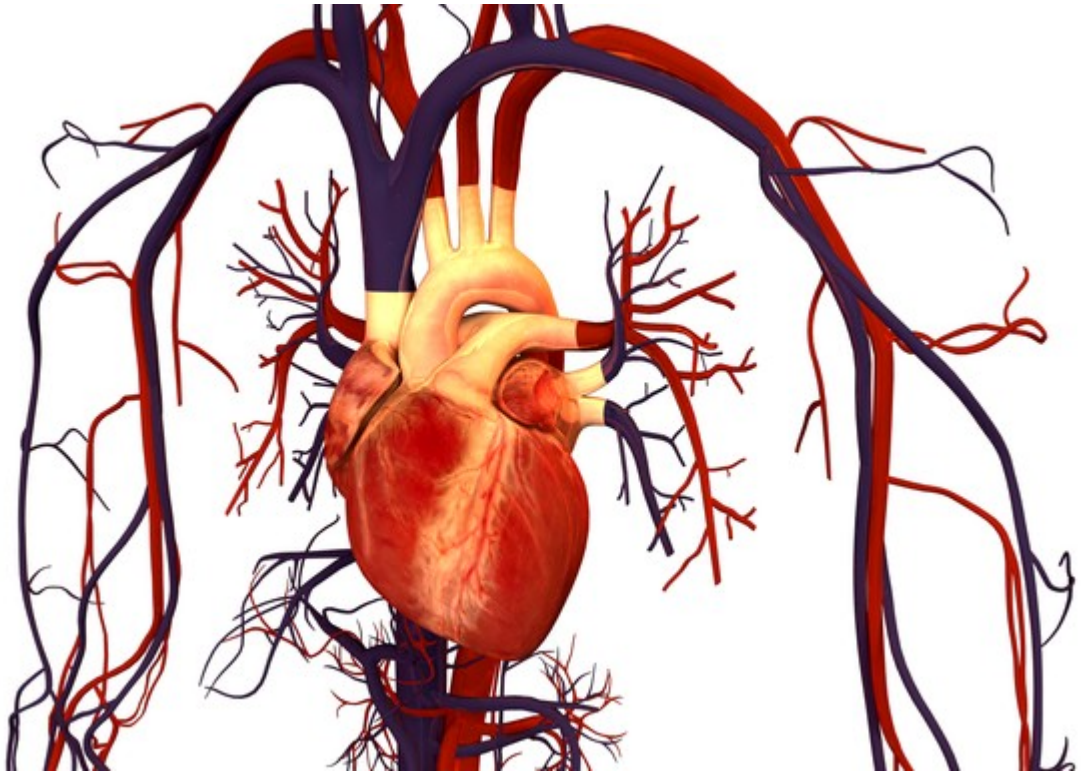


The Circulatory System, Blood, Hemopoiesis

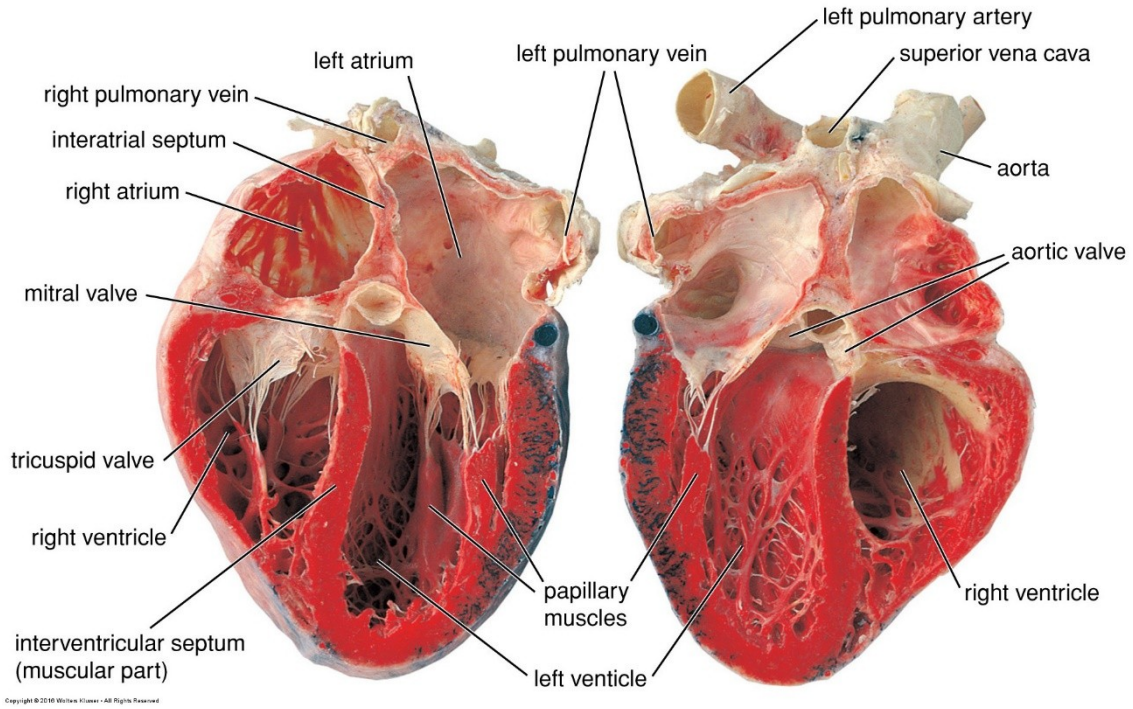
BI 455 CHAPTER 11-13

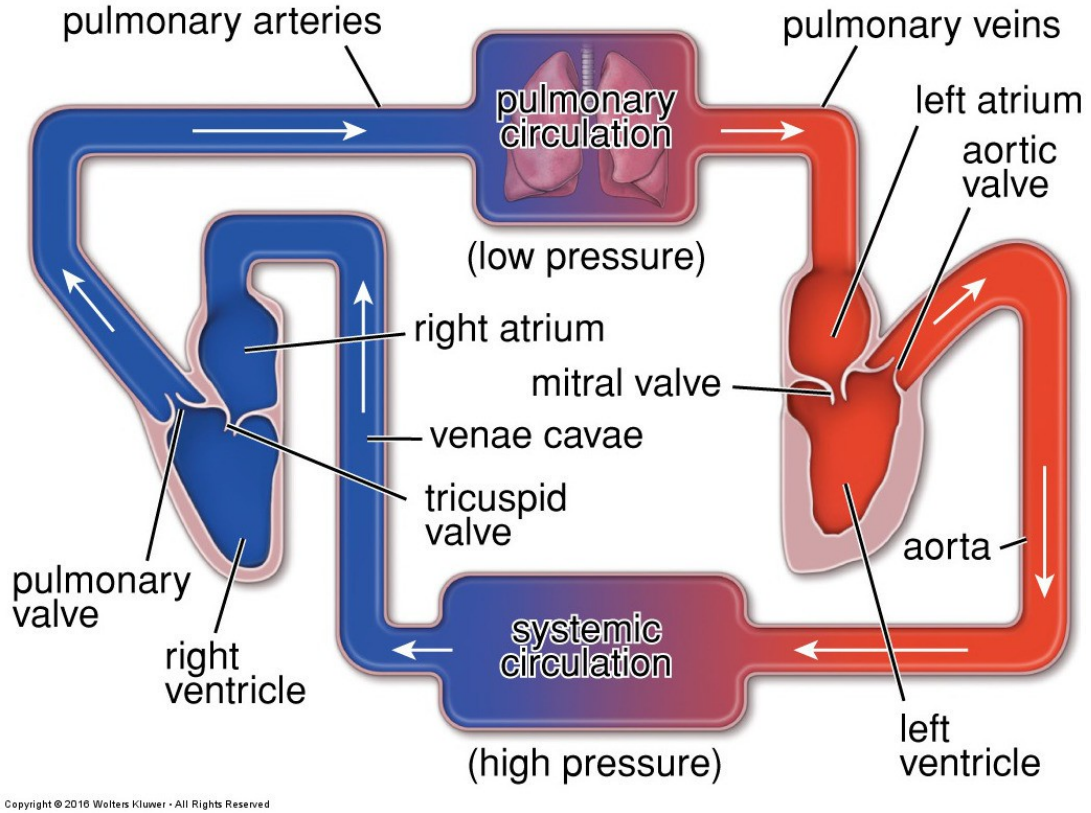
Chapter 11 Circulatory System
Key Points

1. The cardiovascular system includes the heart, blood vessels, and lymphatic vessels. It carries blood and lymph to and from various tissues of the body.
2. The heart is characterized by epicardium, myocardium, endocardium.
3. The conducting system autorhythmically generates heart muscle contractions
4. Arteries are classified based on size and thickness of their tunica media: large arteries (elastic arteries), medium arteries (muscular arteries), and small arteries (including arterioles)
5. Capillaries regulate substance exchange with tissues
6. Veins are divided into four types based on their size: venules, small veins, medium veins, and large veins
7. Lymphatic vessels convey interstitial fluids from tissues to the bloodstream

