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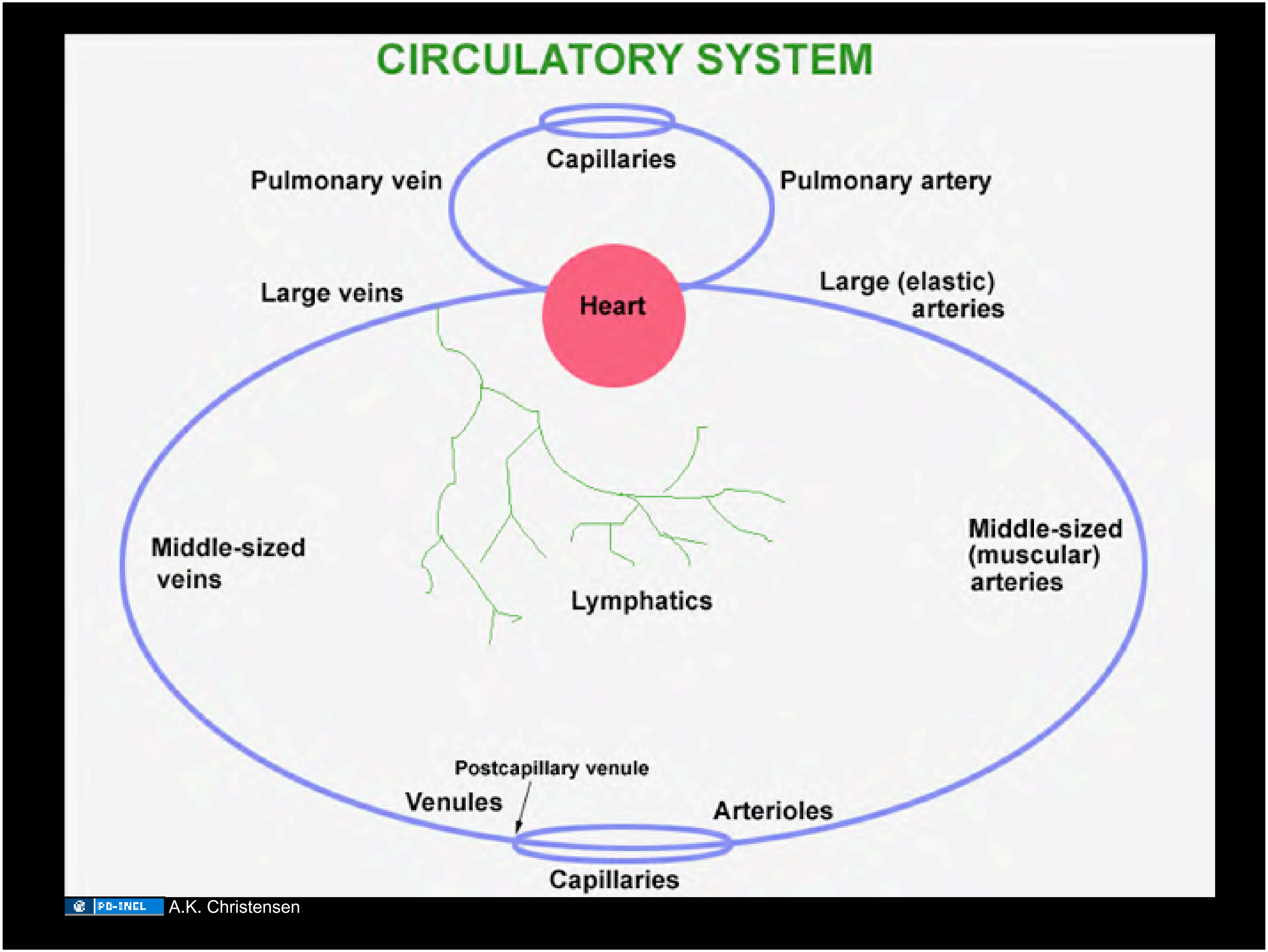
Histology of the Cardiovascular System

M1 – Cardiovascular/Respiratory Sequence

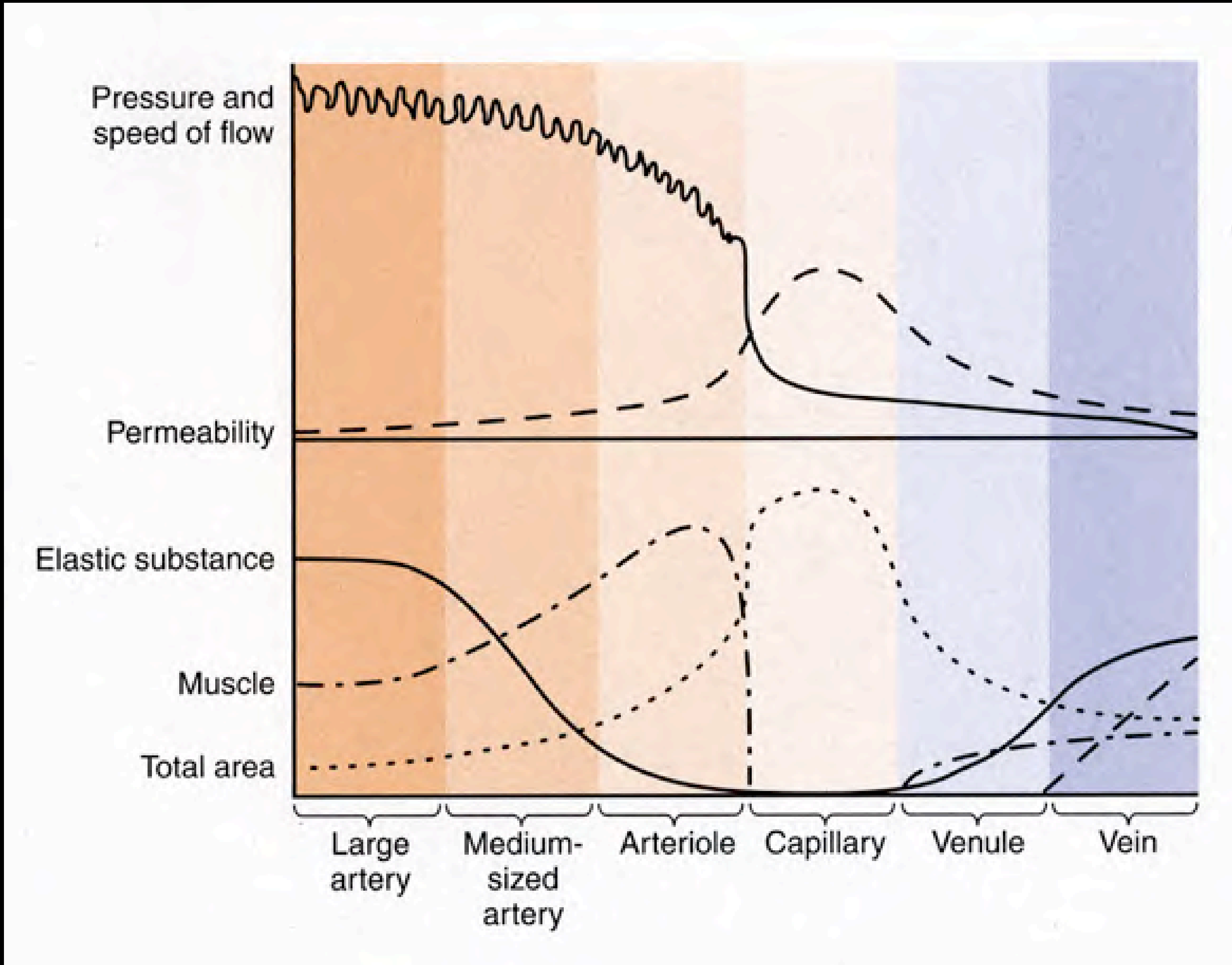
A. Kent Christensen, Ph.D.

Fall 2008

University of Michigan Medical School


CIRCULATORY SYSTEM
Capillaries
Pulmonary vein
Pulmonary artery
Heart
Large veins
Large (elastic) arteries
Middle-sized veins
Lymphatics
Middle-sized (muscular) arteries
Postcapillary venule
Venules
Arterioles
Capillaries
A.K. Christensen

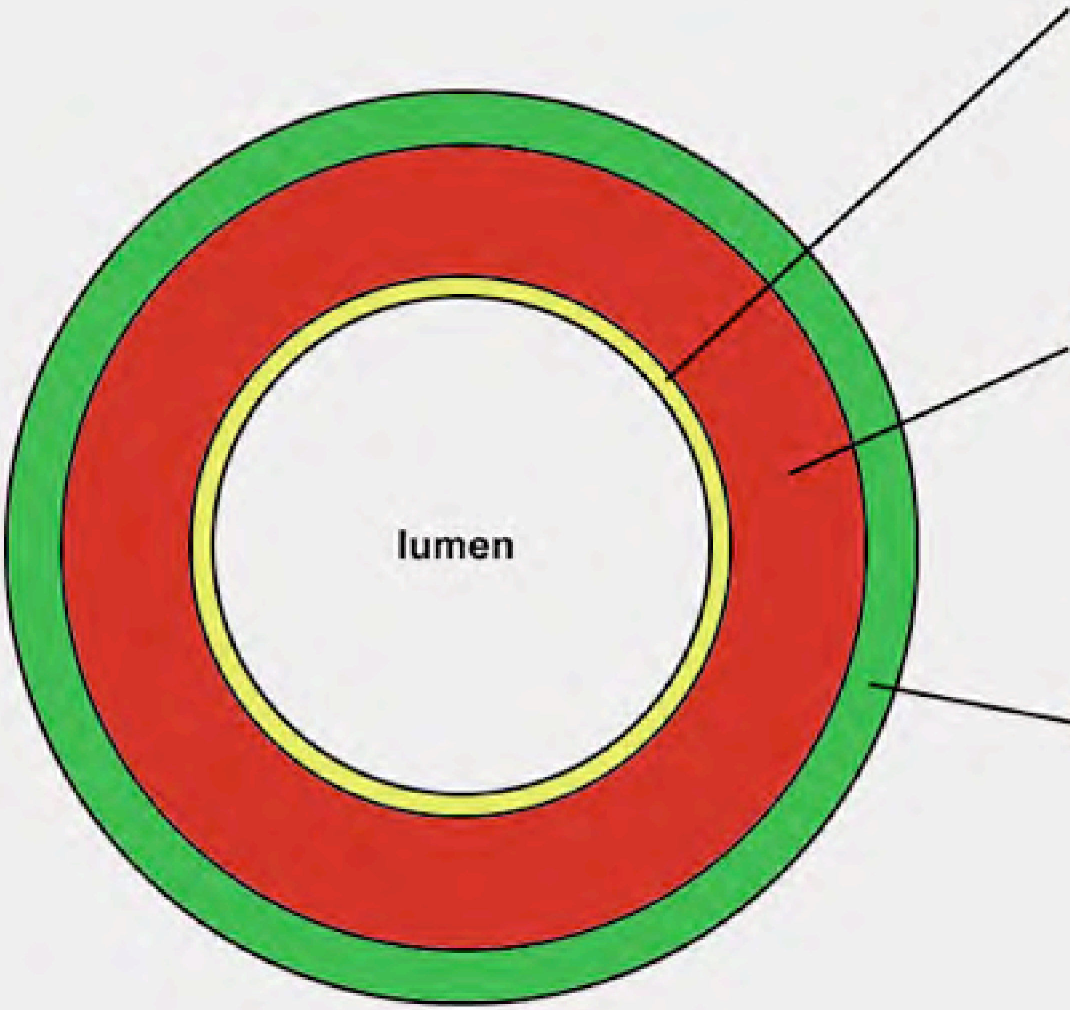
Comparing biophysical and structural characterists of vessels



PD-INEL Junqueira and Carneiro, 10th ed., 2003. page 225

Middle-sized (muscular) artery

Three layers of wall (”tunica” = “coat” in Latin)



Tunica intima

Endothelium + c.t.

Longitudinal orientation

Internal elastic lamina

Tunica media

Smooth muscle, to regulate blood flow

Circular orientation

(Ext. elastic lamina)

