



Circulatory System

Circulatory System


- Composed of two separate, but related components:
 - Cardiovascular system – which carries blood in both directions between the heart and tissues.
 - Lymphatic vascular system – collects lymph and delivers it back to the cardiovascular system.

(Lymph – excess extracellular tissue fluid)


Cardiovascular System




- Composed of the heart, a muscular organ designed to pump blood into two separate circuits:
 - Pulmonary circuit – blood to and from the lungs.
 - Systemic circuit – blood to and from all the organs and tissues.
- Arteries – transport blood away from the heart.
- Veins – drain the capillary beds and form larger and larger vessels returning blood to the heart.

Blood Vessels

- The structure of blood vessels, in particular the aorta,  elastic and muscular arteries and the larger veins, change progressively (or dynamically) throughout life. This is due to the impact of aging and by the effects of common disorder including atherosclerosis, hypertension and diabetes.

General Organization of Blood Vessels

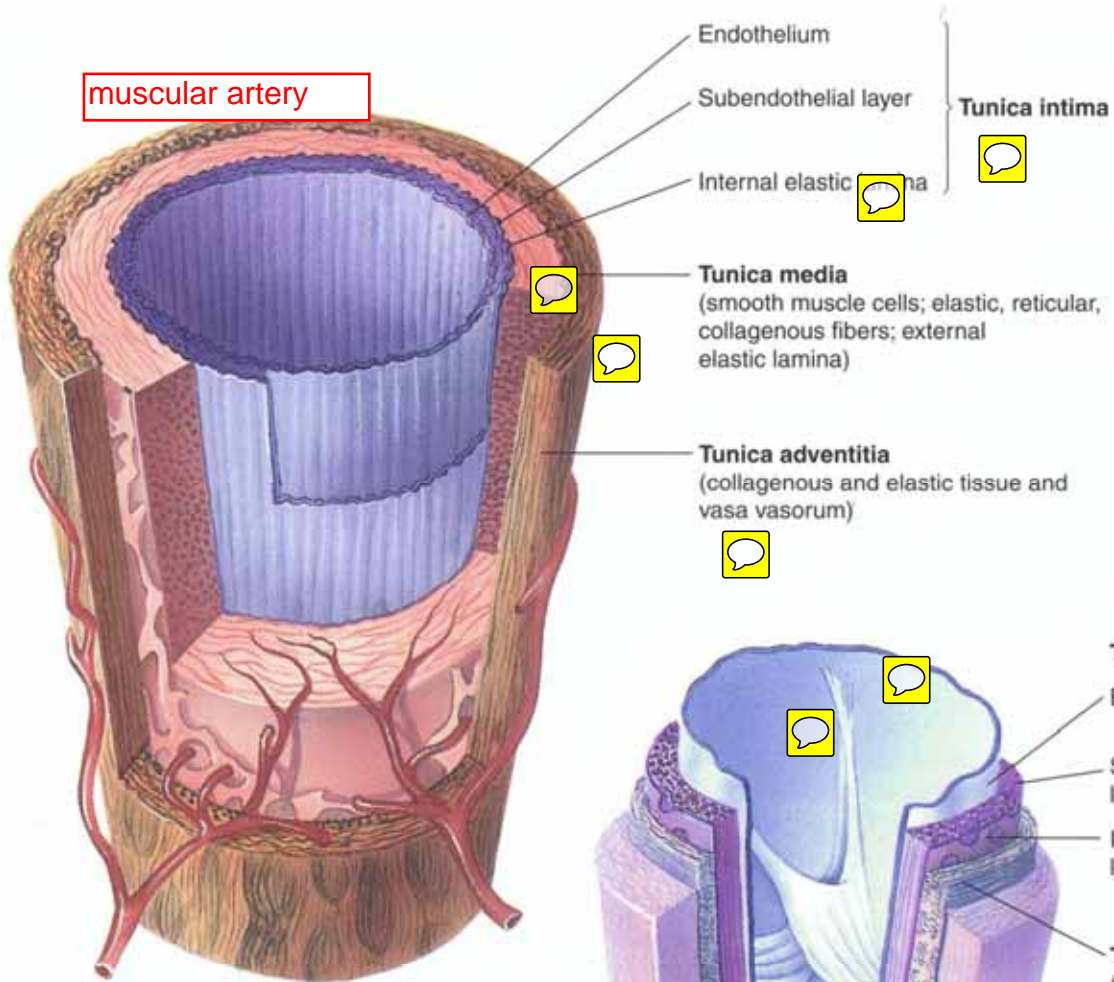
- Generally, all classification of blood vessels depends on how the wall changes. 
- The walls of the arteries are much thicker than in veins of a similar size.
- The lumen of veins are larger compared to a similar sized artery.

the opening; this changes and is always larger in veins than arteries
- Generally, the pressure in a vein is reduced, allowing for a greater volume of blood and hence the need for a larger lumen. 
- Arterial diameter decreases with each branch; vein diameter increases at each convergence – vessel wall changes must occur (# of layers). 


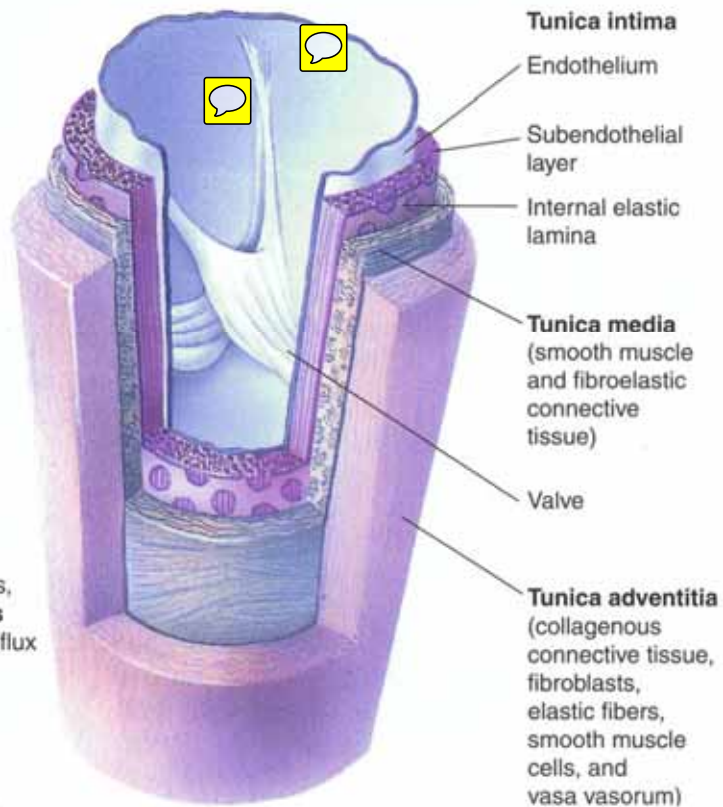
Basic Structure of a Vessel

- Consists of 3 concentric coats or tunics:
 - Tunica Intima
 - Tunica Media
 - Tunica Adventitia

muscular artery



Muscular Artery



Veins, unlike arteries, may possess **valves** which prevent the reflux of blood

H & E stain

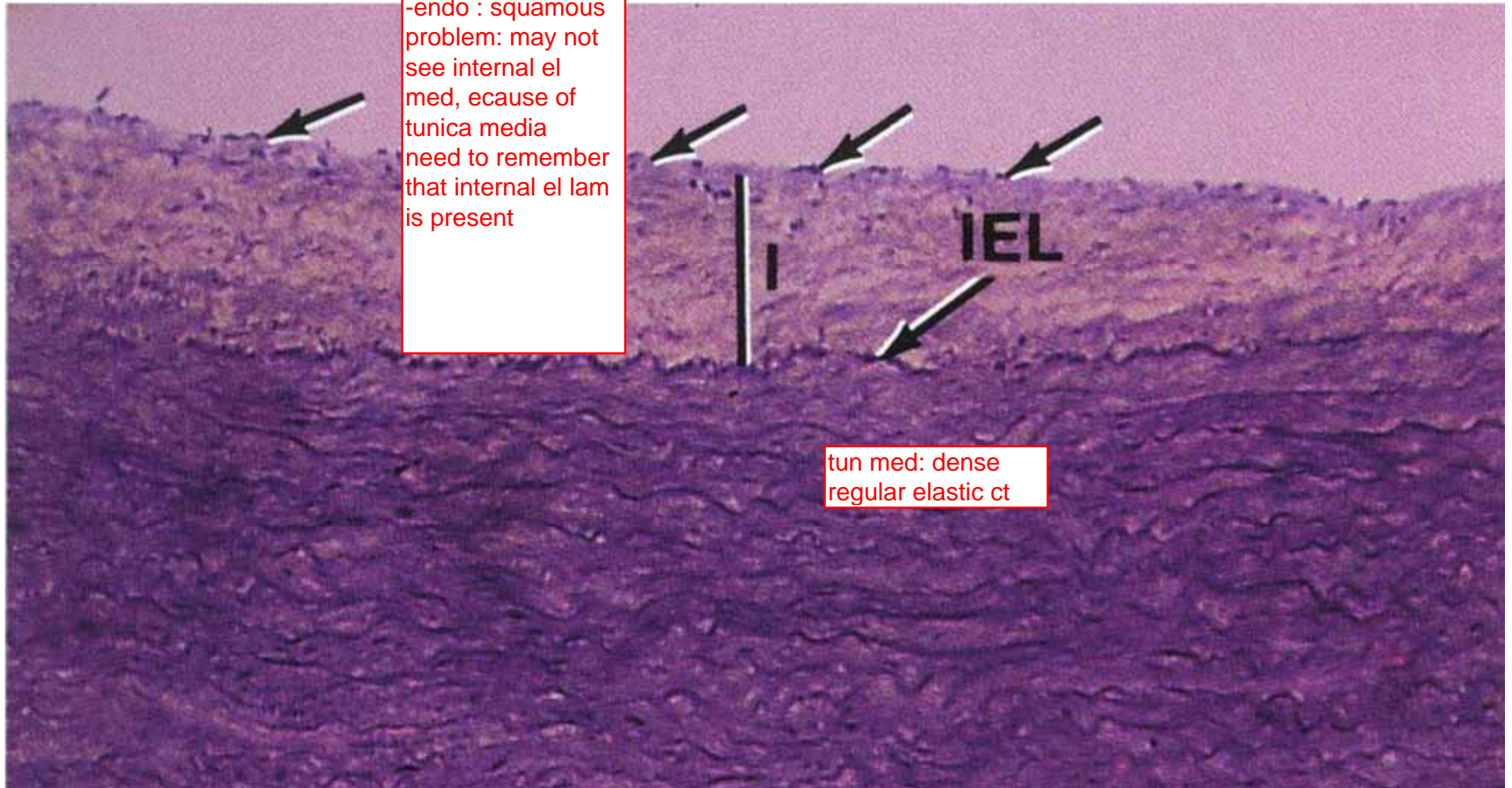
Orcein stain

Tunica Intima

- Consists of
 - A single layer of flattened, squamous epithelial cells – endothelial cells.
 - Underlying basement membrane.
 - Varying amounts of subendothelial connective tissue.
 - Internal elastic lamina – elastic fibres. Well developed in muscular arteries, but may not be present in smaller vessels