http://ed.ted.com/lessons/how-the-heart-actually-pumps-blood-edmond-hui

The heart is a muscular pump that maintains unidirectional flow of blood



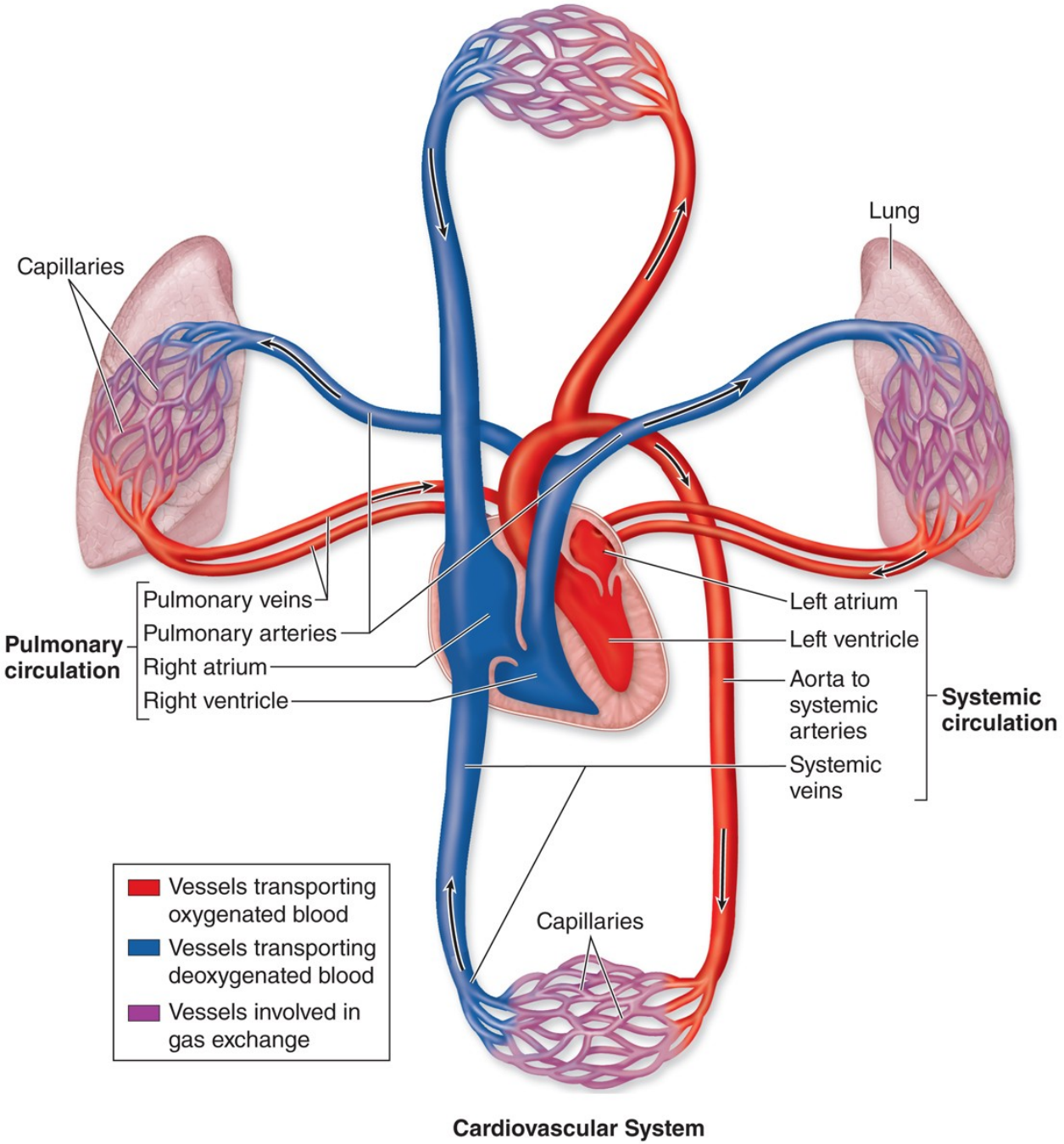


http://ed.ted.com/lessons/how-blood-pressure-works-wilfred-manzano

Circulation

Systemic circuit: tissues → superior and inferior venae cavae → right atrium → right AV valve → right ventricle → pulmonary valve → pulmonary trunk

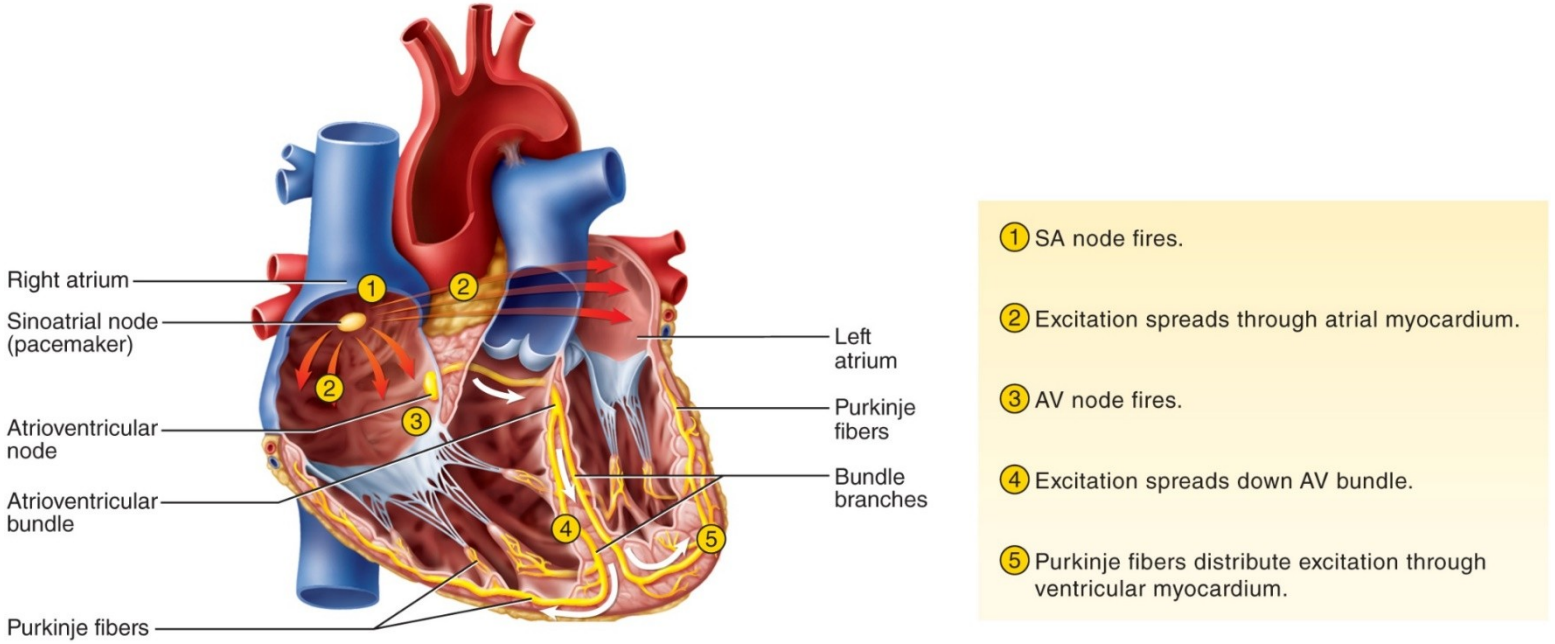
Pulmonary Circuit: Lungs → four pulmonary veins → left atrium → left AV valve → left ventricle → aortic valve → ascending aorta



Autorhythmic heart: Beats without stimuli from nervous system

Heart rhythm cessation: dysfunction in the conducting system → cardiac arrest→ no circulation.
Sudden cardiac arrest is a medical emergency; first-aid treatment such as cardiopulmonary resuscitation (CPR) and defibrillation (electrical resetting of the heart)

Sinoatrial node(SA) fires automatically →
Internodal conduction →
Atrioventricular (AV) node → Atrioventricular (AV) bundle (bundle of His) →
Purkinje fibers

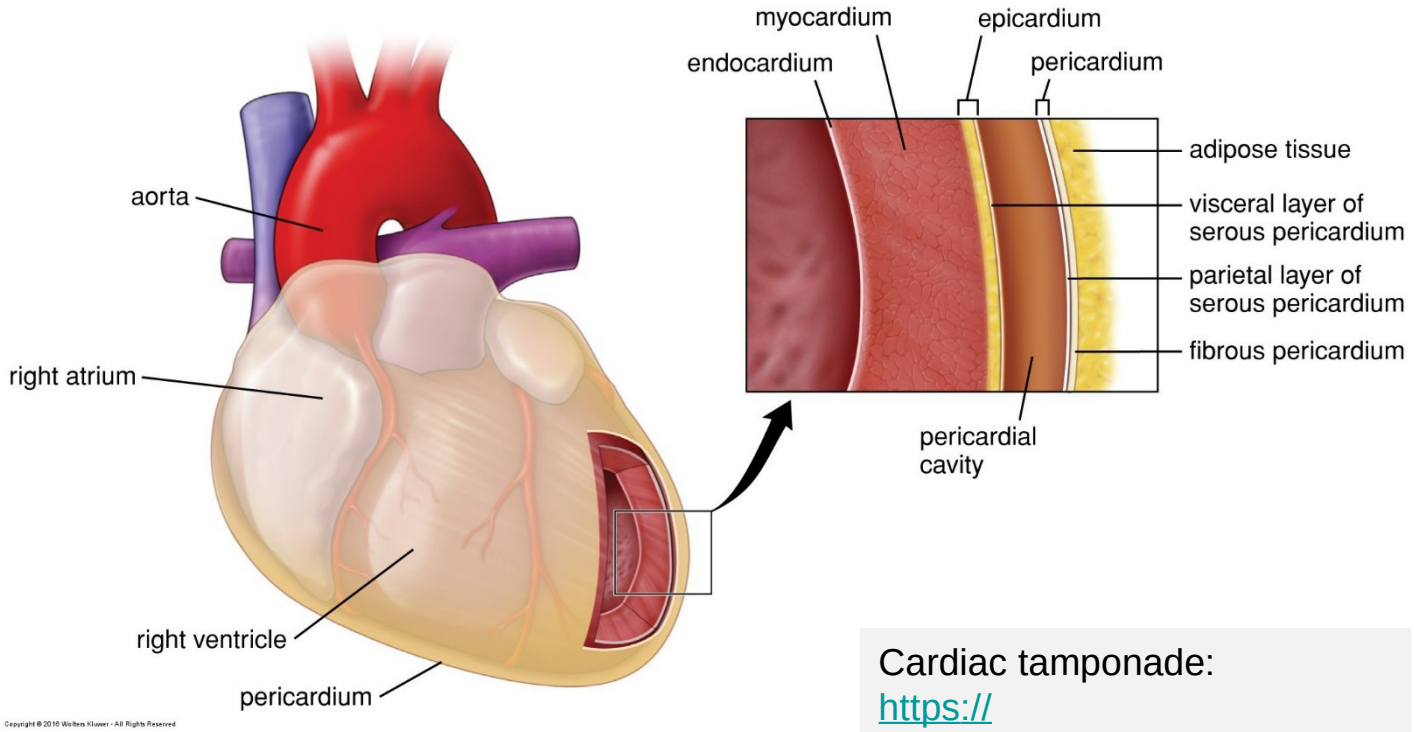


Wall of the heart has three layers: epicardium, myocardium, and endocardium.