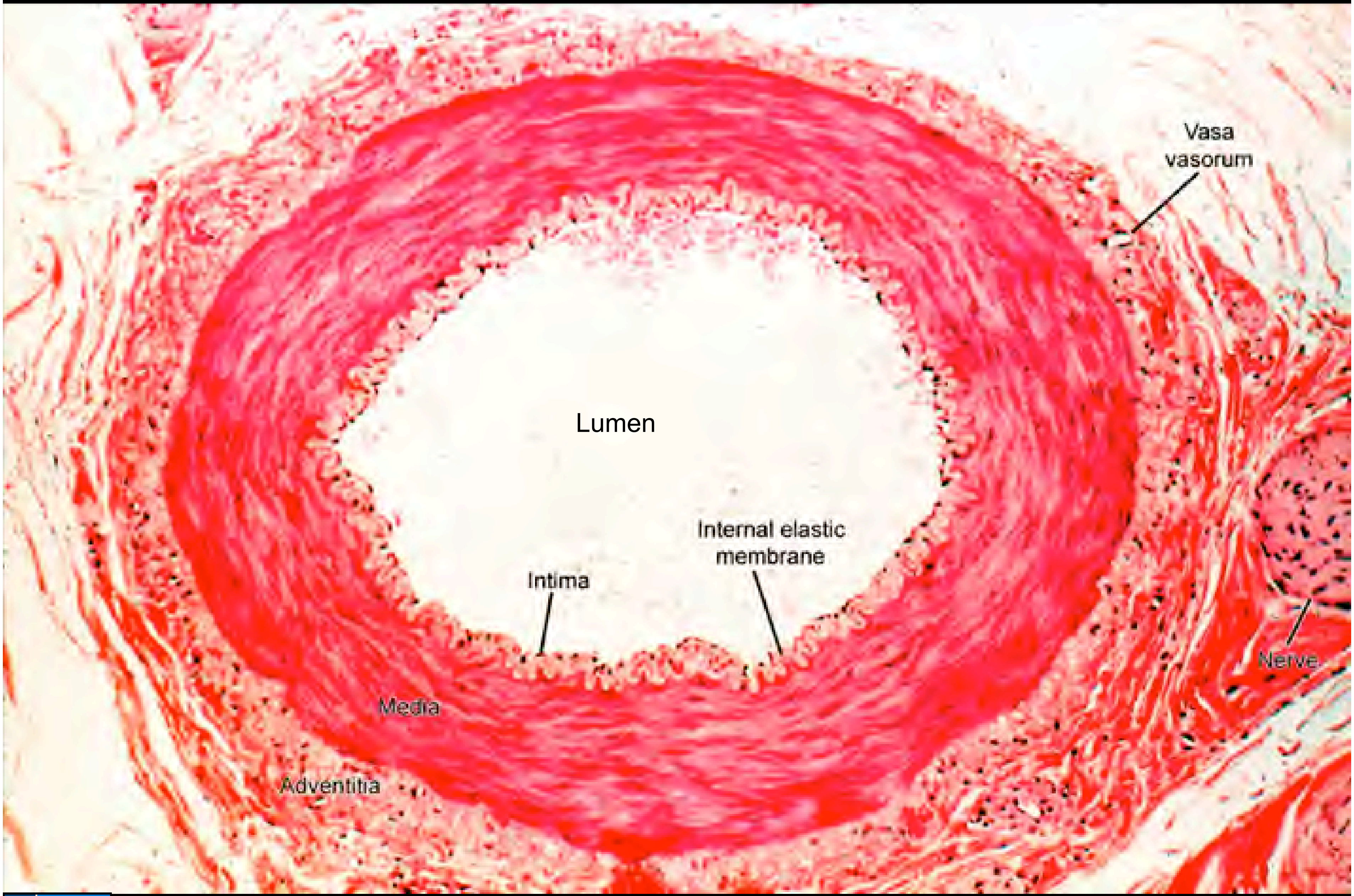
Tunica adventitia

Connective tissue sheath

Longitudinal orientation

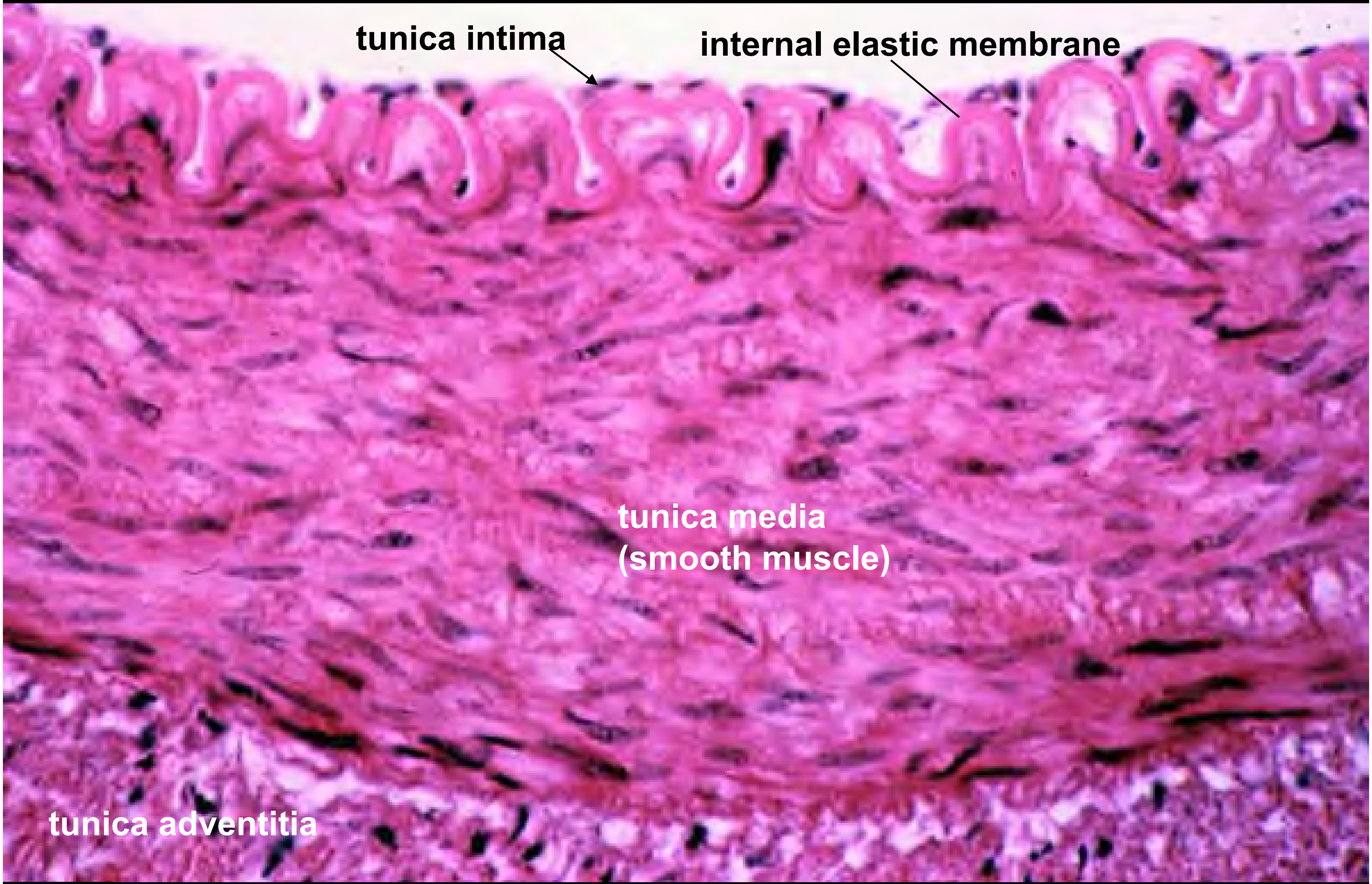
Vasa vasorum

Middle-sized artery, LM



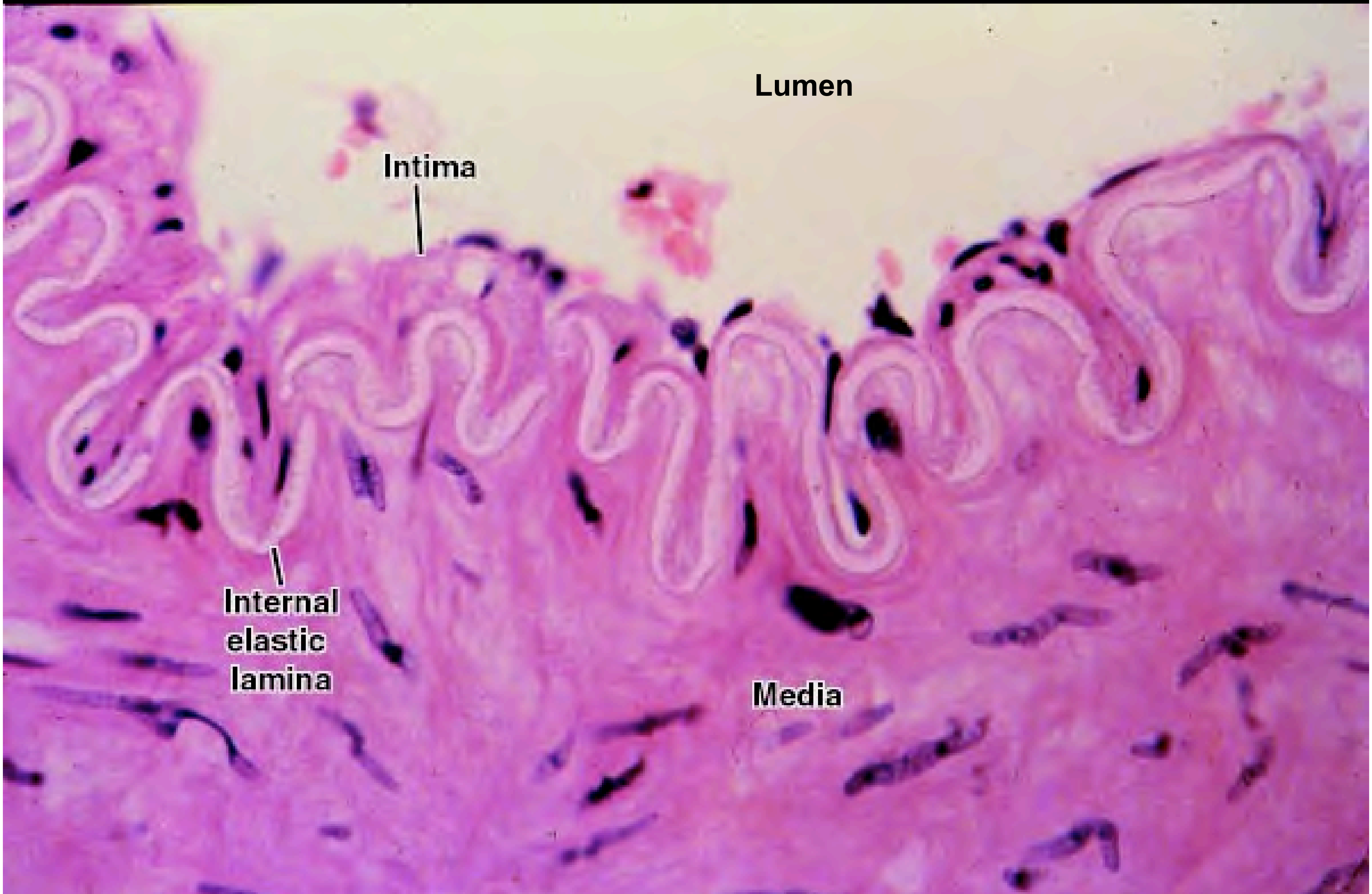
Humio Mizoguti, Kobe Univ Sch Med, slide 255

Artery wall, LM



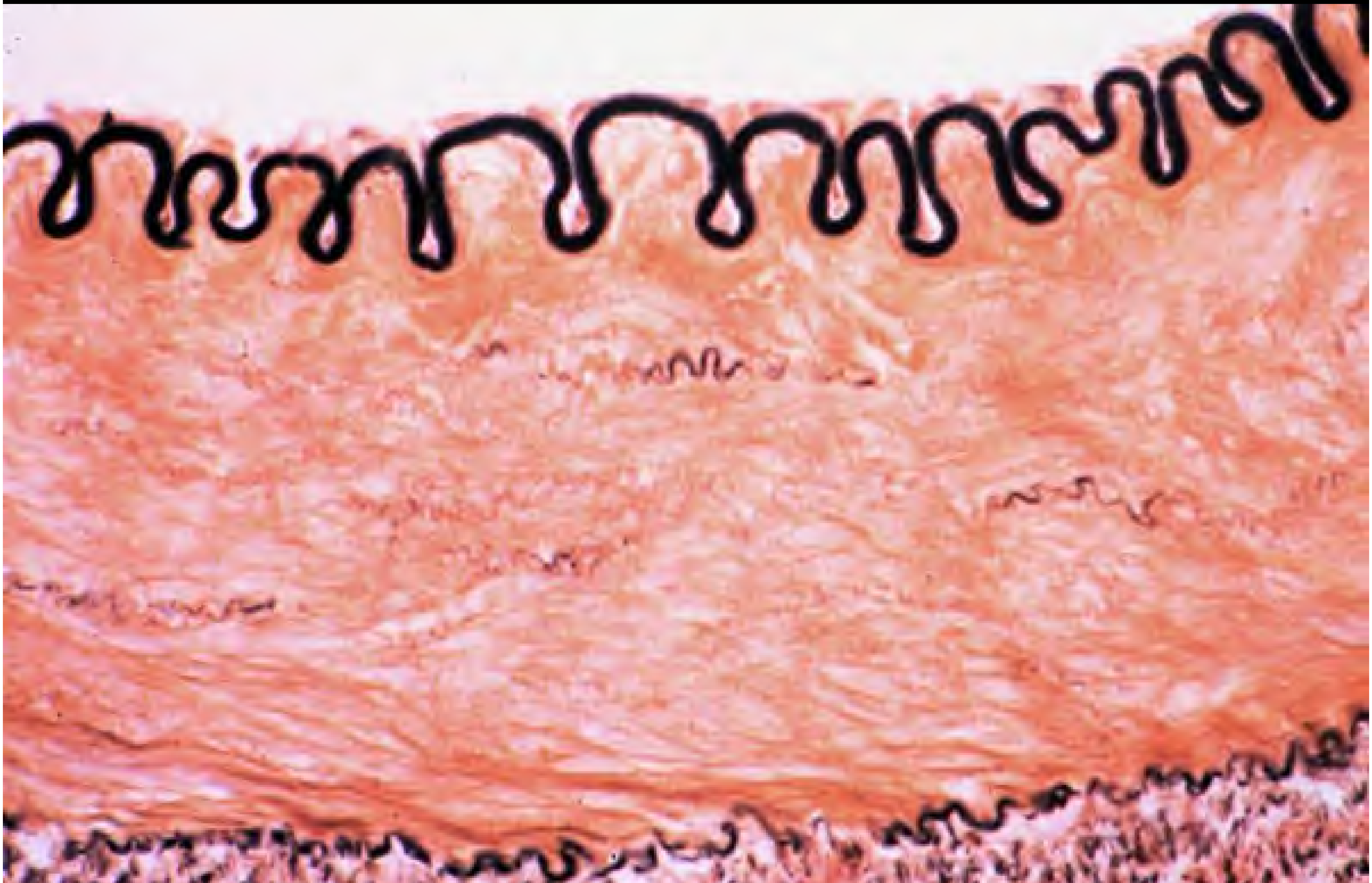
PD-INCL Erlandsen slide set, slide MH-6/C/8

Intima and media, LM



Erlandsen slide set, slide MH-6/C/9

Wall of middle-sized artery, elastin stain, LM



Erlandsen slide set, slide MH-6/D/1

Femoral artery wall, stained for elastin, LM

PD-INCL Humio Mizoguti, Kobe Univ Sch Med, slide 245

Thickening of the tunica intima

Arteriosclerosis (normal aging changes)
Fibrosis, elastic fragmentation

Atherosclerosis (pathological)
Eccentric fibrous thickening, foam cells, lipid deposition, calcification.

Arteriosclerosis. Aortic wall of 62-year-old man. Fibrous intimal thickening, within normal range. Van Gieson's elastic stain.

Sternberg 1992, Histology for Pathologists, p. 196.

Fragmentation of internal elastic membrane, LM

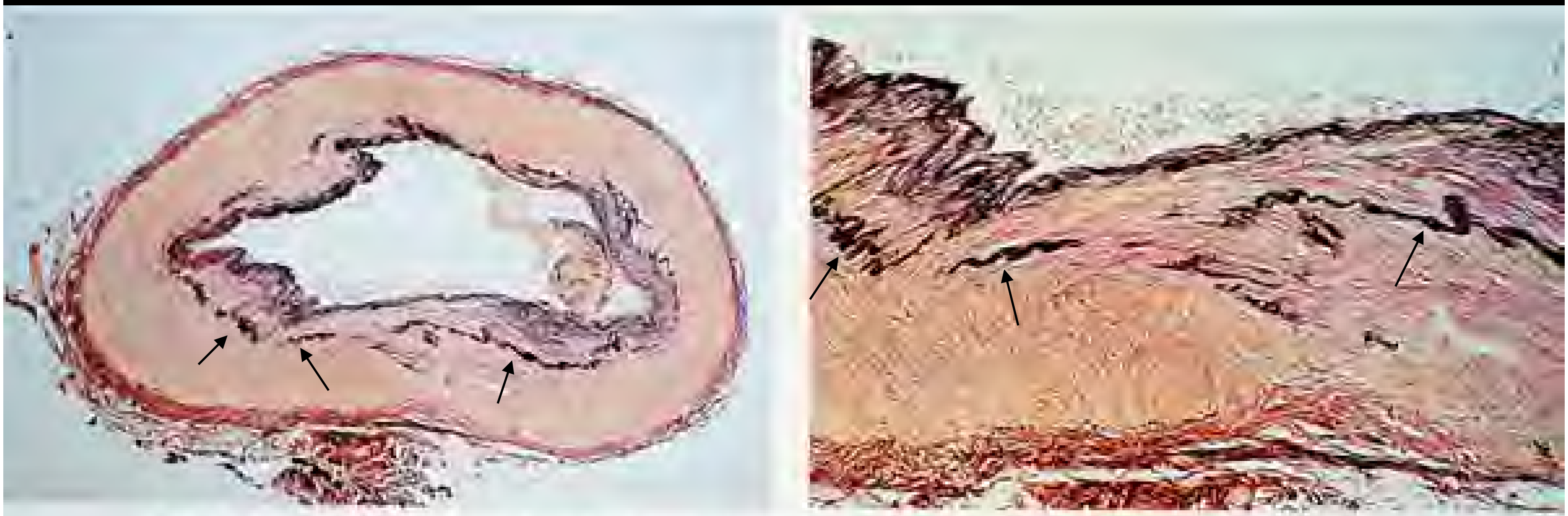
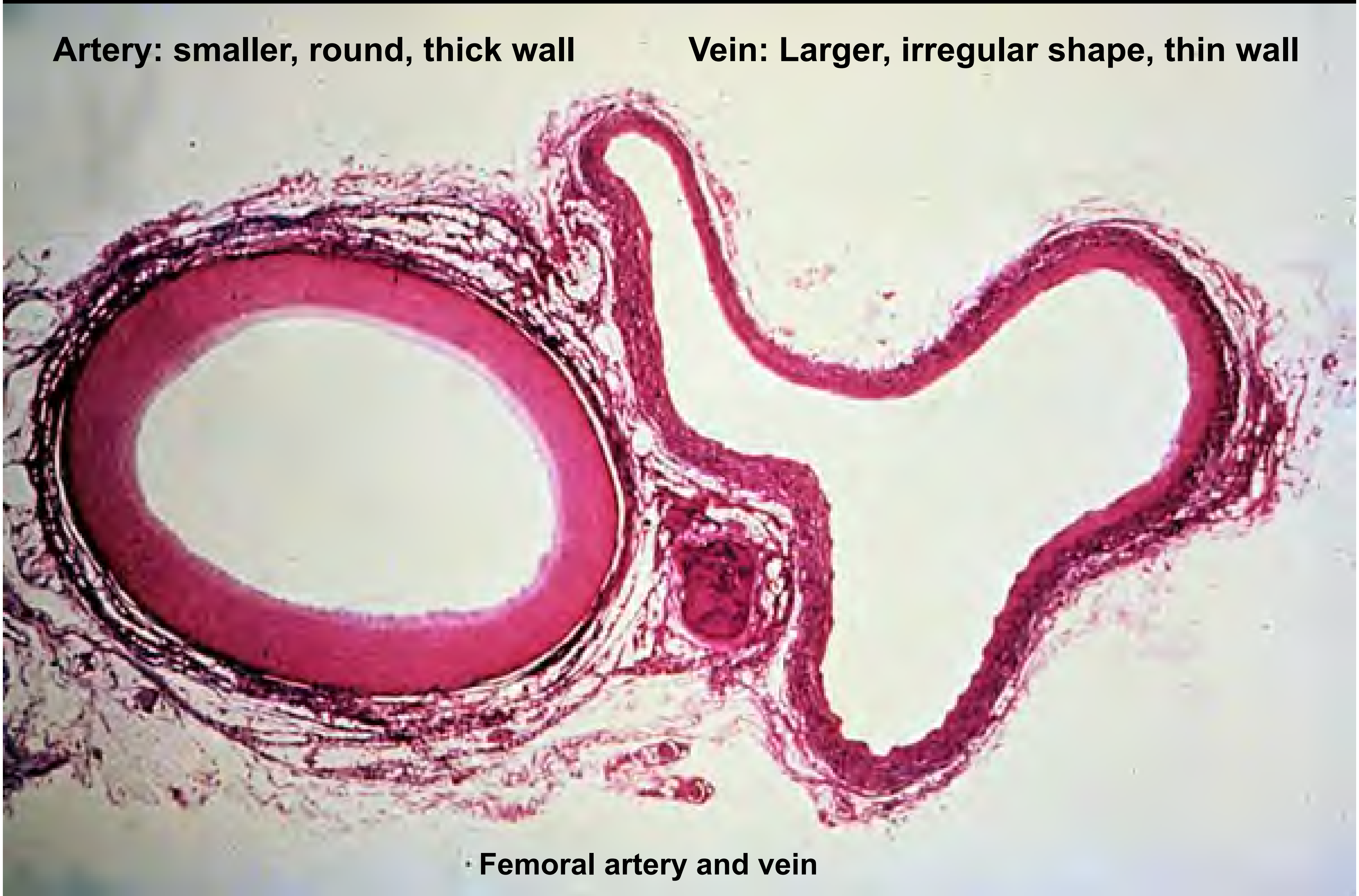


FIG. 4. A,B: Temporal artery from a 72-year-old female who died suddenly from coronary heart disease. There was no past history of headache or temporal arteritis. Note the fragmentation of the elastic lamella with a little associated fibrosis (*red* coloration in **B**). Changes such as these are commonplace in the elderly and must not be interpreted as evidence of previous arteritis. (Elastic van Gieson).

 Sternberg 1992, Histology for Pathologists, p. 198.