Tunica intima

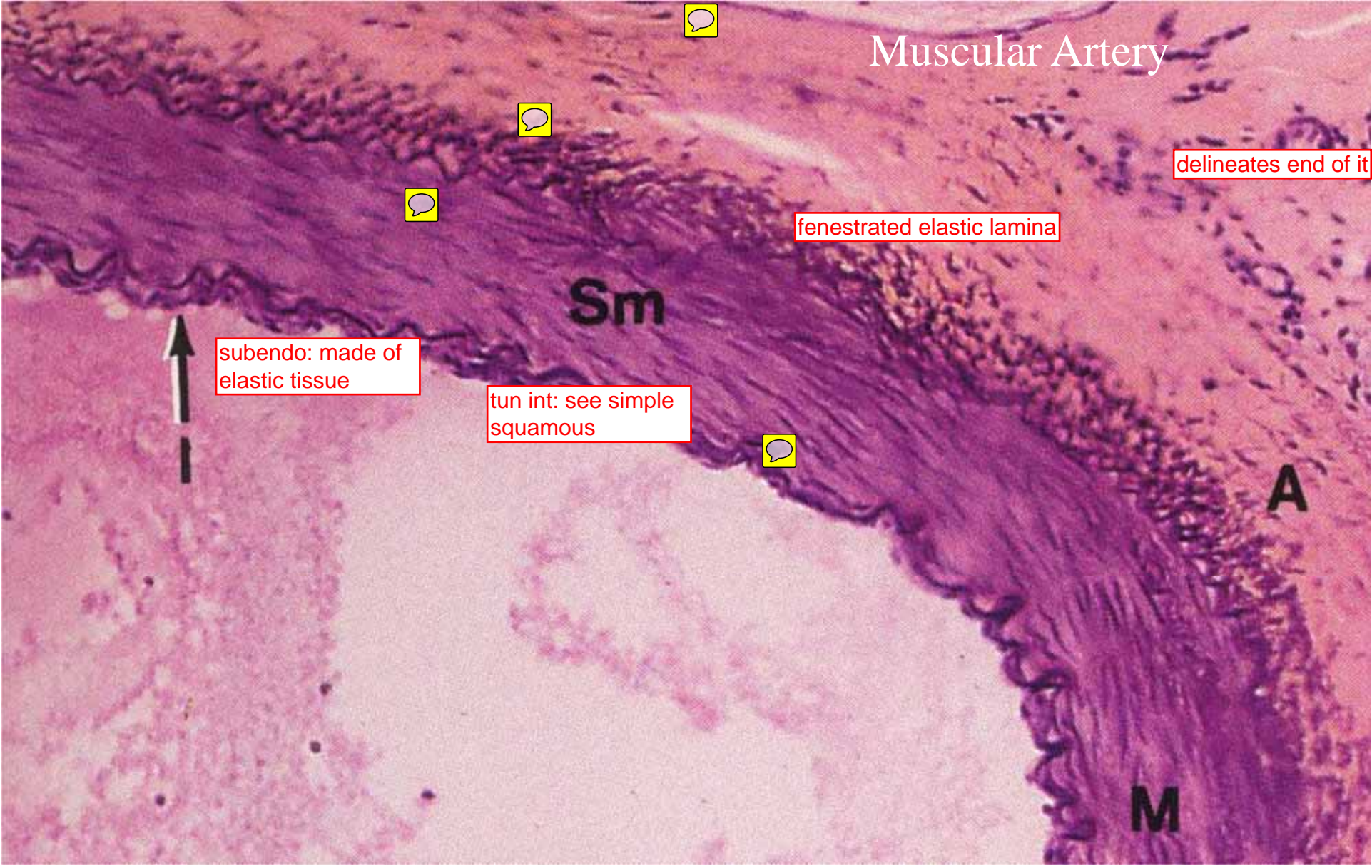
of an aorta, quite thick, has 3 layers
-endo : squamous
problem: may not see internal el
med, ecause of
tunica media
need to remember
that internal el lam
is present



tun med: dense
regular elastic ct

Tunica Media

- Concentric cell layers composed of:
 - Smooth muscle cells
 - Interspersed within the layers of SMC are elastic fibres, type III collagen, and proteoglycans.
- Large muscular arteries have an **external elastic lamina**. More delicate than the internal elastic lamina and separates the T.media from the T.adventitia.
- Capillaries and postcapillary venules do not have a T.media – pericytes replaces the T.media



Muscular Artery

delineates end of it

fenestrated elastic lamina

Sm

subendo: made of elastic tissue

tun int: see simple squamous

A

M

Tunica Adventitia

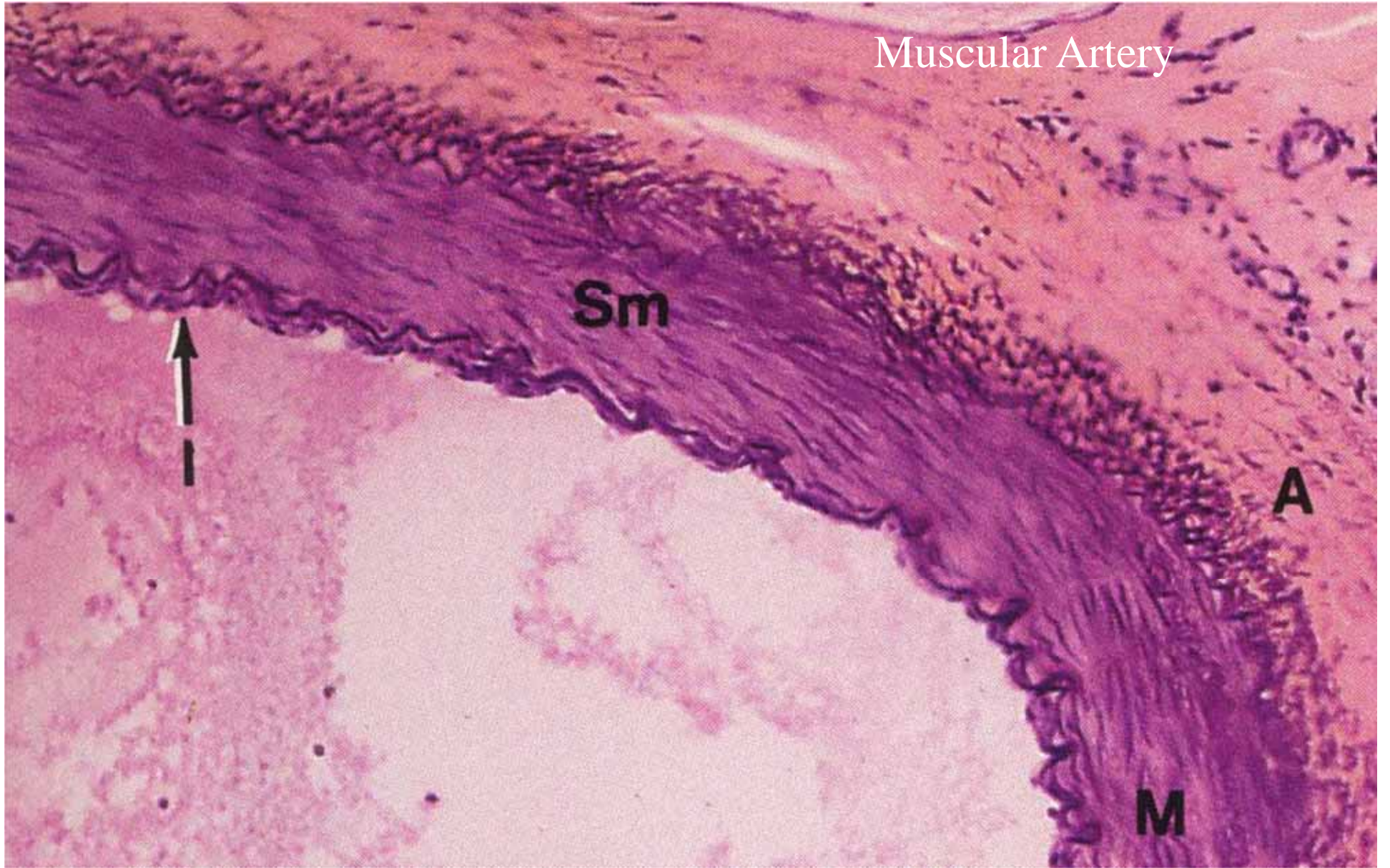
- Consists of:
 - Loose connective tissue.
 - Fibroblasts, type I collagen and elastic fibres (thin layers) – becomes a continuous with the connective tissue elements surrounding the vessels.
 - Larger vessels are supplied with their own blood supply by small arteries called vasa vasorum (L. for vessels of vessels). May supply nutrients/oxygen to the outer portion of the T.media. Nervi vasorum.

Muscular Artery

Sm

A

M



Arteries

The image features a monochromatic blue background. The lower two-thirds of the frame are filled with a close-up view of the ocean's surface, showing gentle ripples and a slight gradient from a lighter blue on the left to a darker blue on the right. The upper third of the frame shows a sky with wispy, white clouds against a deep blue backdrop. The word "Arteries" is printed in a clean, white, sans-serif font in the upper-left quadrant.

Arteries (pl; artery, s)

- Efferent vessels that transport blood away from the heart to the capillary beds.
- Classification of Arteries based on size and morphology:
 - Elastic arteries (conducting arteries)
 - Muscular arteries (distributing arteries)
 - arterioles

TABLE 11-1 Characteristics of Various Types of Arteries

| ARTERY | TUNICA INTIMA | TUNICA MEDIA | TUNICA ADVENTITIA |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Elastic artery (<i>conducting</i>) (e.g., aorta) | Endothelium with Weibel-Palade bodies, basal lamina, subendothelial layer, incomplete internal elastic lamina | 40–70 fenestrated elastic membranes; smooth muscle cells interspersed between elastic membranes; thin external elastic lamina; vasa vasorum in outer half | Thin layer of fibroelastic connective tissue, vasa vasorum, lymphatic vessels, nerve fibers |
| Muscular artery (<i>distributing</i>) (e.g., femoral artery) | Endothelium with Weibel-Palade bodies, basal lamina, subendothelial layer, thick internal elastic lamina | Up to 40 layers of smooth muscle cells; thick external elastic lamina | Thin layer of fibroelastic connective tissue; vasa vasorum not very prominent; lymphatic vessels, nerve fibers |
| Arteriole | Endothelium with Weibel-Palade bodies; basal lamina, subendothelial layer not very prominent; some elastic fibers instead of a defined internal elastic lamina | One or two layers of smooth muscle cells | Loose connective tissue, nerve fibers |
| Metarteriole | Endothelium, basal lamina | Smooth muscle cells form precapillary sphincter | Sparse, loose connective tissue |




Elastic Arteries

- Examples, aorta (including aortic arch), iliac arteries, pulmonary trunk.


Structure:

- T.intima – endothelial cells contain Weibel-Palade bodies which contain von Willebrand factor to facilitates the coagulation of platelets during clot formation.
 - Subendothelial CT layer is narrow and contains a few fibroblasts, a few SMC.

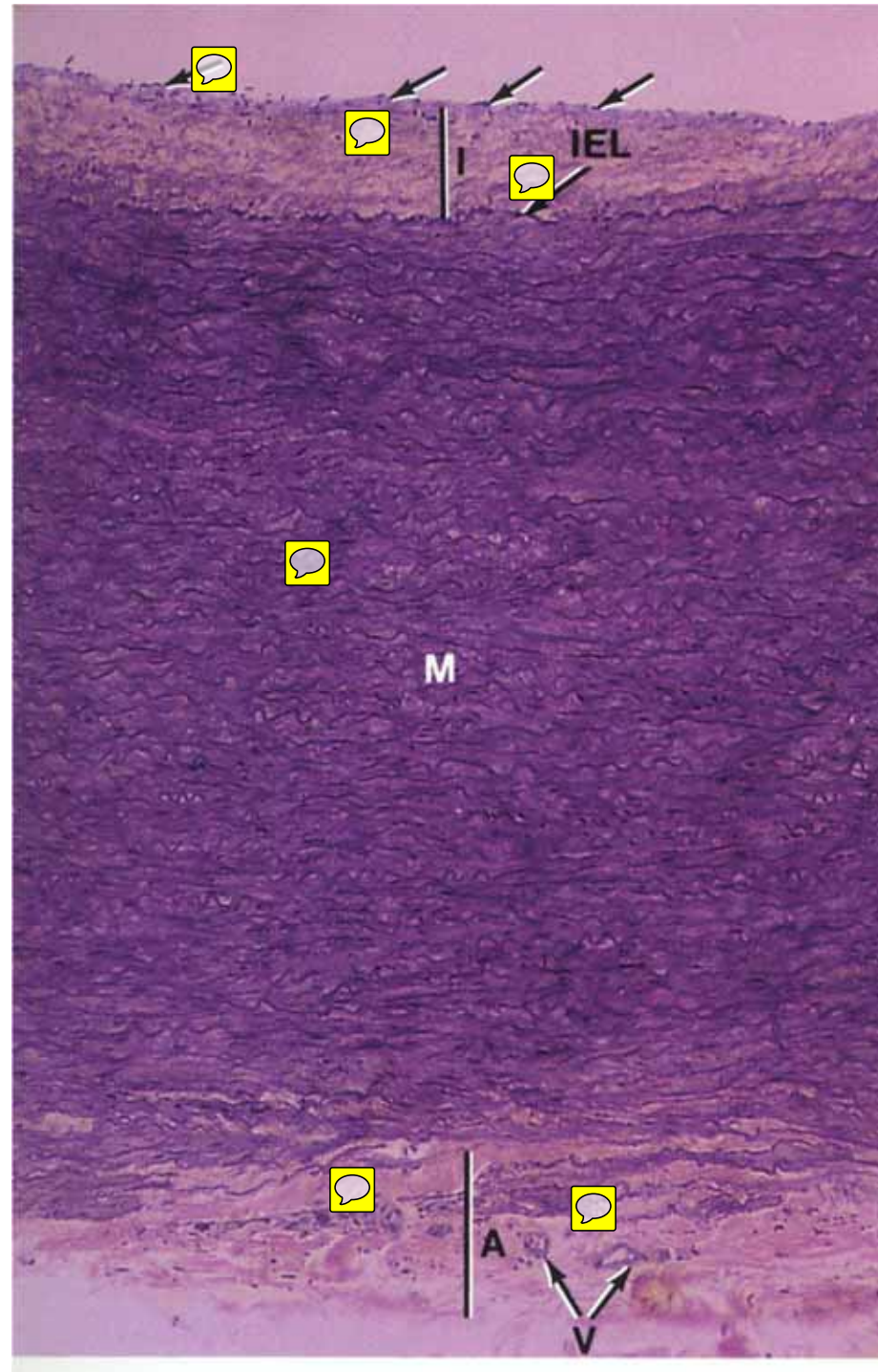
Elastic Arteries

- TI cont: internal elastic lamina is present, thin or incomplete. 
- T.media: 40 – 70 layers of elastic fibres (or membranes); alternating layers circular oriented SMC (longer than normal). External elastic lamina is present (thin). May have vasa vasorum present.  