- **Epicardium (Visceral Serous Pericardium):** Thin layer covering surface of heart
- **Myocardium:** Most of heart mass. Composed of cardiac muscle. Does contractile work of heart, thickness varies according to workload
- **Endocardium:** Lines interior of heart chambers, Covers valve surfaces. Continuous with inner lining of blood vessels

Outside the heart wall: Pericardial cavity, parietal serous pericardium, Fibrous pericardium, adipose tissue

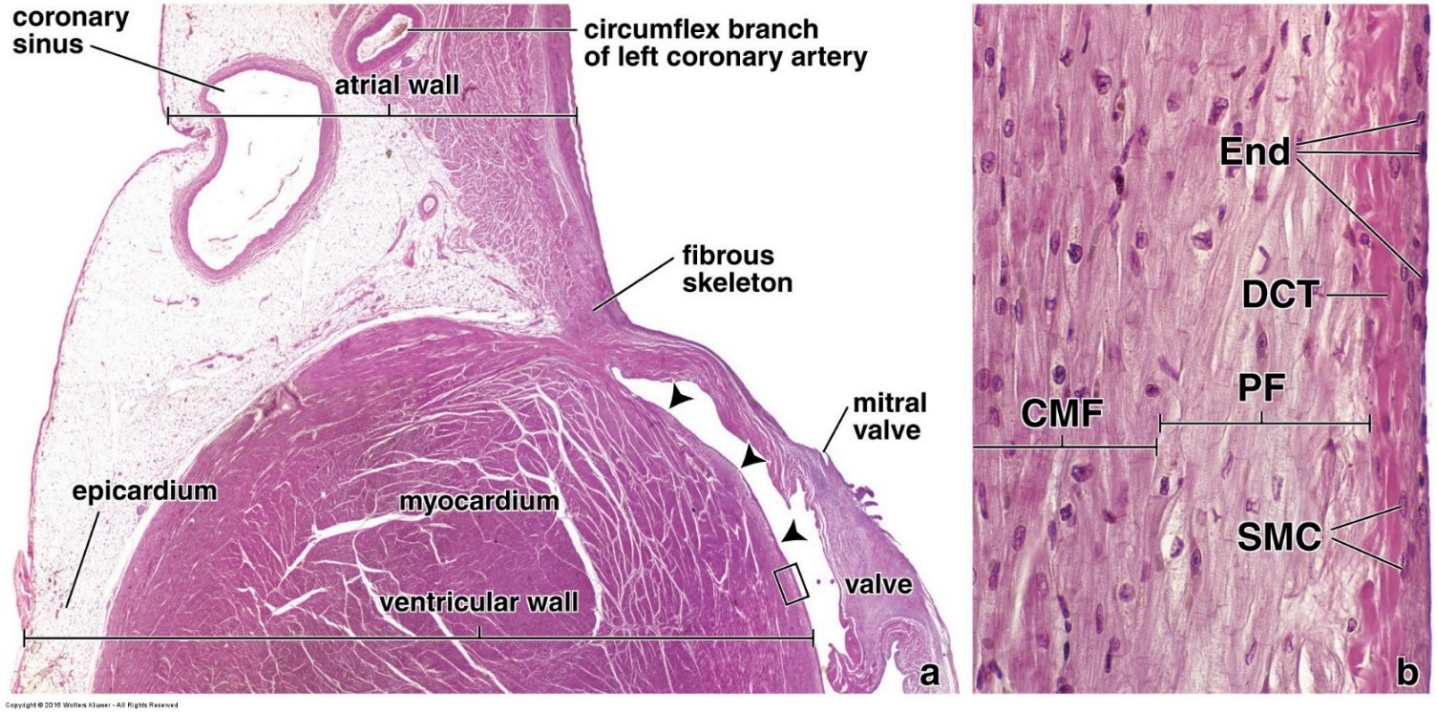
Cardiac tamponade: Fluid accumulation on pericardial cavity compresses heart. Caused by chest injury or pericarditis (inflammation of pericardium)



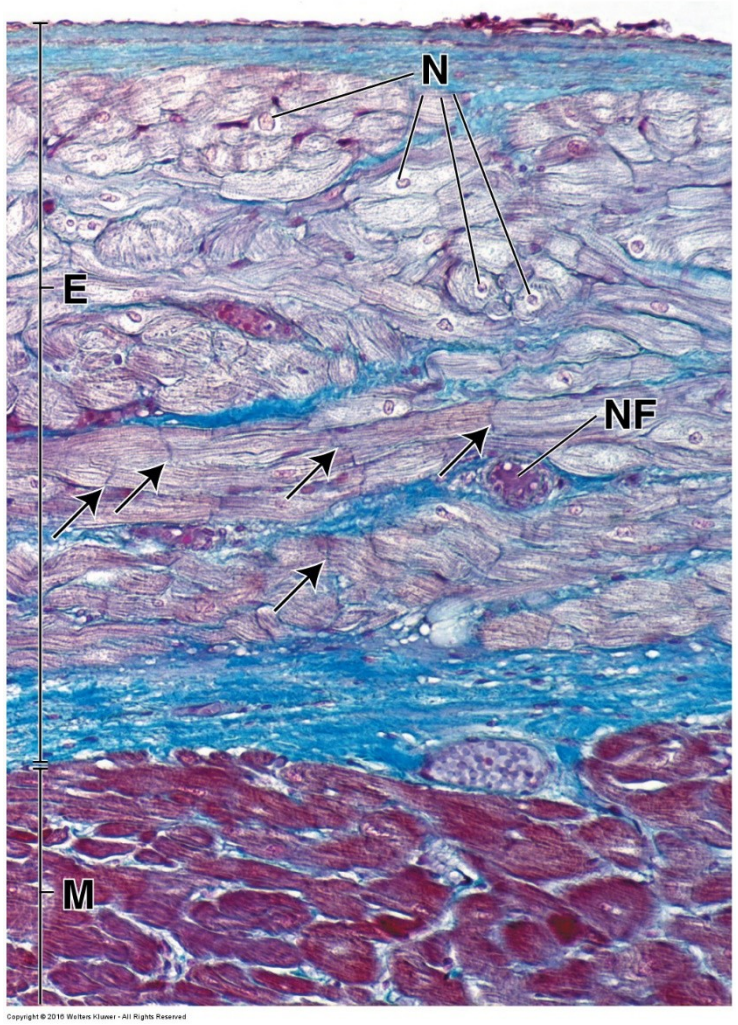
Cardiac tamponade: https://www.youtube.com/watch?v=QwgfuDegC5Y

The conducting system of the heart

Sagittal section of the posterior wall of left atrium and left ventricle: blood vessels of epicardium are surrounded by adipose tissue. Rectangle: Endocardium is squamous inner layer of endothelium (End), middle layer subendothelial dense connective tissue (DCT) containing smooth muscle cells (SMC), deep subendocardial layer of Purkinje fibers (PF). Myocardium: cardiac muscle fibers (CMF).



Conducting system as seen in the ventricular wall

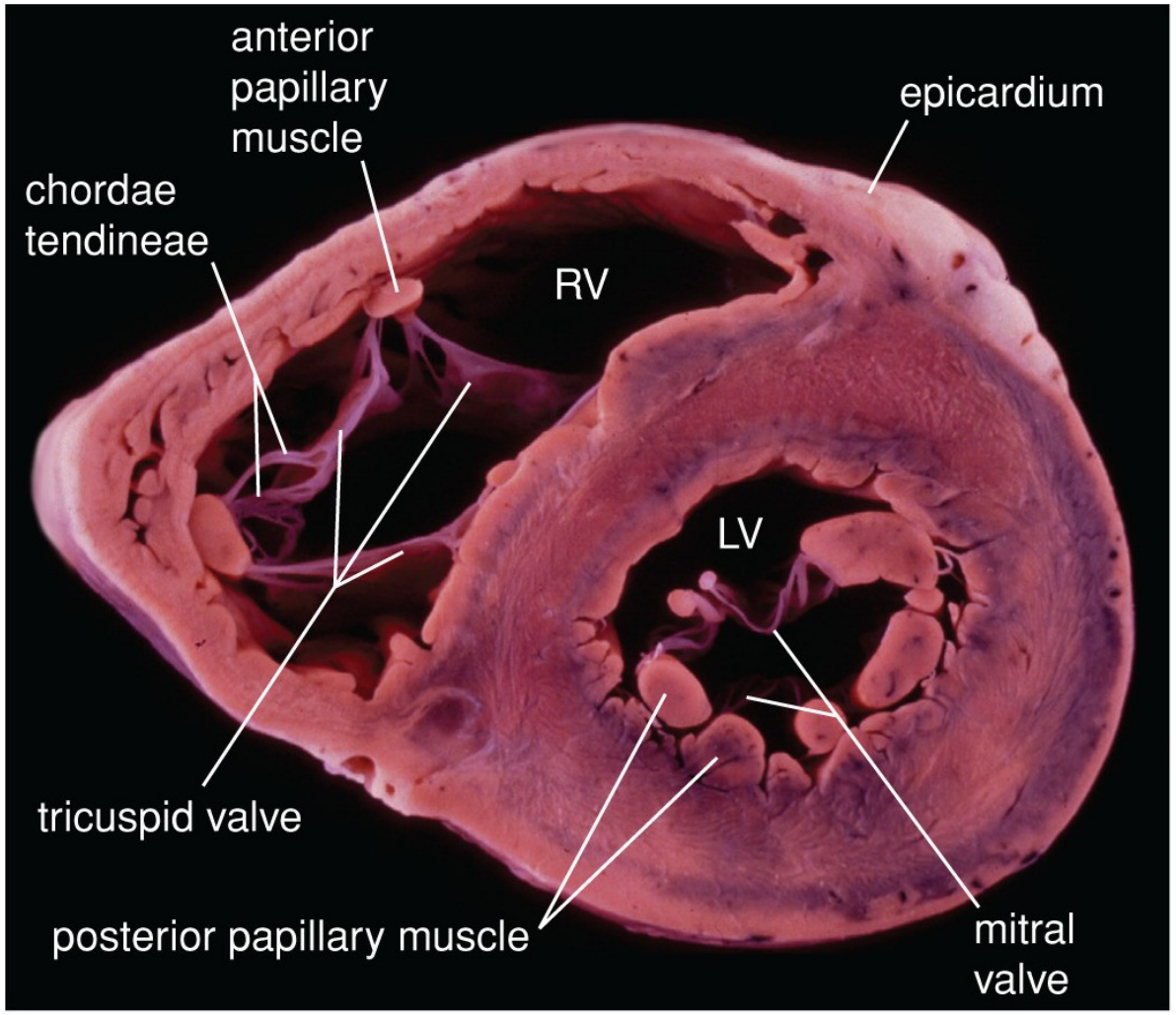


- **Endocardium (E):** The free luminal surface of the ventricle (top) is covered by endothelium and an underlying layer of subendothelial connective tissue (stained blue).

