in each layer.
5. The presence or absence of vasa vasorum.

Slide 67: Elastic artery – Cross section through aorta (H/E)

Slide 49: Elastic artery – Cross section through aorta showing elastic fibres (R/F)

1. This slide is a cross-section through the aorta. View the slide on low magnification. In this view, you should be able to see the lumen, wall and surrounding structures of the blood vessel.
2. Identify:
 - The lumen of the blood vessel
 - Wall of the blood vessel
 - Adipose tissue surrounding the aorta

- Vasa vasorum
- Accompanying blood vessels

1. Is this a cross or longitudinal section?
Cross section.
2. What is the approximate diameter of the lumen of the blood vessel? Use the scale on the image as a guide.
6 mm
3. What is the approximate diameter of the wall of the blood vessel? Use the scale on the image as a guide.
1.5 mm
4. Name the 3 layers and divisions of the wall of the aorta.
See table below.
5. What is characteristic of each layer and divisions of the wall of the aorta?
See table below.
6. What is characteristic of the elastic fibres in each layer?
TI: fibres TM: fenestrated sheets TA: loose network
7. How is the outer border of the tunica intima determined?
Innermost sheet of elastic lamella.
8. How does the inner part of elastic arteries receive nutrients? The outer part?
Inner part: from the lumen. Outer part: Vasa vasorum

3. View the medium and high magnification slides of the elastic artery. In this view, cellular detail should be visible.
 - Identify the 3 layers of the elastic artery.
 - Identify the tissue components present in each layer of the elastic artery.
4. Make an annotated diagram of a partial section of the wall of the elastic artery, indicating the layers, divisions and tissue components. Clearly indicate the elastic elements in each layer and division.

1. What are identifying features of elastic arteries?
Multiple sheets of elastic lamellae in the wall.
2. With increased age and increased blood pressure, a layer in elastic arteries increase in thickness. Name the layer and the component in the layer which cause the increased thickness.
The number of fenestrated lamellae in the tunica media increase with age. With hypertension, both the number as well as the thickness of lamellae are increased.
3. Cells in the wall of the elastic artery are involved with repair (normal) and atherosclerosis (pathological). Name the cells and the originating layer.
Smooth muscle cells from the tunica media.

Slide 69: Muscular artery and medium vein (H/E)

Slide 70: Muscular artery and medium vein showing elastic fibres (R/F)

1. View the slide on low magnification. In this view, you should be able to see the lumens of the blood vessels, the walls and several surrounding structures.

1. How many blood vessels are visible on the slide?
6/5
2. Identify each of the blood vessels on the slide.
3 Arteries, 3 Veins; 2 Arteries, 3 Veins
3. What other structures are visible on the slide?
Accompanying nerves.
4. What is present in the areas between the structures?
Adipose tissue and loose connective tissue.

2. Identify:

- The lumens of the blood vessels.
- Wall of the blood vessels.
- Tissues surrounding the blood vessels.
- Structures accompanying the artery and vein.
- Tissues between the structures.

1. Is this a cross or longitudinal section?
Cross section.
2. What is the approximate diameter of each of the structures on the slide relative to the lumen?
 1. Large open lumen, relative thin wall.
 2. Large irregular lumen, relative thin wall.
 3. Lumen (round) and wall approximating each other, lumen still bigger.
 4. Big collapsed lumen, thin wall.
 5. Big collapsed lumen, thin wall.
 6. Big open lumen, thin wall
3. Name the layers found in the wall of a muscular artery and vein.
See table below.
4. What are the relative thickness of the three layers of the artery and vein with respect to each other?
TI: artery – thin; vein – thin.

TM: artery – thick; vein – medium.

TA: artery – medium; vein – thick.

5. What structure is clearly visible in the wall of the muscular artery?

Tunica media.

6. What is characteristic of each layer and division of the wall of the muscular artery and vein?

See table below.

7. What cells are normally present in the tissues found between the structures on the slide?

See table below.

8. Name the function/s of each of these cells.

See table below.

9. Name the 3 layers of connective tissue associated with nerve bundles.

Endo- , peri- & epineurium.

3. View the medium and high magnification slides of the muscular artery and vein. In this view, cellular detail should be visible.

- Identify the cells (or their nuclei) present in each of the various structures visible on the slide.

1. What is diagnostic of each of the cells visible on the slide?

Endothelium: flattened with bulging nucleus; smooth muscle cells: spindle shaped with elongated nucleus, contraction causes wavy folds in elastic lamellae.

