



CARDIOVASCULAR SYSTEM

SUBJECT : Anatomy
LEC NO. : Lecture 4
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وَقُلْ رَبِّ زِدْنِي عِلْمًا



SCAN ME!

Histology of the Cardiovascular System

(The Heart and Blood Vessels)

Dr. Mustafa Saad (2024)

Histology of the Heart

- The wall of the heart is formed of 3 layers, from the inside-out:

1. Endocardium Inside layer
2. Myocardium
3. Epicardium (visceral pericardium) Outside layer

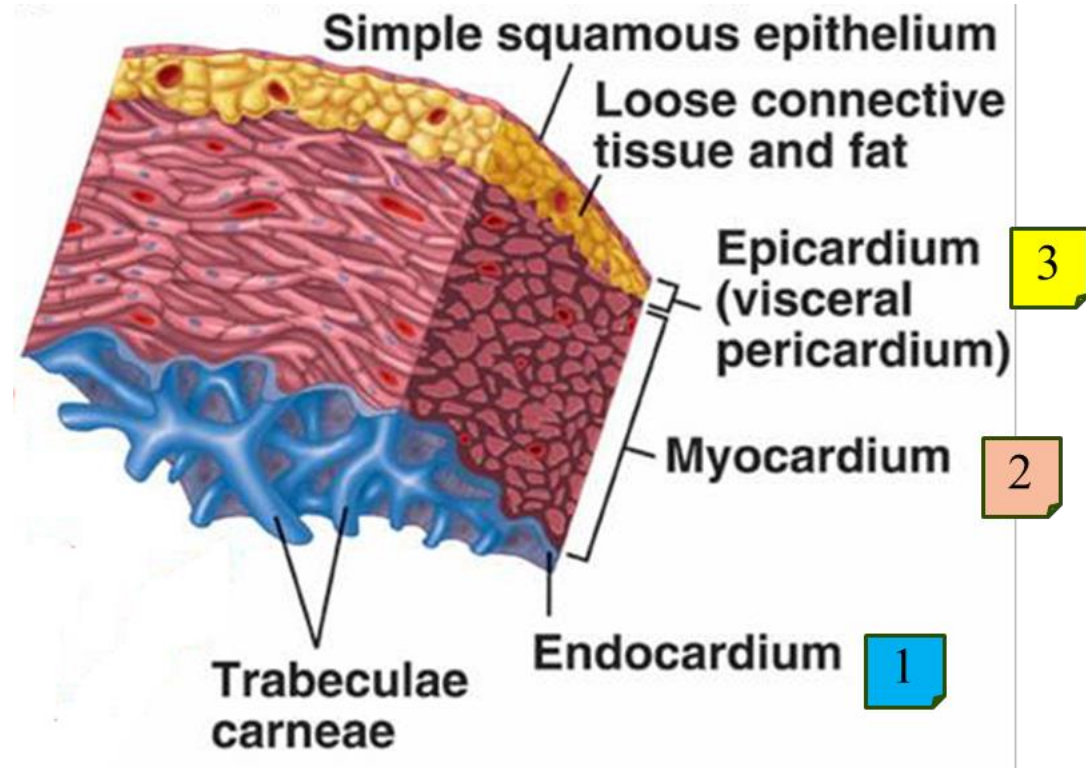


Fig.1: The layers of the heart wall.

The Endocardium:

الطبقة المبطنة للقلب والأوعية الدموية
التي تسمى الـ endothelium

- Formed of:
 - *Endothelium*: simple squamous epithelium in contact with the blood.
 - *Subendothelium*: connective tissue with fibers and fibroblasts.
 - *Subendocardium*: loose areolar connective tissue continuous with the connective tissue of the myocardium. Contains Purkinje fibers and blood vessels.

They are a part of the conducting system of the heart. It is very important.

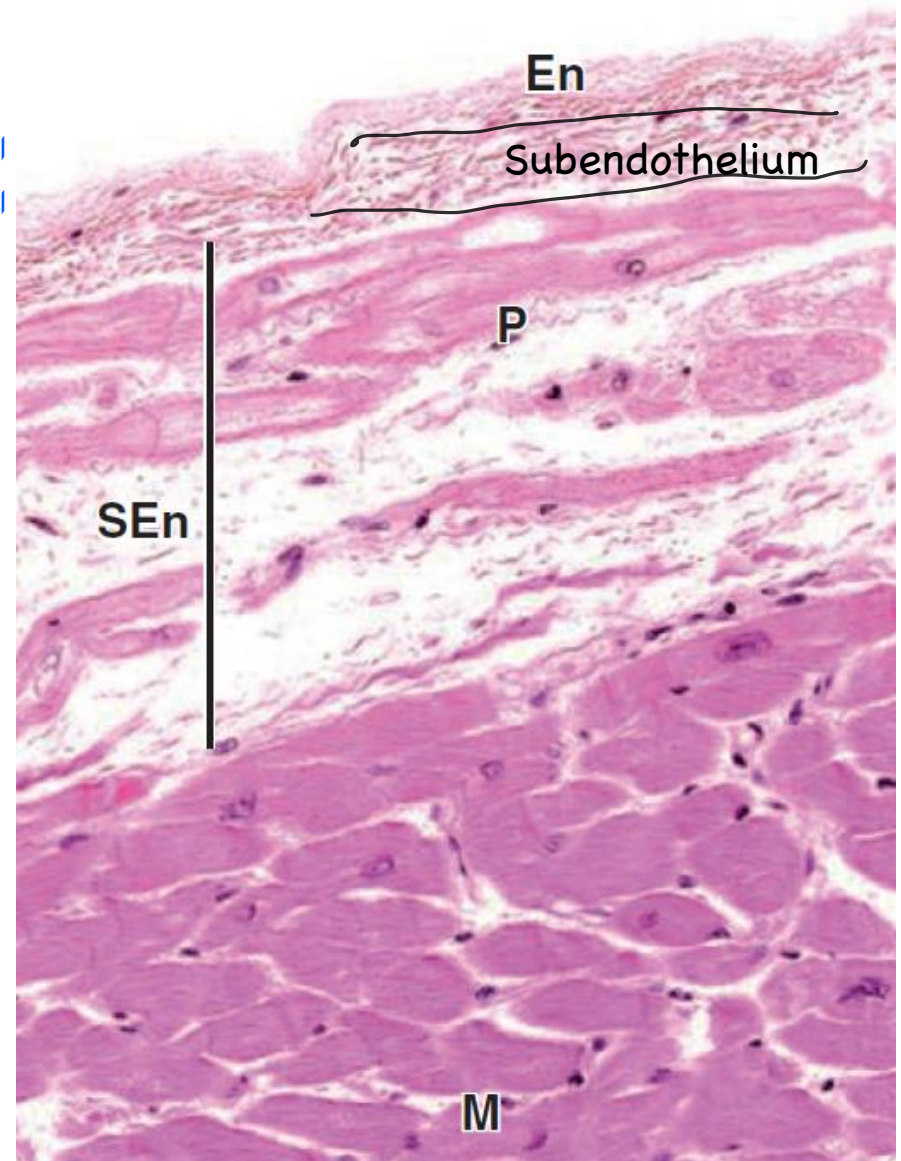


Fig.2: The endocardium. En, endothelium; SEn, subendocardium; P, Purkinje fibers; M, myocardium.

The Myocardium:

The thickness of myocardium differs according to chamber

- The thickest layer of the heart wall. It's thicker in the ventricles, and thickest in the left ventricle. طبعاً هذا اشي منطقي لأنه حسب ال load نحتاج سمك اكثر كلما زاد ال load زادت السماكة
- Composed of cardiac muscle fibers that spiral around the heart chambers and that are attached to the fibrous skeleton of the heart.
- Between the cardiac muscle fibers, we have loose areolar connective tissue (the endomysium).

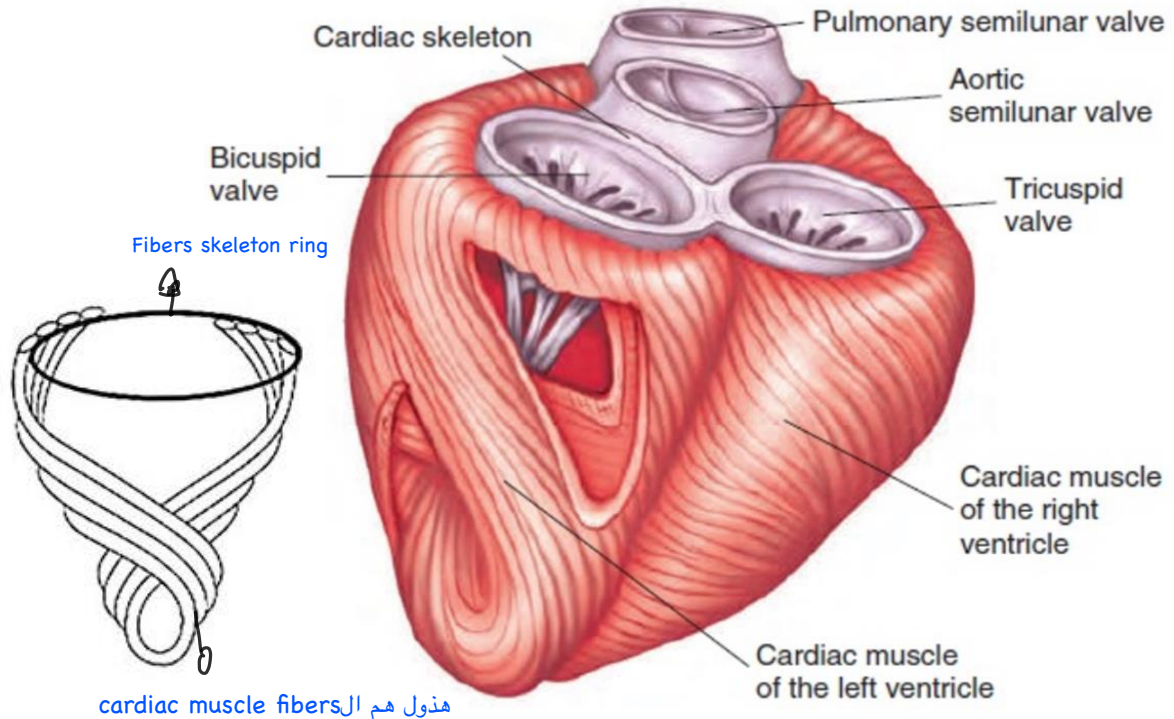


Fig.3: The spiral arrangement of the cardiac muscle fibers and their attachment to the fibrous skeleton.