- **Intercalated discs** in the fibers (arrows).
- **Purkinje fibers**: large amounts of glycogen, pale-staining occupying center portion of the cell surrounded by the myofibrils. Among the Purkinje fibers are course nerves (NF) that belong to the autonomic nervous system

- Nuclei (N) are round and are larger than the nuclei of the cardiac muscle cells in the **myocardium (M).**

The heart wall in cross section



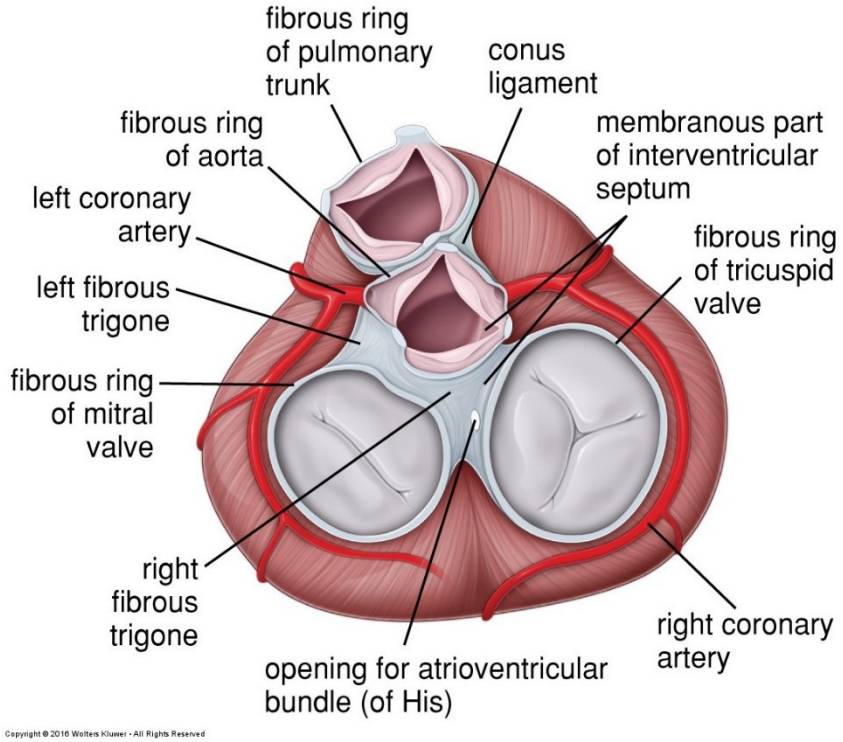
- Atria myocardium is thinner than ventricles
- Atria deliver blood to ventricles, while ventricles deliver to pulmonary and systemic circulations.
- Left ventricle delivers to systemic circulation, which requires more force.

Live Beating Heart and Heart Surgery:
https://www.youtube.com/watch?v=uR4t__B-Zwg

Fibrous skeleton

This fibrous network (indicated in blue) serves for the attachment of cardiac muscle and cuspid valves between the atria and ventricles and for the semilunar valves of the aorta and the pulmonary artery.

❯❯ **MEDICAL APPLICATION** Heart valve defects can be produced by developmental defects, scarring after certain infections, or hypertension.
If valves don't close tightly, backflow of blood produces heart murmur (sound), heart struggles to circulate blood.
Repaired by artificial or large animal donor valve, which lack endothelial covering. Requires exogenous anticoagulant agents to prevent thrombus formation.

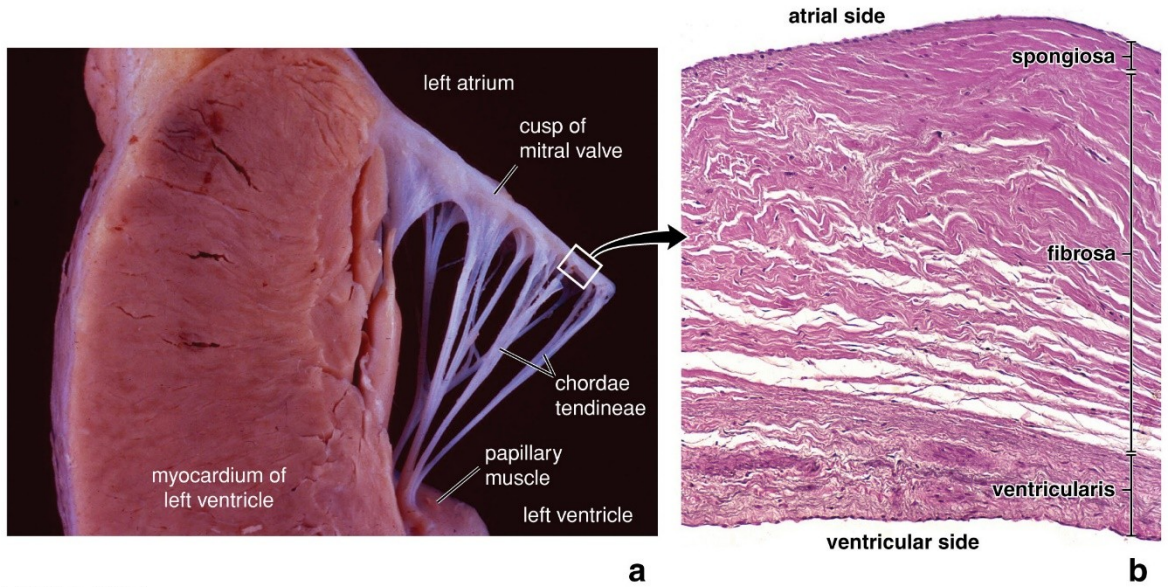


http://www.webmd.com/heart-disease/video/aortic-valve-replacement

Heart Valve: Connective tissue with overlying endocardium

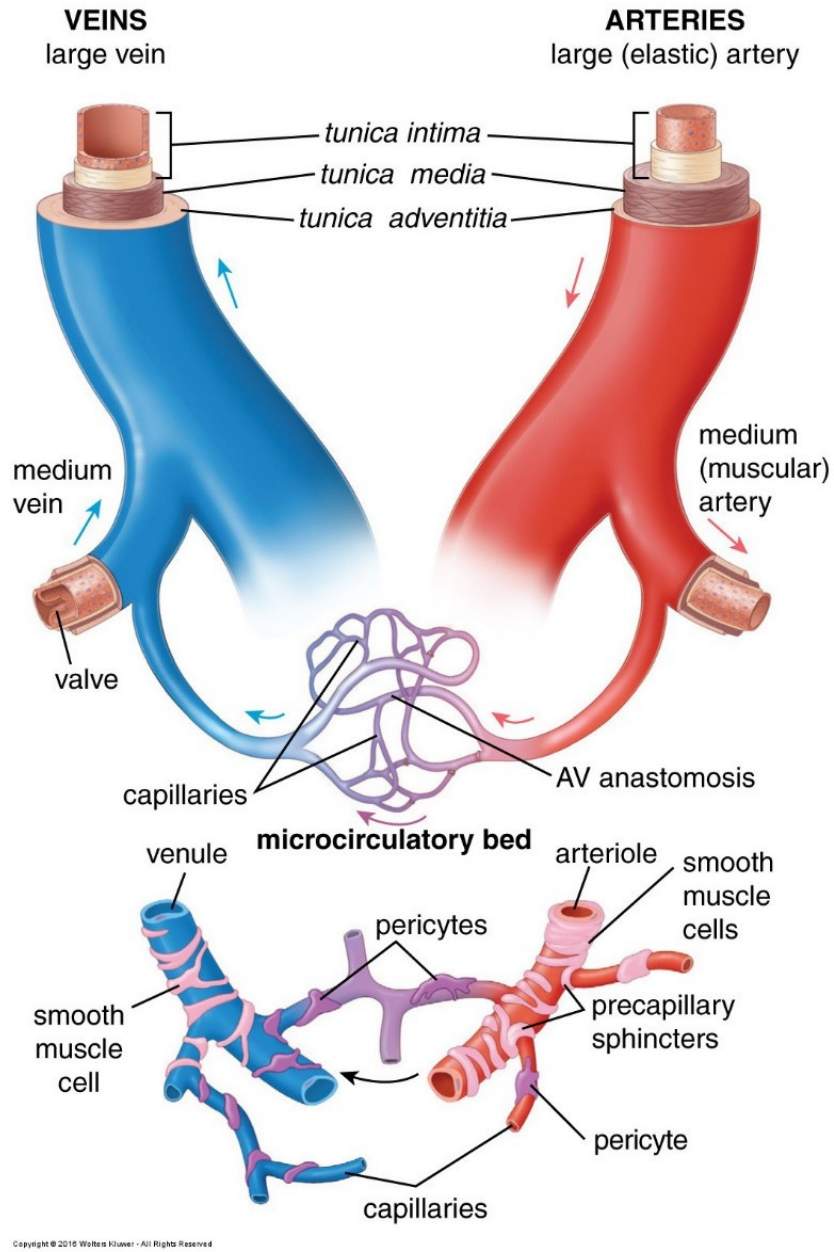
Valve cusps are normally avascular, but cusps are thin enough to allow nutrient diffusion from chamber blood.