2. Are the cells visible in cross, diagonal or longitudinal section?

See table below.

3. Explain the function of each of the cells present in the structures.

See table below.

4. Make an annotated diagram of the low magnification view of the arteries, veins and surrounding structures. For the artery and vein, make an annotated drawing, indicating cellular and structural detail and distribution of fibres. Indicate cross, oblique or longitudinal sections as appropriate. Add the function of each structure.

1. What is characteristic of the elastic fibres of the artery and vein?

Less prominent than elastic artery.

2. How are elastic fibres arranged and distributed in the artery and vein?

Artery – internal and external laminae; Vein – loose fibres.

3. How can the arrangement and distribution of elastic fibres be used to distinguish between a muscular artery and vein?

See above the arrangements of the elastic fibres.

Slide 92: Large vein – cross-section through the vena cava (H/E)

Slide 109: Large vein – cross-section through the vena cava showing elastic fibres (R/F)

1. View the slide on low magnification. In this view, you should be able to see the complete blood vessel, and some of the surrounding tissues. Slide 109 shows only part of the wall of the vessel.
2. Identify:
 - The lumen of the blood vessel.
 - Wall of the blood vessel.
 - Smaller blood vessels in the surrounding tissues.

1. What is characteristic of the lumen of the vena cava as seen on slide 92?

The lumen is relatively large, and collapsed.

2. Are there any clearly defined layers or structures visible at low magnification?

Yes. A thin dark inner band, a striped layer and then bundles.

3. View the medium and high magnification slides of the large vein. In this view, cellular detail should be visible.

1. What are the layers seen in the wall of the vena cava?

See table below.

2. Does the layers in the wall of the vena cava show further divisions? Name the divisions.

See table below.

3. What are characteristic of each of the layers and divisions seen in the wall of the vena cava?

See table below.

4. Make and annotated diagram of the complete vein, including surrounding structures. For a partial section of the wall of the vein, make a detailed drawing showing cellular detail and distribution of fibres. Indicate cross, oblique or longitudinal sections as appropriate. Add the function of each structure.

1. What is the relationship of the three layers with respect to each other?

TI & TM relatively thin, indistinguishable, smooth muscle cells circumferential; TA thick, smooth muscle cells longitudinal.

2. How are elastic fibres distributed in each layer?

TM circumferential, TA longitudinal.

Slide 75: Ductus thoracicus (H/E)

Slide 65: Ductus thoracicus showing elastic fibres (H/E)

1. View the slide on low magnification. In this view, you should be able to see the ductus thoracicus and the surrounding connective tissue.

2. Identify:

- The lumen of the ductus thoracicus.
- The epithelium lining the lumen.
- The different layers comprising the wall of the lymph vessel.
- The surrounding connective tissue.

1. Name the epithelium lining the ductus thoracicus.

Endothelium.

2. List the layers and divisions of each layer comprising the wall of the ductus thoracicus.

Same 3 main layers as arteries and veins, but less defined. Smaller lymph vessels: too delicate to be a vein, too large to be a capillary.

3. What tissue surrounds the ductus thoracicus?

Adipose tissue, loose connective tissue.

3. View the medium and high magnification slides of the ductus thoracicus. In this view, cellular detail should be visible.

- Identify the cells present in each layer of the lymph vessel.
- Identify the cells present in the surrounding connective tissue.

1. Name the cells present in each layer of the wall of the ductus thoracicus.

TI: endothelium; TM: smooth muscle cells, TA: smooth muscle cells.

2. Are the cells orientated parallel or perpendicular to the direction of flow in the vessel?

Parallel to the flow.

4. Make an annotated diagram of the complete ductus thoracicus, including the surrounding connective tissue. For a partial section of the wall of the ductus thoracicus, make a detailed drawing showing cellular detail and distribution of fibres. Indicate cross, oblique or longitudinal sections as appropriate. Add the function of each structure.

1. Describe each layer in the wall of the ductus thoracicus.

TI: thin with lamina elastica interna; TM: thickest with smooth muscle cells; TA: not well defined, smooth muscle cells.