Cardiac muscle fibers

- 1) Cells are branched.
- 2) Centrally located nucleus.
- 3) Cross-striation.
- 4) Branches are connected to each at the intercalated discs, where we have desmosomes and gap junctions.
- 5) Numerous mitochondria.
- 6) Lipofuscin and glycogen granules. sensitize lysosomes to visible light

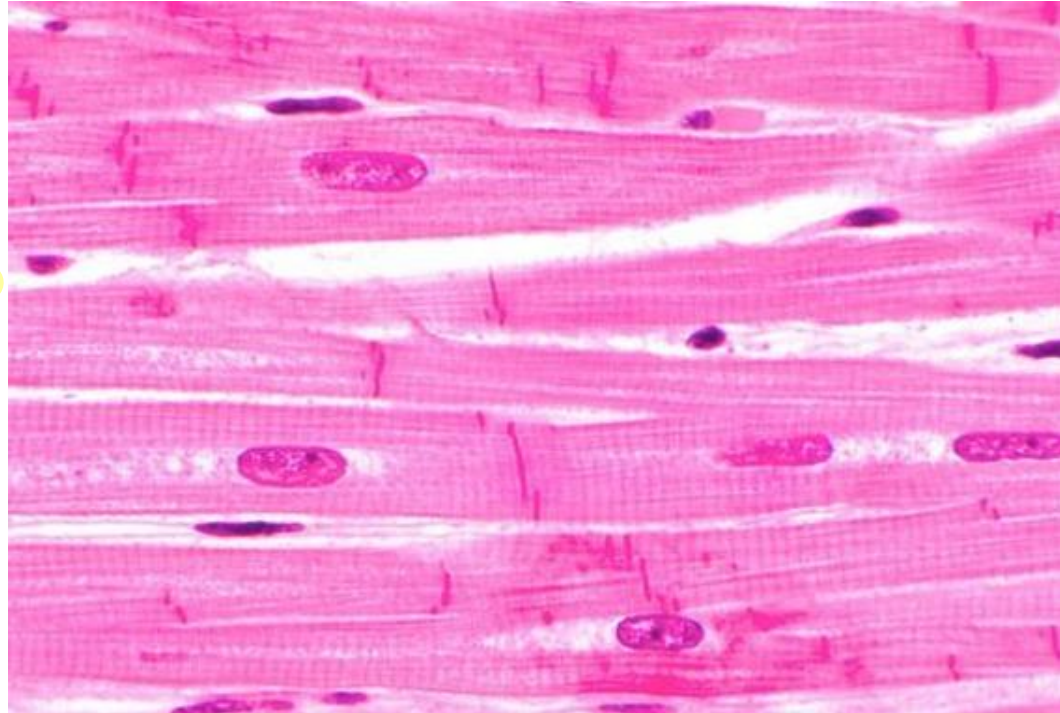


Fig.4: Cardiac muscle cells.

desmosomes هي التي تمسك الخلايا مع بعض وتمنعهم من الانفصال ، وال gap junction الموجودة for easy ، طبعا ، transference of Ca^{2+} ions between the cells so they can contract together as single unit
 ال glycogen هي مصدر الطاقة وعنا ال lipofuscin granules هي عبارة عن old lysosomes تتجمع داخل الخلايا على شكل granules ويكون لونها بني فبنشوفها داخل خلايا كثيرة مثلا ال cardiac muscle وعادة تكون موجودة حوالي النواة

The Epicardium:

هنا الطبقة الثالثة للـ wall of the heart وهي الـ epicardium، طبعا الـ epicardium هو الـ serous membrane وحالته زي اي حالة الـ serous membrane في جسم الإنسان يتكون من الـ simple squamous epithelium و الـ connective tissue، والـ simple squamous epithelium في الـ serous membrane نطلق عليها الـ mesothelium، والـ connective tissue للـ epicardium يحتوي على الـ fat cells وهذا مهم لانه بفرق بين الـ epicardium والـ endocardium التي قد نرا في الـ subendocardial تبعها على الـ purkinje fibers

- Formed of an outer layer of **simple squamous mesothelium**, with an underlying **connective tissue** containing **fat cells**.
- The mesothelial cells produce a **lubricant fluid** (the pericardial fluid) into the pericardial cavity to **prevent friction**. **The major vessels and nerves of the heart lie within the fatty connective tissue.**
- The epicardium correspond to the visceral pericardium and is continuous with the parietal pericardium.

يعني مثلا الـ riht and left coronary artery lie inside the fatty connective tissue

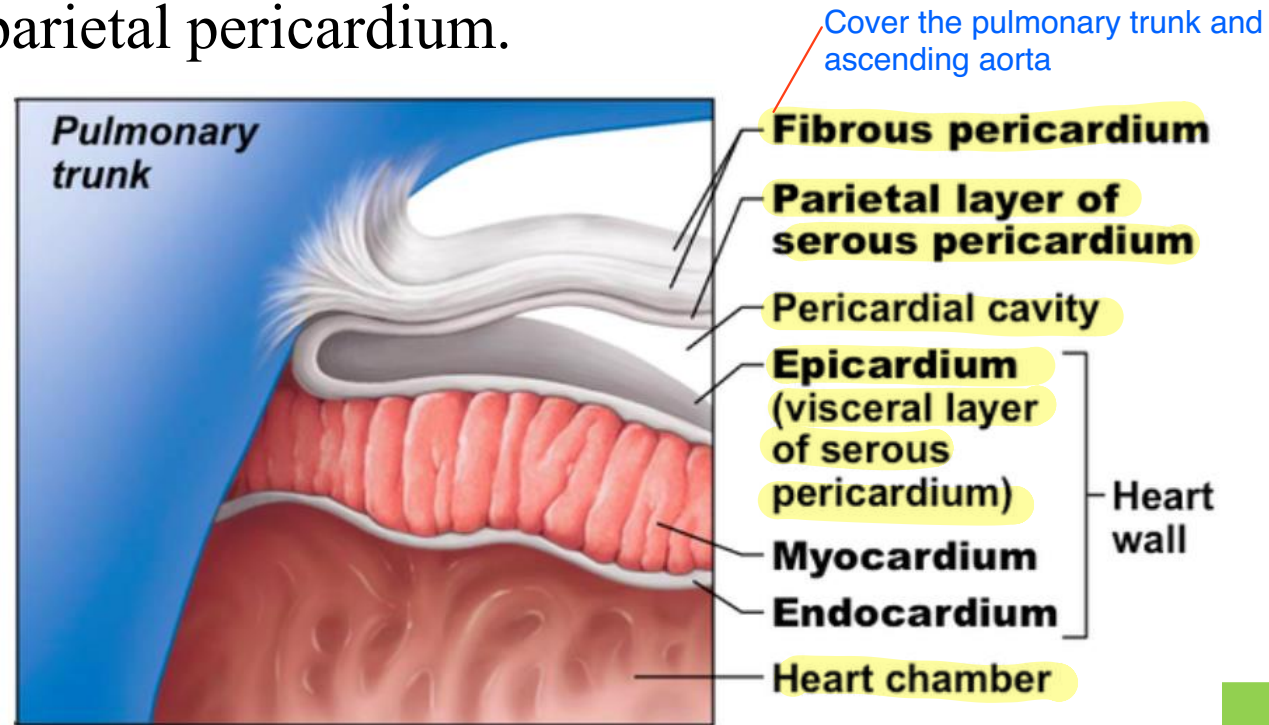


Fig.5: The various layers of the pericardium.