Valvular heart disease: Inflammation of the heart valves (valvulitis) induces **angiogenesis** (blood vessel formation) in the valve and vascularization. This can lead to progressive replacement of elastic tissue by irregular masses of collagen fibers, causing the valve to thicken and then become rigid and inflexible



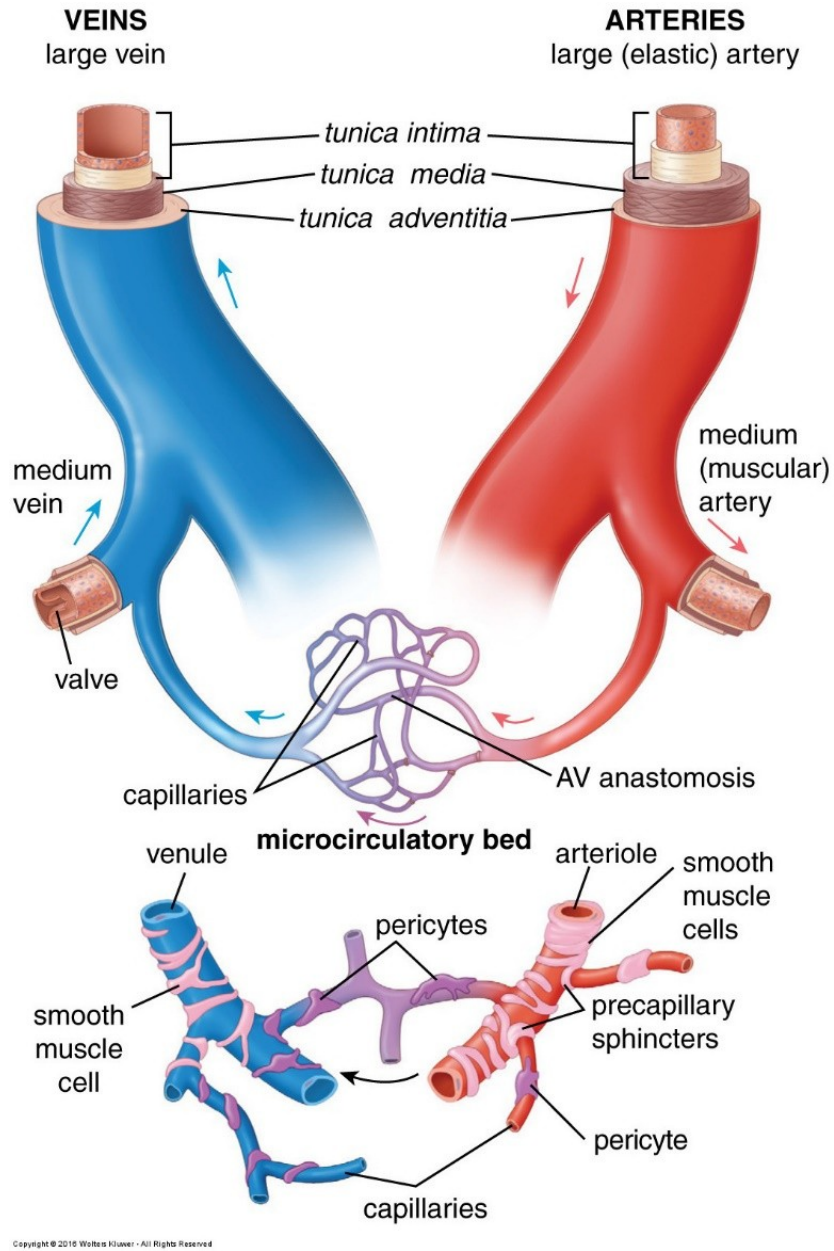
Arteries

Vessel	Diameter	Tunica intima (inner layer)	Tunica media (middle layer)	Tunica adventitia (outer layer)
Large artery (elastic artery)	>10 mm	Endothelium Connective tissue Smooth muscle	Smooth muscle Elastic lamellae	Connective tissue Elastic fibers Thinner than tunica media
Medium artery (muscular artery)	2–10 mm	Endothelium Connective tissue Smooth muscle Prominent internal elastic membrane	Smooth muscle Collagen fibers Relatively little elastic tissue	Connective tissue Some elastic fibers Thinner than tunica media
Small artery	0.1–2 mm	Endothelium Connective tissue Smooth muscle Internal elastic membrane	Smooth muscle (8–10 cell layers) Collagen fibers	Connective tissue Some elastic fibers Thinner than tunica media
Arteriole	10–100 µm	Endothelium Connective tissue Smooth muscle	Smooth muscle (1–2 cell layers)	Thin, ill-defined sheath of connective tissue
Capillary	4–10 µm	Endothelium	None	None

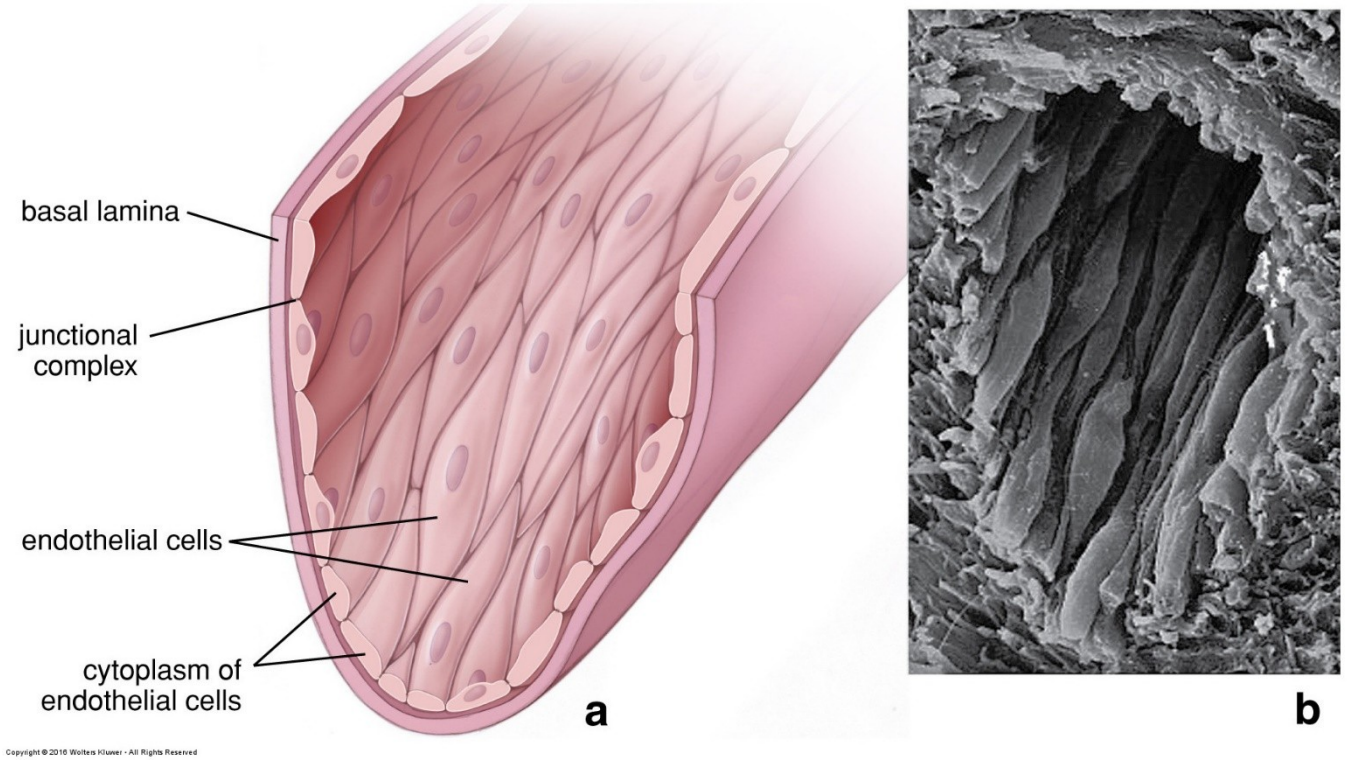


Veins

Vessel	Diameter	Tunica intima (inner layer)	Tunica media (middle layer)	Tunica adventitia (outer layer)
Postcapillary venule	10–50 μm	Endothelium Pericytes	None	None
Muscular venule	50–100 μm	Endothelium	Smooth muscle (1–2 cell layers)	Connective tissue Some elastic fibers Thicker than tunica media
Small vein	0.1–1 mm	Endothelium Connective tissue Smooth muscle (2–3 layers)	Smooth muscle (2–3 layers continuous with tunica intima)	Connective tissue Some elastic fibers Thicker than tunica media
Medium vein	1–10 mm	Endothelium Connective tissue Smooth muscle Internal elastic membrane in some cases	Smooth muscle Collagen fibers	Connective tissue Some elastic fibers Thicker than tunica media
Large vein	>10 mm	Endothelium Connective tissue Smooth muscle	Smooth muscle (2–15 layers) Cardiac muscle near heart Collagen fibers	Connective tissue Some elastic fibers, longitudinal smooth muscles Much thicker than tunica media



In the adult human body, a circulatory system consists of about 60,000 miles of different-sized vessels lined with vascular endothelium



a. The cells are elongated with their long axis parallel to the direction of blood flow. Nuclei of endothelial cells are also elongated in the direction of blood flow.

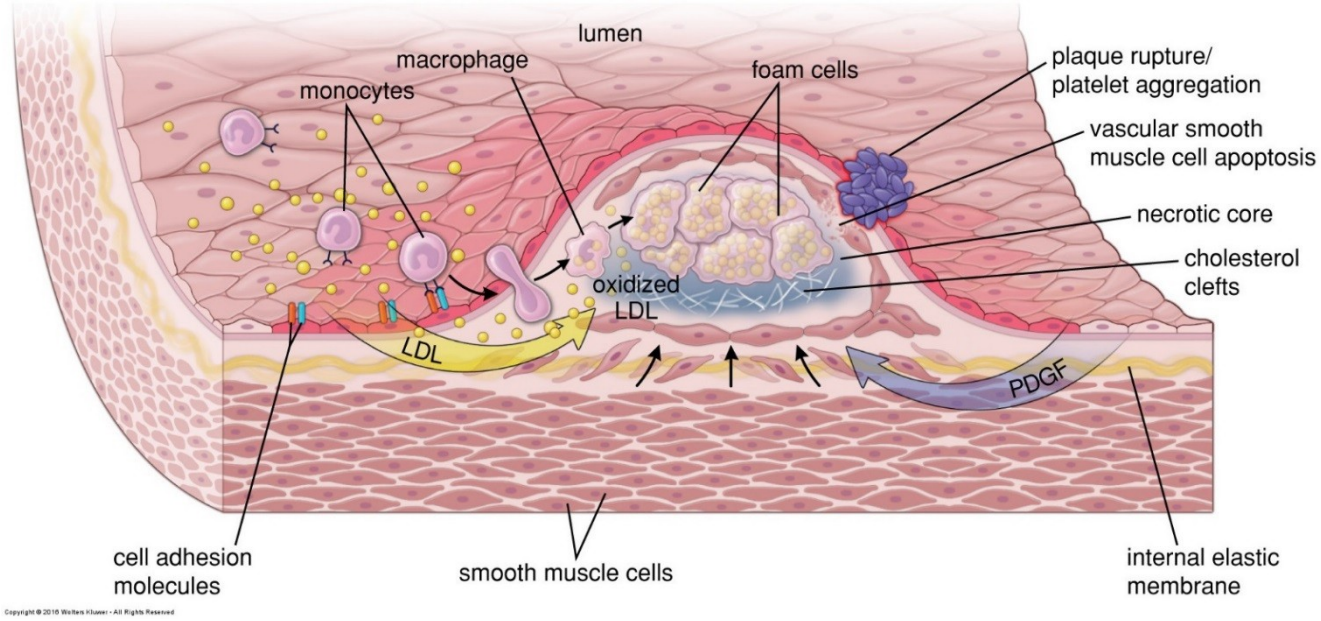
b. Scanning electron micrograph of a small vein, showing the cells of the endothelial lining. Note the spindle shape with the long axis of the cells running parallel to the vessel.