Comparison of companion artery and vein



Compare histology of artery and vein

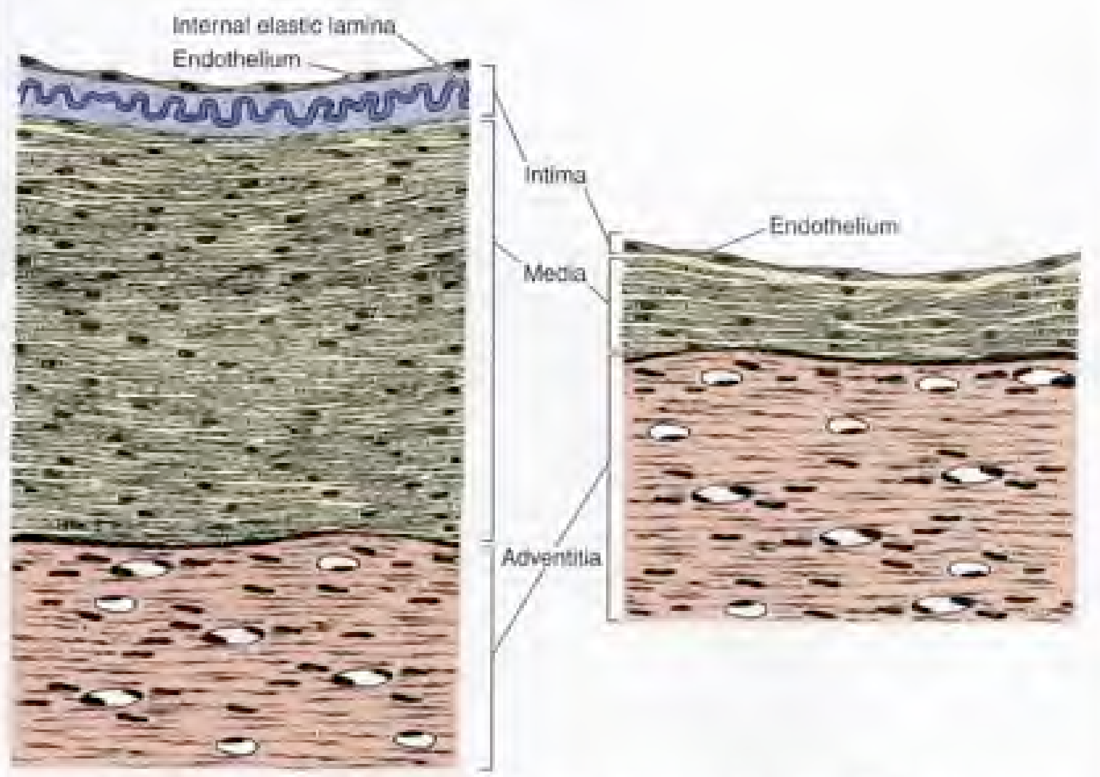
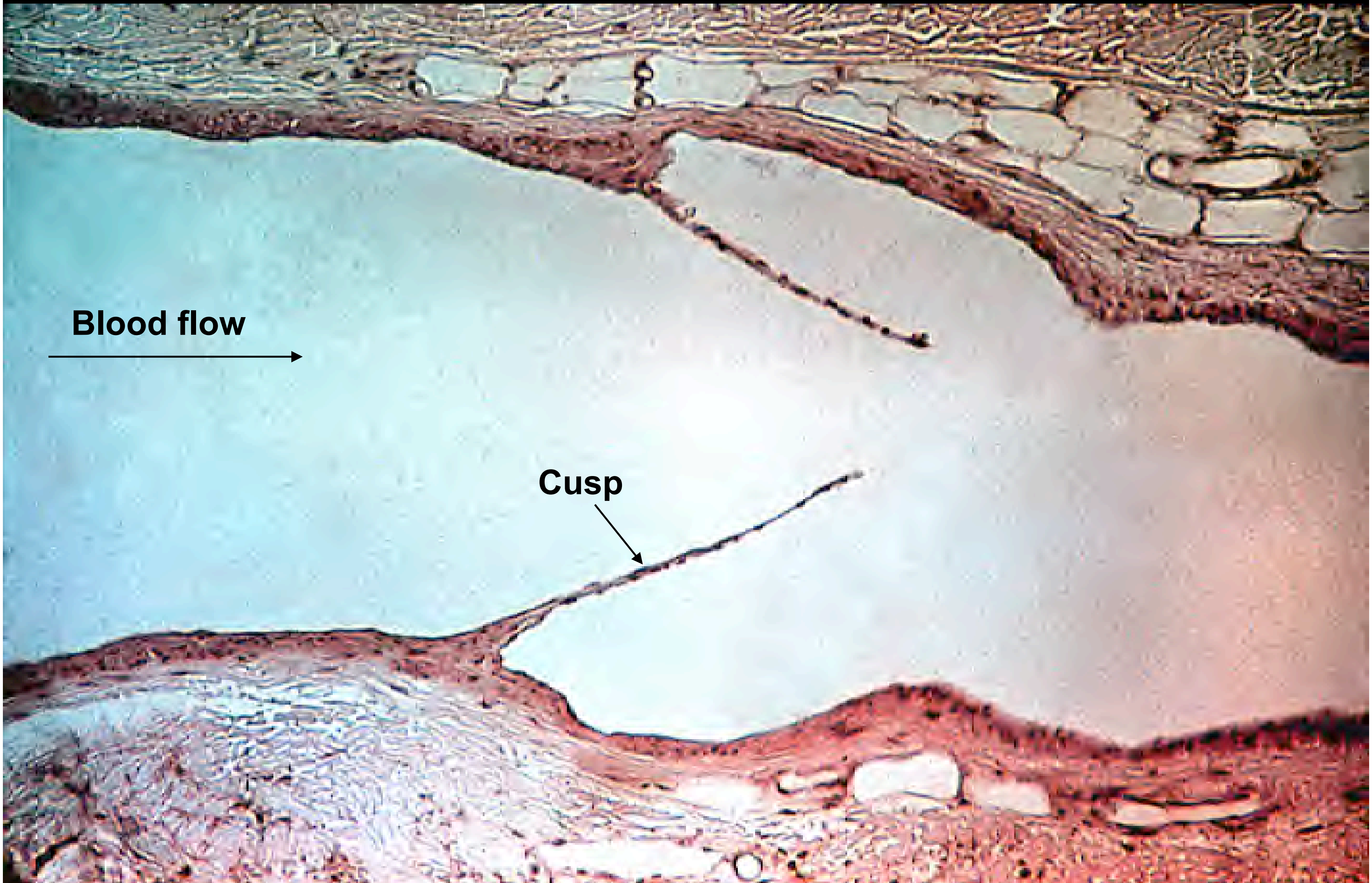


Figure 11–18. Diagram comparing the structure of a muscular artery (**left**) and accompanying vein (**right**). Note that the tunica intima and the tunica media are highly developed in the artery but not in the vein.

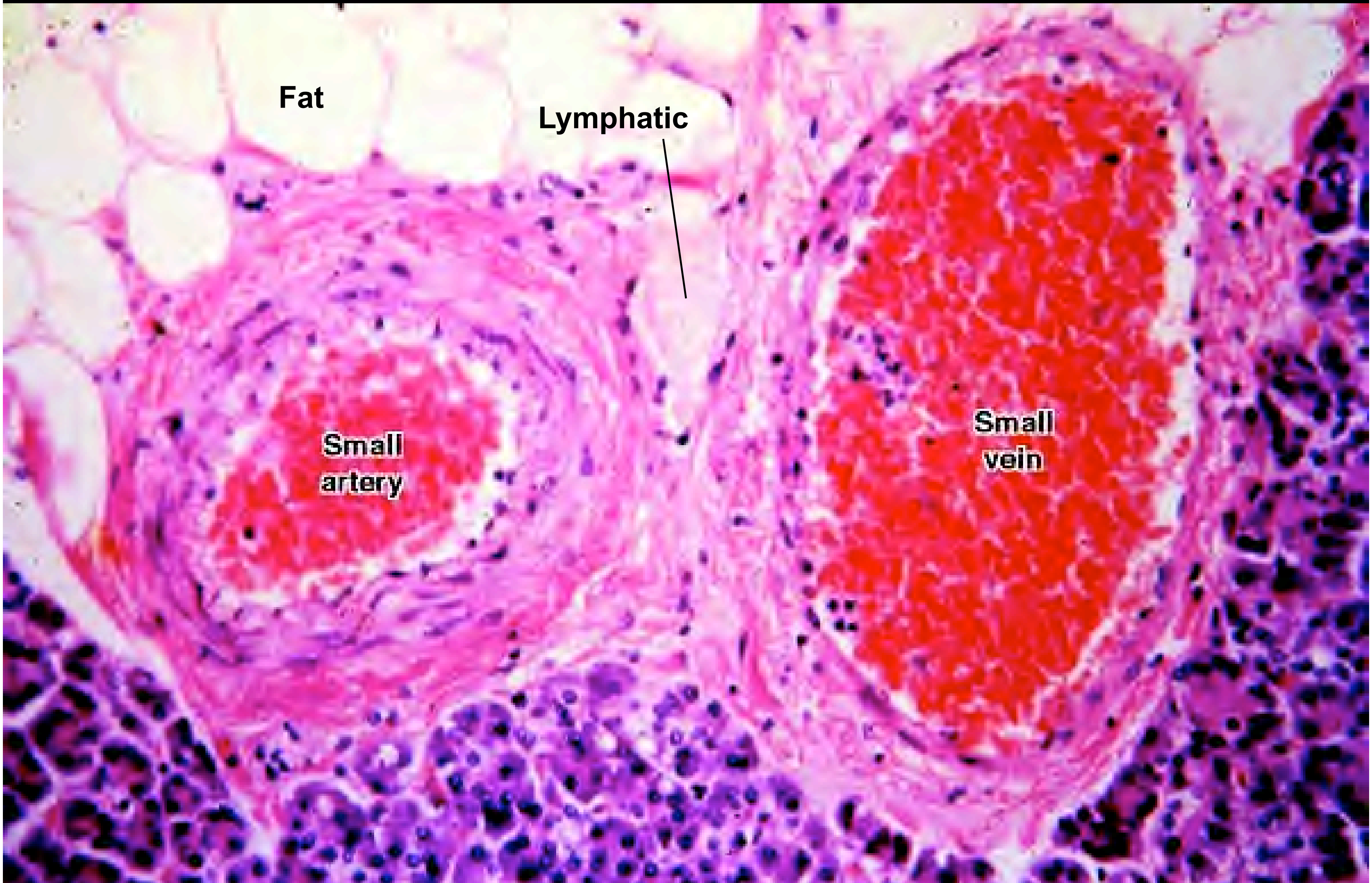
PD-INEL Junqueira and Carneiro, Basic Histology 10th ed., 2003, page 227, fig. 11-18

Valve in a vein, longitudinal section, LM



 Hadley Kirkman, Stanford (originally from Columbia P&S)

Small artery 3and vein, LM



PD-INCL Erlandsen slide set, slide 6/G/5

Arteriole and venule, LM

SEM of smooth muscle sheath around an arteriole

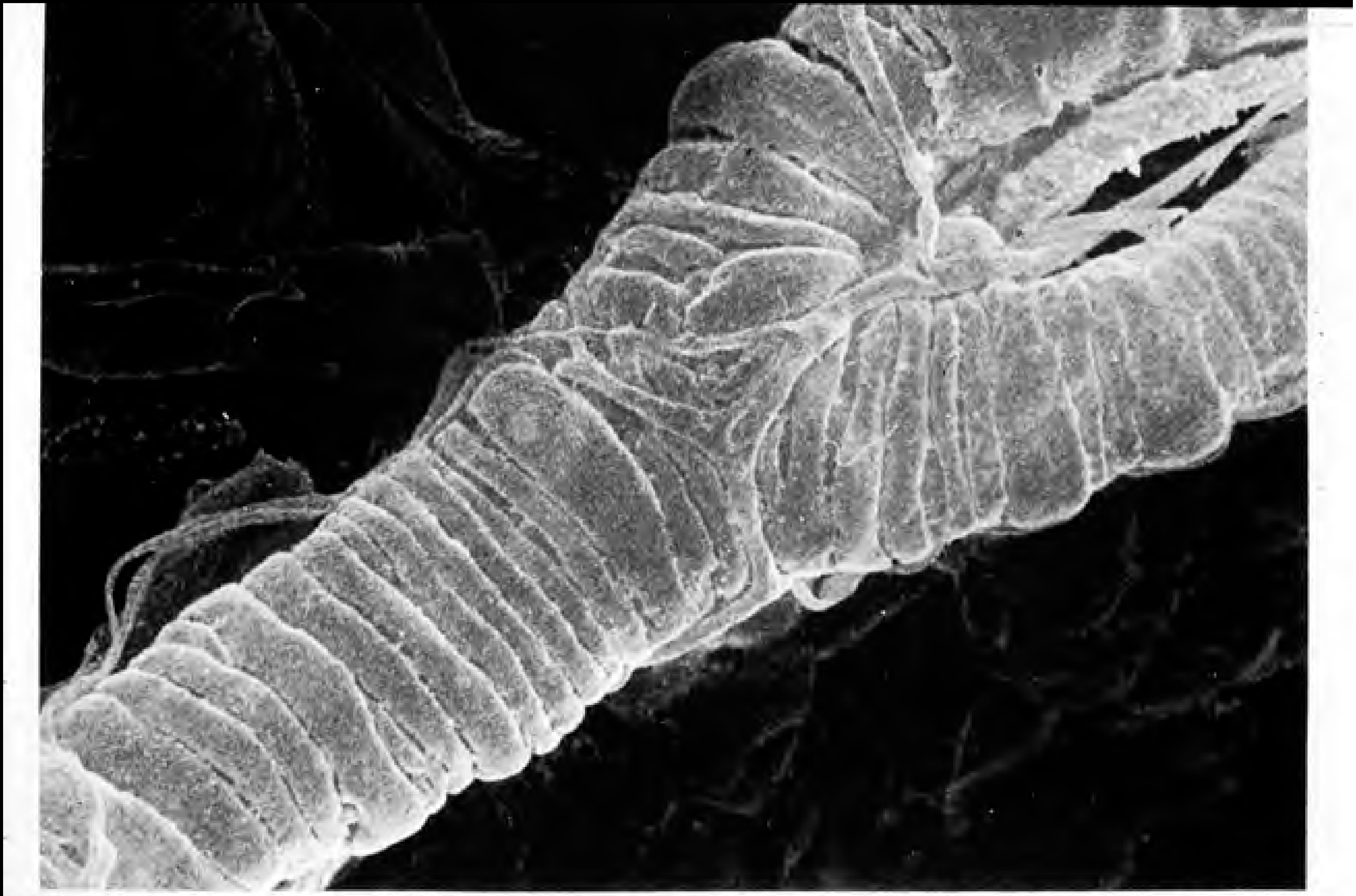
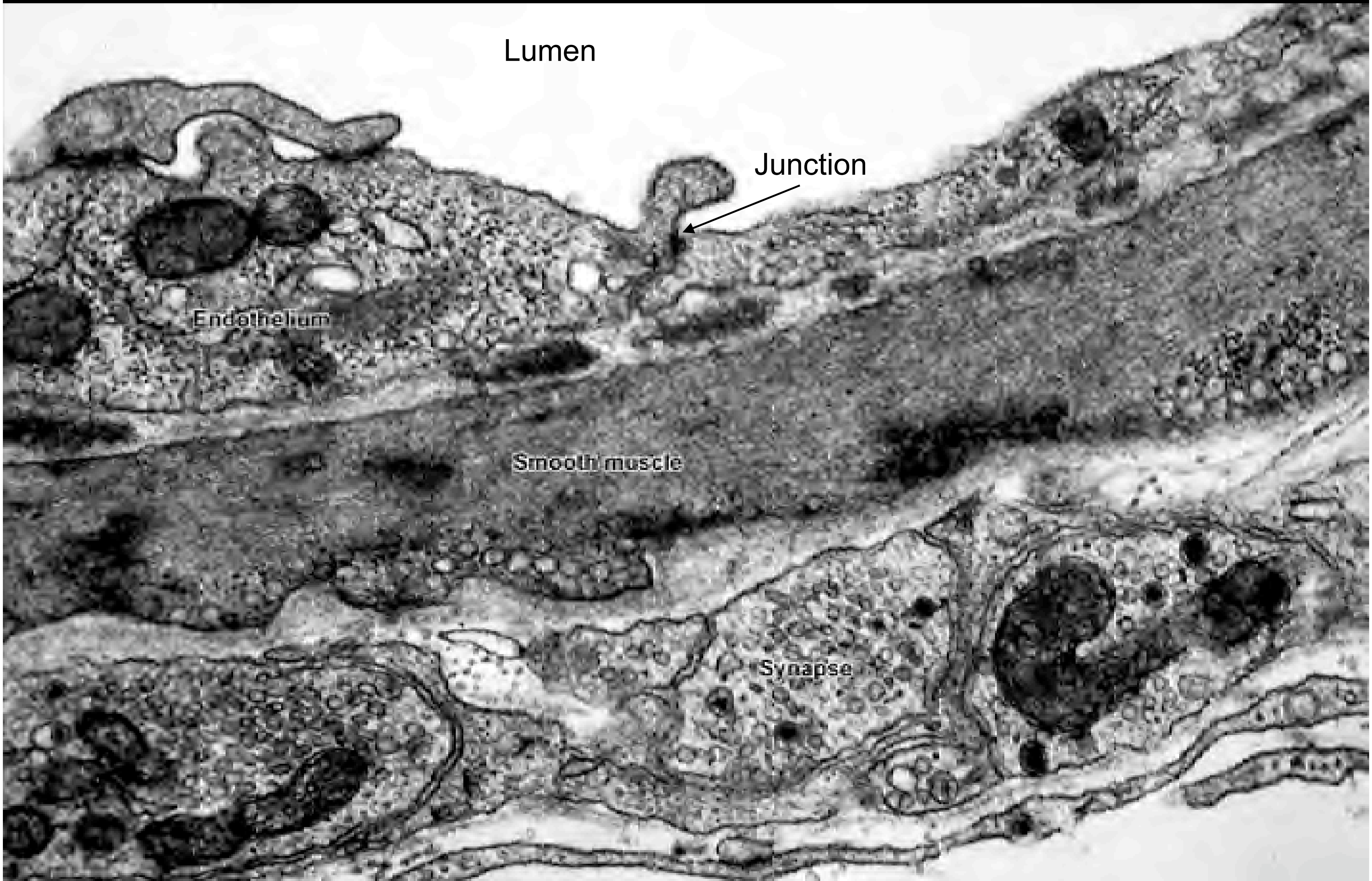


Figure 12–10. Scanning micrograph of a branching arteriole showing the circumferential arrangement of the single layer of smooth muscle cells. (Micrograph from Uehara, Y., and K. Suyama. J. Electron Microsc. 27:157, 1978.)

 Fawcett Histology, 11th ed., 1986, page 375, fig 12-10

Arteriole wall, EM



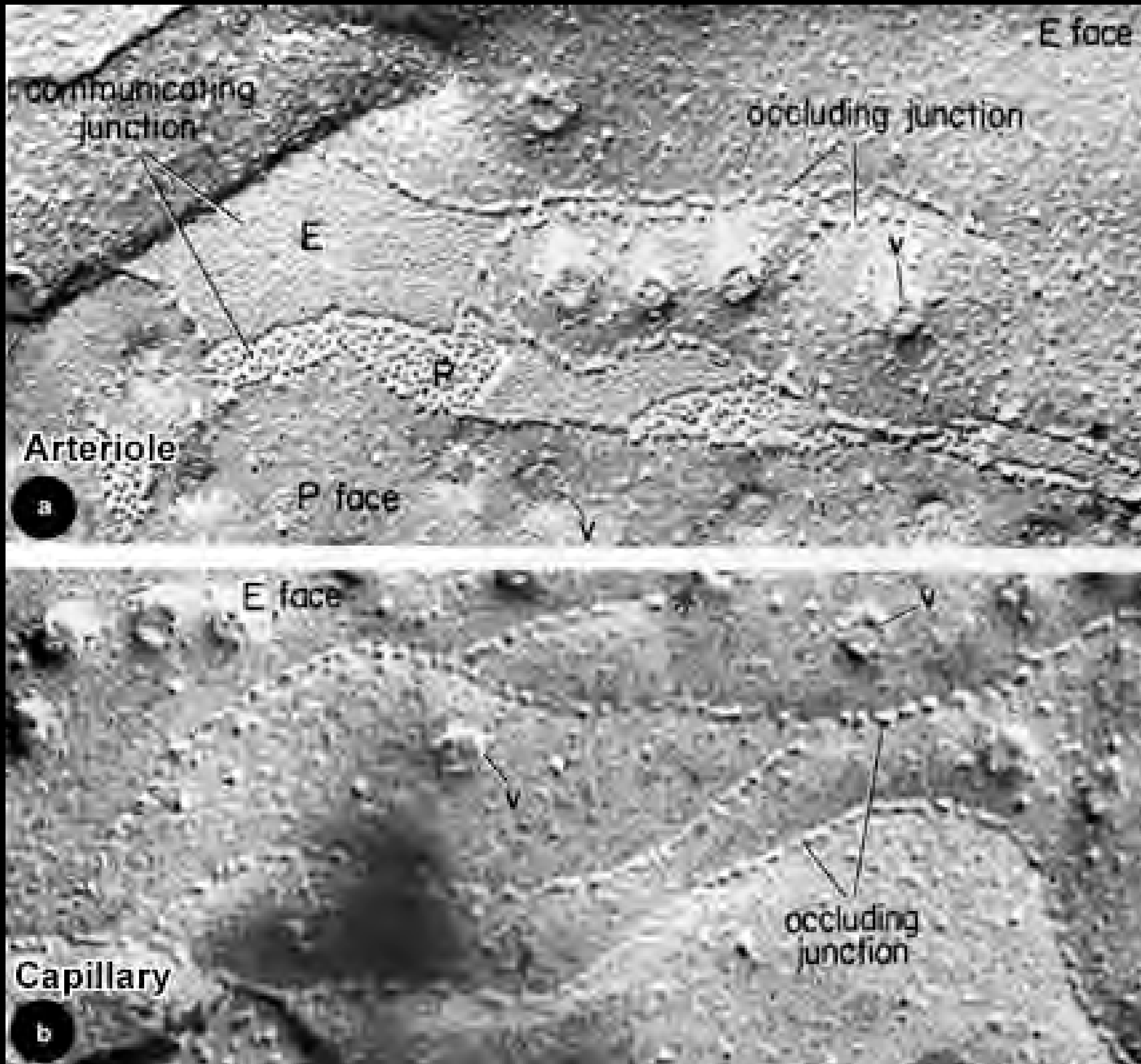
Erlandsen slide set, slide 6/D/5

Occluding (tight) junction, endothelium of capillary, EM

Figure 12–22. Micrograph of the junction of two endothelial cells in a muscle-type capillary. At the arrows the opposing membranes are joined to form an occluding junction. (Micrograph courtesy of E. Weihe.) **(From Fawcett's Histology)**