2. How is the elastic fibres distributed and arranged?

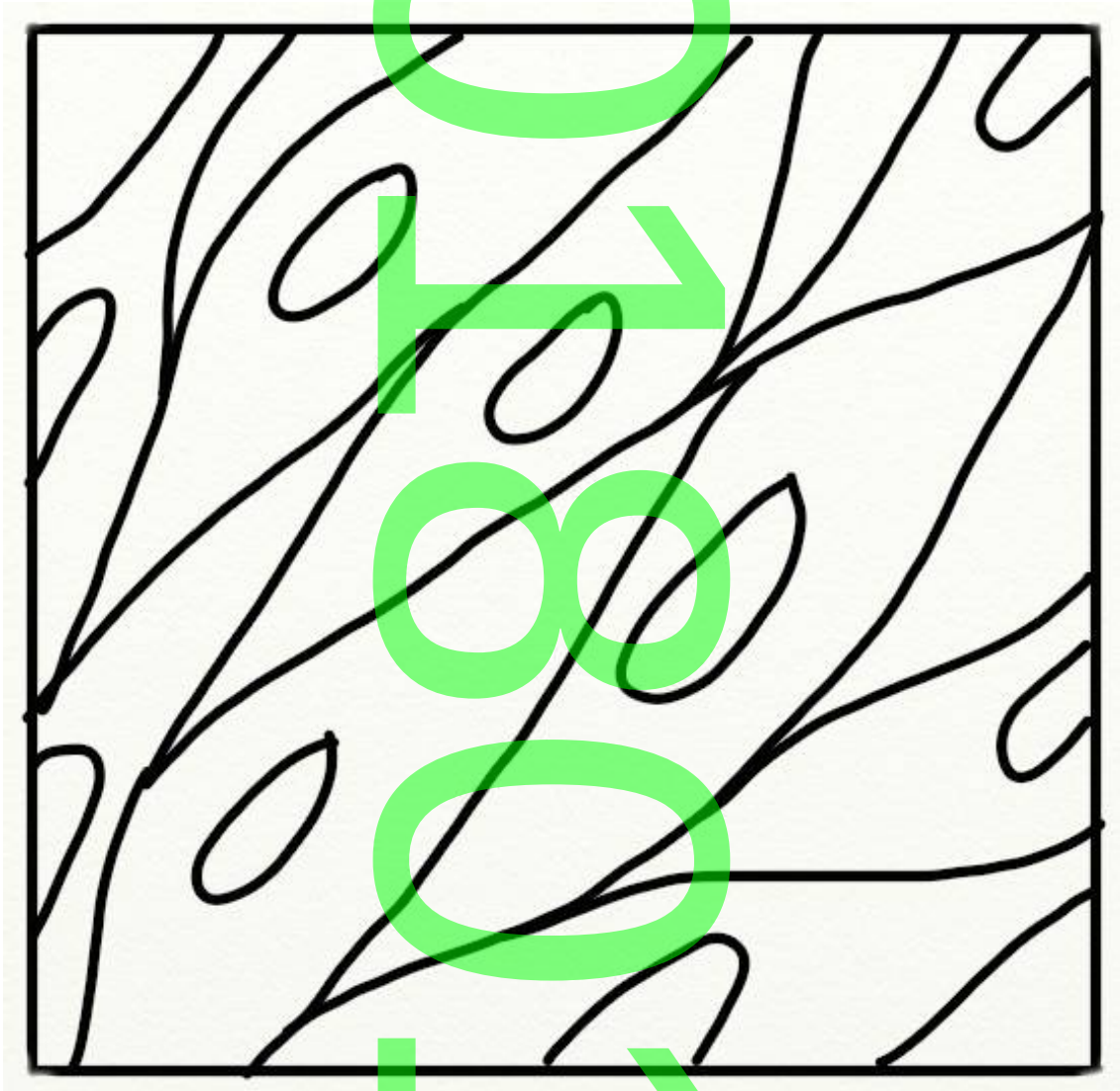
Mostly absent.

3. How does the layers seen in a lymphatic vessel correlate and differ from that of arteries? And veins?

Layers are very ill-defined in lymph vessels and consists mostly of varying amounts of connective tissue and smooth muscle. Smooth muscle in media is orientated circularly and longitudinal in adventitia.

Questions

1. What are the two main component parts of the circulatory system?
Blood circulation and lymph circulation.
2. In this drawing of the endothelium of an elastic artery, which direction does blood flow take place?