Vascular endothelium: continuous layer of fattened, elongated, cells aligned with their long axes in the direction of the blood flow.

Endothelial surface adhesion molecules: Low-density lipoprotein [LDL], insulin, and histamine receptors
Endothelial activation: cells produce new surface that control blood coagulation.

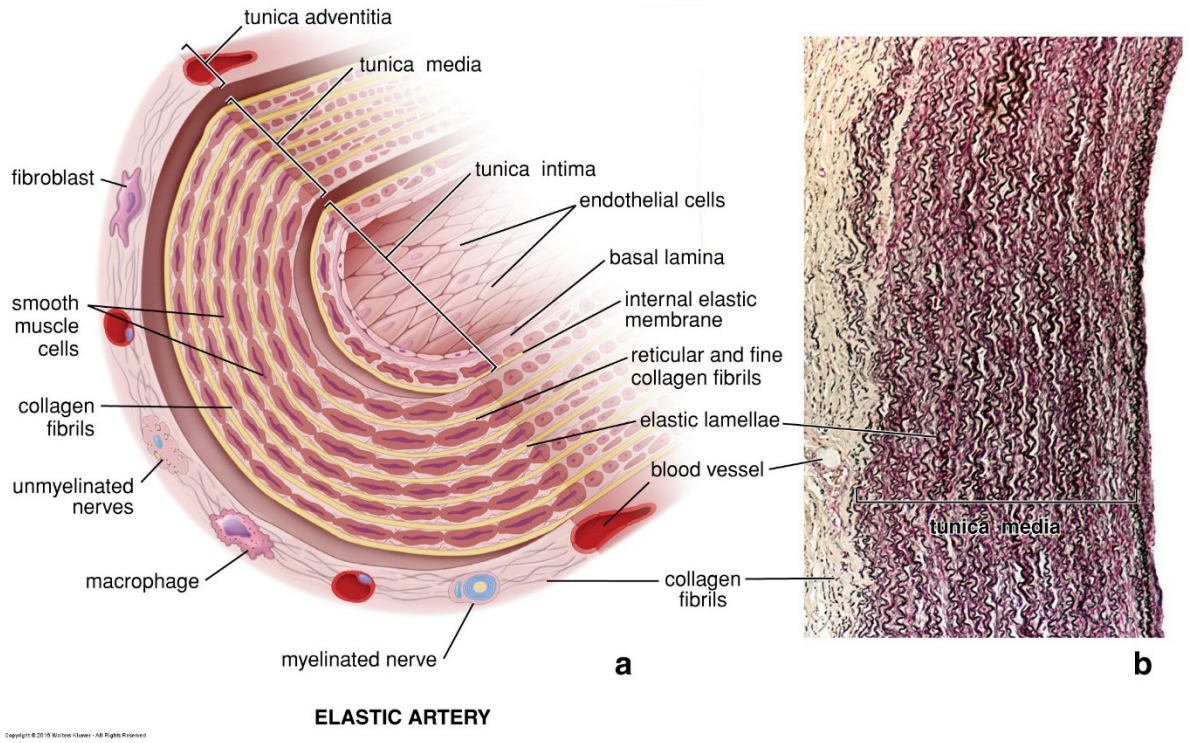
❯❯ **MEDICAL APPLICATION**: Tissue injury → platelet aggregation → clotting.

Emboli (clots) may detach and obstruct distant vessels.
Myocardial infarct, stroke, or pulmonary embolism, are treated intravenously with tissue plasminogen activator, which breaks down fibrin and quickly dissolves the clot.



http://ed.ted.com/lessons/what-happens-during-a-heart-attack-krishna-sudhir

Elastic (large) arteries: Arteries that distend after systole, then recoil to propel blood into circuit



❯❯ MEDICAL APPLICATION

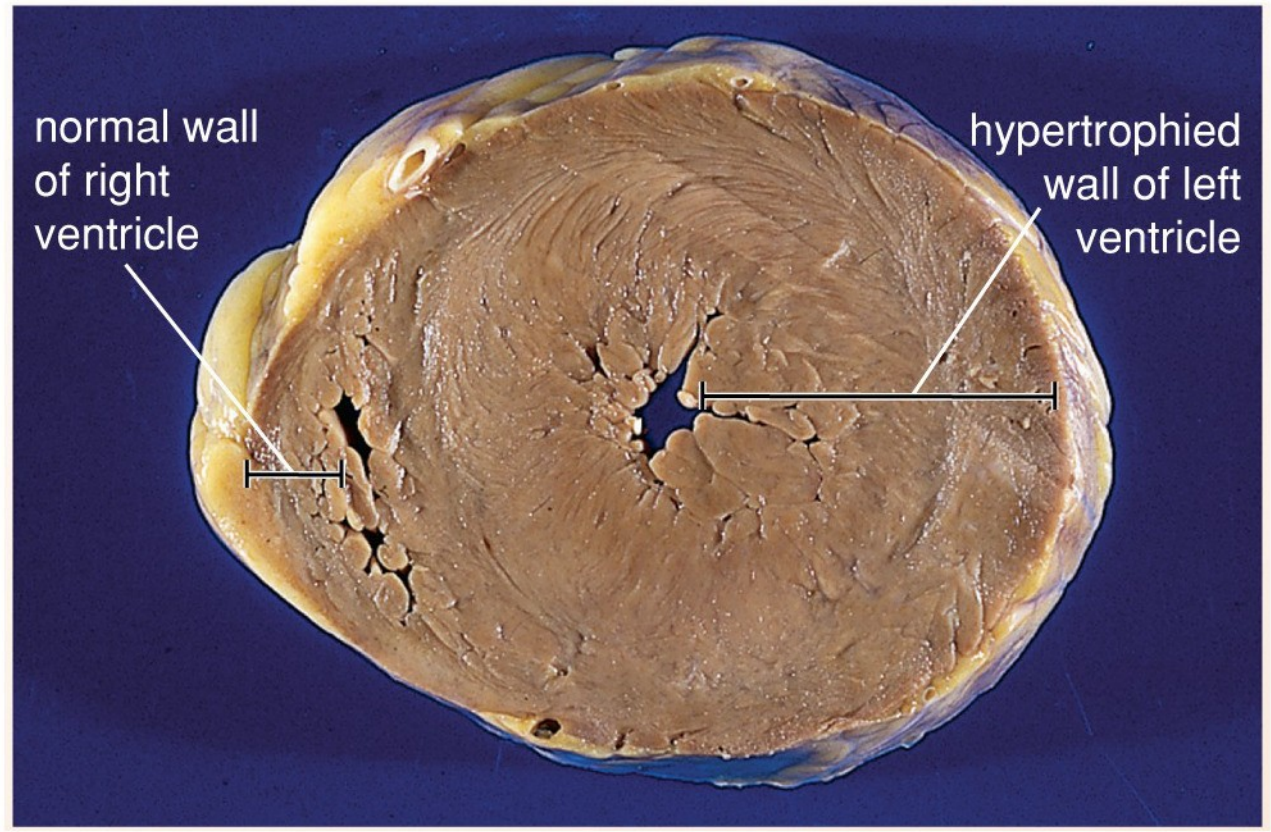
Atherosclerosis (Gr. *athero*, gruel or porridge, and *scleros*, hardening) may play a role in nearly half of all deaths in developed parts of the world. Poor LDL oxidation in the tunica intima induces monocytes/macrophages to remove the LDL. Lipid-filled macrophages (called foam cells) accumulate and produce plaques.

Predisposing factors include dyslipidemia (>3:1 ratios of LDL to HDL [high-density lipoprotein]), hyperglycemia of diabetes, hypertension, and the presence of toxins introduced by smoking.

In elastic arteries, this causes weakening and aneurysms that can rupture. In muscular arteries this can occlude blood flow to downstream vessels, leading to ischemic heart disease.