 Fawcett, A Textbook of Histology, 11th edition, 1986, page 387, fig 12-22

Occluding (tight) junction, endothelium, freeze fracture EM



 Nicolae and Maya Simionescu in Cell and Tissue Biology: a Textbook of Histology, ed. Leon Weiss, 6th edition

Capillary bed between arteriole and venule

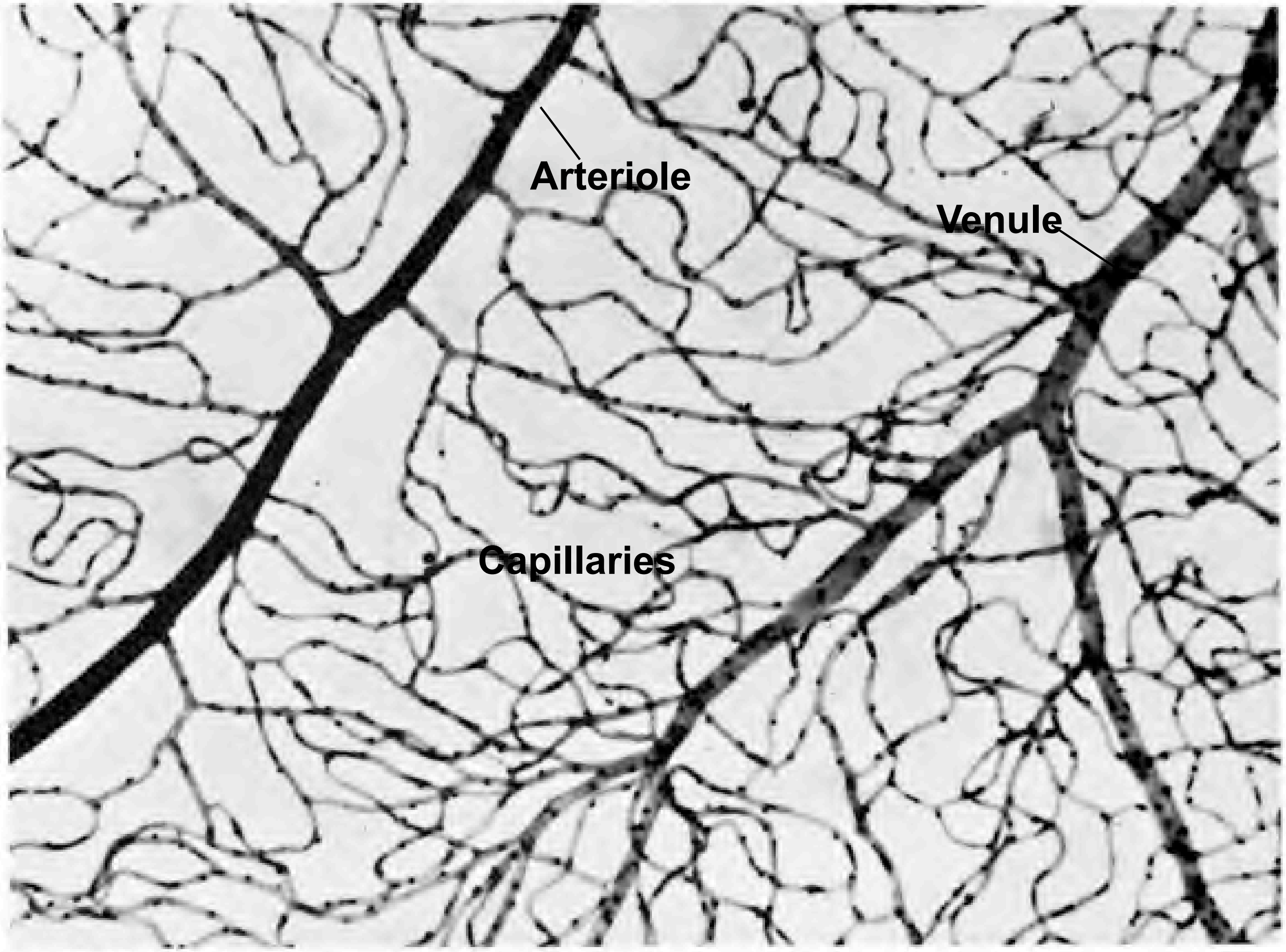
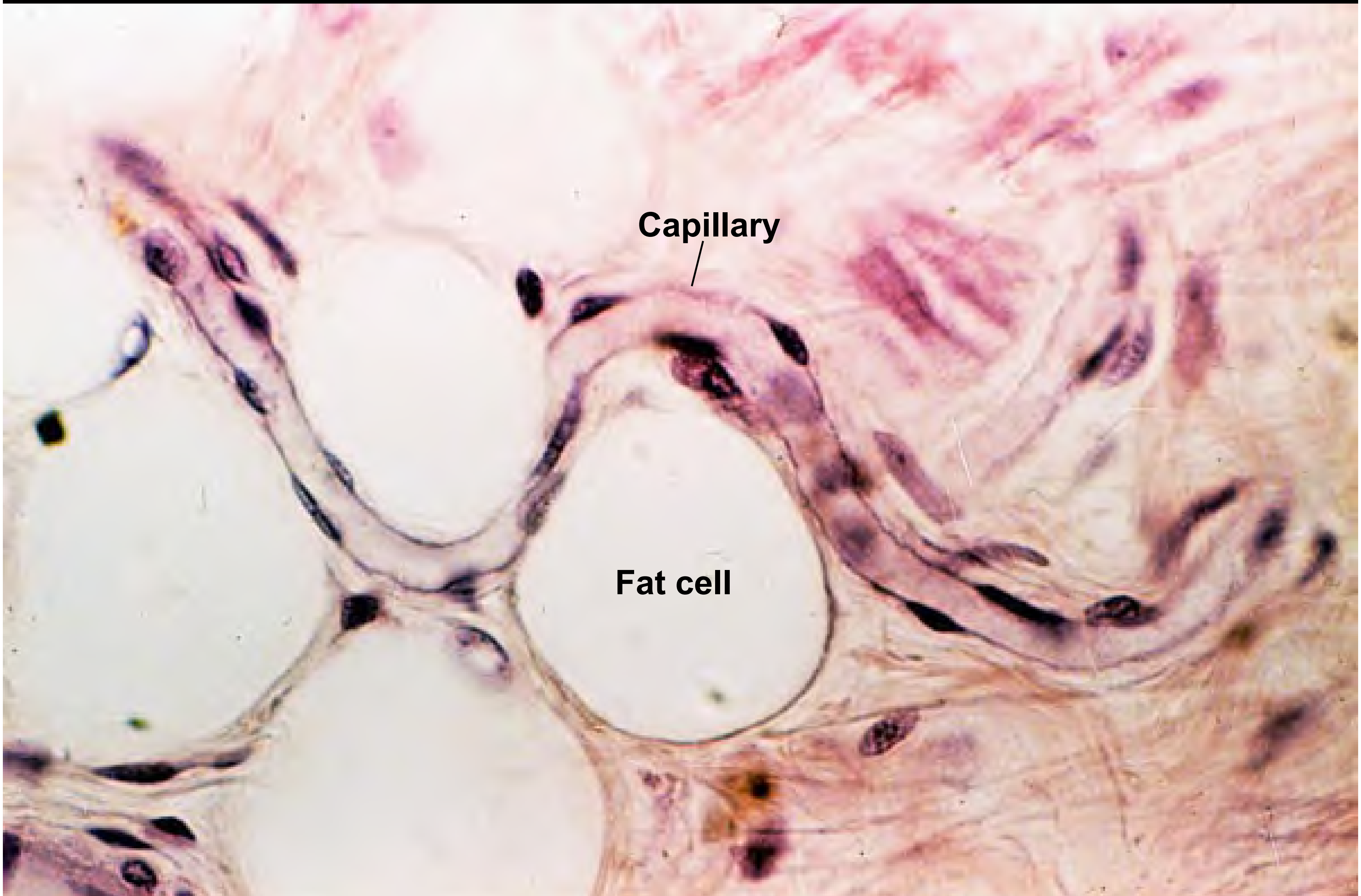


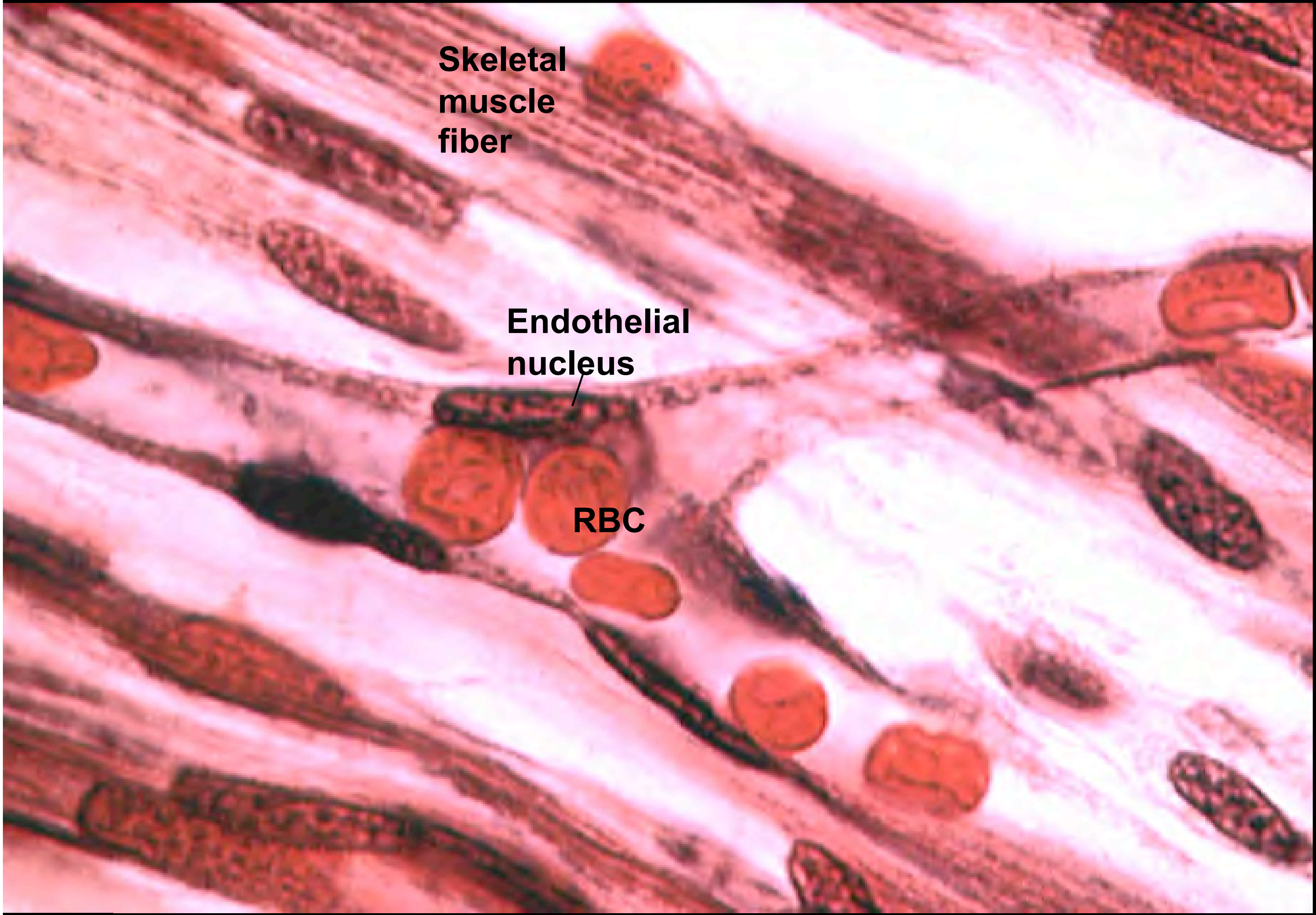
Figure 12–15. Normal human retinal blood vessels. These have been isolated by tryptic digestion of the neural and receptor elements, leaving behind only the vessels. At left is an arteriole, at right a venule, and between them is a network of capillaries of very uniform caliber. (Courtesy of T. Kuwabara.)