3. Describe the maintenance and regulation of blood pressure based on the histological morphology of the circulation system.
Rhythmic contraction of cardiac muscle force blood into arteries, which pulsate. Elastic lamellae in the arterial wall of elastic arteries expand passively to store some of the force. Potential energy from elastic tension is released by elastic recoil during diastole, continuing forward motion. This result in steady blood flow, especially in the terminal parts of the arterial macrovascular system. Muscular arteries regulate blood flow to specific tissues and organs. Never supply in the tunica media controls the contraction and dilation of smooth muscle cells in the media. Smooth muscle fibers and pre-capillary sphincters of the microvascular system regulate blood flow into the capillary bed. During inspiration, negative pressure is created in the thoracic cavity. Blood is returned to the heart with assistance of the negative pressure, compression of the veins by skeletal muscle and the prevention of back flow by valves.
4. On a histological section, what can be used to initially differentiate between arteries and veins of all sizes?

Size of the lumen compared to the thickness of the vessel wall: Arteries have a small lumen, relative to the wall; veins have a large lumen, relative to the wall.

Collapsed or open lumen: Lumen of arteries are usually open, vein, collapsed.

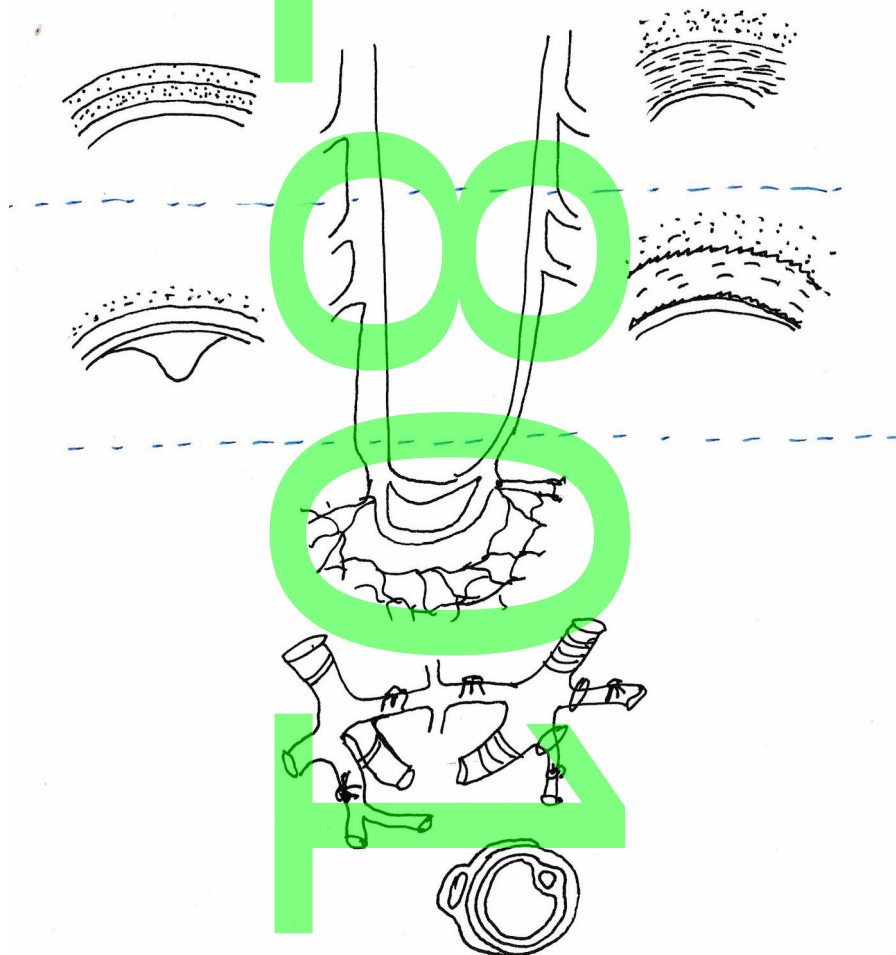
5. Make a schematic diagram, showing the regions and major structural features of blood vessels in each region. Indicate the function of each region.

You should have on your drawing the following items:

Macrovascular and microvascular system.

Heart, elastic arteries, muscular arteries, arterioles, capillaries, cells, venules, valve, vein.

Histological features should include: tunica intima, media and adventitia, smooth muscle cells, pre-capillary sphincters, pericytes, endothelial cells, basal lamina, capillaries.



6. What is the function of elastic arteries?

Conduction tubes.

Maintain continuous and uniform movement of blood flow.

7. On a histological section, what can be used to initially differentiate between arteries and veins of all sizes?

Thick walls keep arteries open, whereas thin-walled veins appear collapsed.

8. What is the function of lymphatic vessels?

Collect and return interstitial fluid and protein (lymph) to the blood stream.

Trafficking route for cells of the immune system during immune surveillance and infection.

Facilitate lipid absorption from the digestive track.