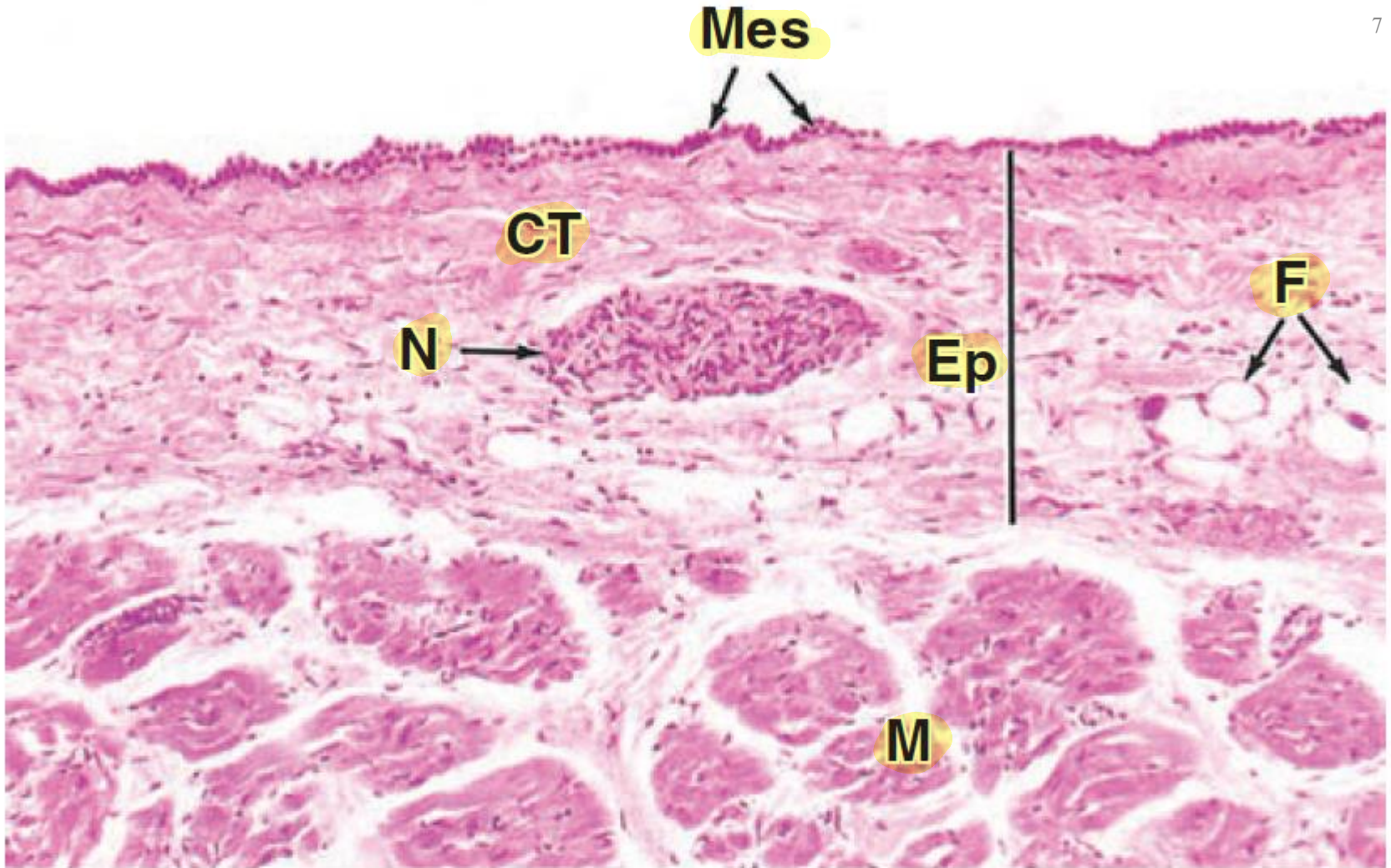


Fig.6: The epicardium. Ep, epicardium; Mes, mesothelium; CT, connective tissue; F, fat cells; N, nerve; M, myocardium.

Other structures in the heart

a) Purkinje fibers:

- Part of the conducting system of the heart. Found in the ventricles.
- Located in the **subendocardial tissue**.
- These are large, pale-staining cardiac muscle fibers with less myofibrils and more glycogen granules.

يعني بما انه ال purkinje fibers تحتوي على less myofibrils و على more glycogen راح يكون لونها افصح (pale) من cardiac muscle cells in the myocardium اللي راح نشوفه بالعملية

b) Fibrous skeleton of the heart:

- **Dense collagenous irregular connective tissue** in the endocardium that serves as:
 - **Base for the heart valves**
 - **Site for attachment of cardiac muscle fibers**
 - **Electrical insulator between atria and ventricle.**

Impulse travels in the heart through the conducting system, conducting system is modified cardiac muscle fibers , fibrous skeleton dense irregular connective tissue that act as electrical insulator , because it cannot conduct impulse

عازل كهرباء

c) Heart valves:

- Valve leaflets are formed of a fibrous core of connective tissue continuous with that of the fibrous skeleton, surrounded on both sides by endothelium.
- They are avascular. They obtain nutrients from the blood in the heart or blood vessels in the base of the valve.

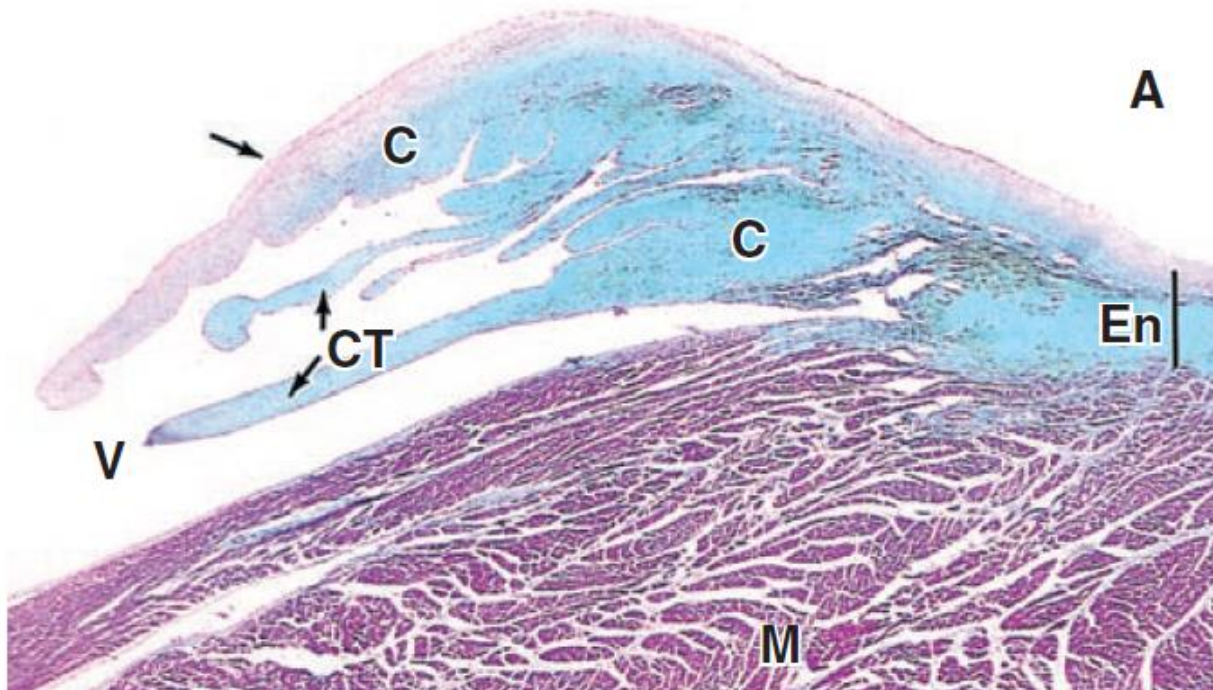


Fig.7: Atrioventricular valve (arrow) between atria (A) and ventricle (V). Note the core of fibrous connective tissue (C) which extends into the chordae tendinea (CT). En, endocardium; M, myocardium.

Histology of the Vessels

General layout of vessel wall

- All blood vessels (**except capillaries**) have the same general layout of their walls. From inside out:
 1. Tunica intima (interna)
 2. Tunica media
 3. Tunica adventitia (externa)

These layers is is general layers for all blood vessels, except **capillaries**
- The difference between the vessels is in the relative **composition** and **thickness** of these layers.

قد يكون التفرقة بينهم غير واضح كثيرا لذلك احنا راح ناخذ اهم المميزات للأنواع المختلفة لل vessels لكن في كثير من الأحيان يكون في تداخل ما بين هاتي الصفات

Tunica intima (interna)

- The *internal* layer of the vessel wall in *intimate contact* with blood.
- Formed of:
 - Endothelium (simple squamous epithelium)
 - Subendothelial loose connective tissue with some smooth muscle cells
 - Internal elastic lamina – a sheet of elastic fibers
Internal elastic Lemina separate Tunica intima from

Tunica media

- The middle layer of the wall.
- Formed of:
 - Smooth muscle cells with connective tissue
 - Elastic fibers
A sheet of elastic fibers
 - External elastic lamina
external elastic lamina separate the tunica media from Tunica externa برضوا

Tunica adventitia (externa)

- The external layer. Usually bound to the surrounding connective tissue

يعني هي الطبقة بتساعد تثبيط blood vessels بال connective tissue لأن هي الطبقة هي نفسها connective tissue and surrounded by connective tissue

- Formed of:

Secondary
resource
of
nutrients

- Dense irregular connective tissue adventitia
- Vasa vasorum (vessels of the vessel). These supply nutrients and oxygen to the adventitia and outer media. The inner media and intima are supplied by direct diffusion from the blood inside the vessel.
- Nervi vasorum (nerves of the vessel). Control the diameter of the vessel by vasodilation or constriction.

nerves contain smooth muscles, and because they contain ال طبعا هذول ال smooth muscles they can control the contraction and dilation of muscles and vessels

، arteries and veins like like we don't ال في بعض الفروقات الموجودة في ال
 have internal and external elastic lumina in the veins.الفرق الثاني
 is the muscular media in the vein is a smaller than the artery, and the
 and the large vein have valves