 Fawcett's Histology, 11th ed., page 382

Capillary, longitudinal section, LM

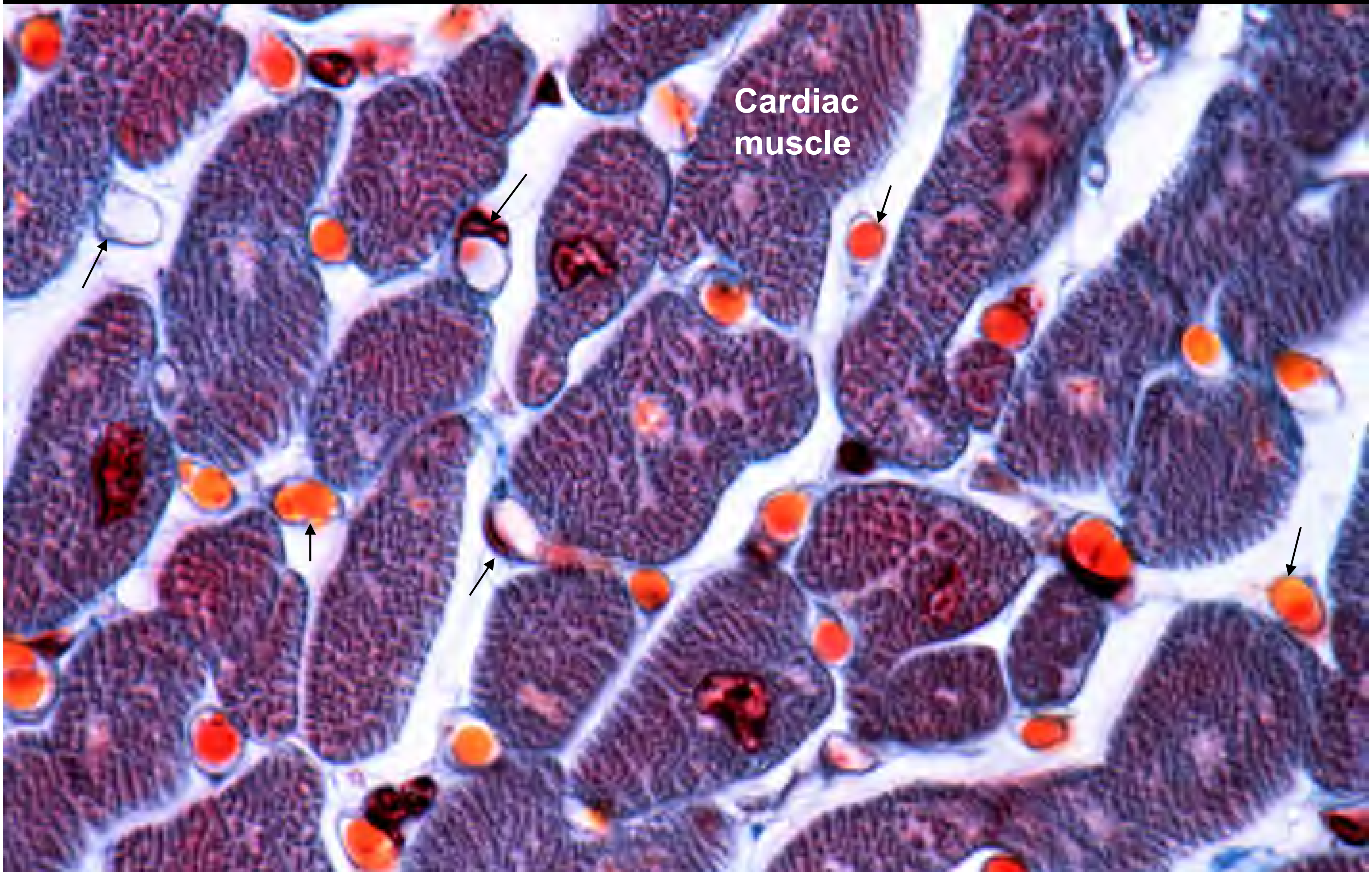


Capillary, longitudinal section, LM



 Erlandsen medical histology slide set (MH). MH-6E4

Capillaries seen in cross section, cardiac muscle, heart, LM



Capillary types, continuous and fenestrated, EM diagram

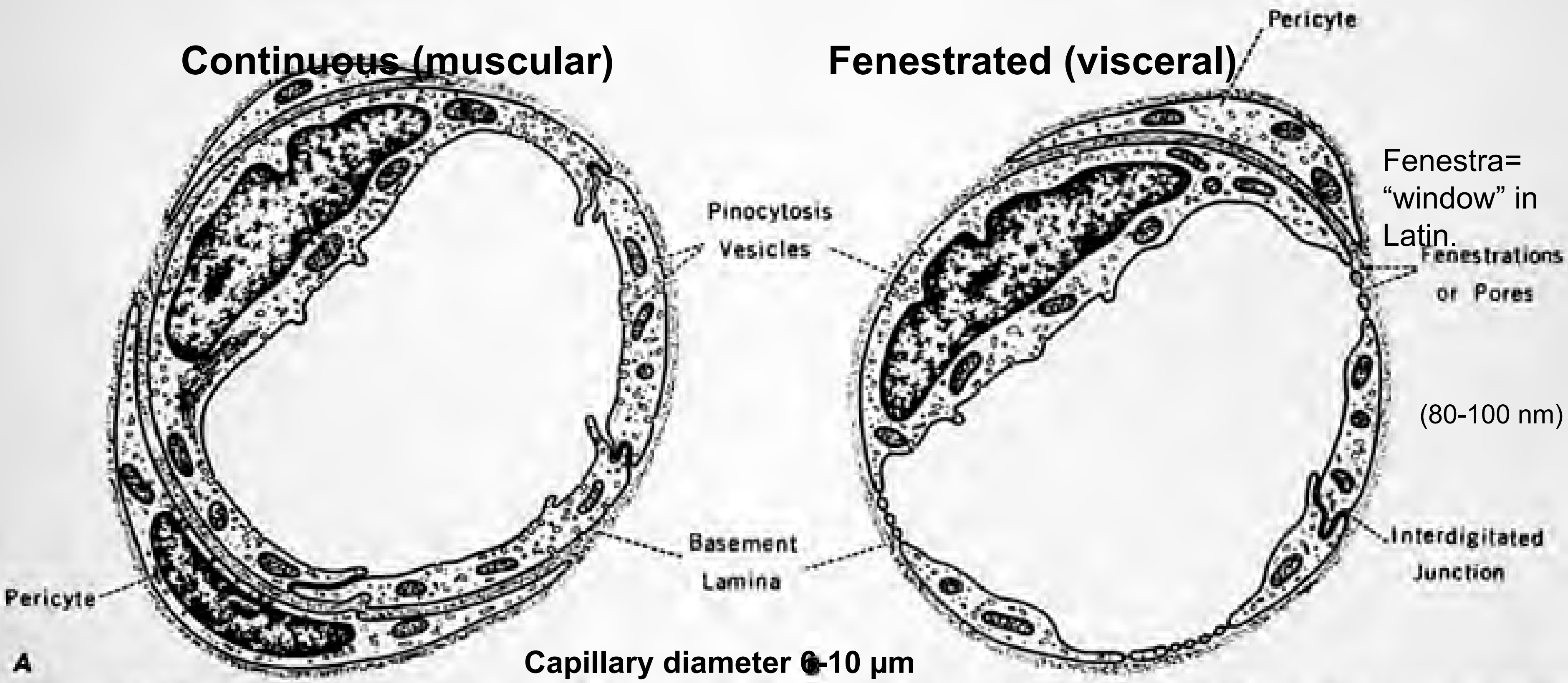


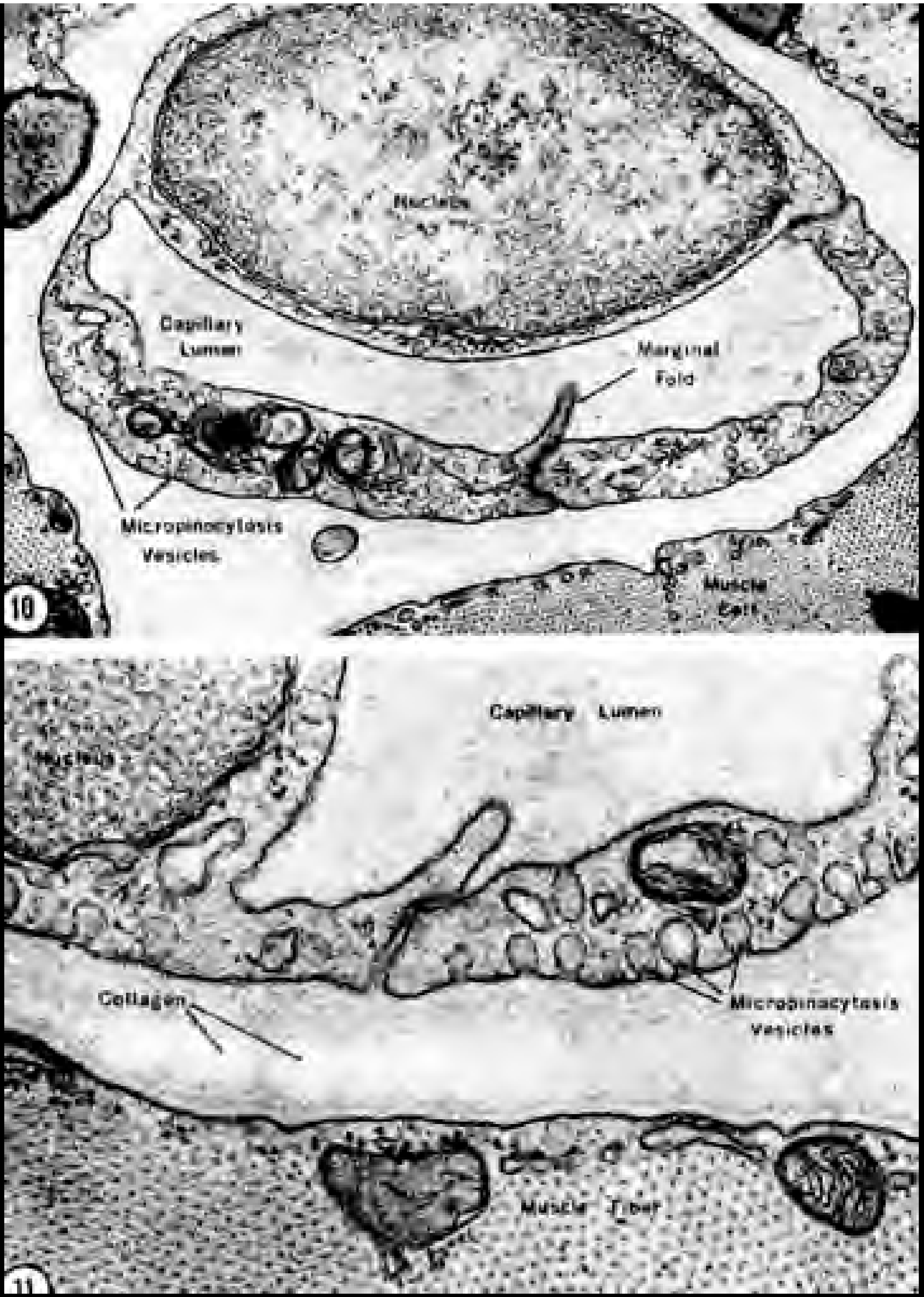
Figure 12–23. Schematic representation of the two most common types of capillaries. *A*, The continuous or muscle type with an uninterrupted endothelium. *B*, The fenestrated type, in which the endothelium varies in thickness and the thinnest areas have small pores closed by an exceedingly thin membranous diaphragm. (After Fawcett, D. W. *In* Orbison, J. L., and D. Smith, eds.: Peripheral Blood Vessels. Baltimore, Williams and Wilkins, 1962.)

 Bloom and Fawcett Histology, 11th ed, fig 12-23, p 387

Continuous: skeletal muscle, lung, CNS, connective tissue, etc.

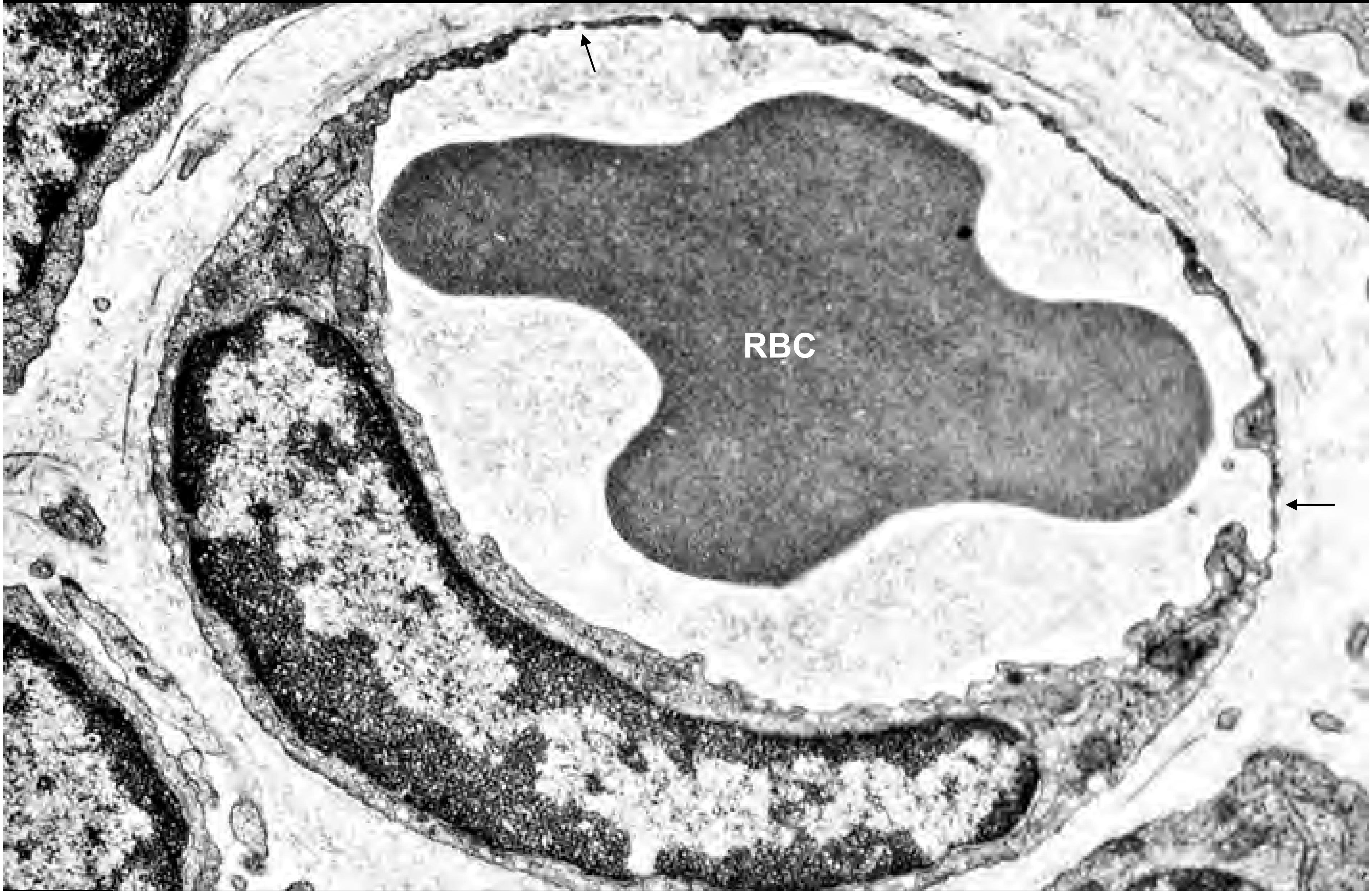
Fenestrated: Intestinal tract, endocrine glands, kidney, pancreas, etc.

Continuous capillary, EM



PD-INCL Don W. Fawcett.

Fenestrated capillary, EM



 Erlandsen slide set, slide 6/E/6

EM of continuous and fenestrated capillary walls

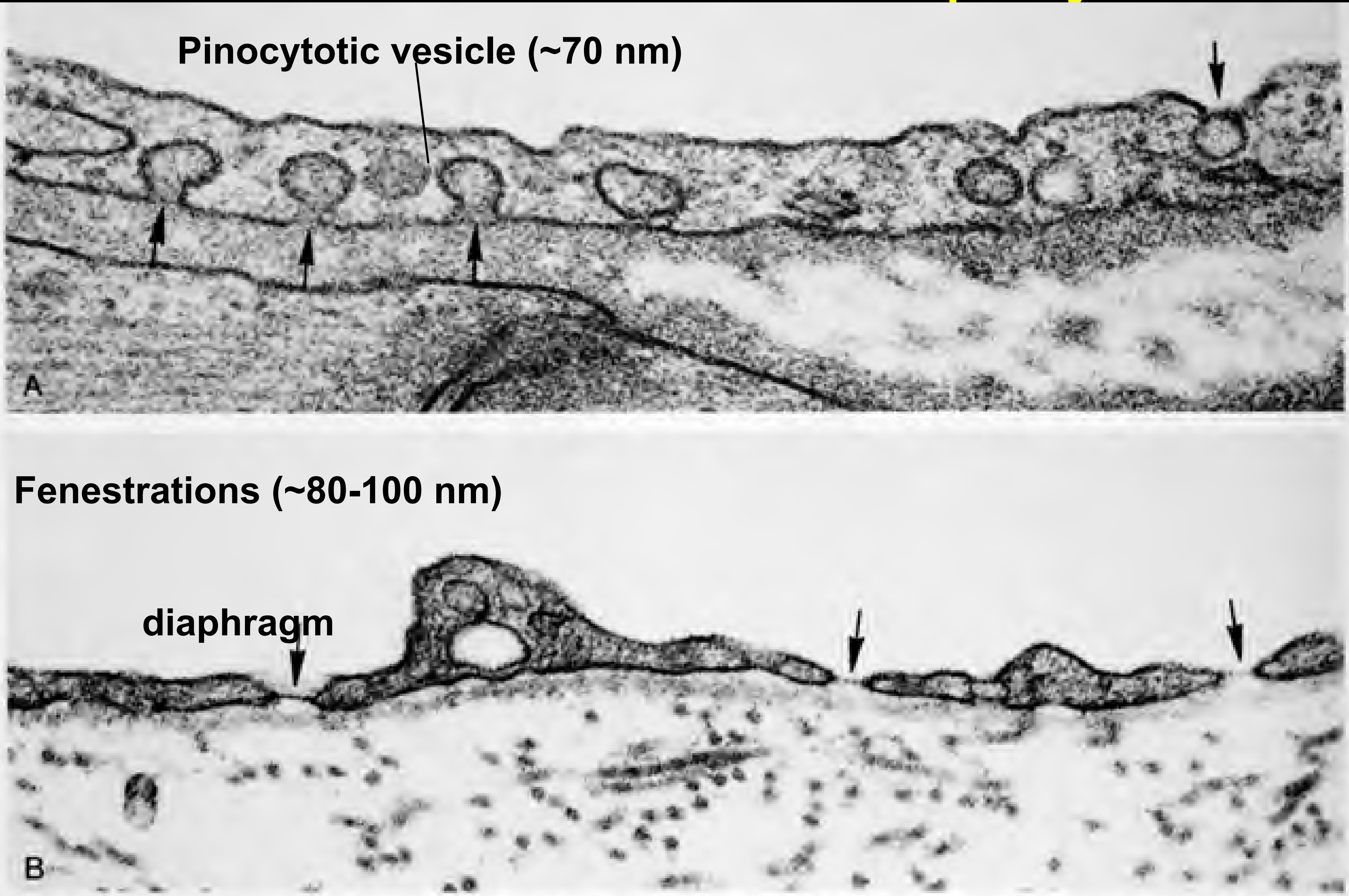


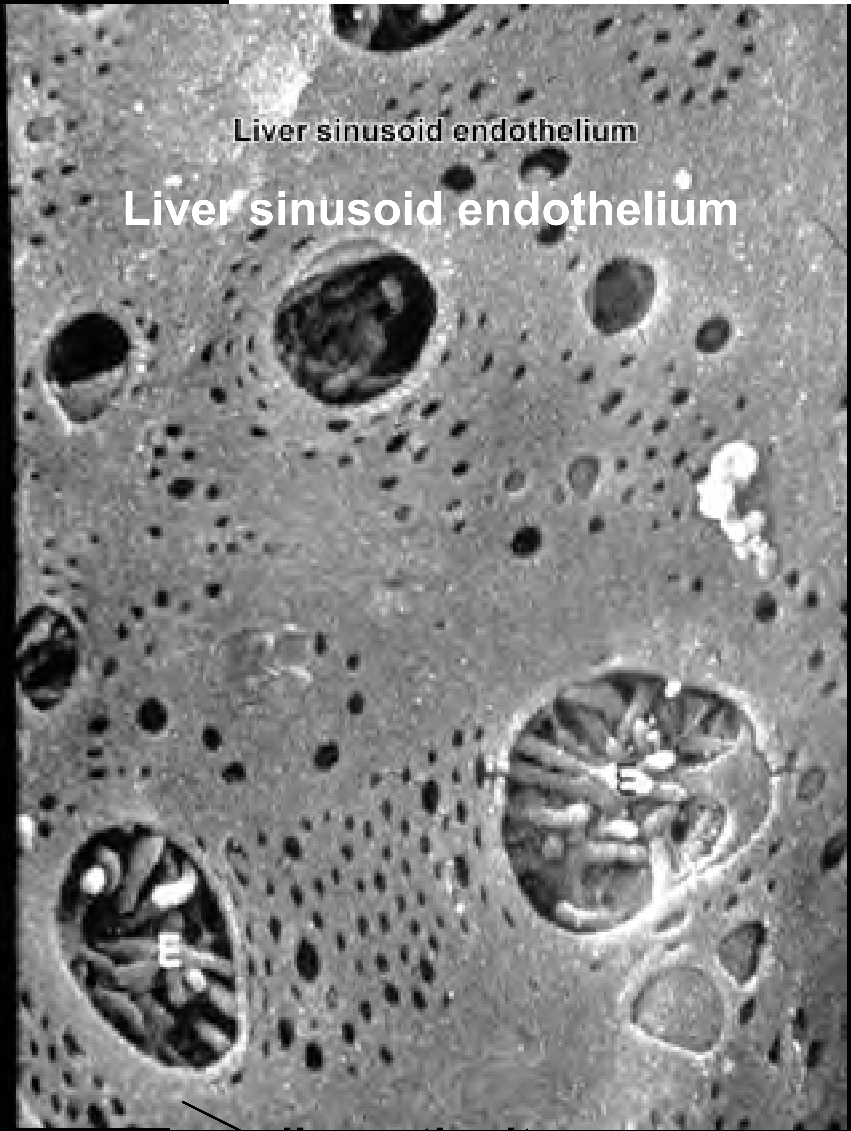
Figure 12–24. Micrographs of segments of endothelium from the two types of capillary. *A,* Endothelium of the muscle capillary endothelium has vesicular invaginations of both adluminal and abluminal plasma membranes *(at arrows)*. *B,* Endothelium of fenestrated capillary from the lamina propria of the colon is extremely thin and has pores closed by thin diaphragms *(at arrows)*. (Micrographs courtesy of E. Weihe.)

 Fawcett Histology, 11th ed, fig 12-24, p 388)

SEM of fenestrated endothelium and liver sinusoid (discontinuous)

Sinusoids are large capillaries (30-40 μm), usually fenestrated. Liver sinusoids have discontinuities (holes).

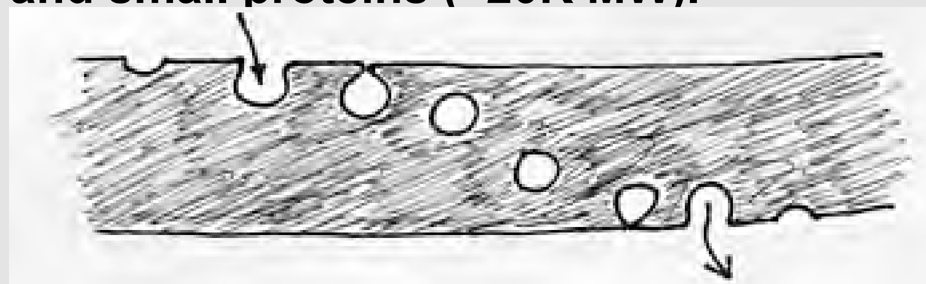
PD-INCL Erlandsen slide set, slide 6/E/8



PD-INCL Erlandsen slide set, slide 6/E/8

Passage of proteins across capillary wall

- Basal lamina of endothelium is not a significant barrier.
- Intercellular tight junctions are usually rather impermeable to water.
- Fenestrations pass mostly water and small proteins (<20K MW).