9. What are end-arteries?

Arteries normally form anastomoses with each other. An end-arteries is an artery that is the only supply of oxygenated blood to a region. No anastomoses occur, and occlusion of the vessel results in necrosis.

10. How are the central artery of the retina, coronary arteries, segmental arteries of the kidneys and arteries entering the brain different from arteries in the rest of the body?

Arteries normally form anastomoses. In case of occlusion, for example a cut through the skin, little or no problems result. These group of blood vessels does not have anastomoses and occlusion will result in necrosis.

11. How are the central artery of the retina, coronary arteries, segmental arteries of the kidneys and arteries entering the brain similar?

These are all end-arteries. Arteries normally form anastomoses, providing blood in case of occlusion in one part. In some areas, no anastomoses exist. These are called end-arteries. Occlusion results in necrosis.

12. What happens when end-arteries are occluded?

Necrosis in the region supplied by the end-arteries.

13. What is a portal system? Give an example of portal systems.

A system of vessels interposed between two capillary beds. Examples are the portal veins, hypophyseal-portal system and the glomerulus in the kidney.

14. Compare the structure of the vena cava with elastic arteries.

The tunica media is the thick in the artery, thinner in the vena cava. The aorta contains smooth muscle and elastic lamella layers, whereas there are only smooth muscle layers in the vein.

15. There is no clear dividing line between elastic and larger muscular arteries. Name 4 characteristics that is used as diagnostic of muscular arteries.

1. Elastic material decrease
2. Smooth muscle cells predominant in TM
3. Prominent lamina elastica interna
4. Often also clear lamina elastica externa

16. What morphological feature is characteristic of medium veins?

Valves, particularly in the inferior part of the body.

17. What mechanism facilitate return of blood to the heart?

Gravity superior to the heart. Valves inferior to the heart. Muscle action on the blood vessels.

18. Describe the general structure of veins in comparison to arteries.

Larger diameter, thinner walls – collapsed on slides.

More connective tissue.

Same 3 layers, but no lamina elastica interna or externa – boundaries less distinct.
Thinner tunica media.

Upper body – thin media – drain by gravity.

Lower body – thicker media due to more smooth muscle cells – active propulsion of blood towards heart.

Structure varies a lot, arbitrarily divided into small, medium and large veins.

19. The ductus thoracicus ultimately starts as a blind-ending tube in the micro-capillary beds.

20. What mechanism drives lymphatic flow?

Valves to prevent back flow driven by compression of adjacent skeletal muscle.

Memorandum

Slide 67

1. Is this a cross or longitudinal section?

Cross section

2. What is the approximate diameter of the lumen of the blood vessel? Use the scale on the image as a guide.

6 mm

3. What is the approximate diameter of the wall of the blood vessel? Use the scale on the image as a guide.

1.5 mm

4. Name the 3 layers and divisions of the wall of the aorta.

See table below.

5. What is characteristic of each layer and the divisions of the wall of the aorta?

See table below.

6. What is characteristic of the elastic fibres in each layer?

TI: fibres TM: fenestrated sheets TA: loose network

7. How is the outer border of the tunica intima determined?

The outer border of the TI is the innermost fenestrated elastic layer.

8. How does the inner part of elastic arteries receive nutrients? The outer part?

Inner part: diffusion from the lumen; outer part from vasa vasorum

Elastic artery		aorta, subclavian, pulmonary trunk, pulmonary arteries, common carotid artery	
elastic membranes		conducting	
Layer	Division / Component	Description / Characteristic	Function
Tunica intima		Relatively thick	

	Endothelium	Oriented parallel to direction of blood flow	Synthesize and secrete <u>vWF</u> into the blood.
	Basal lamina	thin	Support endothelium
	Subendothelial CT	Smooth muscle cells	Longitudinal <ul style="list-style-type: none"> • Contractile • Secrete: <ul style="list-style-type: none"> • Ground substance • fibers
		Fibroblasts	Scattered
		Fibers – elastic & collagen	
		Amorphous ground substance	
	Lamina elastica interna	Innermost elastic layer	
Tunica media		Thickest	
	Smooth muscle cells	spiral layers	<ul style="list-style-type: none"> • Synthesis of CT • Repair of vascular wall • Atherosclerosis
	Fenestrated sheets elastin	Concentric ^Number + ^thickness with ^age	<ul style="list-style-type: none"> • Holes facilitate diffusion of substances
	Collagen fibres		
	Elastic fibers		
	Amorphous ground substance		
	Lamina elastica externa	Outermost elastic layer	
	Fibroblasts		
Tunica adventitia		Relatively thin Connective tissue layer	
	Collagen fibres	Circular bundles	Prevent expansion beyond physical limit during systole (bursting).