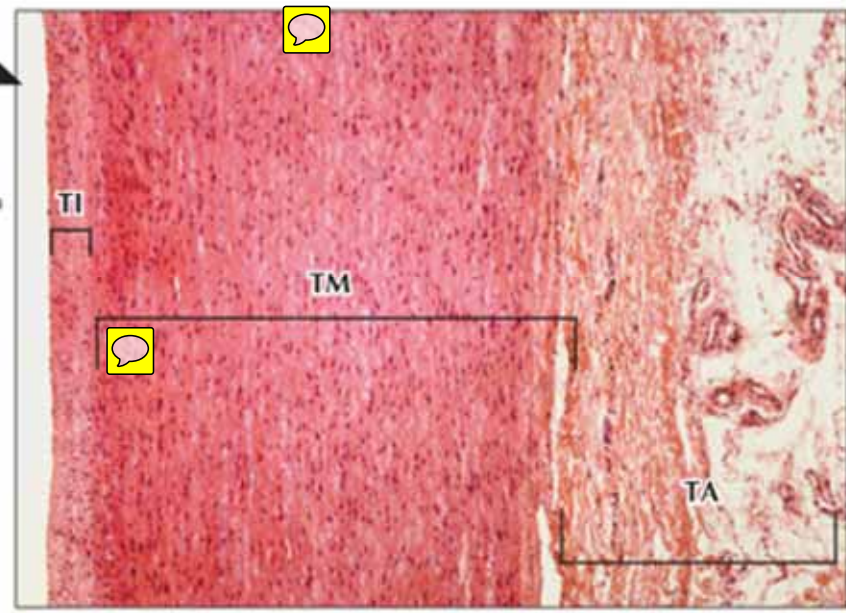
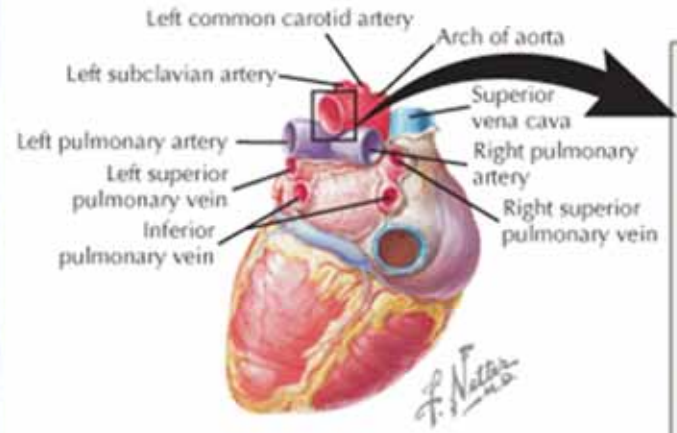
Elastic Arteries

- T.adventitia: thin layer containing fibroblasts, type I collagen, elastic fibres, vasa vasorum, nervi vasorum, and the odd lymphatic vessel. 
- Function: elastic properties → shock absorber – stretch and recoil to withstand the pressures from the ventricle.

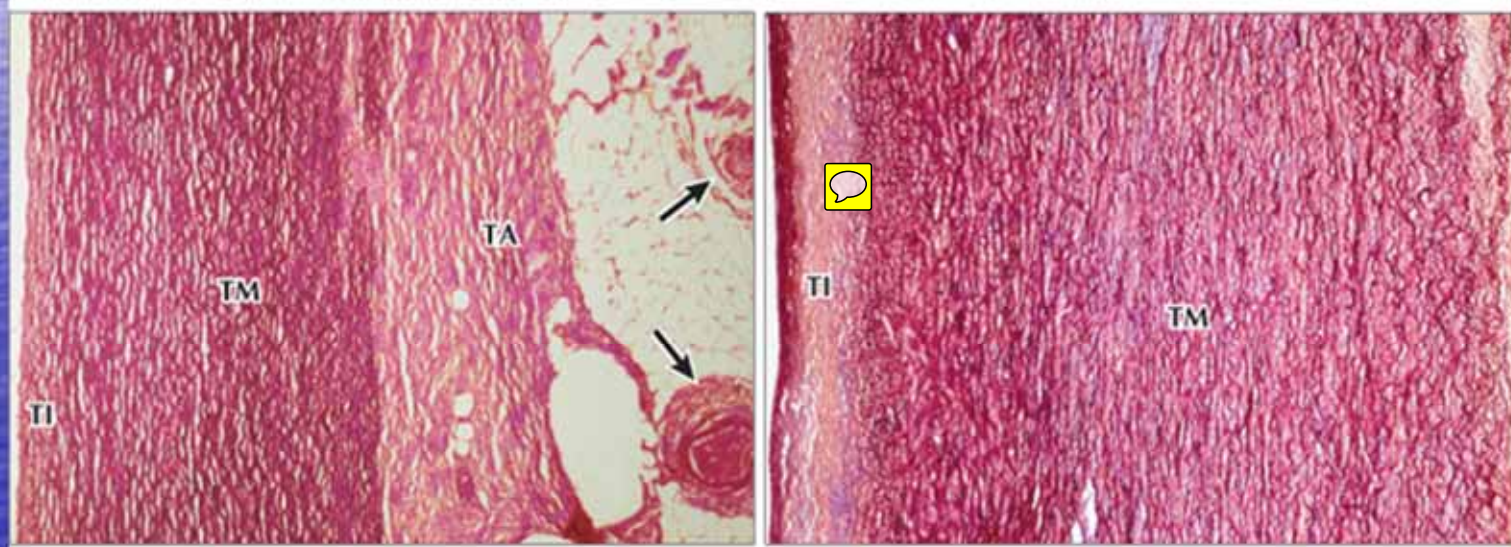
Elastic Artery
(x122)



▼ Heart viewed from below and behind.





► **LM of part of the aortic wall.** The intima (TI) abuts the lumen (left). A thick media (TM) and an outer adventitia (TA) are also shown. Nuclei in the media at this magnification are mostly those of smooth muscle cells. Elastic laminae are not easily seen with this stain and need special preparative and staining methods for elucidation. 60×. H&E.



▲ **Comparative LMs of the wall of the aorta of a newborn (Left) and 25-year-old (Right).** In both vessels, a relatively thin tunica intima (TI) merges with a prominent tunica media (TM). This stain specifically demonstrates elastic tissue, a prominent feature of these arteries. The number of elastic laminae—the dark, wavy bands—increases with age. Vasa vasorum (arrows) occupy loose connective tissue of the adventitia (TA). 60×. Gomori aldehyde fuchsin.



Muscular Arteries

- Includes most arteries arising off the aorta, excluding the aortic arch  and the bifurcation of the abdominal aorta.
- Sizes - down to 0.1 mm considered to be arteries (medium and small arteries)
- Identifying characteristic is a thick T.media composed of smooth muscle cells. 


Muscular Arteries

- T.intima: thinner than in elastic arteries and contains fewer SMC in the subendothelial layer.
 - Very distinctive internal elastic lamina. May appear very thick → duplicate IEL, called a **bifid IEL**.
- T.media: composed predominately of SMC (circular orientation)

Muscular Arteries

- T.media: small arteries → few as 4 layers of SMC and larger arteries → many as 40 layers of SMC. 
- Present is elastic fibres and type III collagen (via SMC) → dispersed within the intercellular spaces. 
- External elastic lamina is present and may be several layers of thin elastic sheets (larger vessels).

Muscular Arteries

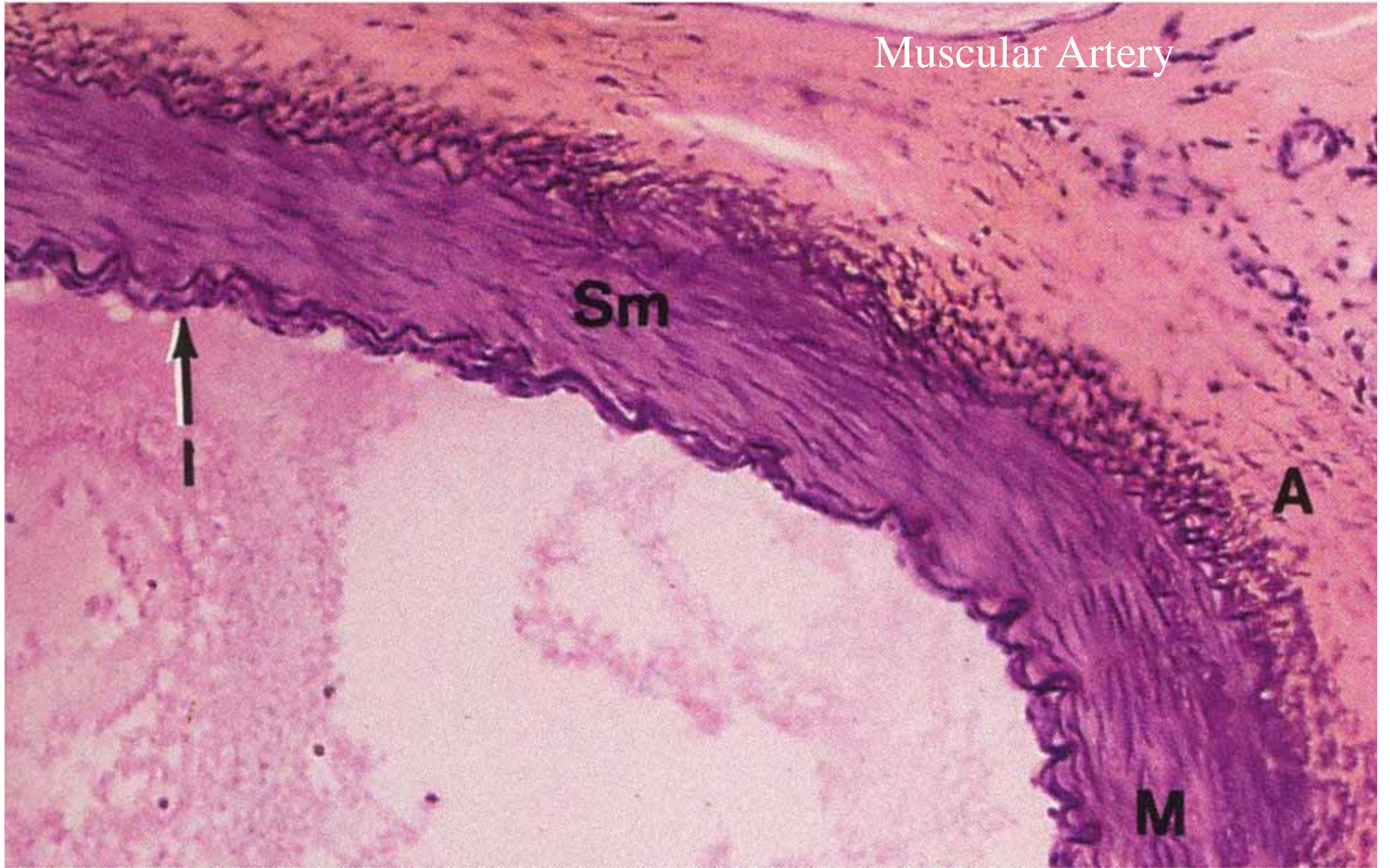
- T.adventitia: consists of elastic fibres,  collagen fibres (via fibroblast) longitudinal orientation and blend into the surrounding CT.
 - Contains the usual vasa vasorum (?) and nervi vasorum.
- Function: distribution of blood to the body.