Mechanism (bidirectional):

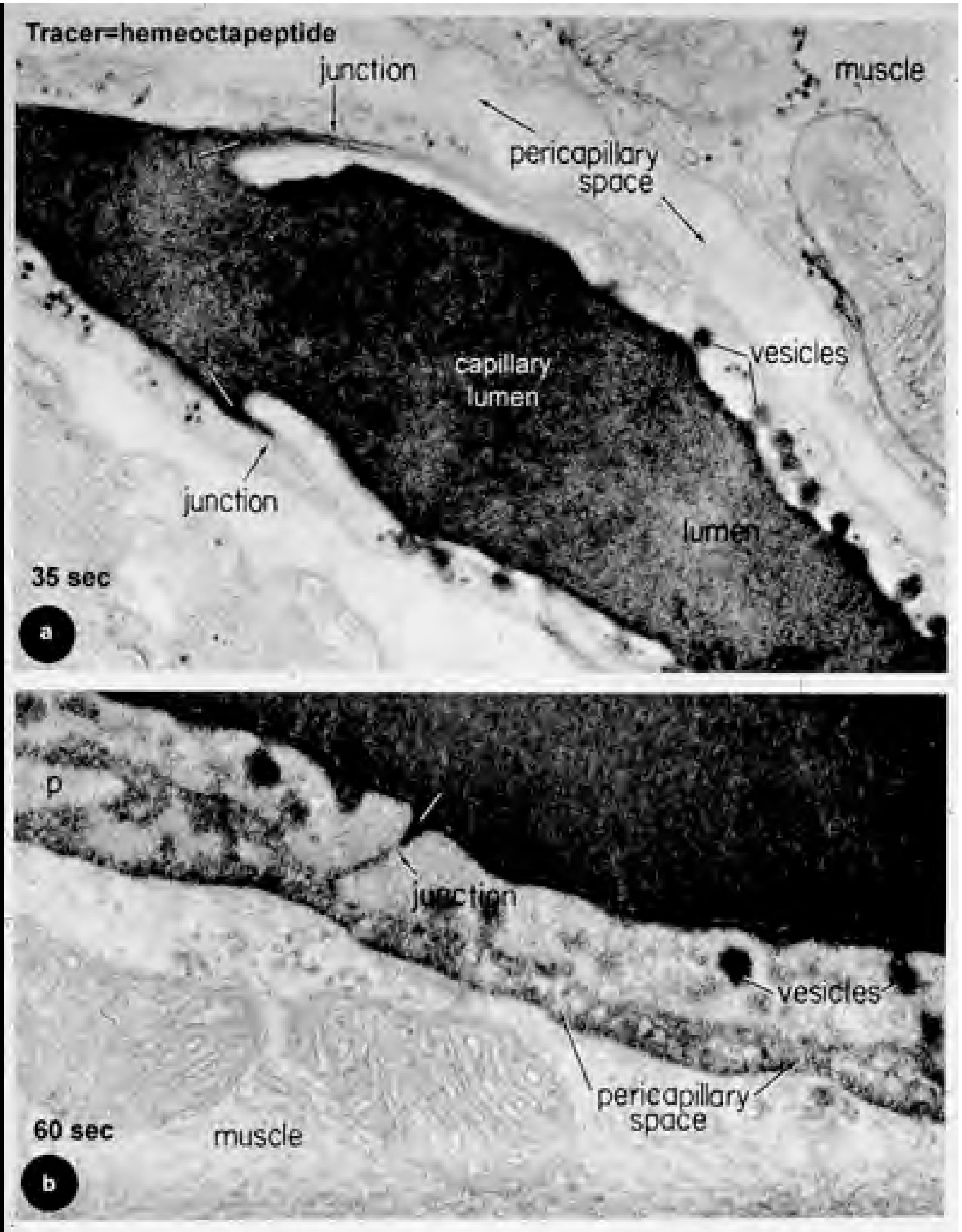
- Discrete shuttling of vesicles
  - Non-specific fluid phase uptake (pinocytotic vesicles).
  - Specific receptor-mediated transport (coated vesicles with clathrin). For example: albumin, insulin, transferrin, LDL.

Correlation with physiology

- Physiologist's "large pore" transport is probably this vesicular transport.
- Physiologist's "small pore" transport is probably between endothelial cells and through fenestrations.

EM tracer protein experiment to test for vesicle transport

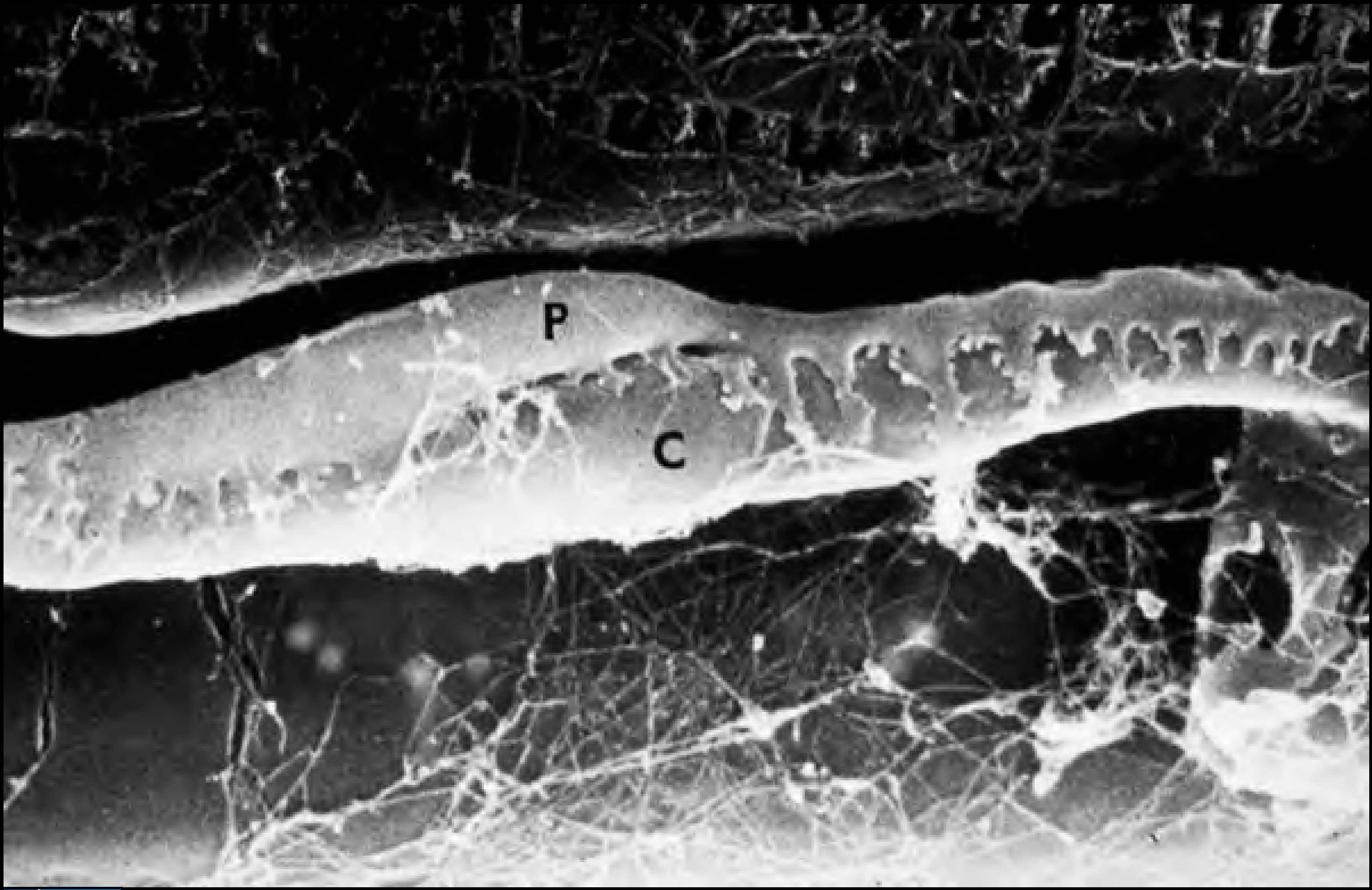
- At 35 seconds, tracer protein is in the lumen and in pinocytotic vesicles, but not in pericapillary space.
- At 60 seconds, tracer protein is in the lumen, pinocytotic vesicles, and in the pericapillary space, showing that the protein has been transported across the endothelial wall.
- Tight junctions between endothelial cells prevent passage between the cells.



Weiss Histology, 6th ed, fig 10-31, p 388

Pericytes (Rouget cells) are common on capillaries and on postcapillary venules , EM

SEM of a pericyte (P) on a capillary (C)



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Possible pericyte functions: (1) Stem cell to repair capillary damage or for new growth, (2) contractility (has smooth muscle type myosin, actin, tropomyosin).

Arteriovenous anastomosis (shunt), a short circuit

Image of arteriovenous anastomosis removed

Original Source: Wheaters, Figure 9.18

- In cold weather you don't want to lose heat at the skin surface, so the shunts are open, and not much blood goes to the skin papillary loops (capillaries).
- In hot weather the shunts are closed, so blood goes to the skin papillary loops, and the blood can thus be cooled by evaporation of sweat at the skin surface.

Heart, Diagram

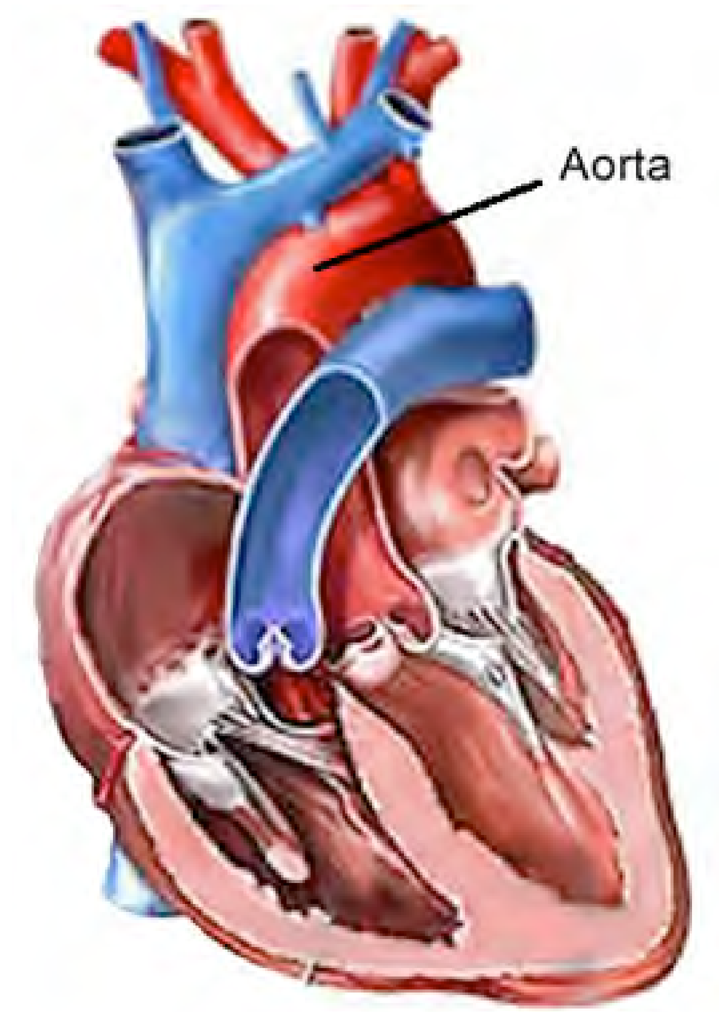
HEART WALL

Endocardium = endothelium + connective tissue (like intima)

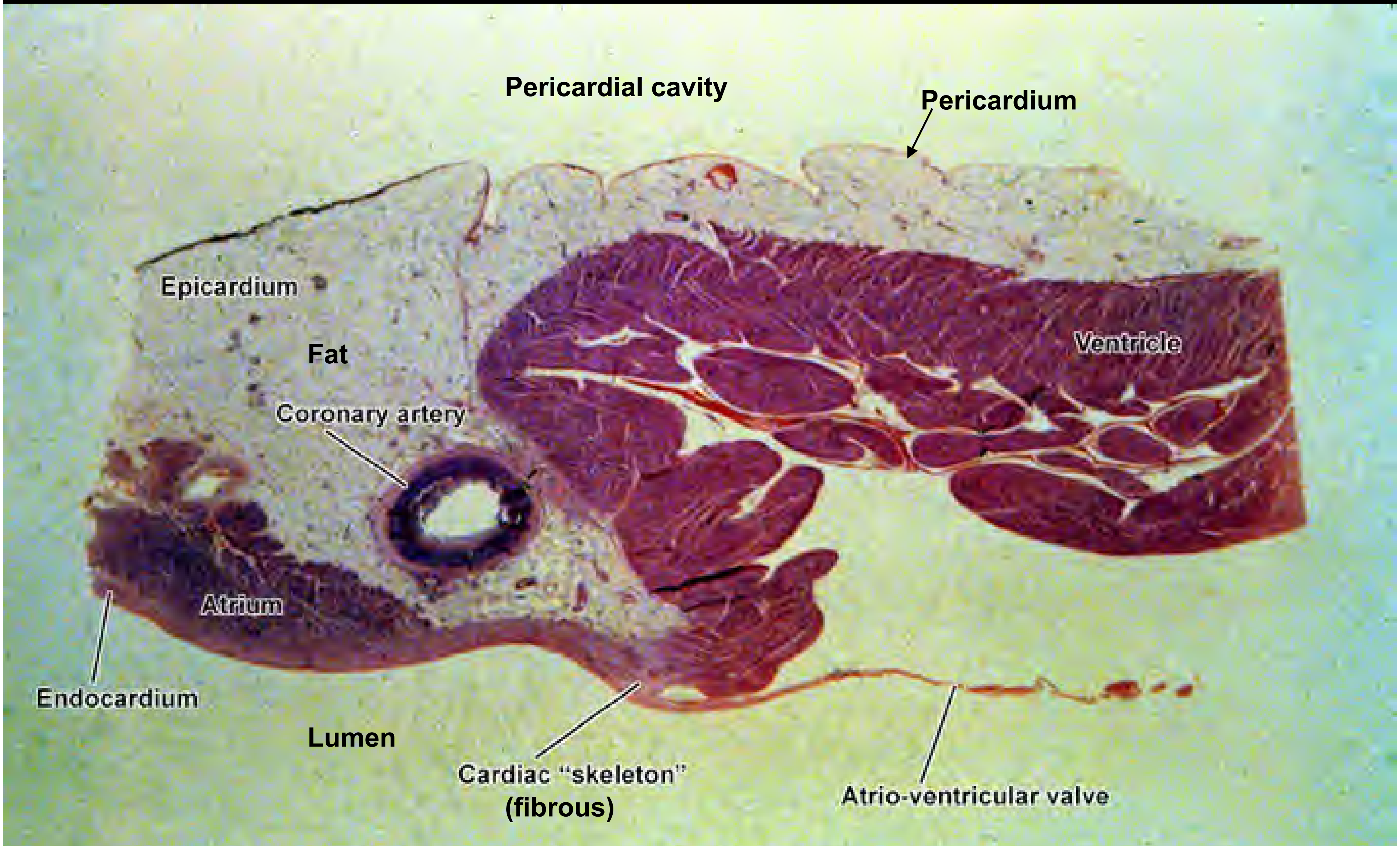
Myocardium = thick cardiac muscle (like media)

Epicardium = visceral pericardium = simple squamous epith + fatty connective tissue

The AV valve margins are supported by chorda tendinae and papillary muscles.



Wall of atrium and ventricle, heart, LM



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Cardiac fibrous skeleton (in blue)

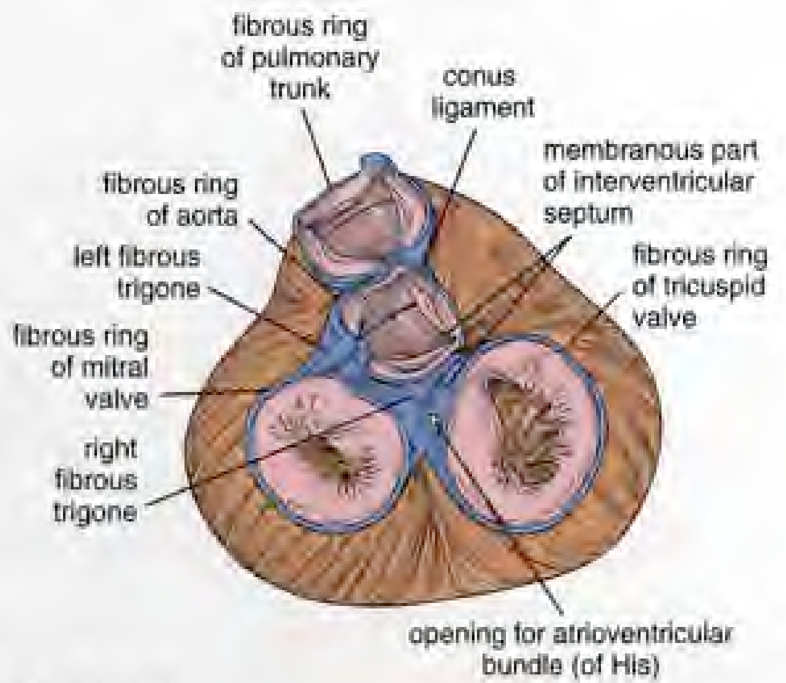
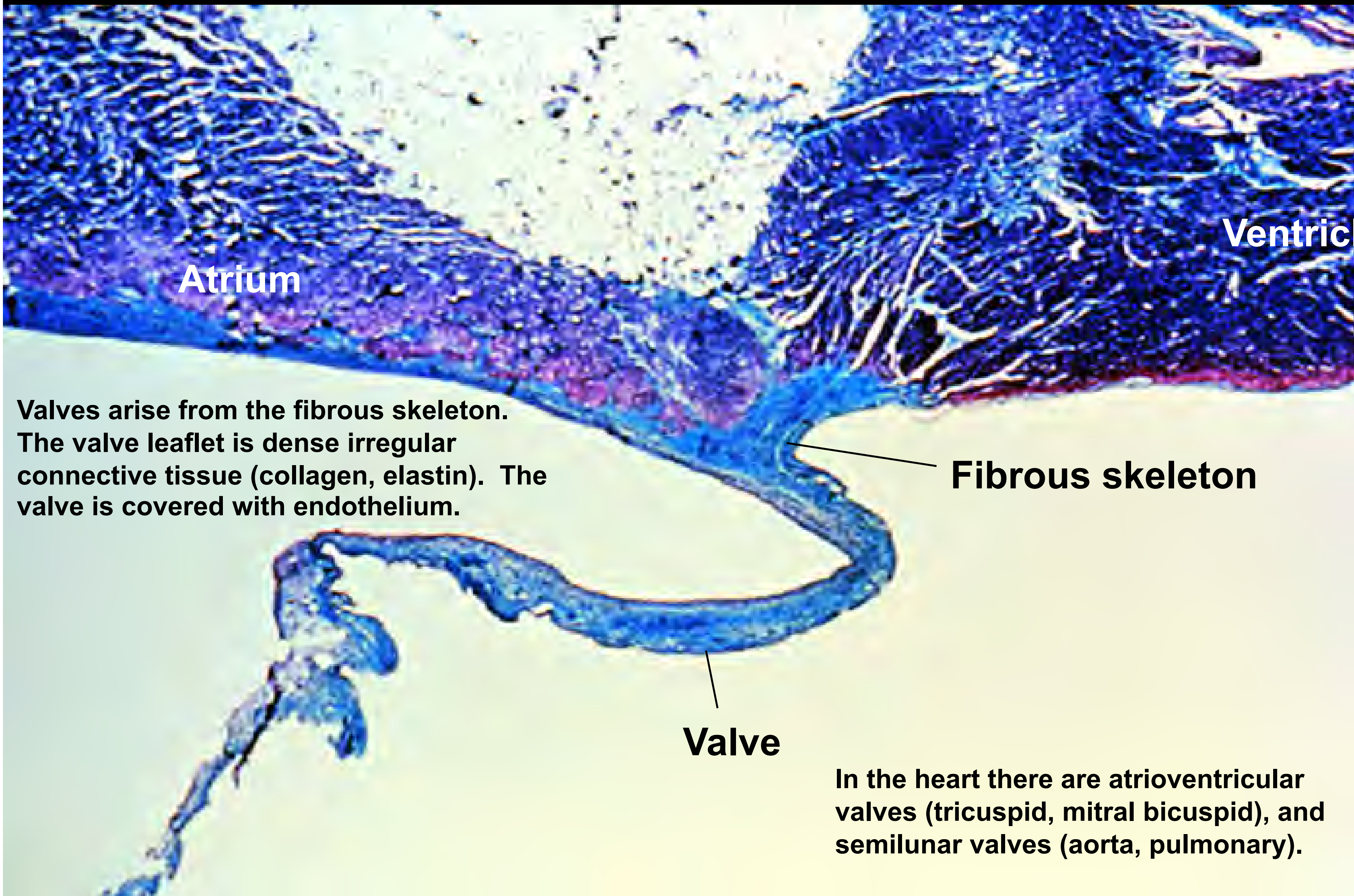


FIGURE 12.18

Fibrous skeleton of the heart as seen with the two atria removed. This fibrous network *(indicated in blue)* serves for the attachment of cardiac muscle; it also serves for the attachment of the cuspid valves between the atria and ventricles and for the semilunar valves of the aorta and the pulmonary artery. The atrioventricular bundle passes from the right atrium to the ventricular septum via the membranous septum of the fibrous skeleton.