	Elastic fibres	Loose network	
	Cells: fibroblasts & macrophages		
	Blood vessels (vasa vasorum)	Penetrate media	Nutrients to outer layer of wall
	Nerves (nervi vascularis)		

Muscular artery

Muscular artery		majority of arteries, most of the rest	
smooth muscle		distribution	
Layer	Division / Component	Description / Characteristic	Function
Tunica intima		Thinner than elastic	\wedge age > \wedge thickness due to lipid deposition
	Endothelium	flattened	
	Basal lamina	thin	
	Subendothelial CT	sparse	
		may contain smooth muscle cells	longitudinal
	Lamina elastica interna	Well defined Wavy	
Tunica media			
	Smooth muscle cells	spiral fashion	contraction maintain BP
		4-10-40 layers	
	Collagen fibers		
	Little elastic material		
	No fibroblasts		
	Lamina elastica externa		
Tunica adventitia		thick = TM	
	Loose CT		

	Fibroblasts		
	Collagen fibers	longitudinal	
	Elastic fibers	longitudinal	
	Adipose cells		
	Blood vessels (vasa vasorum)		Penetrate and supply TM & TA
	Unmyelinated sympathetic nerves		

Large vein

Large vein		vena cava, portal veins, brachiocephalic veins, renal veins	
		return blood to heart	
Layer	Division / Component	Description / Characteristic	Function
Tunica intima		Not clearly defined	
	Endothelium		
	Basal lamina		
	Subendothelial CT		
	Smooth muscle cells		
Tunica media		Relatively thin or absent	
	Smooth muscle cells	circumferentially arranged	
	Collagen fibers		
	Some fibroblasts		
Tunica adventitia		Thickest	
	Collagen fibers		
	Elastic fibers	longitudinal	
	Fibroblasts		
	Smooth muscle cells	longitudinal	

Small to medium veins

Small to medium veins			
Layer	Division / Component	Description / Characteristic	Function
Tunica intima			
	Endothelium		
	Basal lamina	Thin	
	Subendothelial CT	Thin	
	Smooth muscle cells	Few	
	Lamina elastica interna	Thin if present	
Tunica media		Thin	
	Smooth muscle cells	Just below TA Circular ?? Longitudinal ??	
	Collagen fibers		
	Elastic fibers		
	Scattered fibroblasts		
Tunica adventitia		Thicker	
	Loose CT		
	Collagen fibers	Longitudinal	
	Elastic fibers	Network	
	Few fibroblasts		
	Few smooth muscle cells		
	Vasa vasorum, lymph vessels, unmyelinated	In medium veins	

	nerve vessels		

	Tunica intima	Tunica media	Tunica adventitia
Small veins	Endothelium	3 layers circular smooth muscle cells	Collagen
0.1 – 1 mm	Thin BL		Elastic fibers
			Few fibroblasts
Medium veins	Endothelium	3 – 4 layers smooth muscle cells	Main part
Superficial and deep veins Deep veins Veins of the viscera	Thin BL	Separated collagen fibers	Loose CT
1 – 10 mm	Thin subendothelial CT	Scattered fibroblasts	Thick collagen fibers
	Valves – folds of intima (absent CNS & viscera)		Some elastic fibers
			Smooth muscle cells
			Vasa vasorum, lymph vessels & nerves
Large veins	Endothelium	Thin or absent	Thick
Vena cava Portal veins Renal veins	Thin BL	Smooth muscle cells	Elastic fibers
>10 mm	Thin subendothelial CT		Smooth muscle cells
	No valves		Vasa vasorum, lymph vessels & nerves

Venules

- Collapsed lumen
- Thin endothelium – lymphoid organs = cuboidal epithelium
- Thin BL
- Pericytes

- External to this:
 1. Fibroblasts
 2. Collagenous fibers
- Larger venules – 1/2 layers flattened smooth muscle cells

Venules		Site of lymphocyte and granulocyte migration	
Layer	Division / Component	Description / Characteristic	Function
Tunica intima			
	Endothelium	Cuboidal in lymphoid organs	Primary site vasoactive agents
	Basal lamina	Thin	
	Pericytes	Incomplete initially, bigger vessels complete	
Tunica media			
	1 – 2 layers smooth muscle flattened		
Tunica adventitia			