http://www.webmd.com/heart-disease/video/atherosclerosis

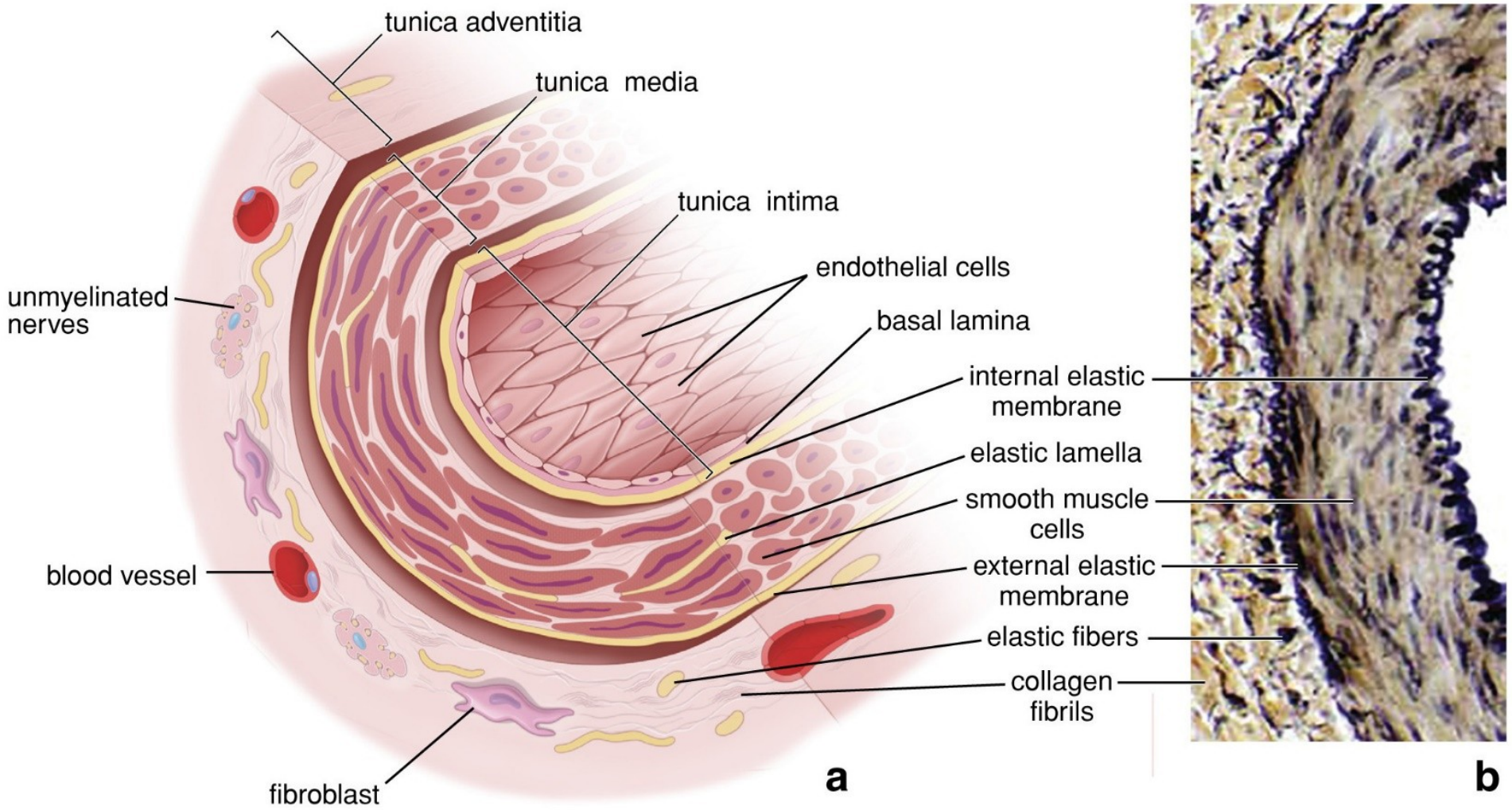
Hypertension



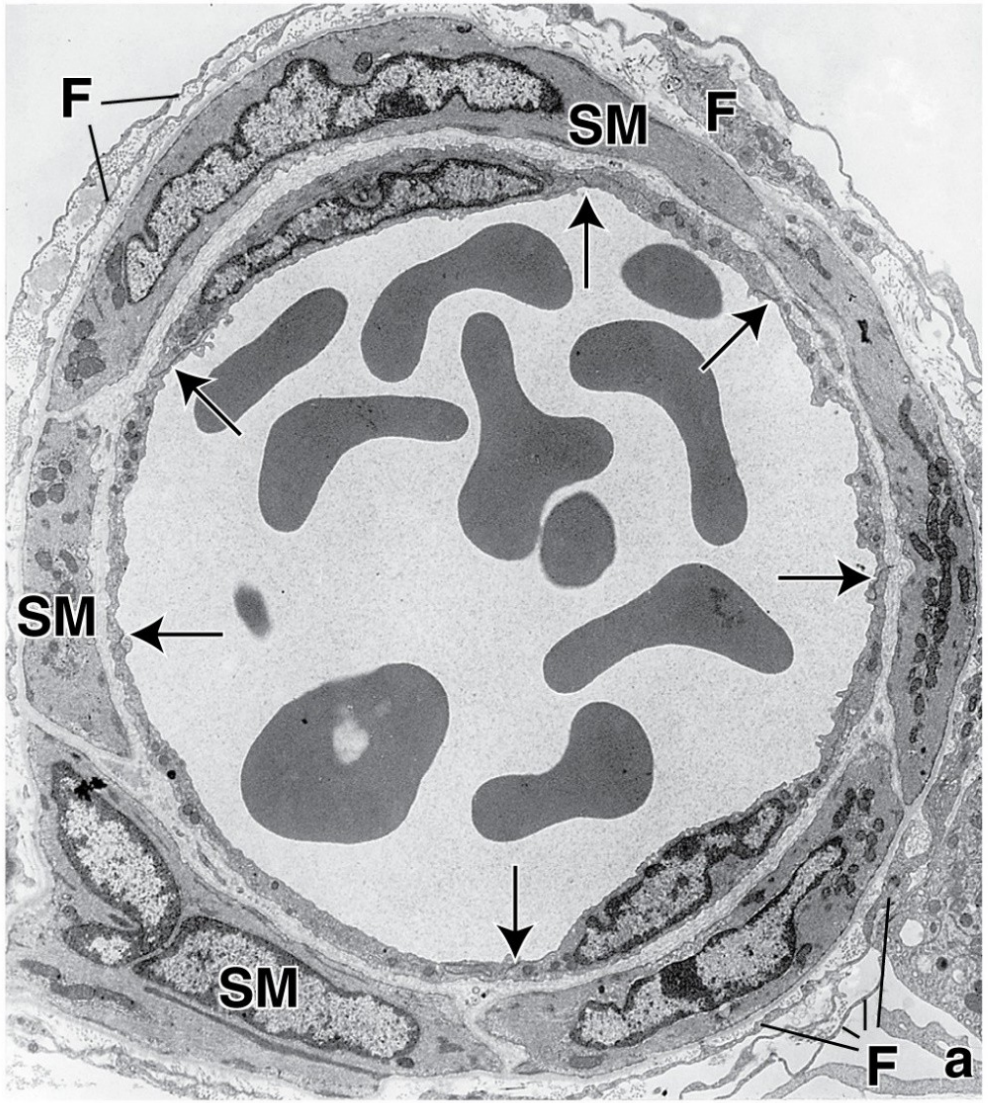
Atherosclerosis reduces diameter of small muscular arteries and arterioles is reduced, which leads to increased vascular resistance.

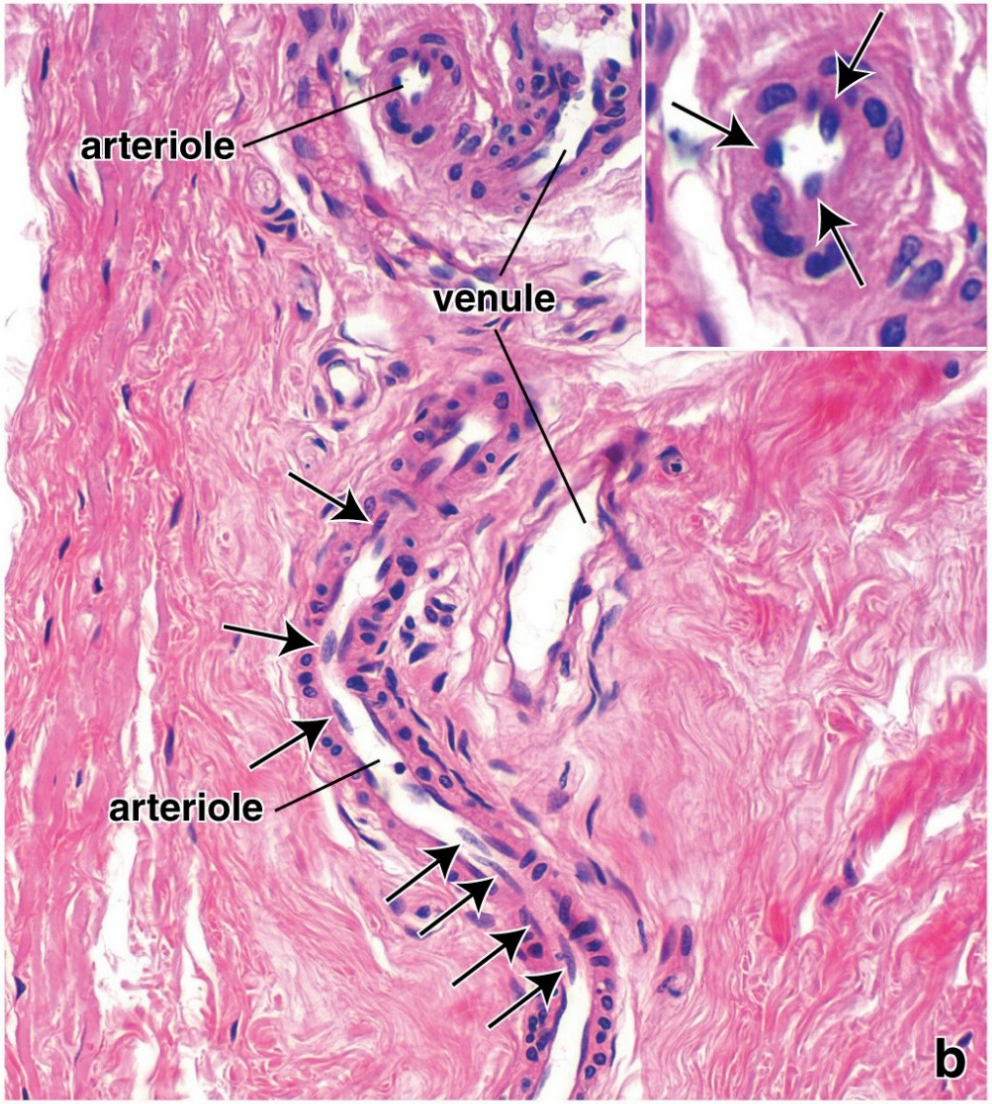
This causes compensatory left ventricular hypertrophy. Ventricular hypertrophy in this condition is caused by an increased diameter (not length) of cardiac muscle cells with characteristic enlarged and rectangular nuclei. Left ventricular hypertrophy is a common manifestation of **hypertensive heart disease**