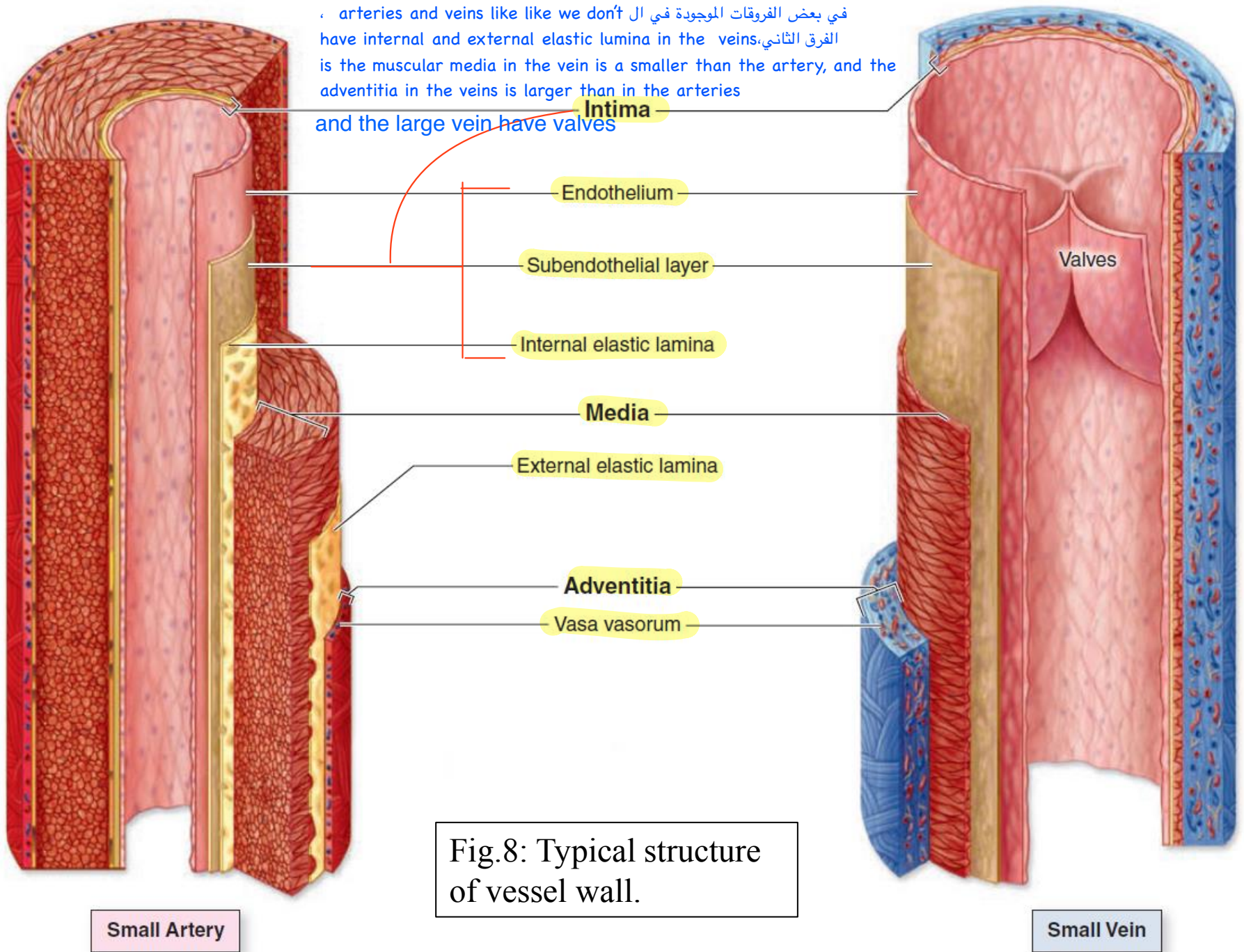


Fig.8: Typical structure of vessel wall.

Histology of the Vessels - Arteries

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?smooth muscles and elastic fibers مهم نعرف الفرق بين ال

The largest artery

main component of blood vessels is smooth muscles and elastic fibers هسه

smooth muscles is acidophilic structures and they appear red under the microscope. elastic fibers in another hand ال

Elastic arteries مهم تتذكر ذكر الفرق بينهم عشان نعرف افرق بين المختلف blood vessels ,requires special stain and they appear thin, wavy dark lines

- These include the aorta and the pulmonary trunk and their main branches.
- They are ‘conducting arteries’ that carry blood to the smaller arteries.
 - *Tunica intima*: typical structure with smooth muscle cells. The internal elastic lamina may not be clearly recognized.
 - *Tunica media*: the thickest layer. Contains numerous fenestrated elastic laminae alternating with layers of smooth muscle fibers. The fenestrations allow nutrient to pass through.

ال elastic arteries are made up of elastic lamina هيك
 - *Tunica adventitia*: typical structure with prominent vasa vasorum due to thick walls.

Between media and adventitia we have the external elastic laminate

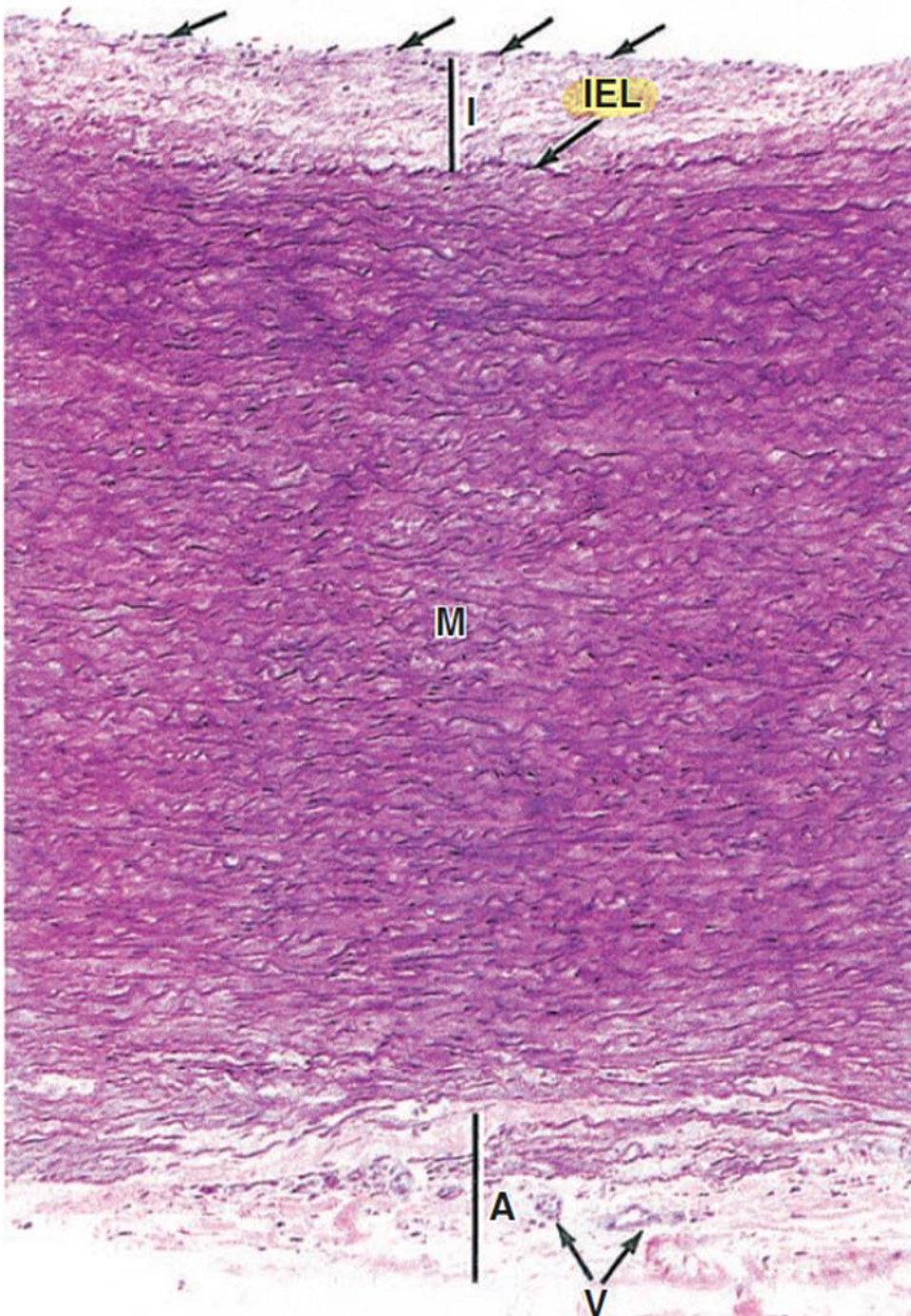


Fig.9: Elastic artery (aorta). Note the three layers of the wall: intima (I), media (M), and adventitia (A). Arrows at the top indicate the endothelium. The internal elastic lamina (IEL) can be seen in this image. V, vasa vasorum. Special stain was used to show the elastic fibers.

هو ندر نشوف ال internal and external elastic lamina بوضوح عكسال elastic arteries ليش ؟
لانتال smooth muscles is acidophilic and appears in red واحنا قلنا ل
وال internal and external elastic lamina is dark وهيك ندر نشوفهم بوضوح

Muscular arteries

- These are ‘*distributing arteries*’ that distribute blood to the organs.
 - *Tunica intima*: thin with typical structure. The internal elastic lamina is prominent.
 - *Tunica media*: the thickest layer. Contains numerous layers of smooth muscle fibers, with some elastic laminae. The external elastic lamina is prominent.
 - *Tunica adventitia*: typical structure.