Ductus thoracicus as example of lymphatic vessels

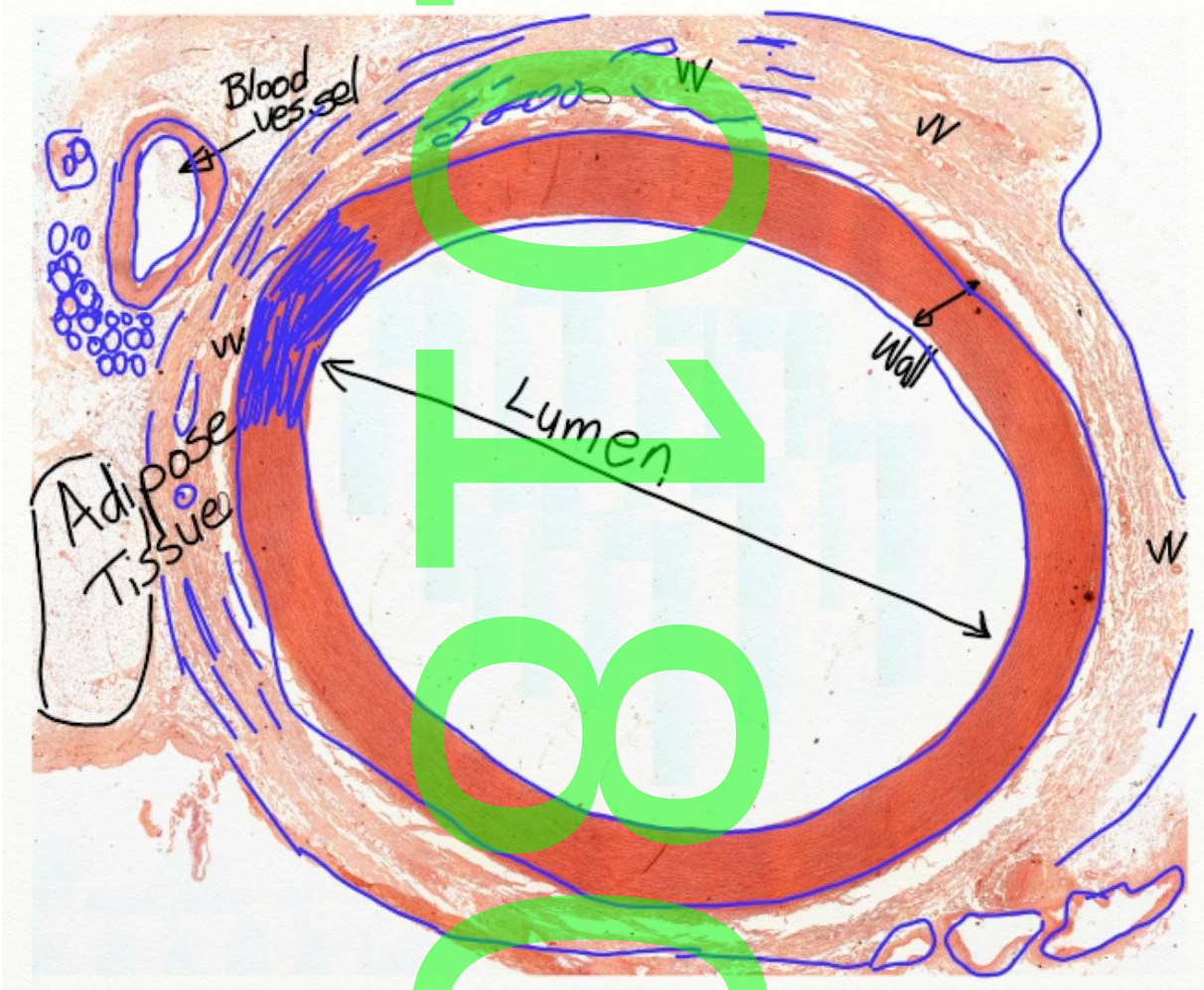
- Endothelium tubes lacking continuous BL.
- Allows high permeability.
- Increased thickness – increased CT – bundles smooth muscle.