Muscular Artery

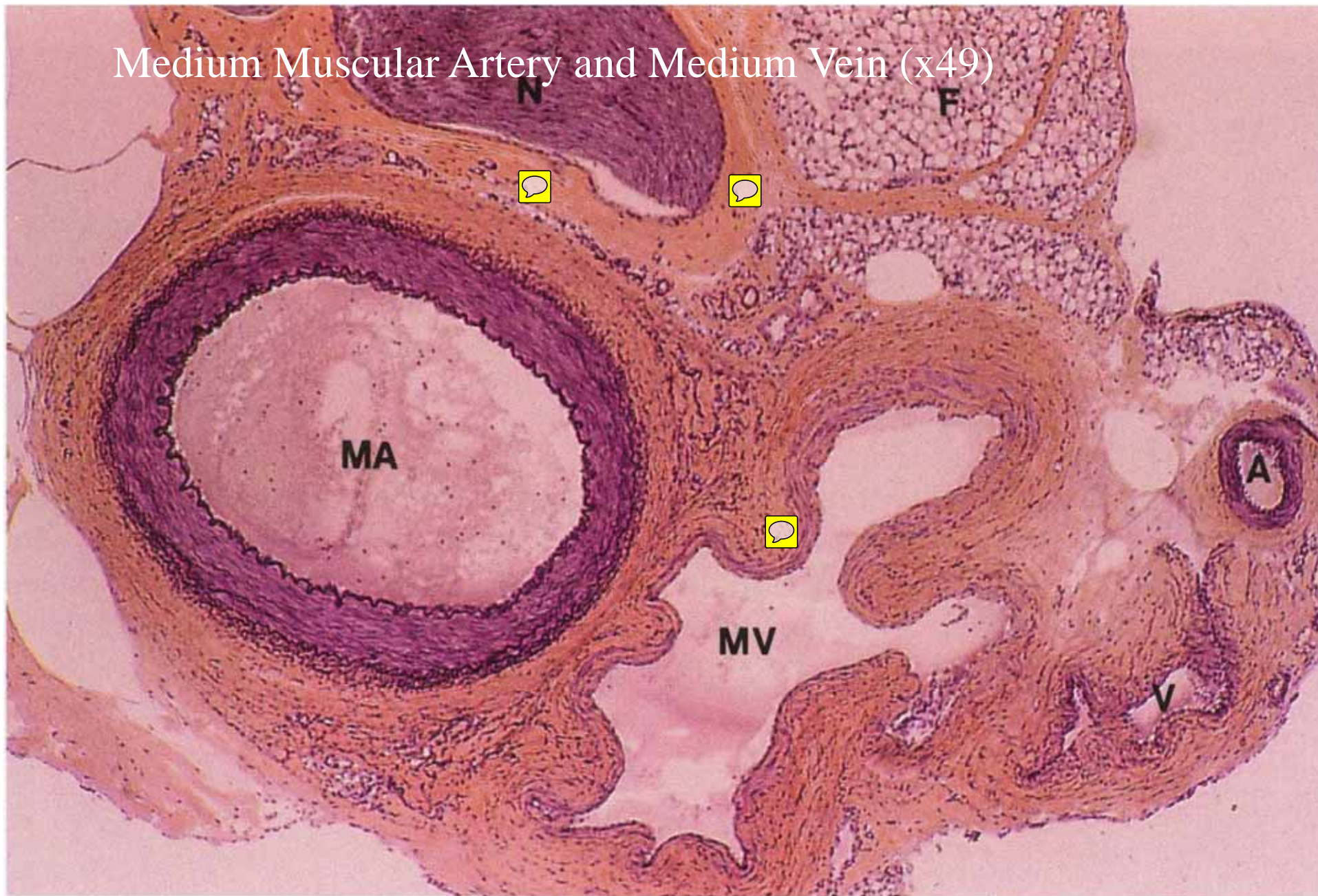
Sm

A

M



Medium Muscular Artery and Medium Vein (x49)



(x122)



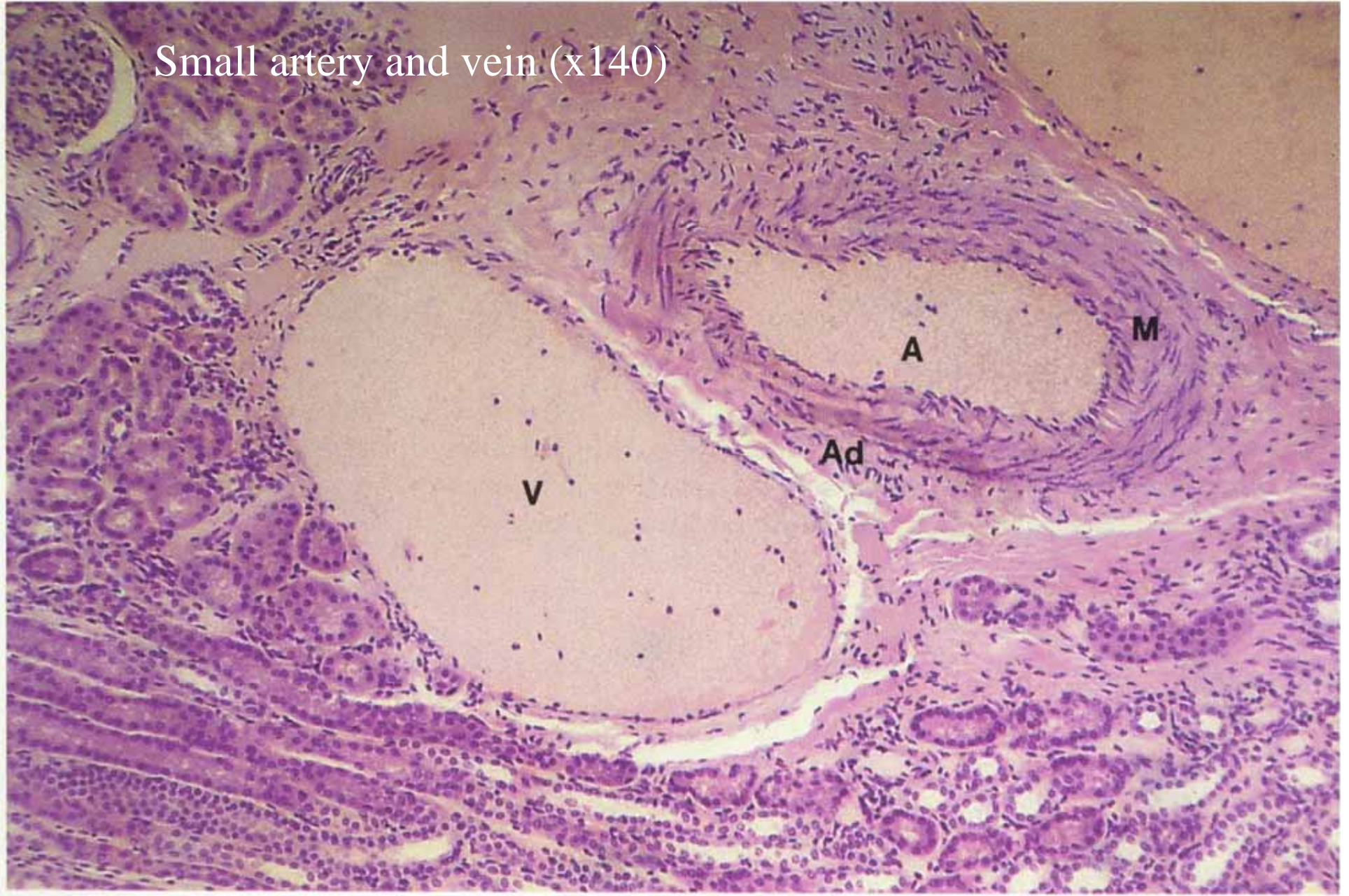
Arterioles (small arteries)

- Arteries with a diameter of < 0.1 mm are called small arteries.
- Width of the wall of an arteriole is approximately equal to the diameter of its lumen.
- T.intima: has a thin endothelial layer of type III collagen and elastic fibres (few).
 - Thin IEL is present (fenestrated) in larger arterioles, but absent in small arterioles.

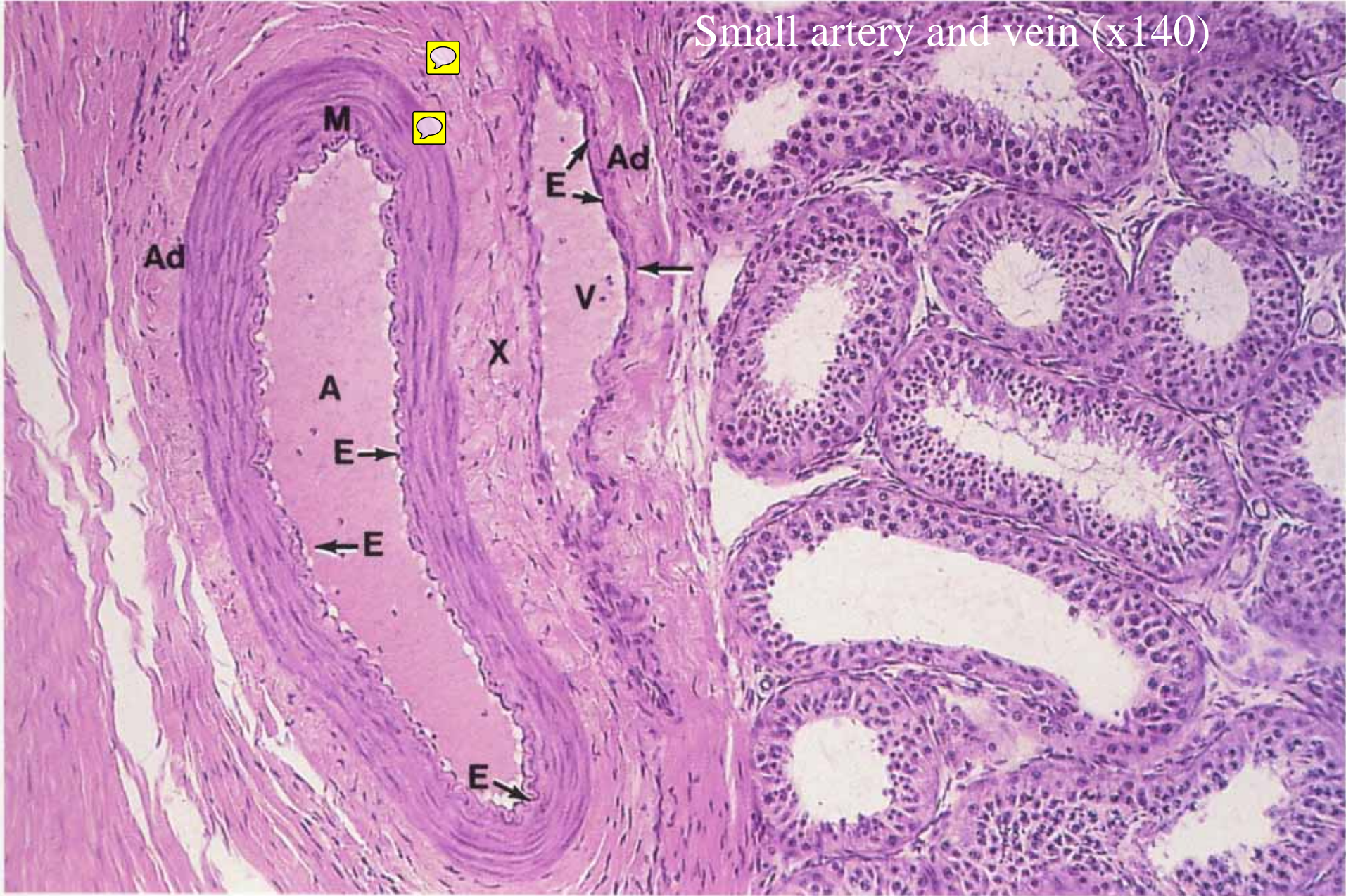
Arterioles

- T.media: large arterioles – 2 to 3 layers of SMC; small arterioles – usually 1 layer of SMC. No external elastic lamina (EEL).
- T.adventitia: present sparingly, consists of fibroelastic CT with a few fibroblasts.
- Function: plays a role in blood pressure regulation.

Small artery and vein (x140)



Small artery and vein (x140)



Arteriole (3) (x869)



Veins




Veins

- Conducts blood away from the organs and tissues to the heart.
- Outnumber arteries, larger lumen (reduces pressure) and able to accommodate more blood (~70% total blood is in the veins).
- Histological, veins parallel arteries, but are usually collapsed due to the thin walls and less elastic fibres.

Classification of Veins

- Three major Groups:
 - Small – 15 – 20 μm diameter.
 - Medium - $> 20 \mu\text{m} < 1 \text{ cm}$
 - Large - $> 1 \text{ cm}$
- Three tunics, but the muscular and elastic layers are not well developed and the connective tissue component is more pronounced compared to arteries.

Valves of Veins

- Many medium veins  have valves to prevent the backflow of blood.
- Abundant in the veins of the legs (gravity thing)
- Valves are composed of two leaflets composed of a thin fold of the intima protruding out into the lumen.
- Leaflets are structurally reinforced by collagen and elastic fibres.
- Any backflow of blood forces the valves to close preventing the the backflow.