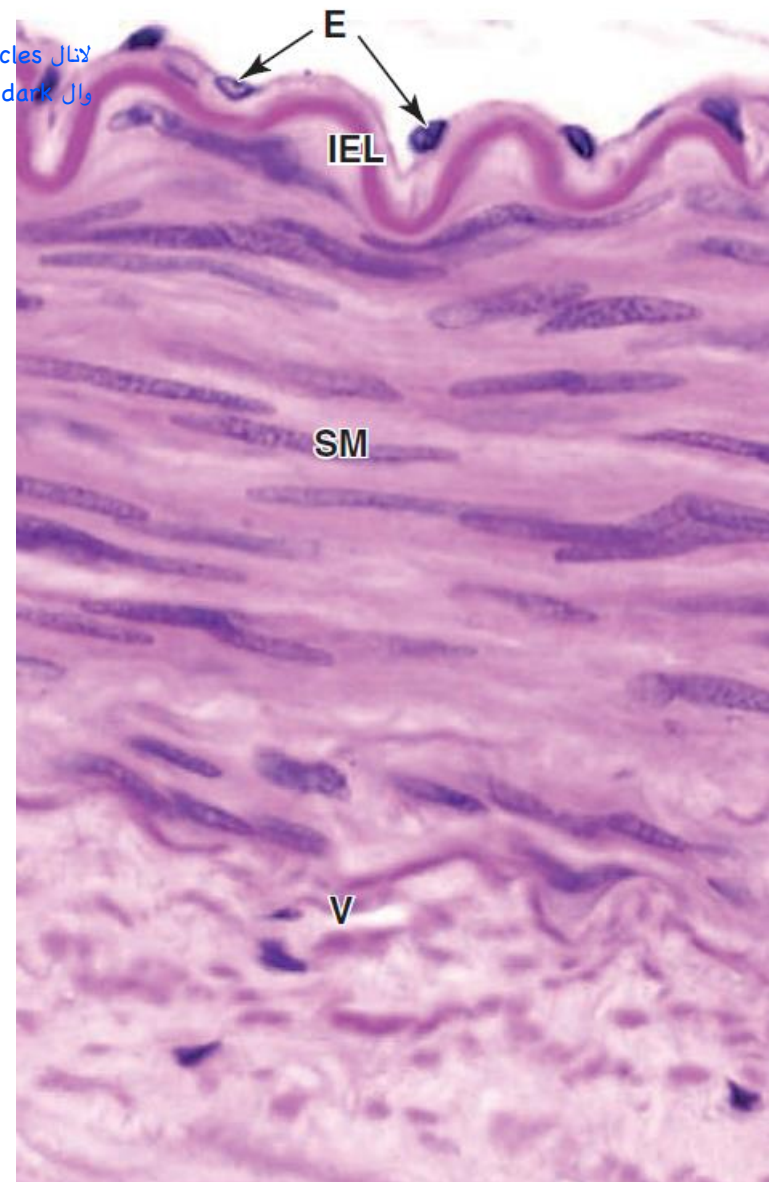


Fig.10: Muscular artery. Note the thin intima with the lining endothelium (E) and the prominent internal elastic lamina (IEL). The media is mostly smooth muscle fibers (SM). The adventitia is external with vasa vasorum (V).

Arterioles

- Arterial branches that are $<0.1\text{mm}$ in diameter. It's the beginning of the microvasculature of the organ.

~~✗~~ *Tunica intima*: very thin with no elastic lamina.

- *Tunica media*: formed of only 1-3 layers of smooth muscle fibers, with no elastic laminae.
- *Tunica adventitia*: thin.

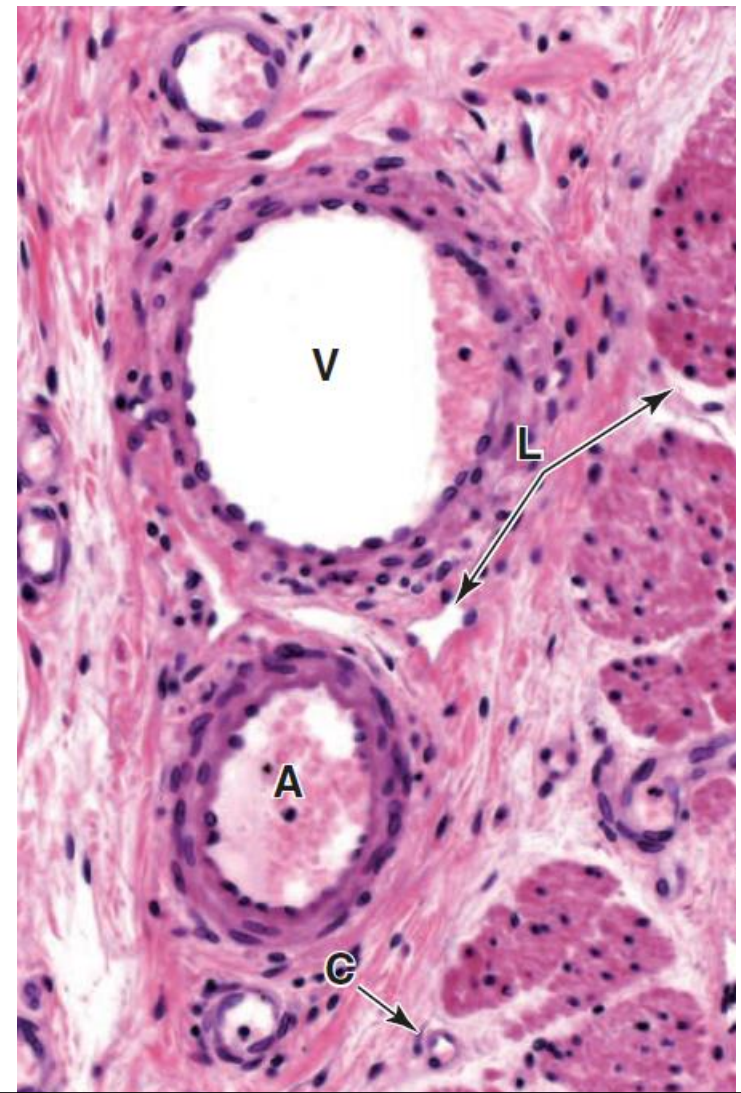
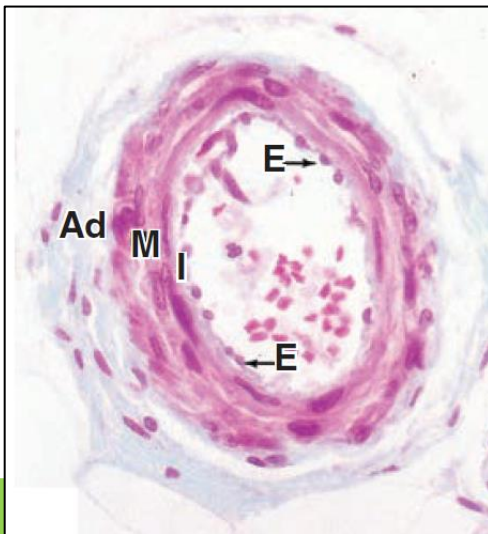


Fig.11: Microvasculature of an organ. A, arteriole. These give rise to capillaries (C), which then drain into a venule (V). Also shown are lymphatic vessels (L). To the left, wall of an arteriole: intima (I), media (M), and adventitia (Ad). E, endothelium.

- Capillaries arise from arterioles. The smooth muscles of the arterioles act as sphincters to control the flow of blood into the capillaries.
- Arterioles, also, give rise to '*thoroughfare channels*' that connect the arterioles to the *postcapillary venules*. Capillaries arise from the initial segment of these channels, which are called *metarterioles*. The flow of blood into the capillaries from the metarterioles is controlled by smooth muscle '*precapillary sphincters*'.
- Capillaries drain into the venous side of the thoroughfare channel which lacks smooth muscles.