 Ross. Histology: A Text and Atlas, 4th ed., page 343

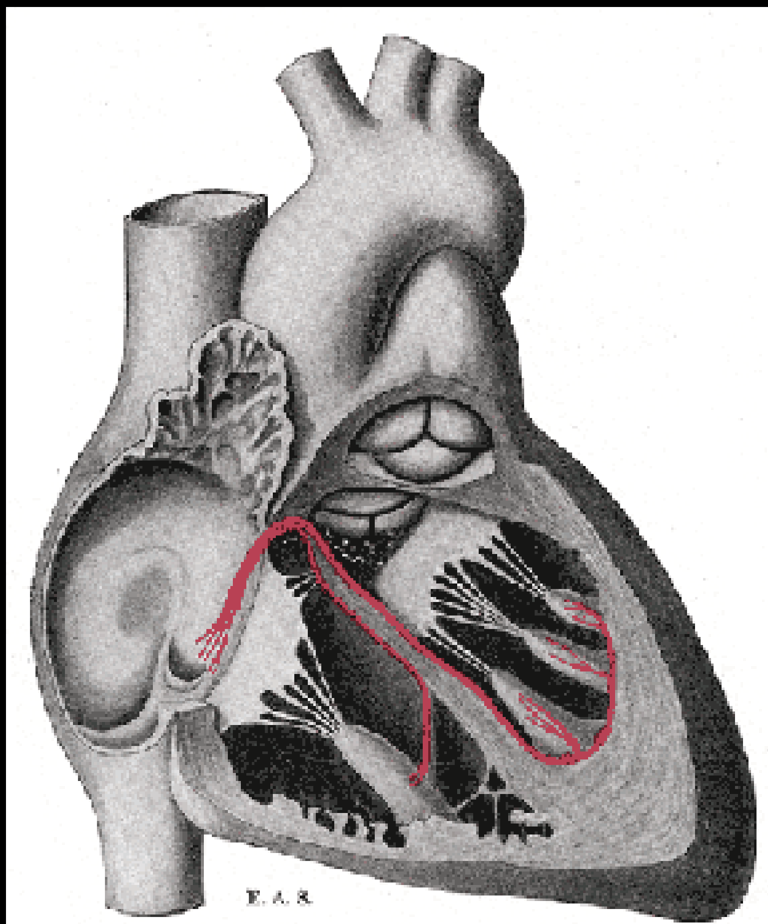
Atrio-ventricular valve, LM



Valves arise from the fibrous skeleton. The valve leaflet is dense irregular connective tissue (collagen, elastin). The valve is covered with endothelium.

In the heart there are atrioventricular valves (tricuspid, mitral bicuspid), and semilunar valves (aorta, pulmonary).

Diagram of heart, showing cardiac conduction system



PD-EXP Gray's Anatomy, wikimedia commons

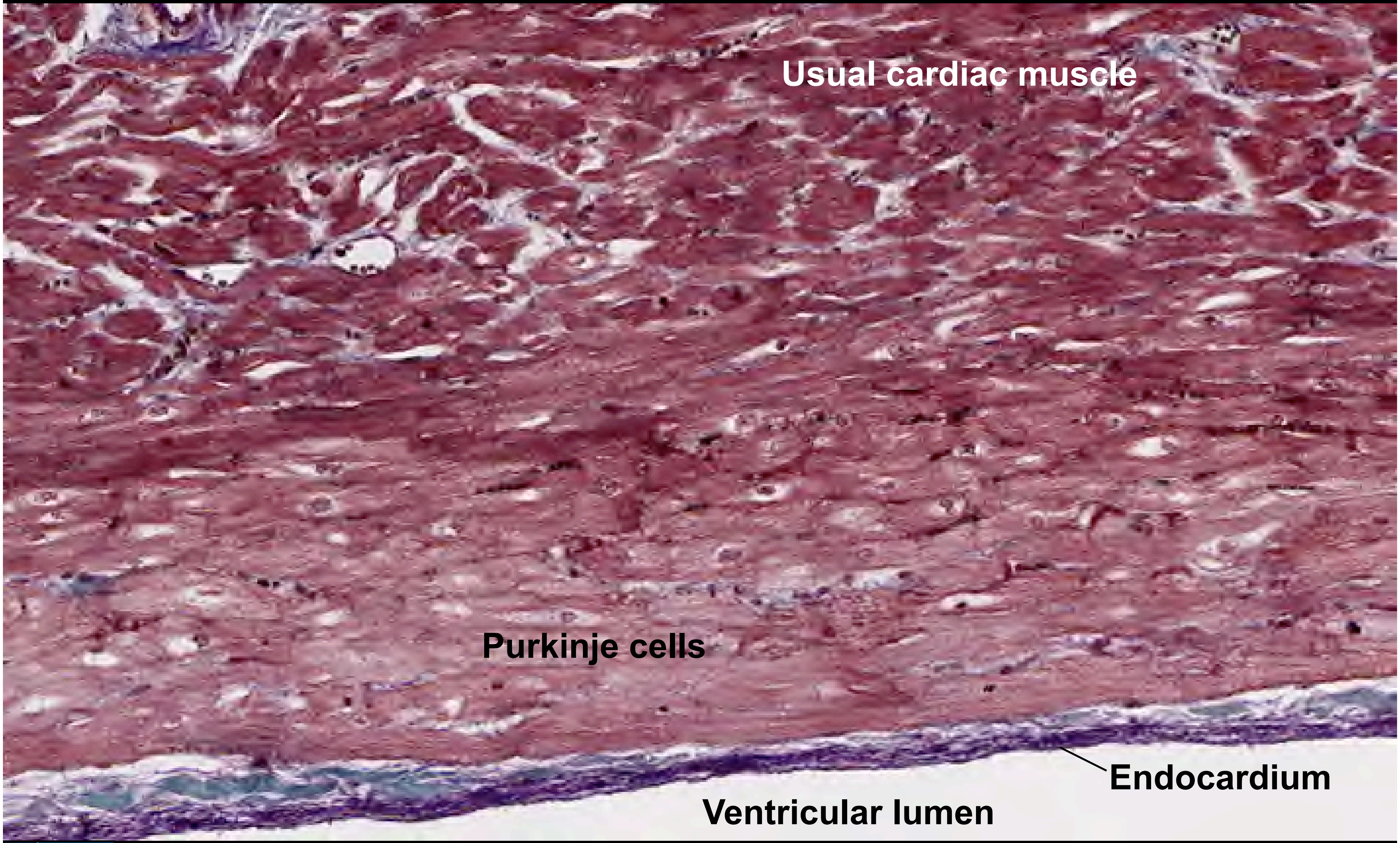
Sinoatrial (SA) node: Pacemaker.

Atrioventricular (AV) node.

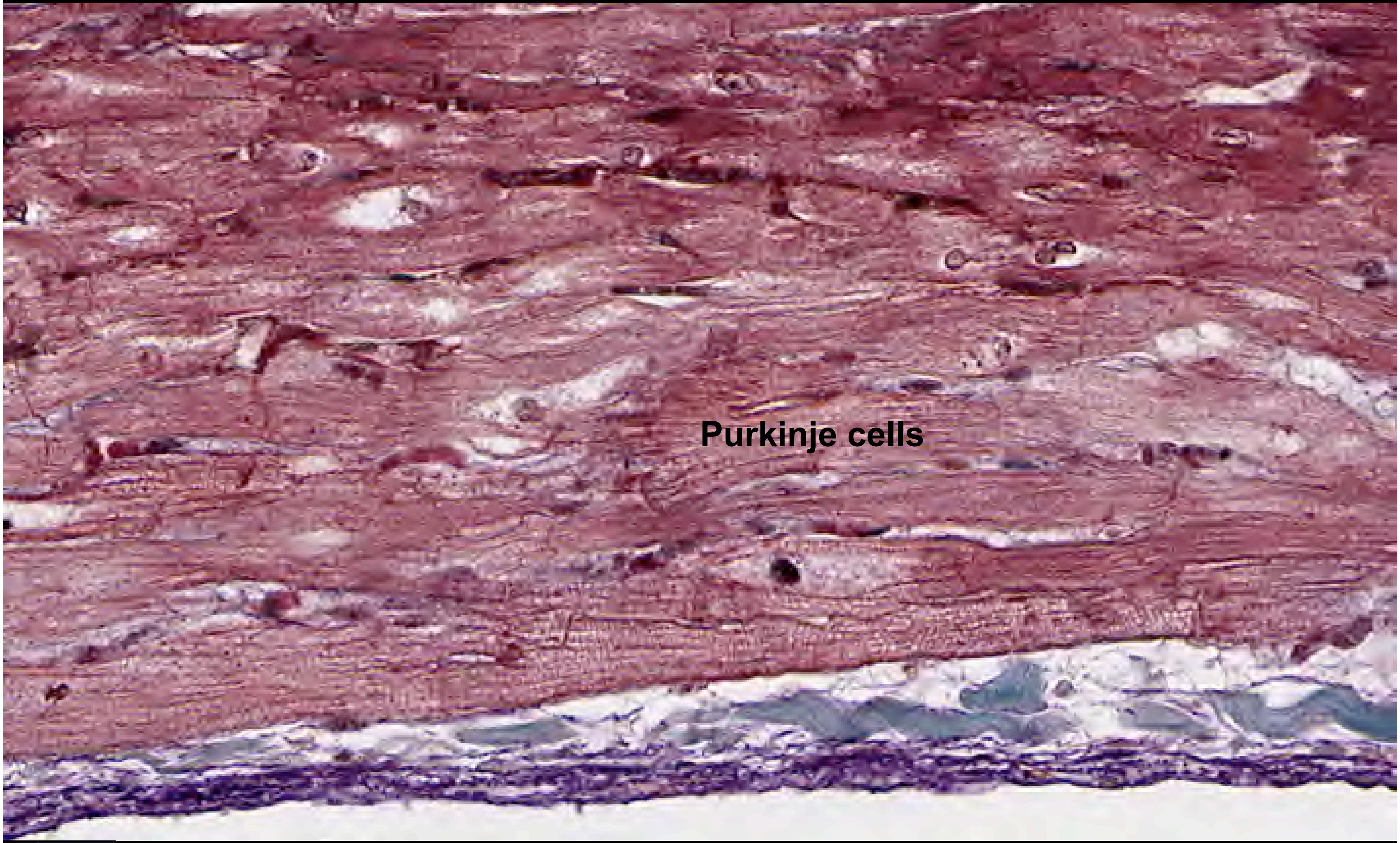
Atrioventricular bundle (of His): conducts across the AV septum (fibrous skeleton).

Purkinje fibers (composed of Purkinje cells). Branches to supply both ventricles (apex first). In ventricle subendocardial layer.

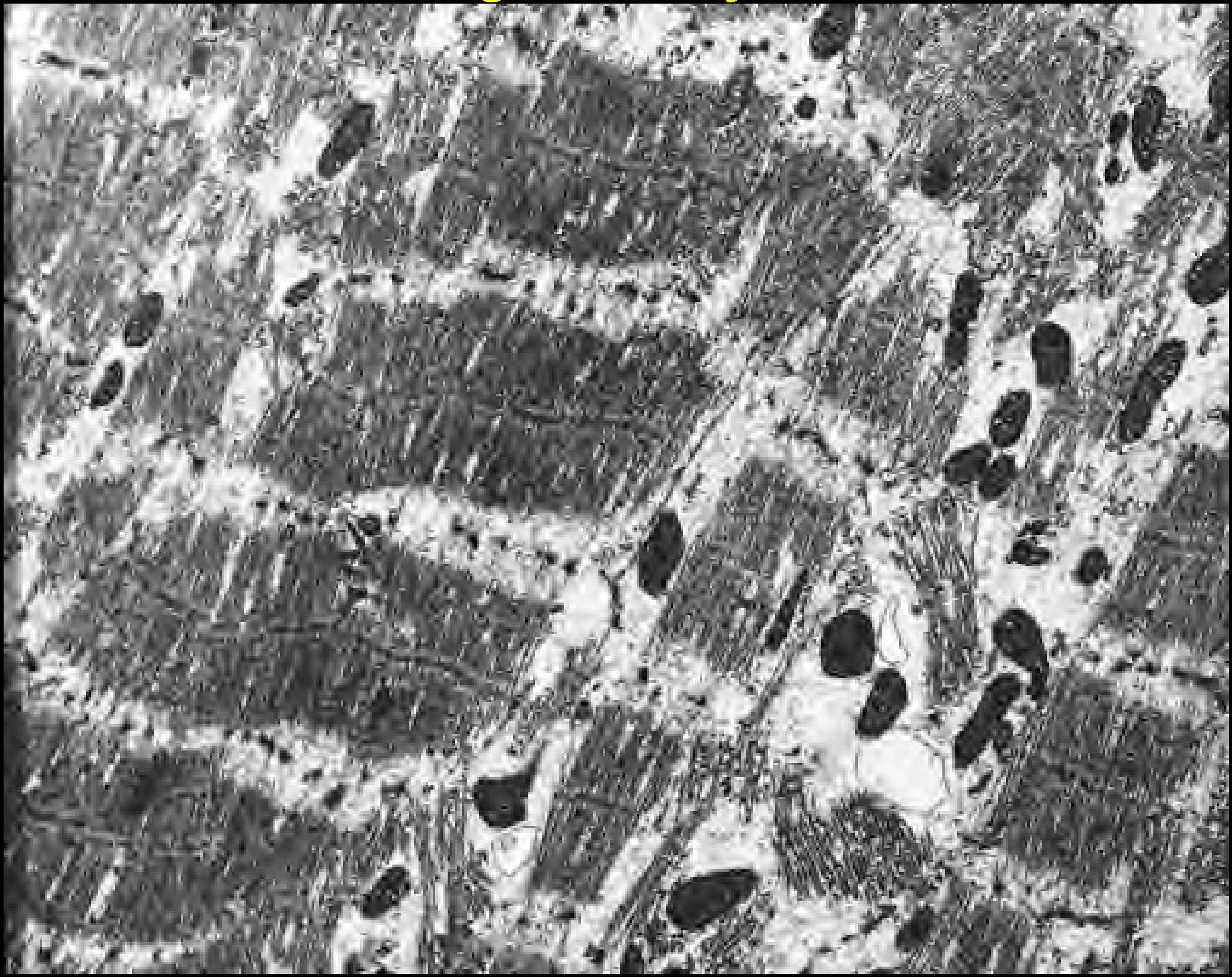
Purkinje cells, human heart



Purkinje cells, human heart (detail)



EM of Purkinje cell, showing sparse and disorganized myofibrils



 Griepp, in Weiss Histology, 6th ed, p 414

Large (elastic) arteries: wall of aorta

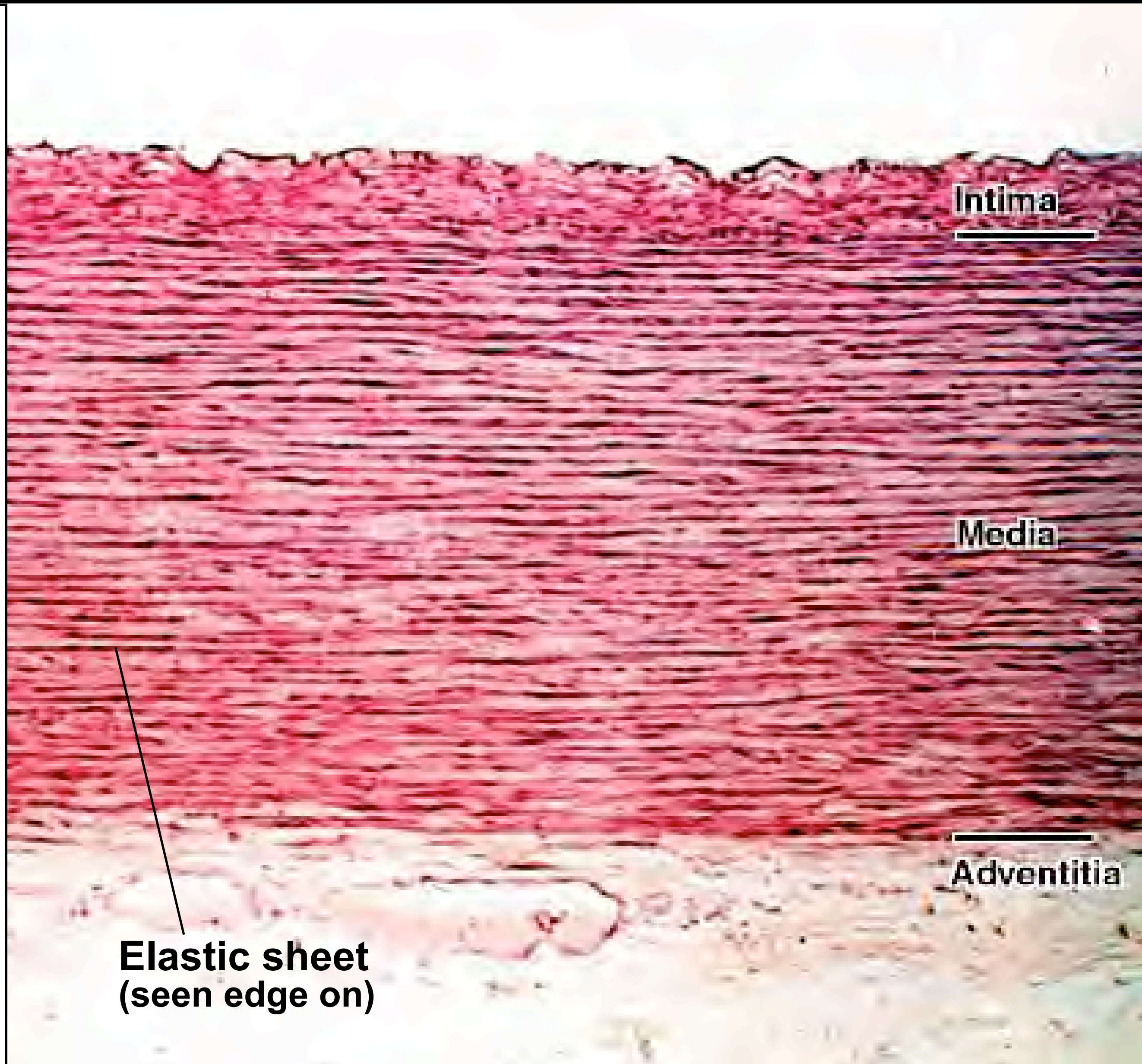
Large arteries: aorta, pulmonary, brachio-cephalic, common carotid.