Small vein with valve (x128)

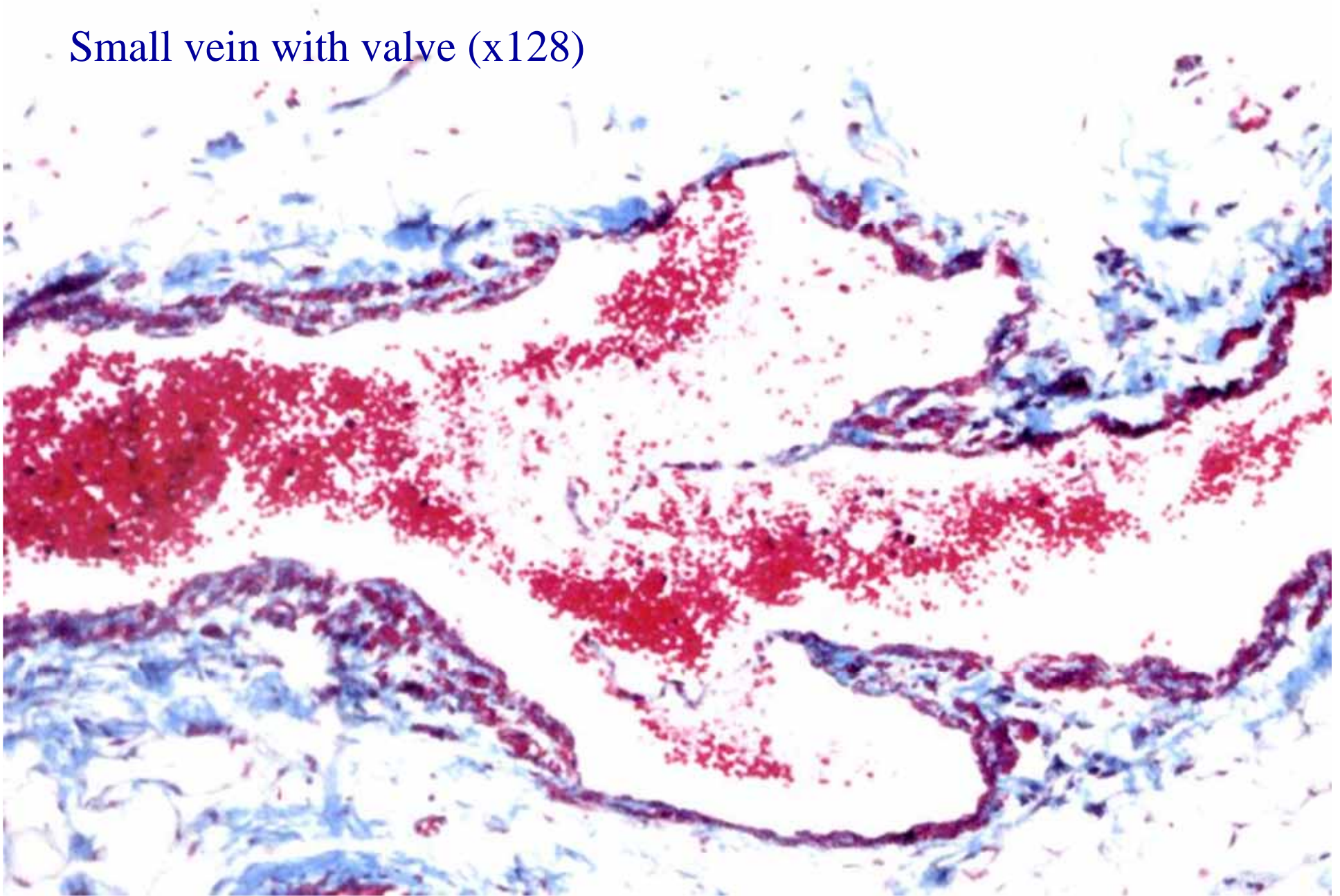


TABLE 11-2 Characteristics of Veins

| TYPE | TUNICA INTIMA | TUNICA MEDIA | TUNICA ADVENTITIA |
|------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Large veins | Endothelium; basal lamina, valves in some; subendothelial connective tissue | Connective tissue; smooth muscle cells | Smooth muscle cells oriented in longitudinal bundles; cardiac muscle cells near their entry into the heart; collagen layers with fibroblasts |
| Medium and small veins | Endothelium, basal lamina; valves in some; subendothelial connective tissue | Reticular and elastic fibers, some smooth muscle cells | Collagen layers with fibroblasts |
| Venules | Endothelium, basal lamina (pericytes, postcapillary venules) | Sparse connective tissue and a few smooth muscle cells | Some collagen and a few fibroblasts |

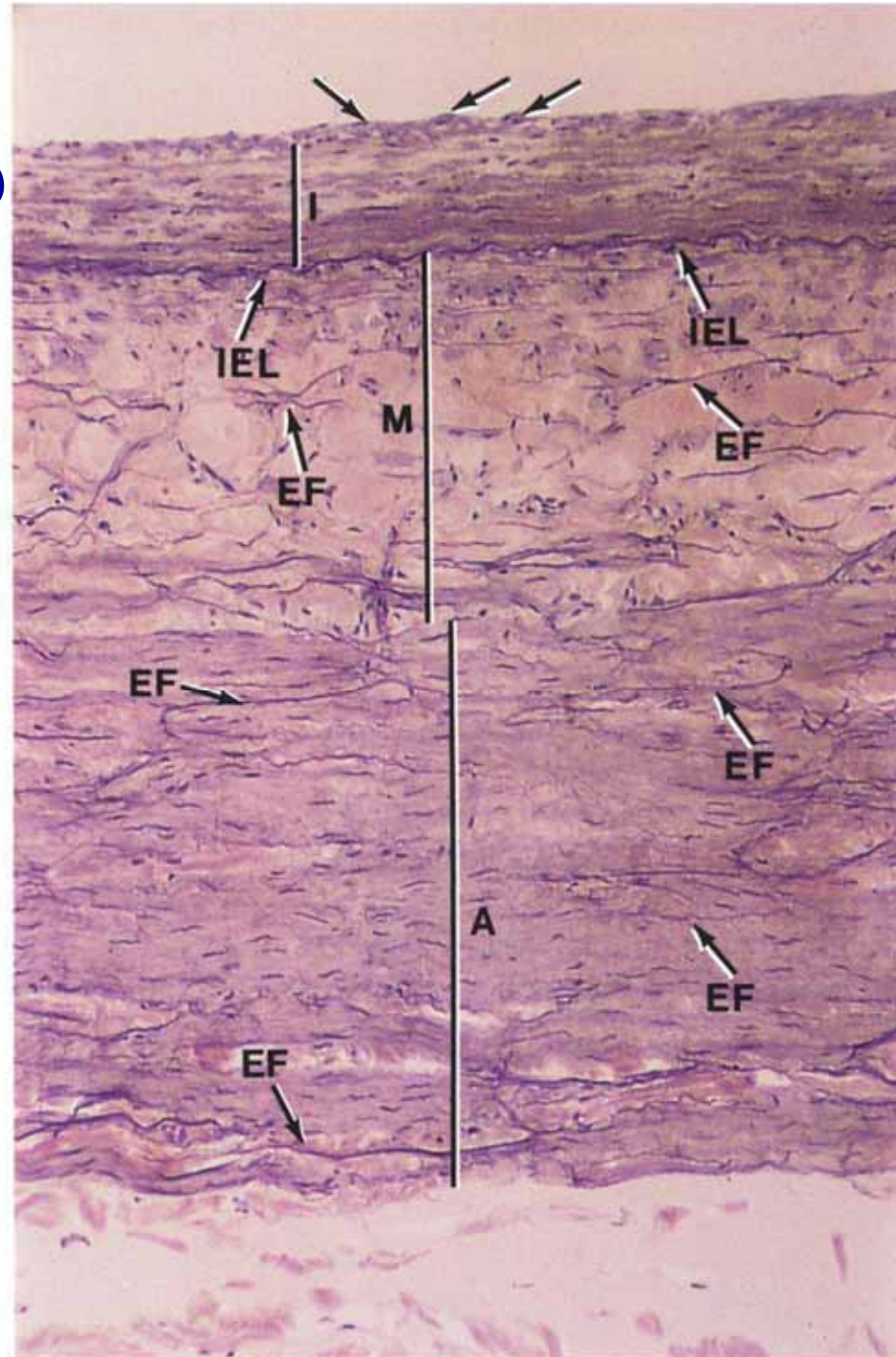
Large Veins

- Major veins, including the vena cava, pulmonary, portal, renal, jugular veins.
- T.intima – typical endothelium and reticular fibres, may have elastic fibres present (IEL present), thicker subendothelial CT layer compared to medium veins (fibroblasts and a network of elastic fibres).
- T.media – absent? in most large veins, excluding pulmonary and some larger veins in the legs. These have a well defined SMC layer. The other veins have a well defined T.adventitia in place of the T.media.

Large Veins

- T.adventitia – contains many elastic and collagen fibres, and usually a vasa vasorum present.
- Inferior vena cava has SMCs (longitudinal) present in the T.adventitia .
- Pulmonary veins and vena cava may have cardiac muscle present in the T.adventitia (near the heart)

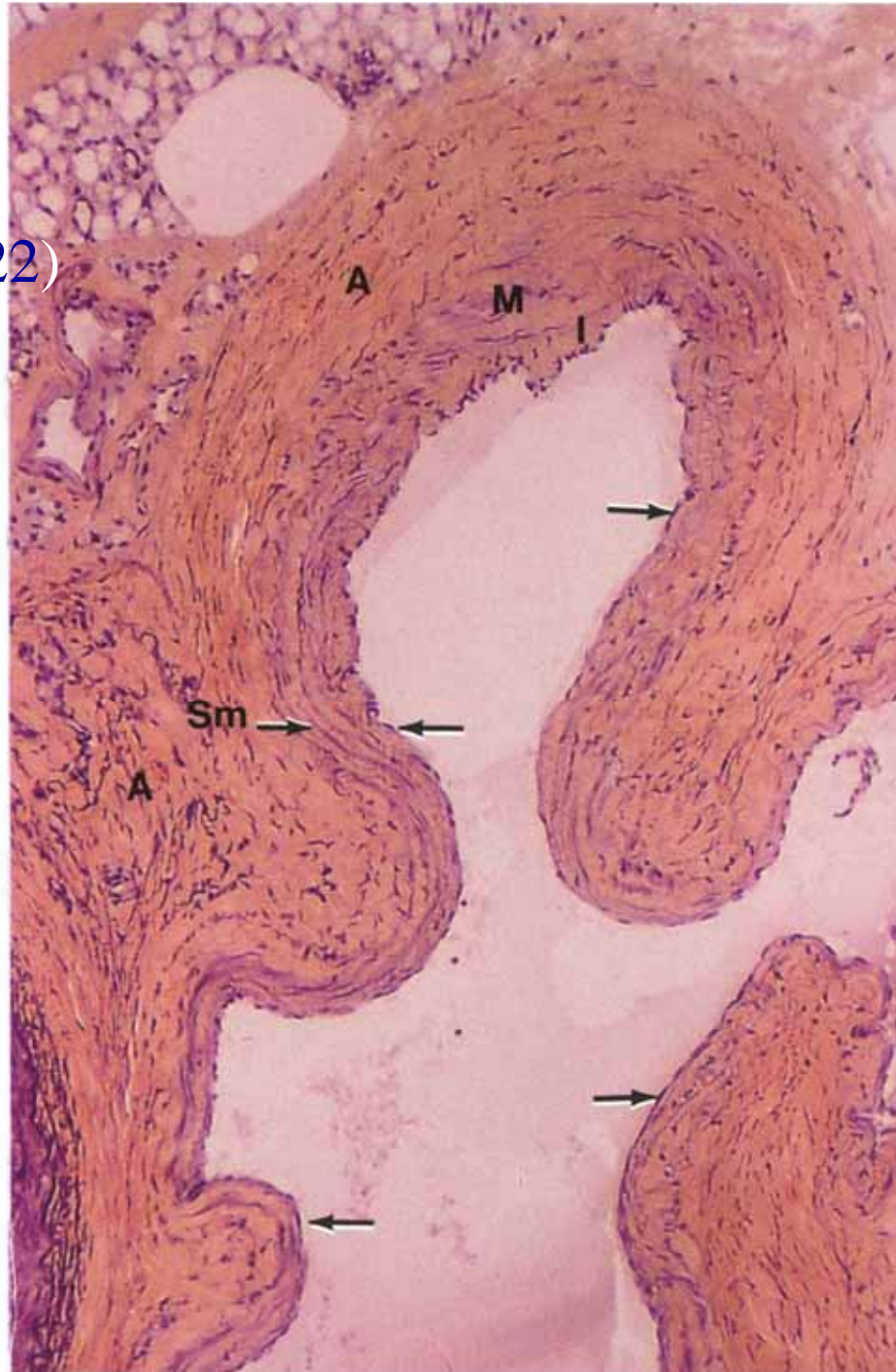
Vena cava (x122)