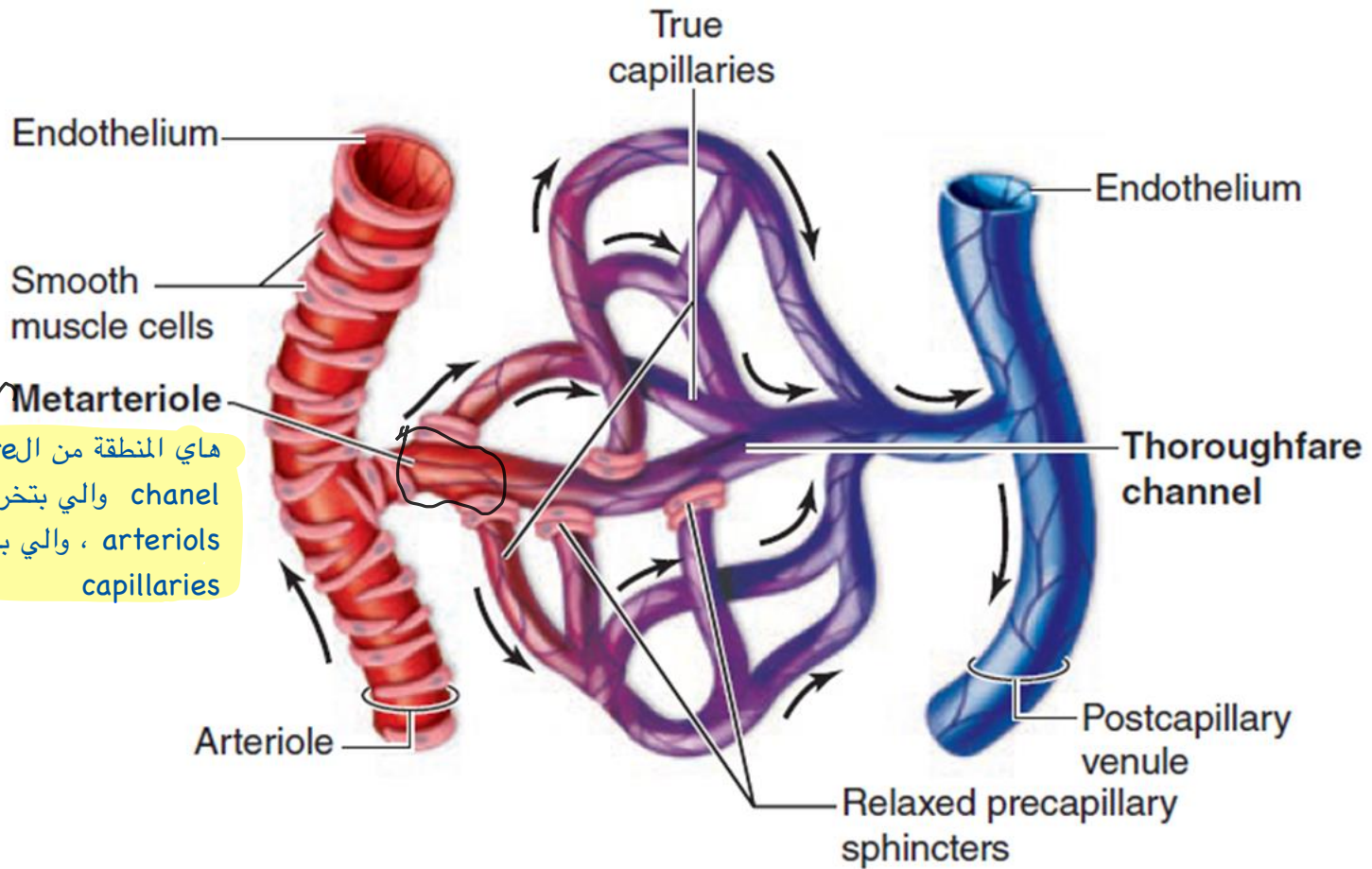


Fig.12: Microvasculature of an organ. The flow of blood through the capillaries is controlled by the contraction and relaxation of the precapillary sphincters.

Histology of the Vessels - Capillaries ²⁰

- Capillaries are the smallest vessels in the body. With a diameter of 4-10 μ m, **blood cells can pass only one at a time.** من أكثر ما هو صغير خلايا الدم تعبر بس بس خلية واحدة في الثانية
- Exchange of gases and nutrients occur through the thin capillary walls. **The density of the capillaries depends on the metabolic activity of the organ.**
- They are formed of **simple squamous endothelium** rolled up in a tube surrounded by **basal lamina** and **pericytes**. The endothelial cells:
 - Are connected by **tight junctions**
 - **Contain pinocytotic vesicles** وجود الـ pinocytotic vesicles دليل على أن الخلية تنقل المواد من خلالها ، يعني أنها تنقل المواد من جهة من الخلية إلى الجهة الأخرى بسموها الـ trans cytolysis
 - Release substance that **prevent coagulation of blood, control passage of WBC into tissues, and affect vessels diameter**

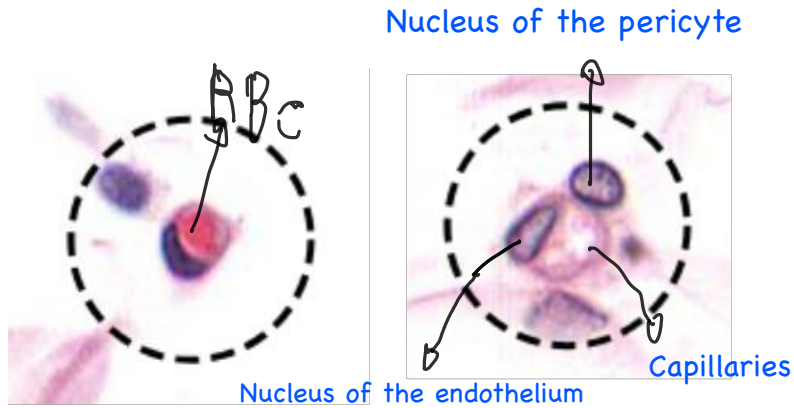
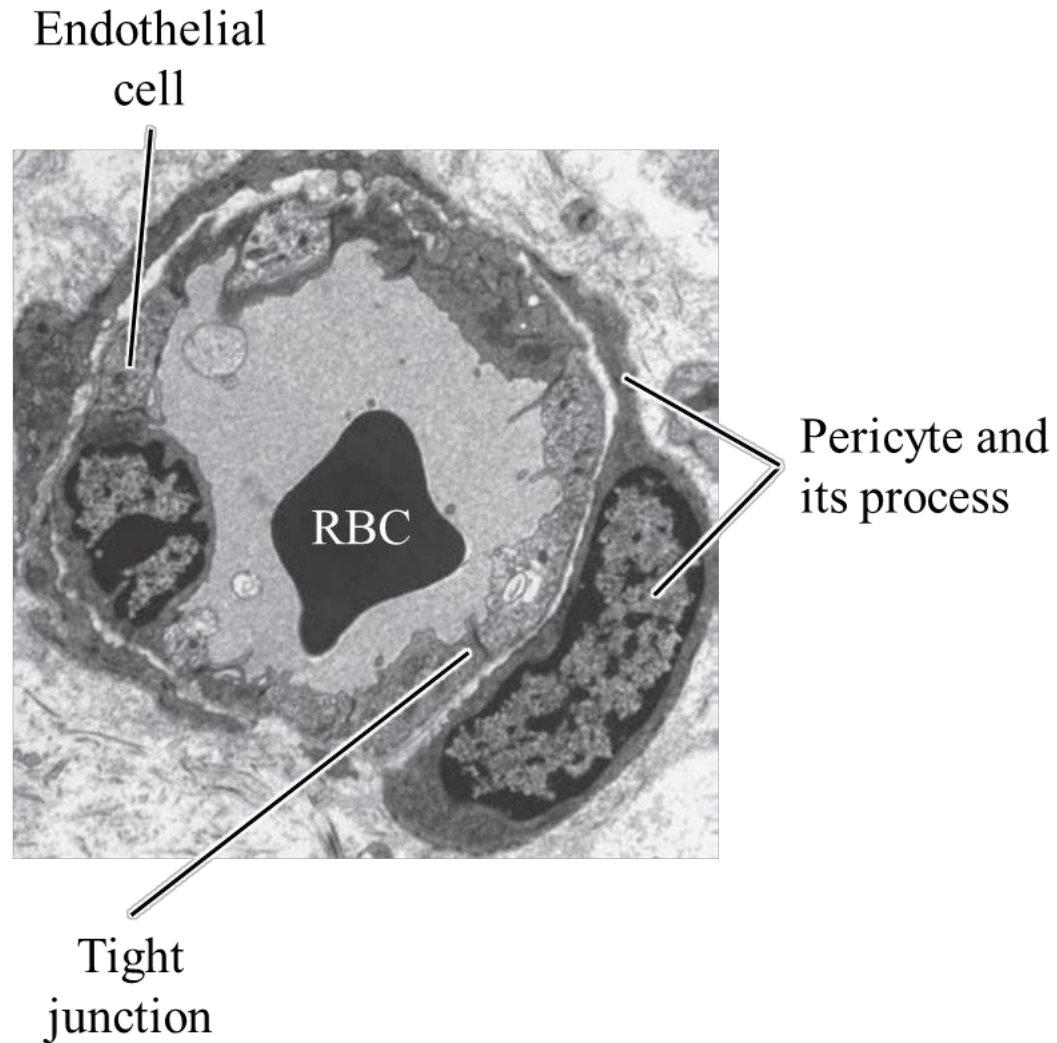


Fig.13: Capillaries. Above, light microscope images. In the top-left image, a red blood cell is filling the capillary. In the top-right image, the nucleus just outside the capillary belongs to a pericyte. To the right, electron microscope image of a capillary.



Types of capillaries

a) **Continuous capillaries** The most common type

- Many tight **junctions** between **slightly overlapping endothelial cells**. This allows well-regulated exchange across the cells.
- The most common type of capillary. Found in **muscle, connective tissue, lungs, exocrine glands, and nervous tissue**.

b) **Fenestrated capillaries**

- Have a sieve-like structure in which the endothelial cells are penetrated by **numerous small circular fenestrations** that allows **more extensive exchange**.
- Some fenestrations are covered by very thin **diaphragms** of **proteoglycans**; others may represent **membrane invaginations** that **temporarily involve both sides of the very thin cells**. The basement membrane however is continuous.
- Fenestrated capillaries are found in some organs, such as the **kidneys, intestine, choroid plexus, and endocrine glands**.

c) Discontinuous capillaries (sinusoids)

- The endothelium has large perforations without diaphragms and irregular intercellular clefts. In addition, the basement membranes is highly discontinuous.
- These features and larger diameter of these capillaries permit maximal exchange of macromolecules as well as allow easier movement of cells between tissues and blood.
- Sinusoidal capillaries of this type are found in the liver, spleen, and bone marrow.