Intima has abundant elastic fibers, oriented longitudinally.

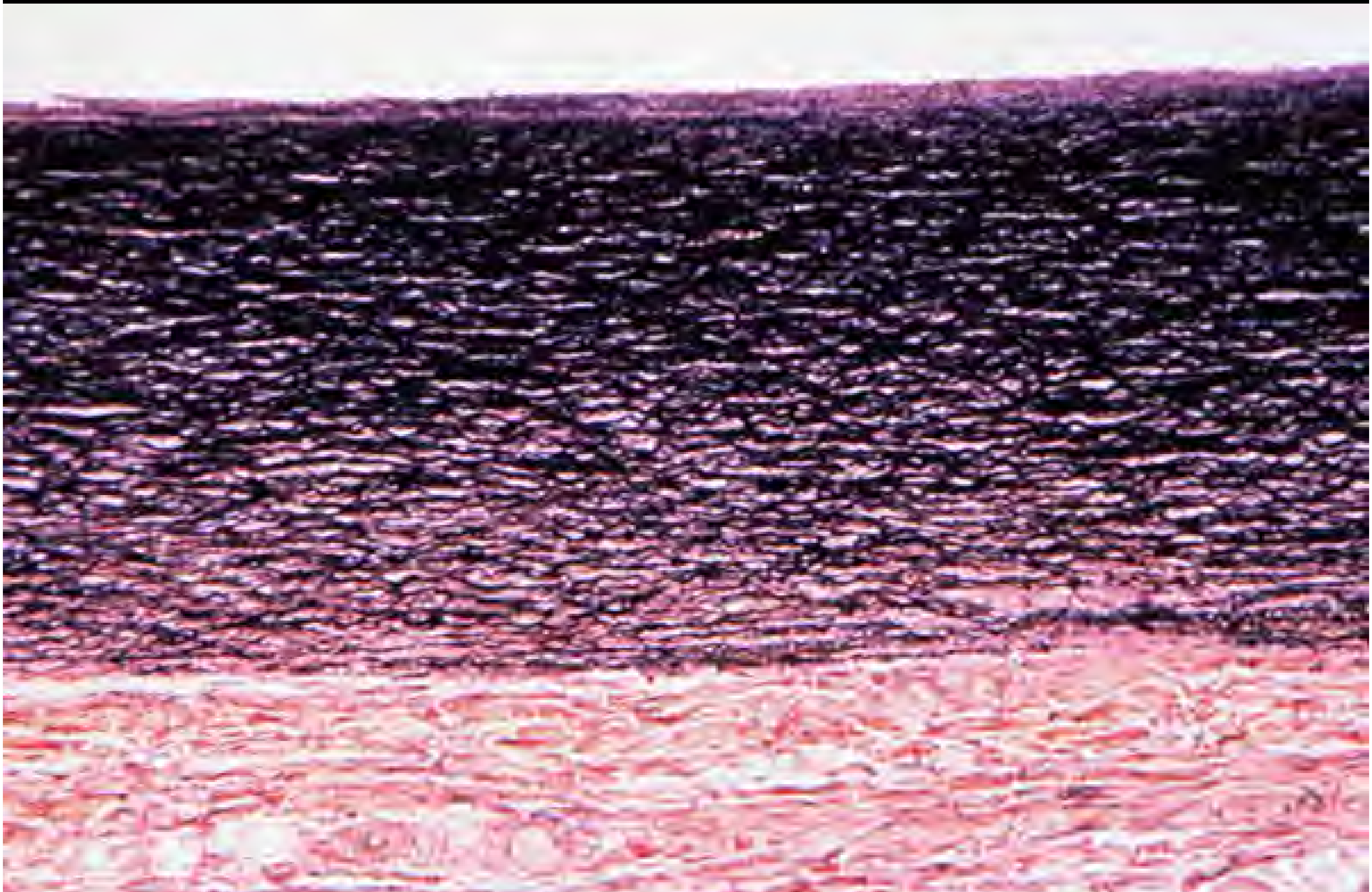
Boundary between the intima and media often unclear by LM.

Media has abundant concentric elastic sheets (fenestrated) and smooth muscle cells (that make the extracellular matrix and elastic sheets).

Adventitia rather thin.

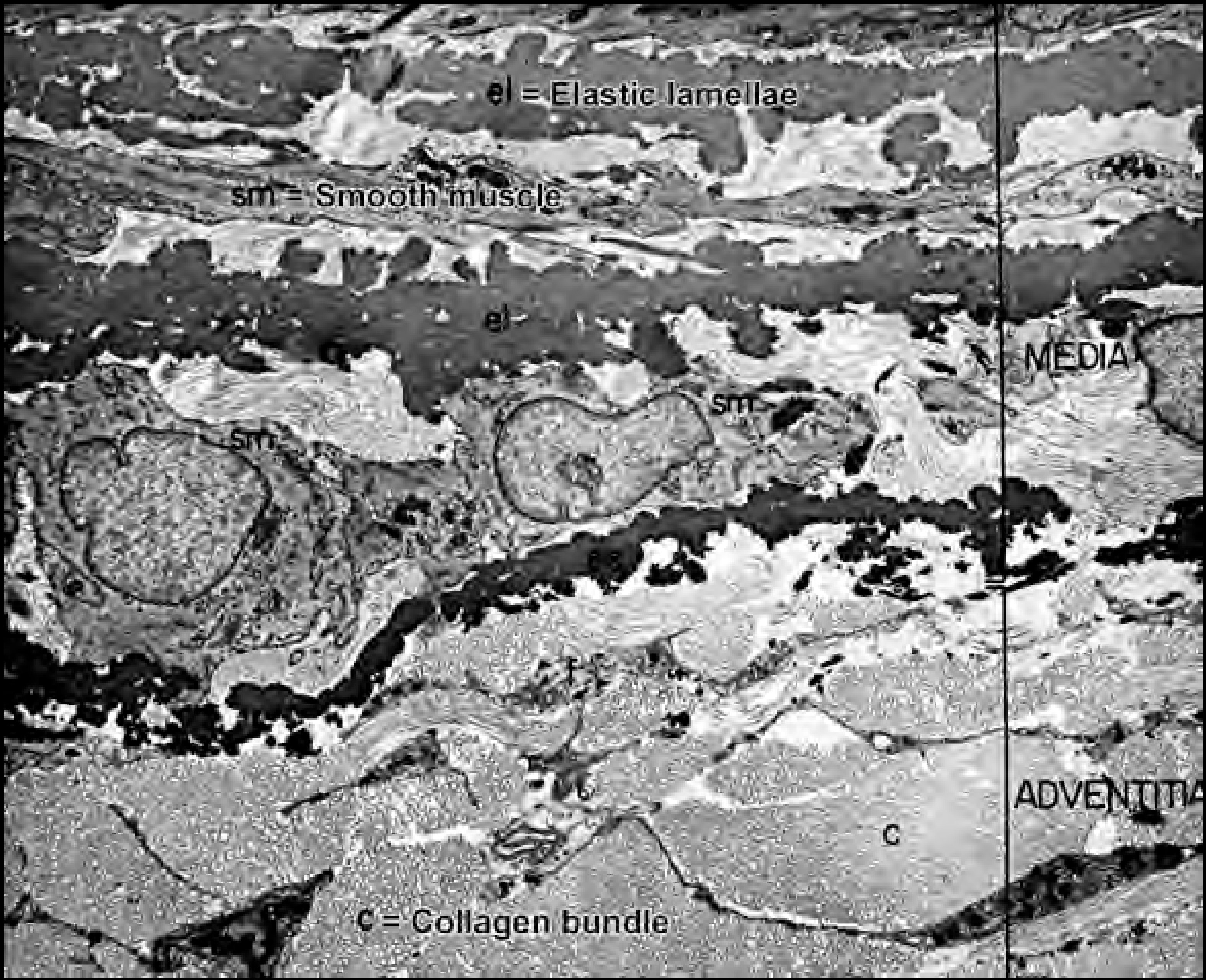


Wall of aorta, stained for elastin, LM



 Erlandsen slide set, slide 6/C/2

EM of aortic wall, media & adventitia



PD-INCL Simionescu and Simionescu, in Weiss Histology, 6th ed, fig 10-10, p 369

Large veins: inferior vena cava, very low power

Large veins: vena cava, external jugular, pulmonary, external iliac.

Wall quite thin. Intima usual. Media thin or absent. Adventitia prominent, usually containing longitudinally-oriented smooth muscle bundles. Valves present

Wall of the vena cava, showing longitudinal smooth muscle in adventitia, LM

 Humio Mizoguti, Kobe Univ Sch Med), slide 229

LYMPHATIC VESSELS

- Lymphatic vessels drain excess fluid from the tissues. They begin as blind lymphatic capillaries which take up excess tissue fluid. Lymph vessels contain no RBCs, but have some lymphocytes.
- Lymph flows through larger and larger collecting vessels, with histology resembling that of venules and veins (with valves).
- Occasional lymph nodes are interposed in the lymphatic vessel pathway, so the lymph flows through them (macrophages monitor the lymph, lymphocytes may engage in immune activities).
- Lymph reaches the thoracic duct and right lymphatic duct, both of which empty lymph into veins at the base of the neck, thus restoring the fluid and any content (proteins, etc.) to the blood.

Lymphatic capillary

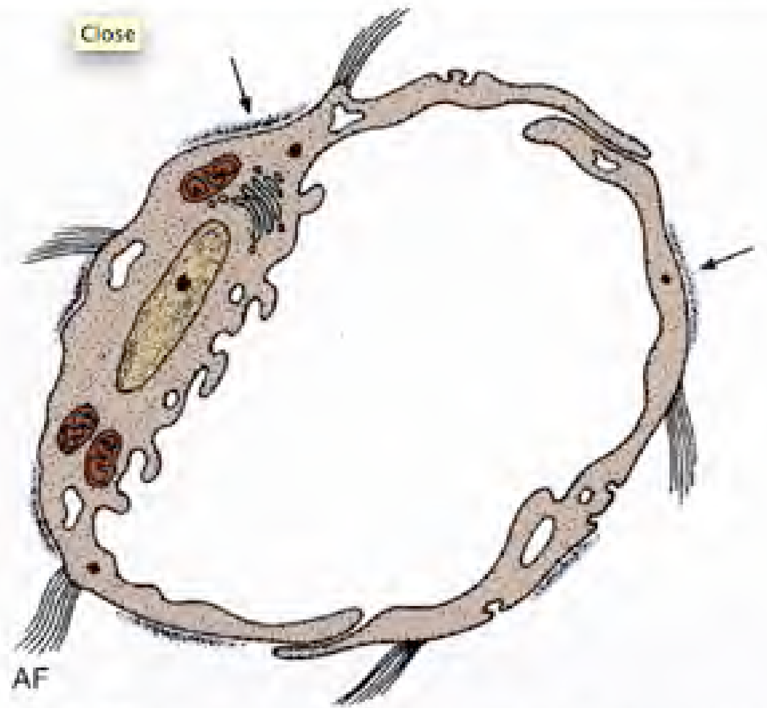
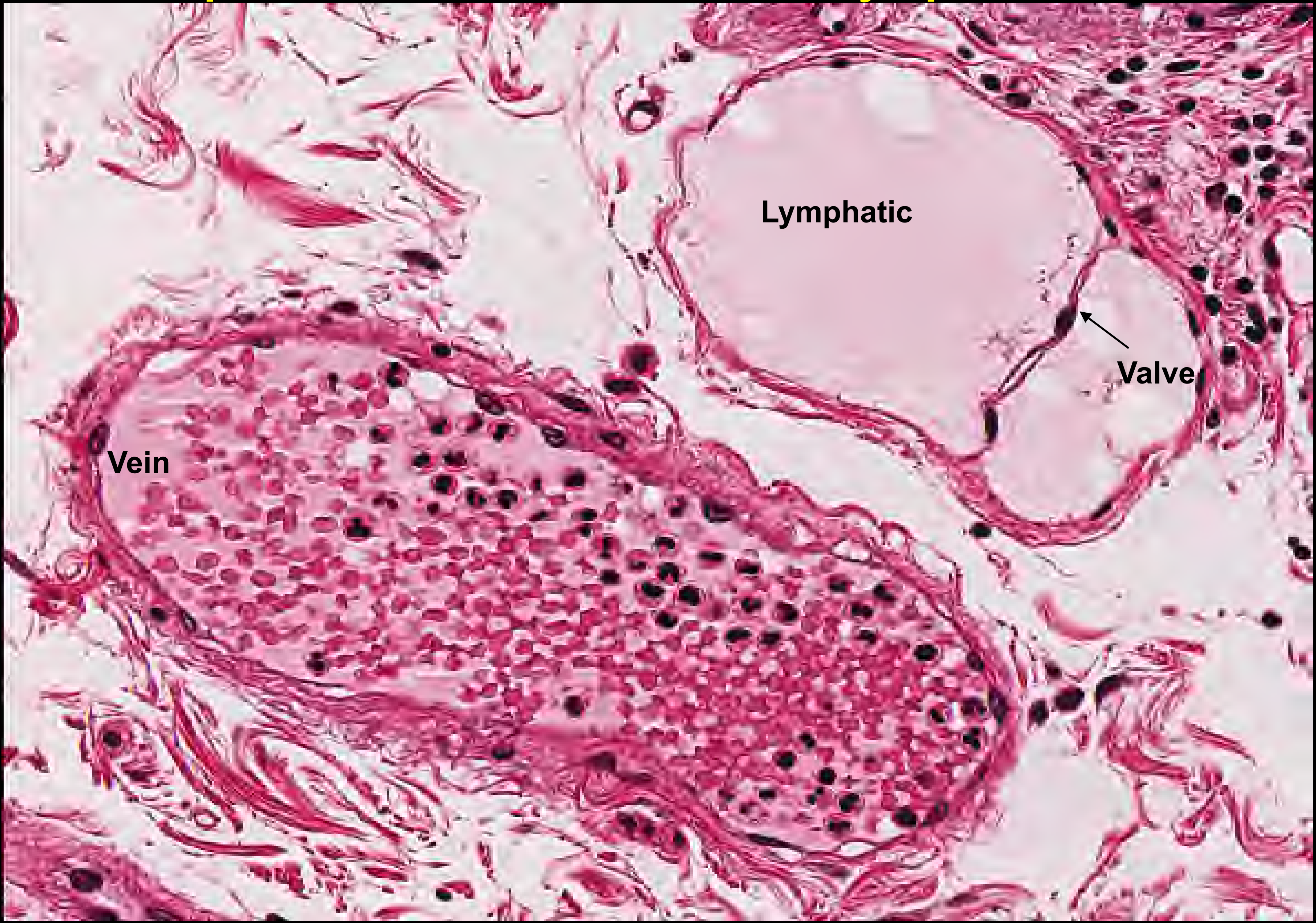


Figure 11–22. Structure of a lymphatic capillary at the electron microscope level. Note the overlapping free borders of endothelial cells, the discontinuous basal lamina (arrows), and the attachment of anchoring fibrils (AF). (Courtesy of J James.)

PD-INEL Junqueira and Carneiro, Basic Histology 10th ed., 2003, page 230, fig. 11-22

Comparison of a small vein and a lymphatic vessel



A.K. Christensen

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Slide 10: Erlandsen slide set, slide MH-6/D/1
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Slide 13: Sternberg 1992, Histology for Pathologists, p. 198.
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Slide 18: Humio Mizoguti, Kobe Univ Sch Med, slide 260
Slide 19: Fawcett Histology, 11th ed., 1986, page 375, fig 12-10
Slide 20: Erlandsen slide set, slide 6/D/5
Slide 21: Fawcett, A Textbook of Histology, 11th edition, 1986, page 387, fig 12-22
Slide 22: Nicolae and Maya Simionescu in Cell and Tissue Biology: a Textbook of Histology, ed. Leon Weiss, 6th edition, 1988, page 395, figure 10-38.
Slide 23: Fawcett's Histology, 11th ed., page 382
Slide 24: Humio Mizoguti, Kobe Univ Sch Med, slide 261
Slide 25: Erlandsen medical histology slide set (MH). MH-6E4
Slide 26: Erlandsen slide set, slide MH-6/E/3
Slide 27: Bloom and Fawcett Histology, 11th ed, fig 12-23, p 387
Slide 28: Don W. Fawcett.
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Slide 30: Fawcett Histology, 11th ed, fig 12-24, p 388)
Slide 31: Erlandsen slide set, slide 6/E/8
Slide 32: A. Kent Christensen
Slide 33: Weiss Histology, 6th ed, fig 10-31, p 388
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Slide 36: Original Source, Wheaters, Figure 9.18
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Slide 39: Ross. Histology: A Text and Atlas, 4th ed., page 343
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Slide 48: Humio Mizoguti, Kobe Univ Sch Med, slide 234
Slide 49: Humio Mizoguti, Kobe Univ Sch Med), slide 229
Slide 51: Junqueira and Carneiro, Basic Histology 10th ed., 2003, page 230, fig. 11-22
Slide 52: A. Kent Christensen