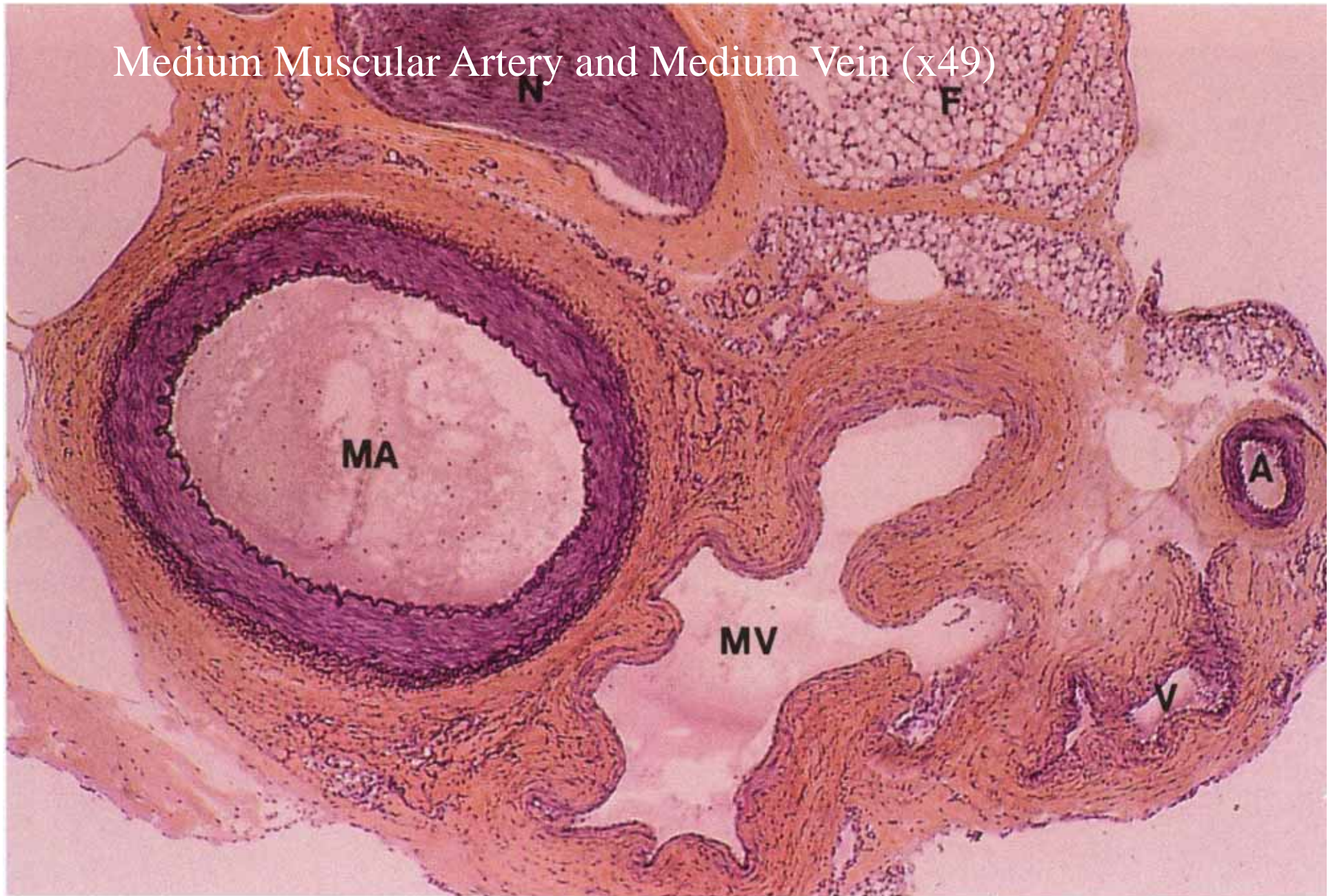
Medium Veins (< 1cm)

- T.intima – typical endothelium and reticular fibres. No IEL, but may have elastic fibres present.
- T.media – SMCs loosely organized interwoven with collagen and fibroblasts.
- T.Adventitia – thickest of the tunics – longitudinally arranged collagen and elastic fibres with a few SMCs.

Medium Vein (x122)



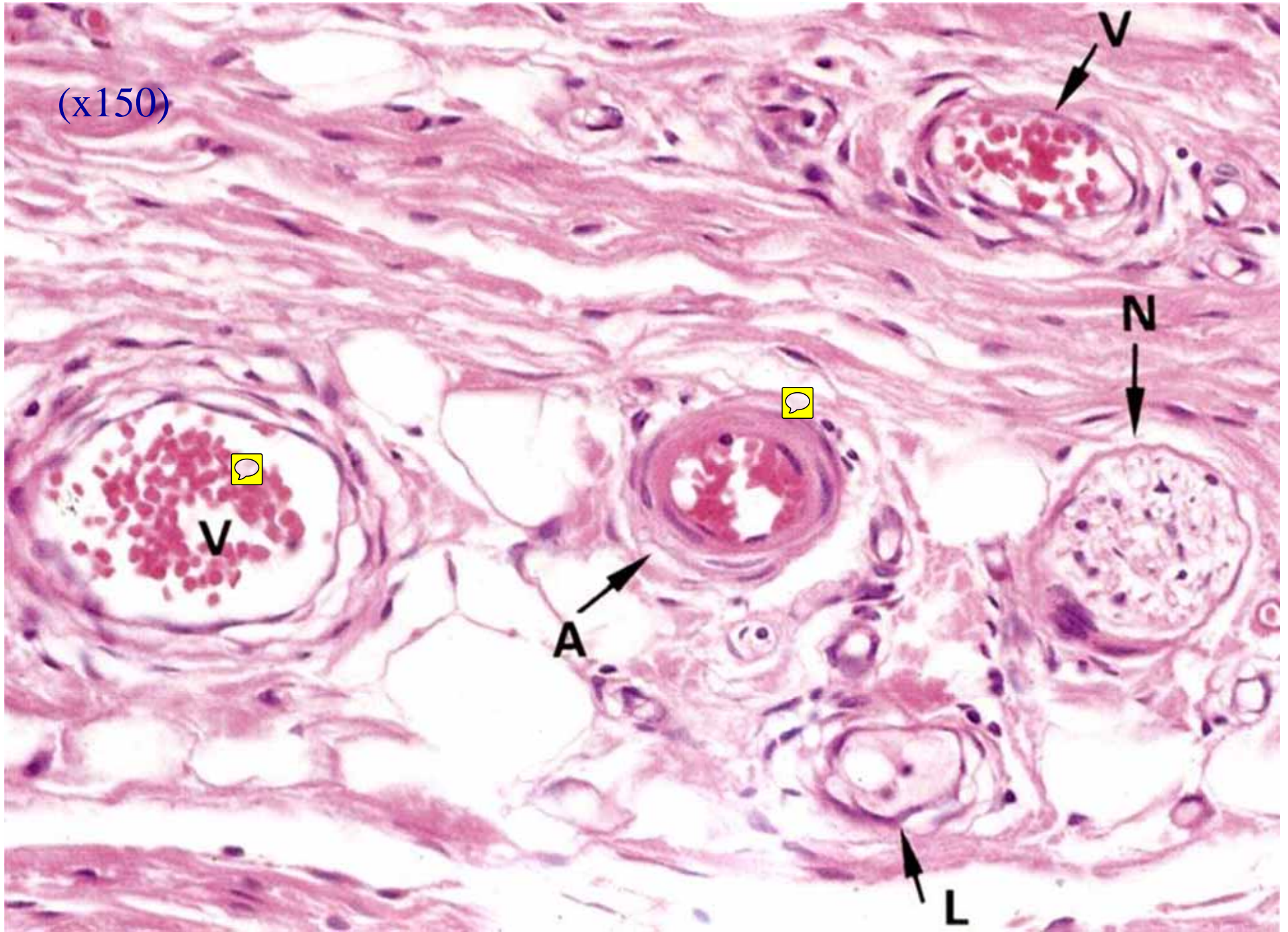
Medium Muscular Artery and Medium Vein (x49)



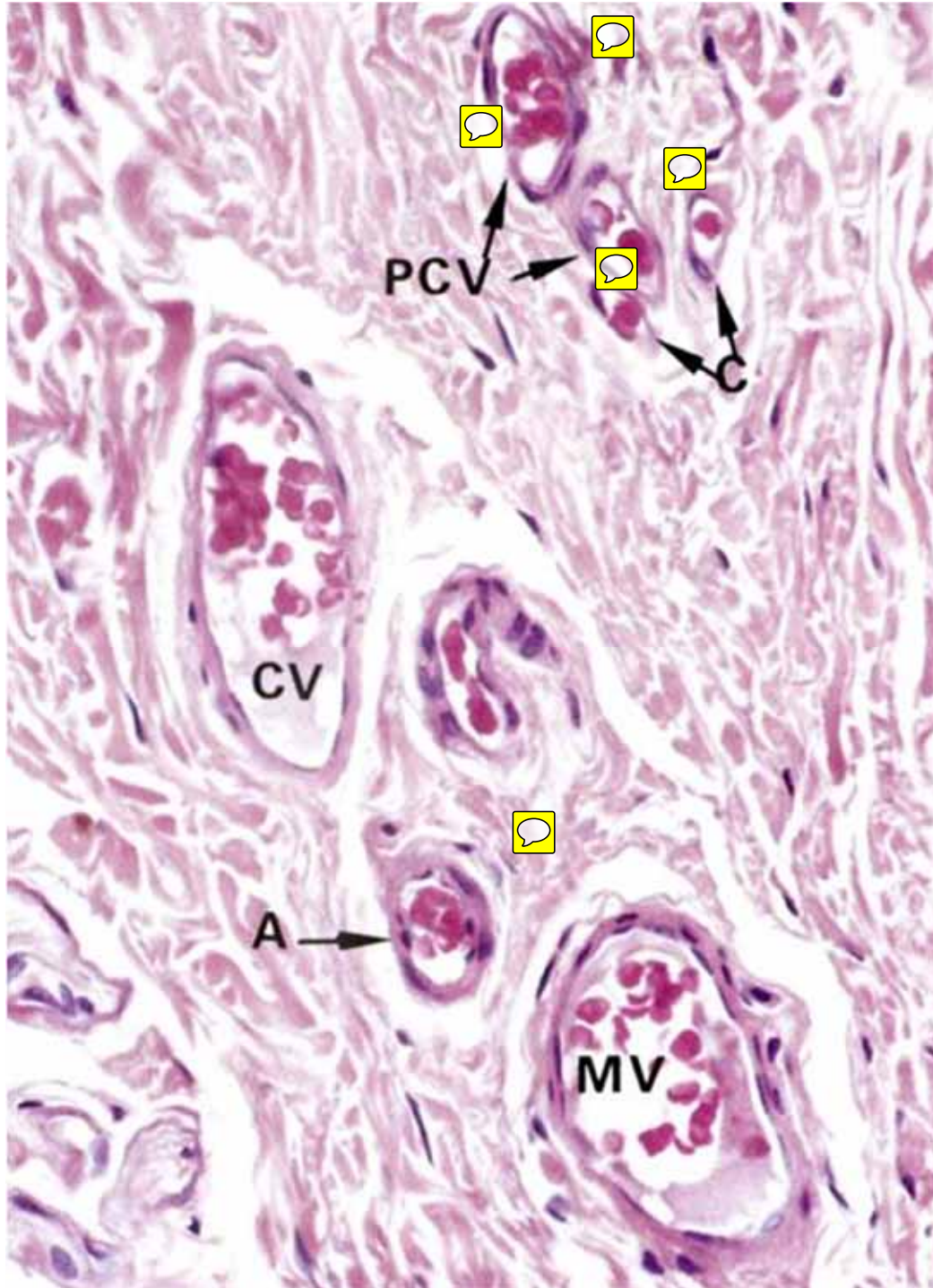
Venules and Small Veins

- Structure similar to capillaries – thin endothelium surrounded by reticular fibres and pericytes.
- Material exchange takes place in the capillaries and in the postcapillary venules (very permeable walls) – preferred location for the emigration of leukocytes into the CT proper