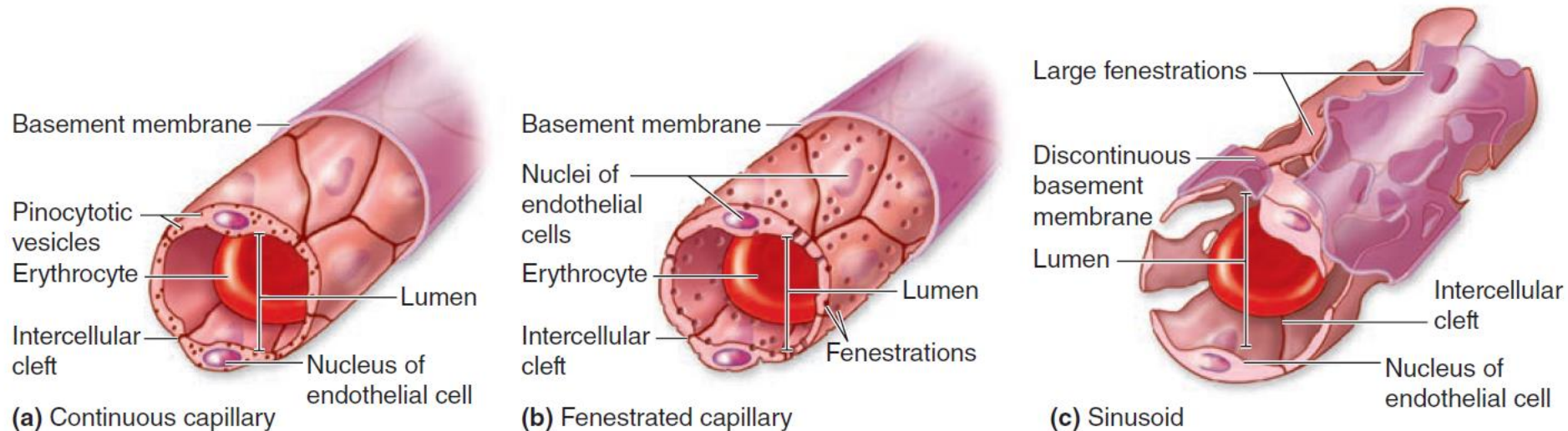


Fig.14: Types of capillaries.

Pericytes

connected tissue cell يعني أنهم

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المهم ننتبه انها pericytes يعيق مرور المواد عشان هيك هو موجود
حول ال continuous capillary and post-capillary venules

- Mesenchymal cells with long cytoplasmic processes that surround continuous capillaries and post-capillary venules.
- They are surrounded by a basal lamina that merges with the basal lamina of the capillary.
- They have well-developed networks of myosin, actin, and tropomyosin indicating that pericytes dilate or constrict capillaries, helping to regulate blood flow.
- They help form new capillaries after injury.

عشانهم يحتوى على ال myosin and actin and other substance so they can contract And when they contract, they can change the diameter of the Capillary And so they can regulate the blood flow through the capillaries

Nucleus of pericytes

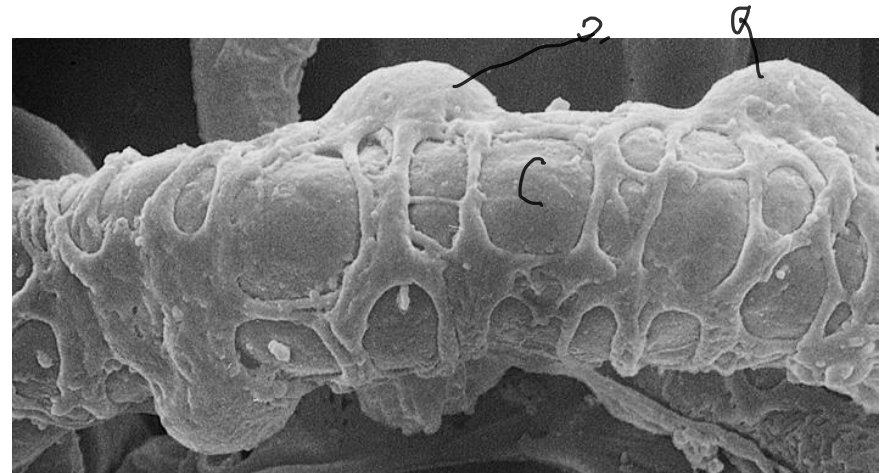


Fig.15: SEM of a capillary surrounded by pericytes.

Types of circulations

Simple pathway: Arteriole → Capillary bed → Venule --- **Most common**

Arteriovenous shunts: blood is shunted directly from **arterial** to **venous side** bypassing capillaries ---

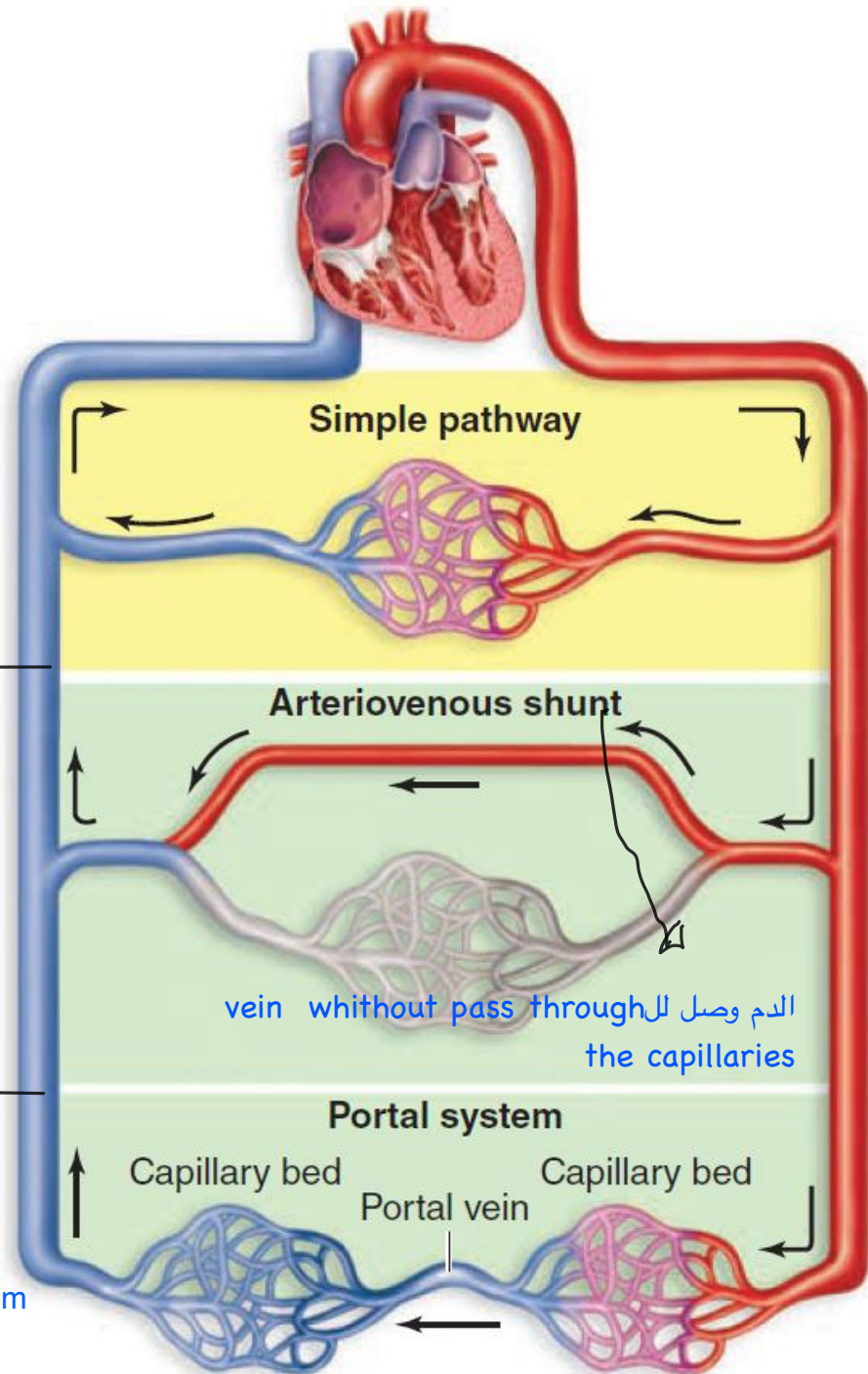
Skin

regulation of body heat
مثال عليه موجود على الجلد (skin) وهذا يساعد على

Portal systems: **capillary bed 1** → **portal vein** → **capillary bed 2** ---

Hepatic portal systems

For example blood go to digestive system



Histology of the Vessels - Veins

Venules

- *Postcapillary venules*
 - Similar to capillaries (endothelium and basal lamina) surrounded by pericytes. Larger diameter.
 - Site where white blood cells leave the circulation to enter inflamed tissue.

يعني هو احنا راح نرجع للطبقت ال
(/ tunica intima / media) و

- *Collecting and muscular venules*
 - Have distinct tunica media with only 2-3 layers of smooth muscles.