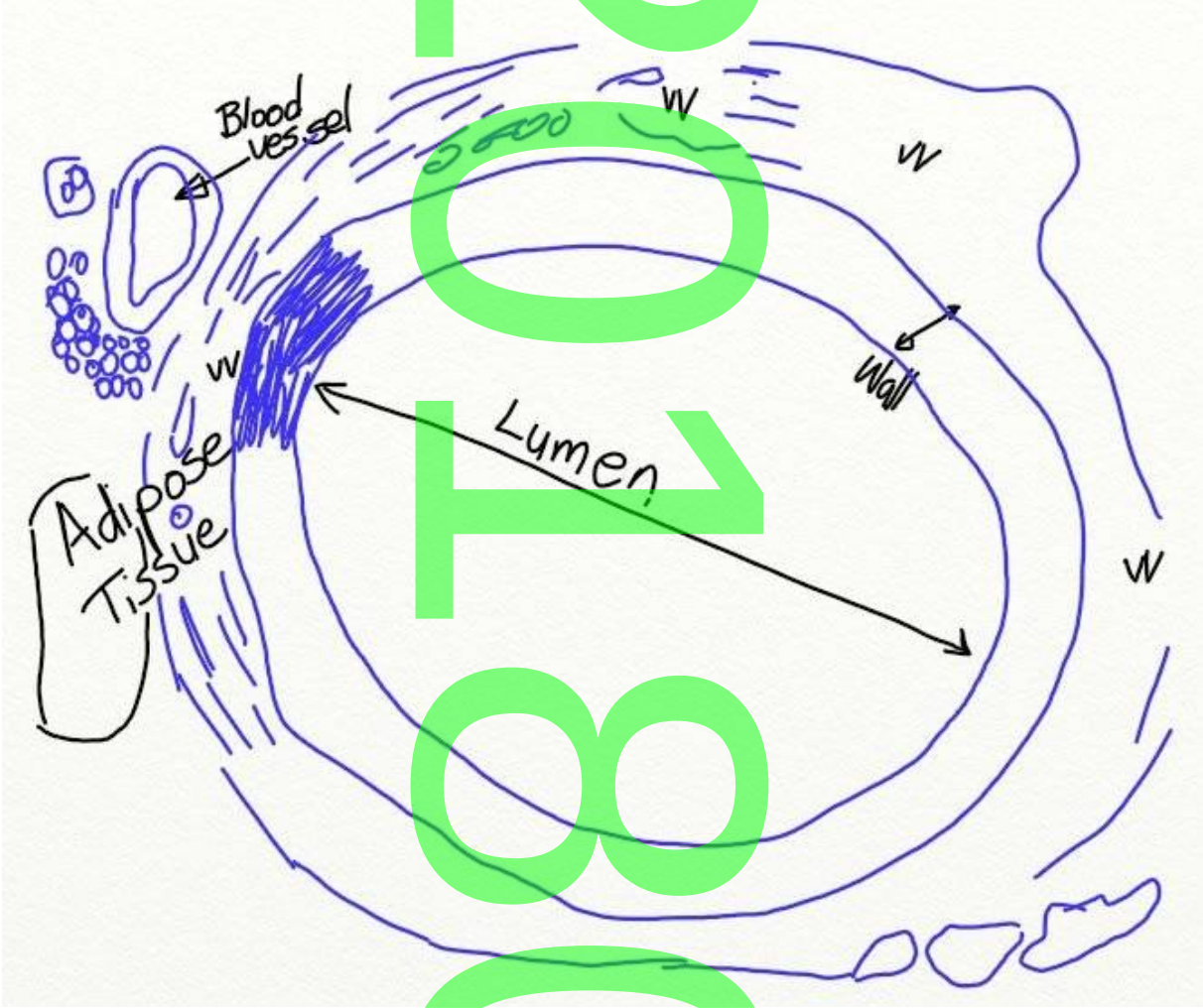
Scratch

Comparison of Tunics in Arteries and Veins

	Arteries	Veins
General appearance	Thick walls with small lumens Generally appear rounded	Thin walls with large lumens Generally appear flattened
Tunica intima	Endothelium usually appears wavy due to constriction of smooth muscle Internal elastic membrane present in larger vessels	Endothelium appears smooth Internal elastic membrane absent
Tunica media	Normally the thickest layer in arteries Smooth muscle cells and elastic fibers predominate (the proportions of these vary with distance from the heart)	Normally thinner than the tunica externa Smooth muscle cells and collagenous fibers predominate
Tunica externa	External elastic membrane present in larger vessels Normally thinner than the tunica media in all but the largest arteries Collagenous and elastic fibers	External elastic membrane absent Normally the thickest layer in veins Collagenous and smooth fibers predominate
	Nervi vasorum and vasa vasorum present	Nervi vasorum and vasa vasorum present Some smooth muscle fibers

Example of drawings





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