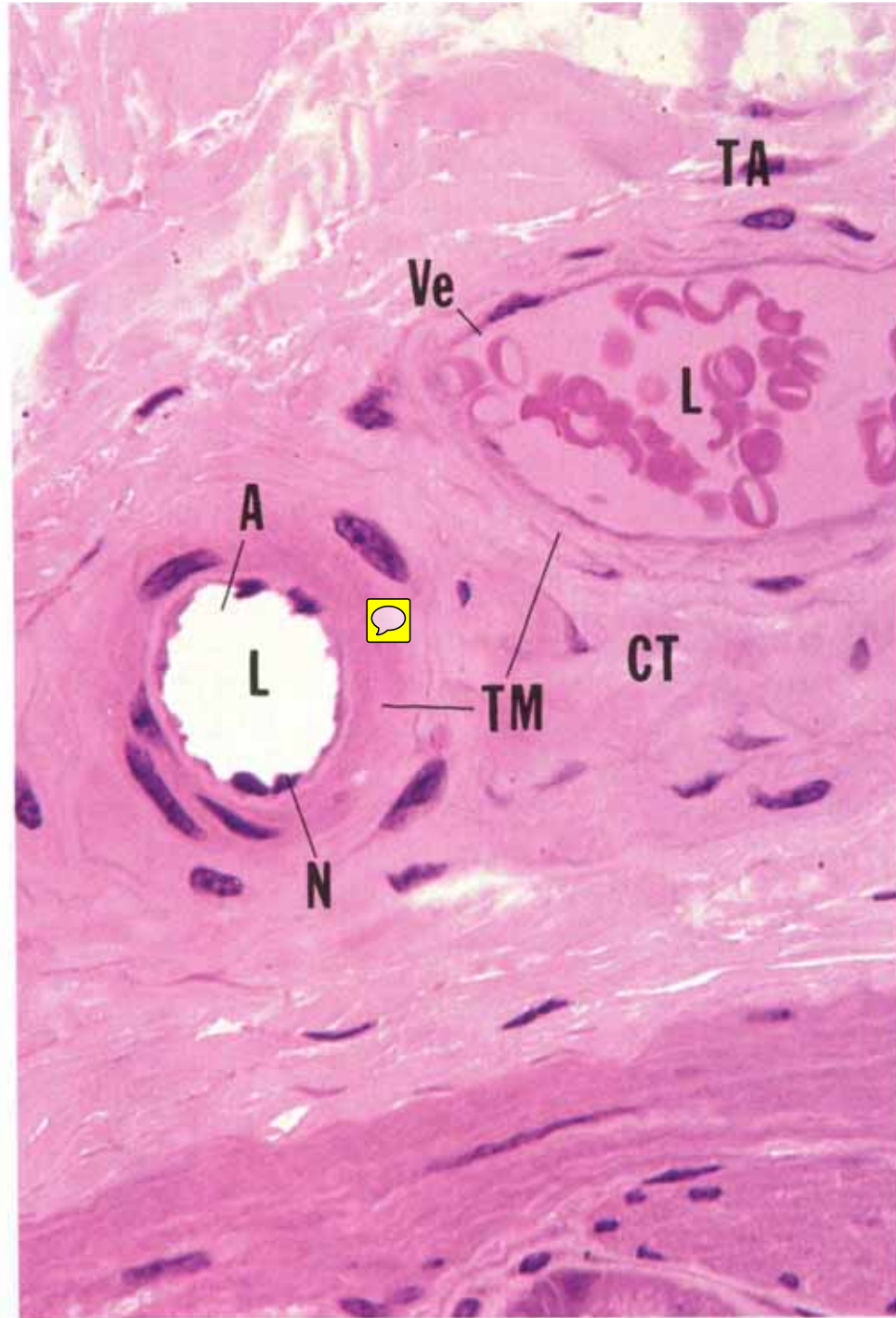
(x150)



(x480)



(x540)



lec exam will have
everything UP TO
CAP

Capillaries

- Arise from the terminal ends of the arterioles.
- Form a highly branched network between the arterioles and venules.
- Three types of capillaries:
 - Continuous
 - Fenestrated
 - sinusoidal or sinusoids

General Capillary Structure

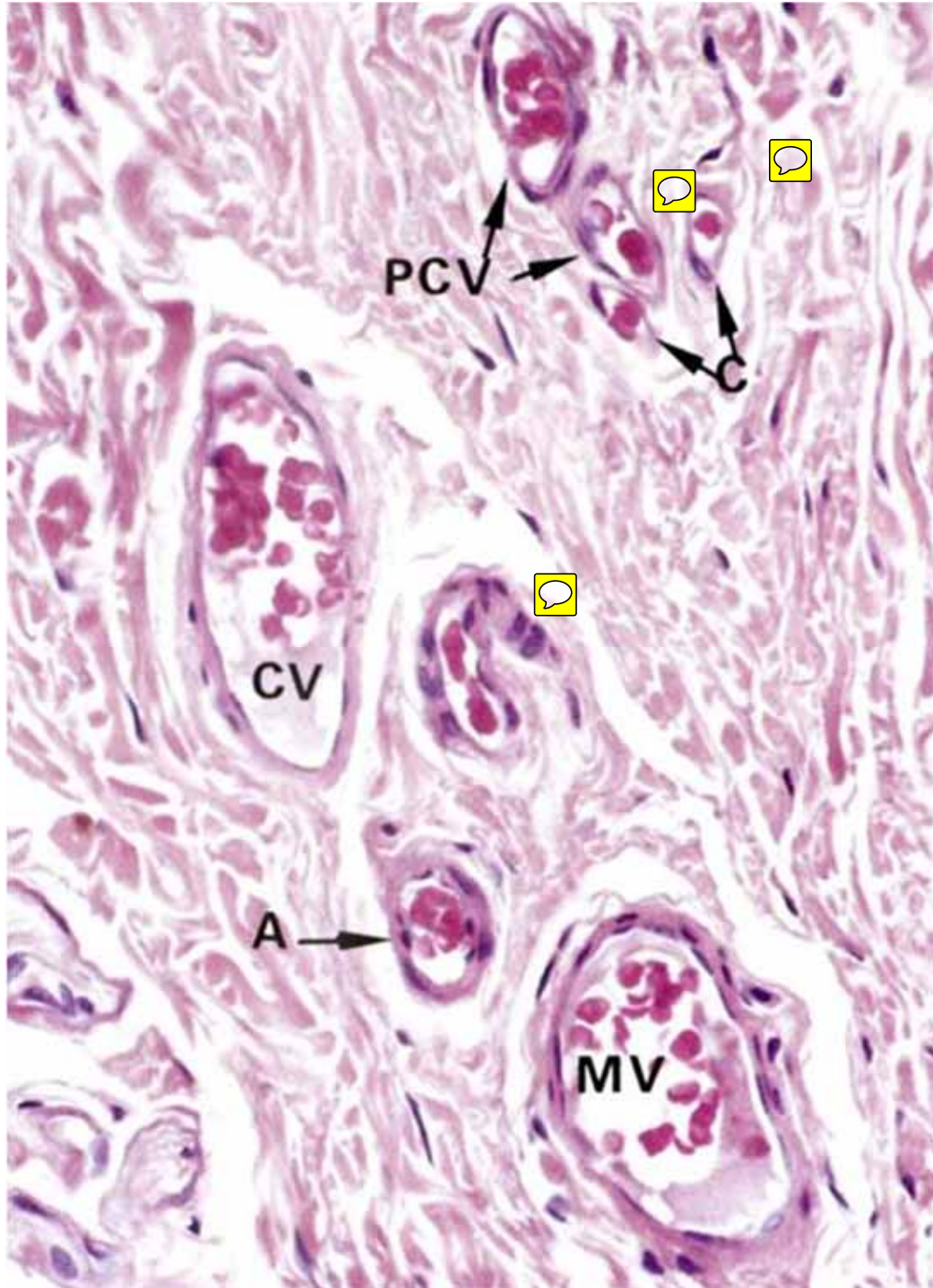
look at other
vessels and in
terms of size to ID
s

- Usually short, ranging from 0.25 μm to 1 mm (in muscle), but an average diameter of 7 μm is typical.
- Single layer of squamous endothelial cells, flattened, and the nucleus may bulge into the lumen. Rolled into a tube.
- Pericytes located along the outside of capillaries – surrounds them.

esp seen in
fenestrated and c

help adjust
pressure

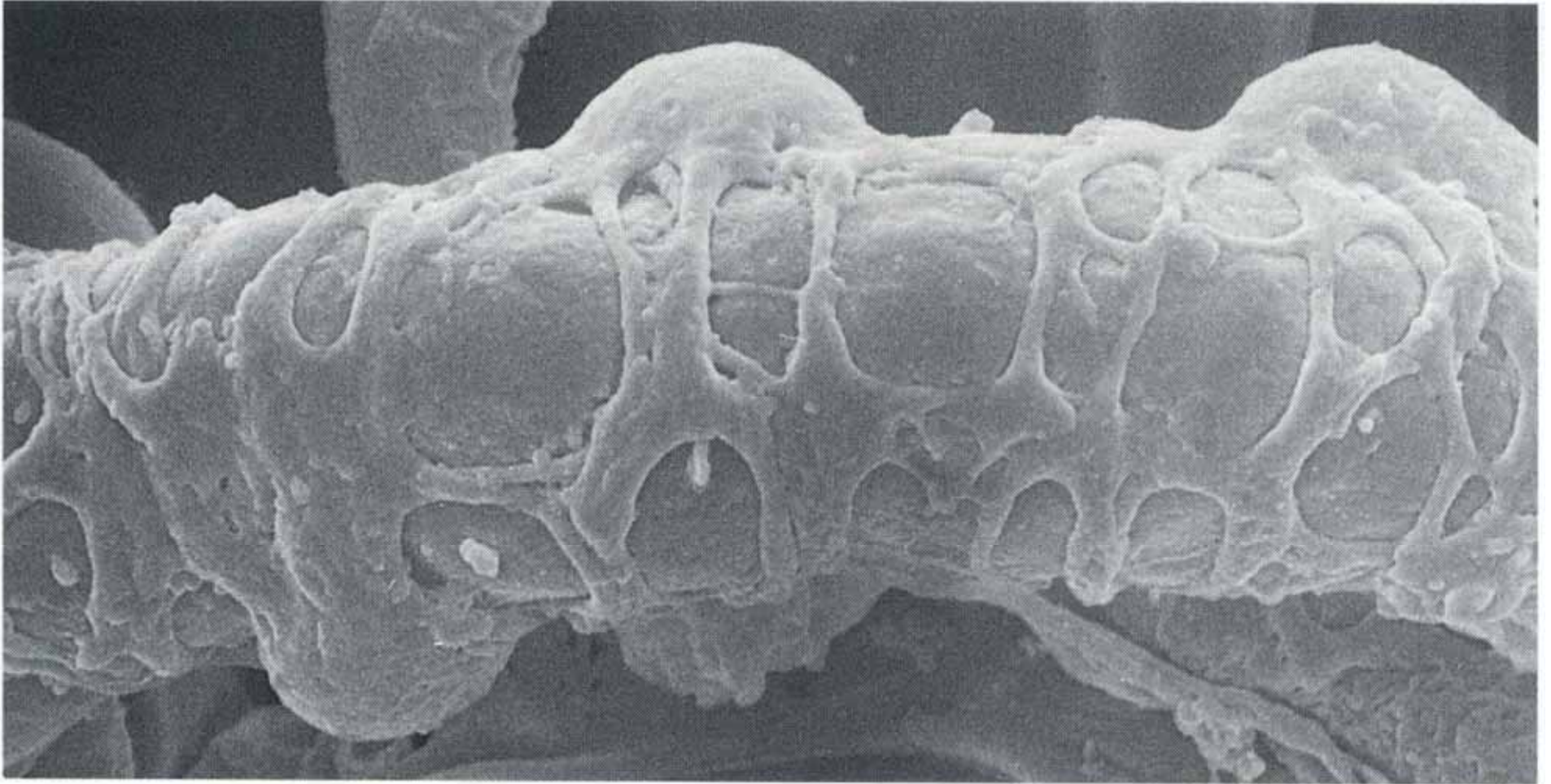
(x480)



Pericytes

- Derived from undifferentiated mesenchymal cells.
- Posses characteristics of both SMC and endothelial cells (differentiate into them?).
- Long processes that surround the capillaries and may form gap junctions with endothelial cells.
- Contain isomyosin, contraction?, may play a role in blood flow regulation.