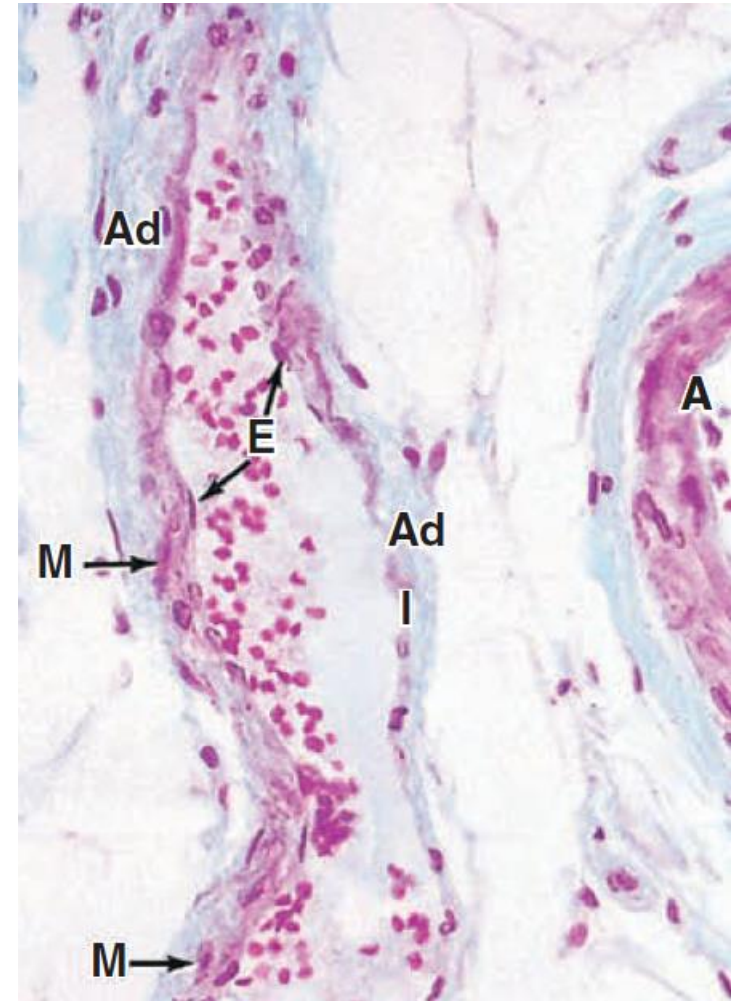


Fig.16: Muscular venule. I, intima. E, endothelium. M, media. Ad, adventitia. Note the large lumen and the thin wall (compare with the arteriole A).

Small and medium veins

كيف عرفنا أنها muscular artery ال media لونها احمر

- Accompany the **muscular arteries**.
- The tunica intima is usually **thin**. The **media has small bundles of smooth muscle cells** (3-5 layers) mixed with a network of reticular fibers and delicate elastic fibers. The **adventitia is thick and well developed** with several collagen fibers.
- **Medium veins posses valves**.

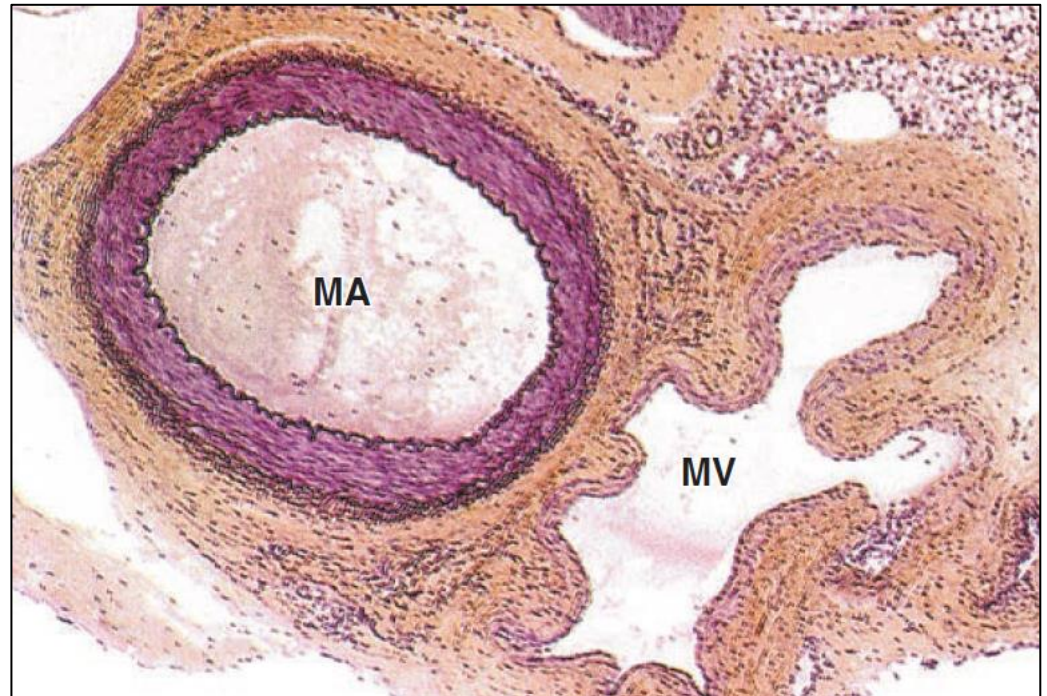


Fig.17: Medium vein (MV) accompanying a muscular artery (MA).

Large venous trunks

- Accompany the large elastic arteries.
- Intima is well-developed. Media has alternating layers of smooth muscle (>5) and connective tissue. The tunica adventitia is thicker than the media in large veins and frequently contains longitudinal bundles of smooth muscle. Both the media and adventitia contain elastic fibers, and an internal elastic lamina may be present.
- Possess valves which are folds of the tunica intima that prevent backflow of blood. They are most numerous in the veins of the leg.
- Vasa vasorum are numerous in the large veins because blood in the lumen is deoxygenated.

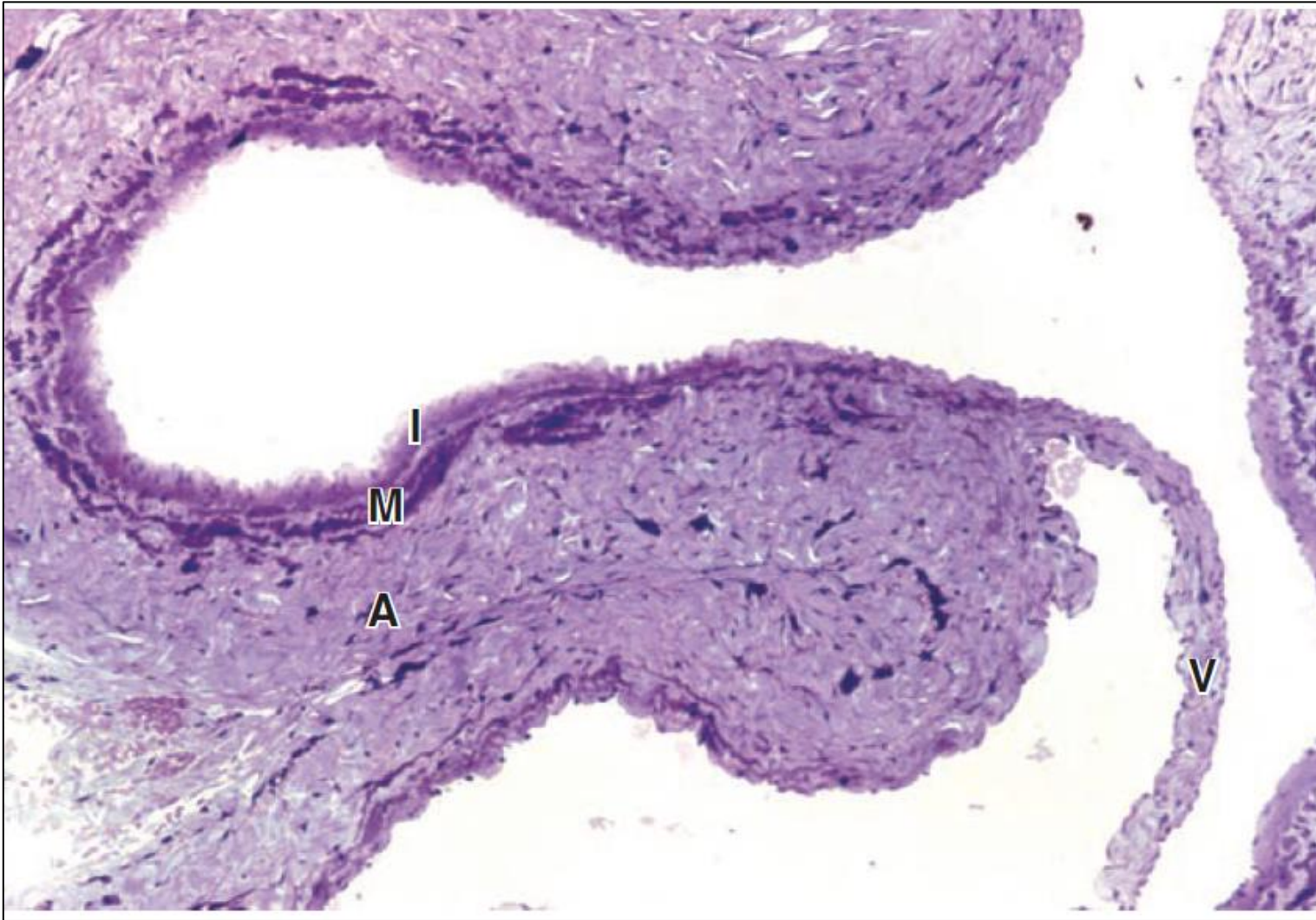


Fig.18: Large vein with distinct intima (I), media (M), and adventitia (A). Note the valve (V).