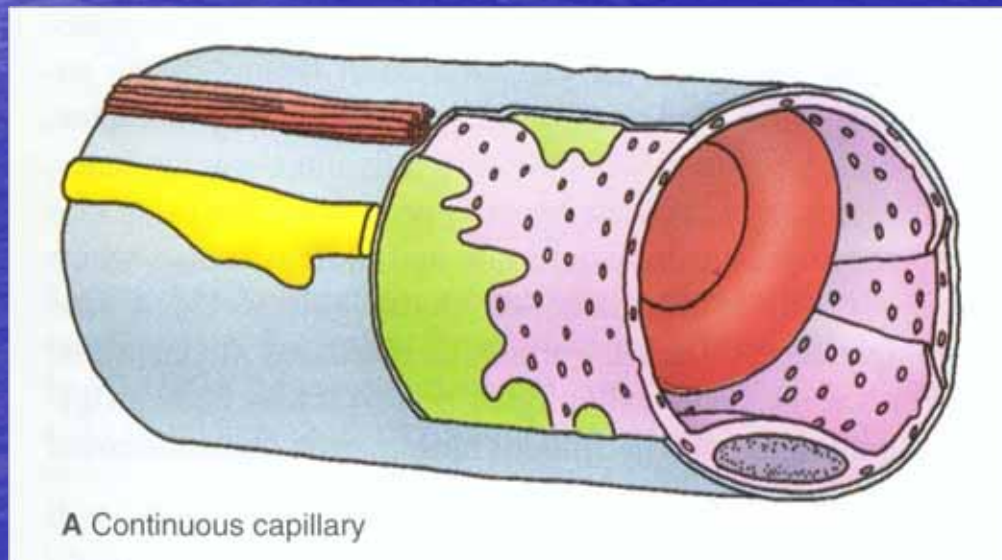
Pericytes (x5,000)



Continuous Capillaries

type located in
blood brain barrier,
O₂ diffuses easily
others not so much

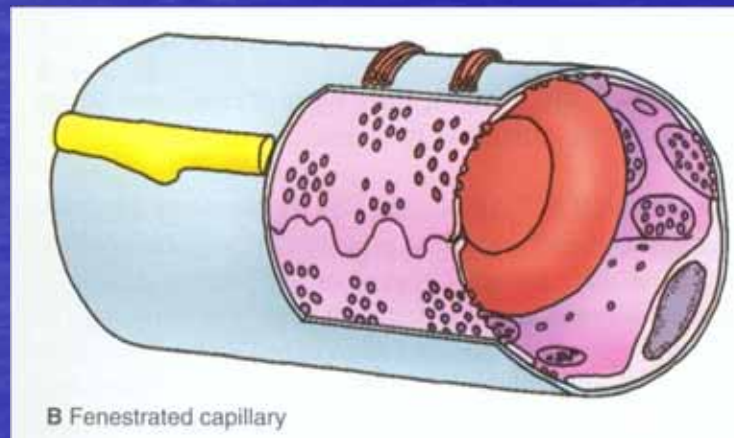
- No interruptions or pores (fenestrae) in their walls.
- Found in muscle, nervous, and connective tissue.



Fenestrated Capillaries

- Pores or fenestrae present in their walls.
- Pore size is ~ 60 to 80 nm diameter.
- Located in the pancreas, intestinal mucosa, and endocrine glands.

located in areas of
absorption/
secretion



Sinusoidal Capillaries

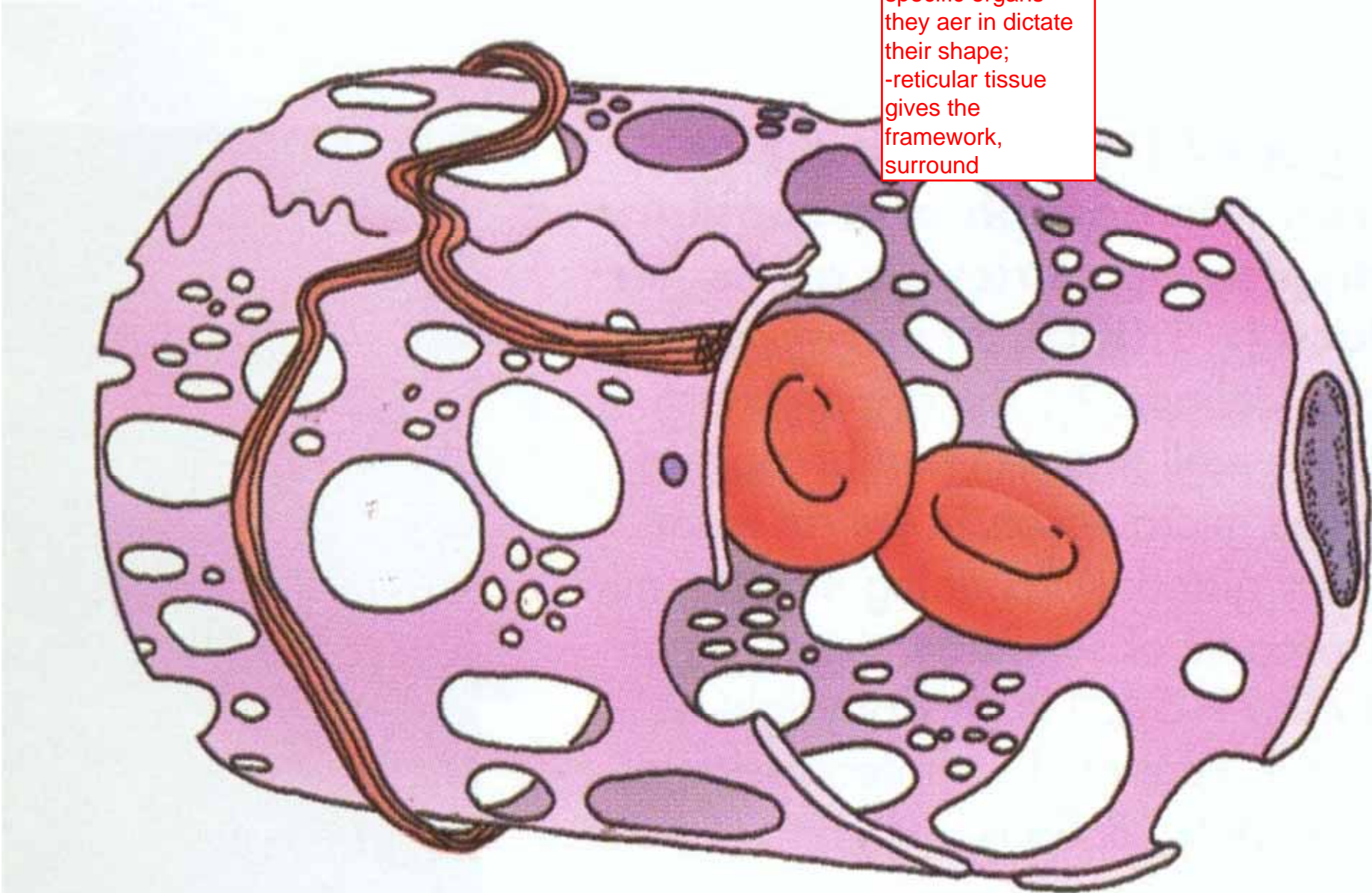
av capillary=8
microns, these
(sinu caps) can be
huge,

shape during dev

- “vascular channels” – irregular pools of blood or channels that conform to the shape of the structure in which they are located – dynamic.
- Pores or tiny holes; a discontinuous endothelial wall. Allows exchange between the blood and tissue. Usually associated with macrophages.
- Located in the liver, spleen, lymphoid organs, bone marrow and certain endocrine glands

simple squamous
endothelial cells

have retic tissue
arnd



specific organs
they are in dictate
their shape;
-reticular tissue
gives the
framework,
surround

C Sinusoidal (discontinuous) capillary

Lymphatic Vascular System

if you know what veins look like, you know what these look like...they are a weaker version of them

- Series of vessels designed to remove excess tissue fluid (lymph) from the interstitial spaces → return it to the cardiovascular system. to venous side
- Open system → no pump, no circulation of fluid. so what powers/drives the suction?
- Begins as lymphatic capillaries, which drains excess fluid into successively larger vessels → two lymphatic ducts.

Lymphatic Vascular System

what exactly are
the ducts?

- Two lymphatic ducts → lymph is returned to the venous system (junction of the internal jugular and the subclavian veins).
- Lymph nodes are located along the path of lymphatic vessels to filter the lymph (more next week).

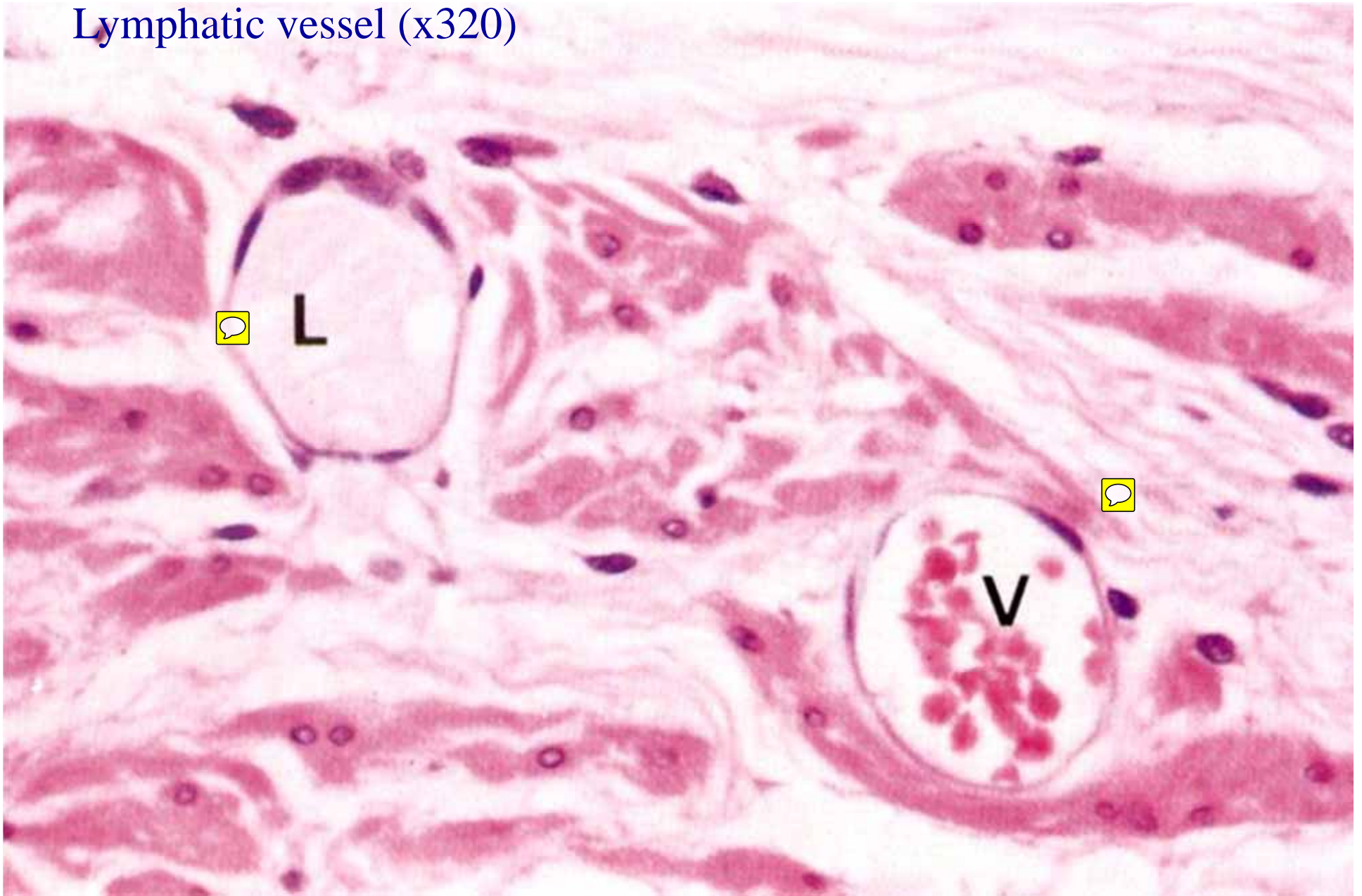
Lymphatic Vessels

- Lymphatic capillaries:
 - Single layer of endothelial cells with an incomplete basal lamina.
 - No pores, no tight junctions.
 - Have lymphatic anchoring filaments or bundles made of collagen fibres – helps to maintain vessel shape.

Lymphatic Vessels

- Small and Medium vessels
 - Characterized by the presence of valves (similar to veins).
 - Key – veins show RBCs, lymphatic vessels do not, but may show lymphocytes present.
- Large vessels – structurally resemble small veins – larger lumina and thinner walls – thin layer of elastic fibres below the endothelial layer and a thin layer of SMC → blends in with the surrounding CT. Very hard to distinguish the tunics in lymphatic vessels.

Lymphatic vessel (x320)



Lymphatic vessels with valve (x40)



larger the vessel,
the easier to tell
apart from a vein
-



Next week: Lymphatic tissue and
Lymph Nodes