Medium (muscular) arteries: more smooth muscle and less elastin in tunica media

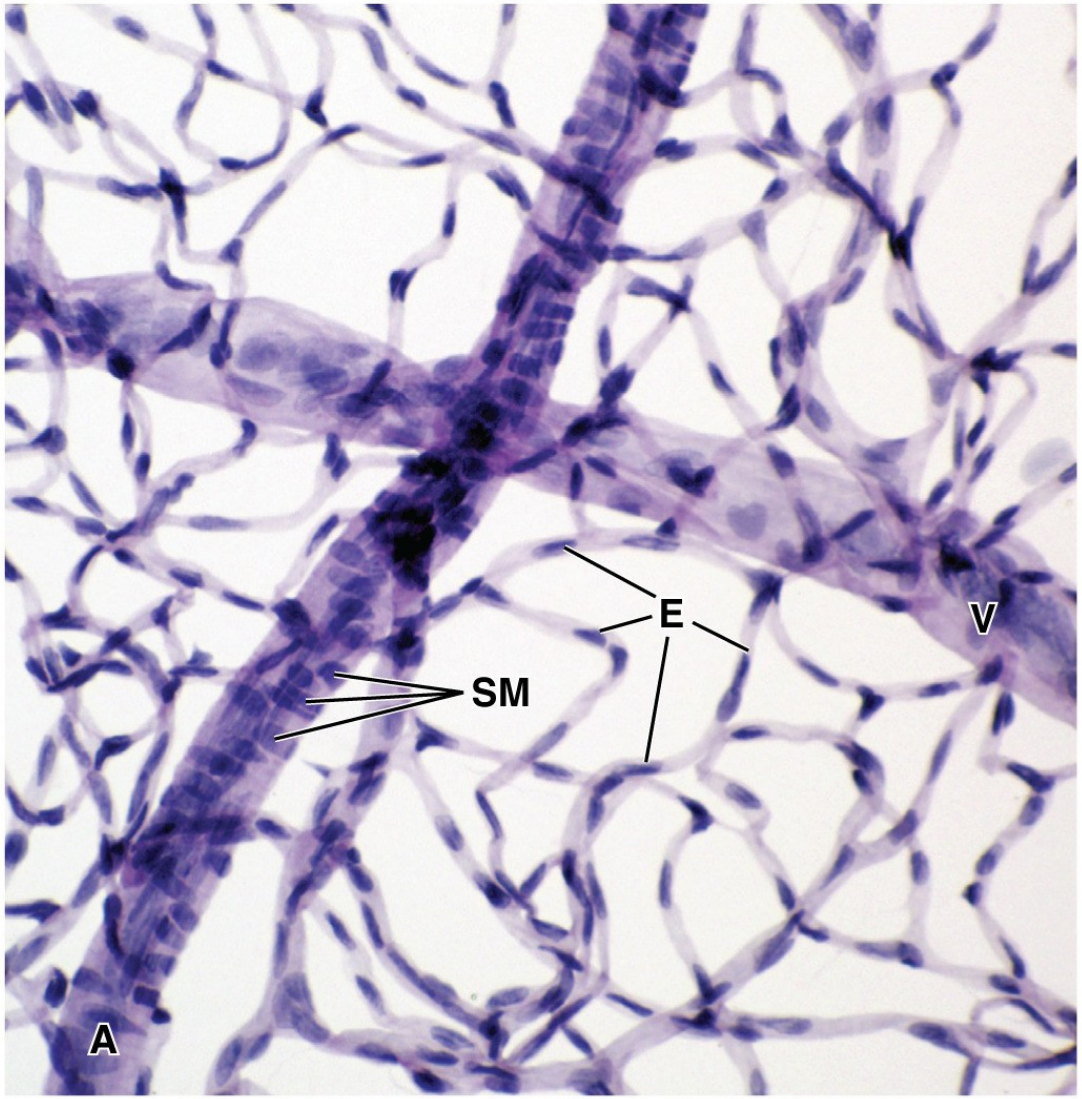


Small arteries (8 muscle cell layers) and arterioles (1-2 muscle cell layers)





Capillaries: smallest diameter blood vessels, often smaller than the diameter of an erythrocyte



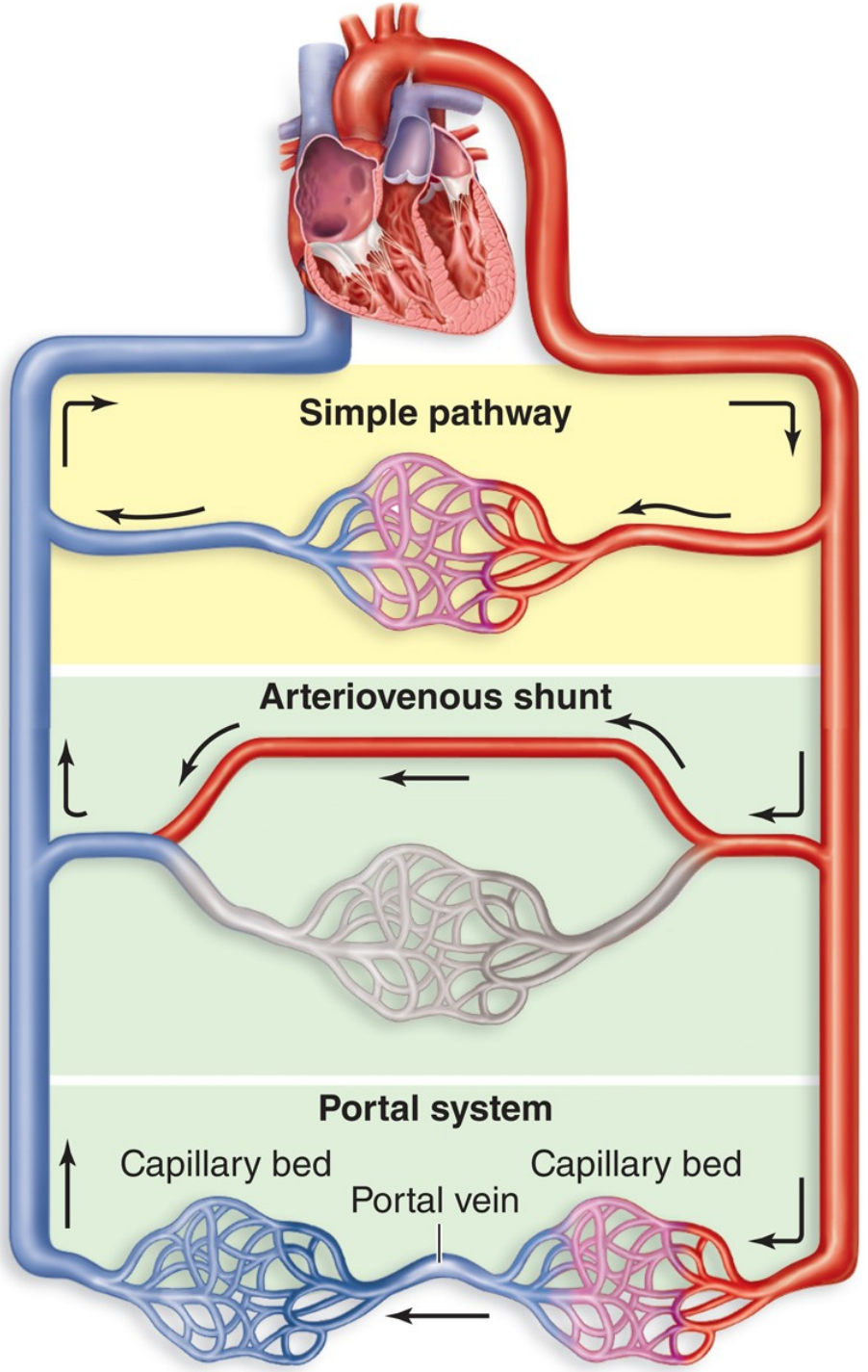
Capillaries allow fluids containing gases, metabolites, and waste products to move through their thin walls.

The human body contains approximately 50,000 miles of capillaries. Each consists of a single layer of endothelial cells and their basal lamina. The endothelial cells form a tube just large enough to allow the passage of red blood cells one at a time. In many capillaries, the lumen is so narrow that the RBCs fold to pass through.

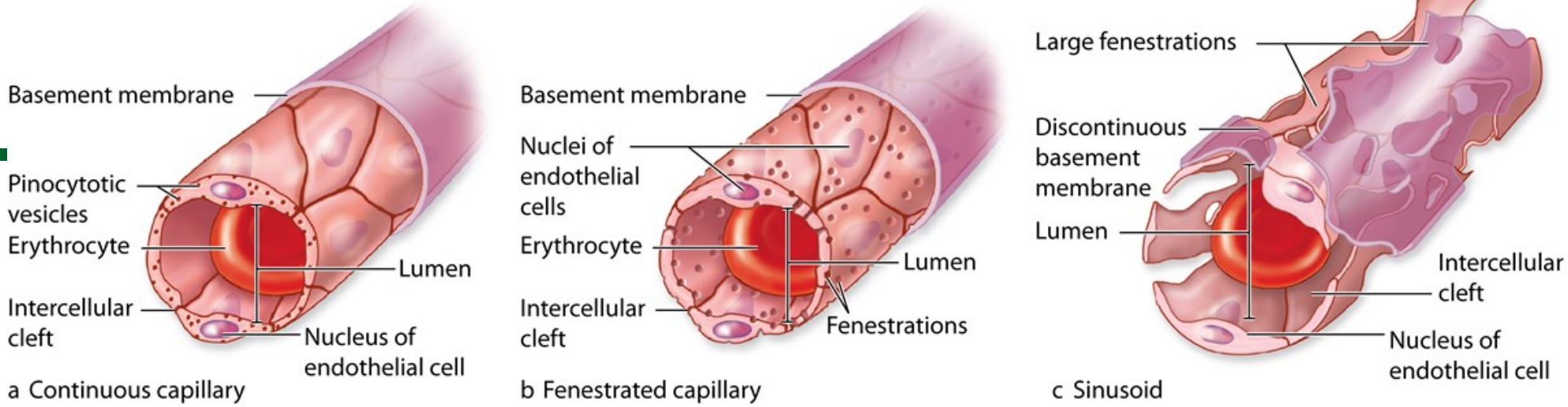
Microvascular pathways

Arteriovenous (AV) shunts (anastomoses): Connect the arterial and venous systems and temporarily bypass capillaries. Common in skin to prevent heat loss.

Venous portal systems: allows molecules entering the blood in the first set of capillaries to be delivered quickly and at high concentrations to surrounding tissues at the second capillary bed, which is important in the anterior pituitary gland and liver.

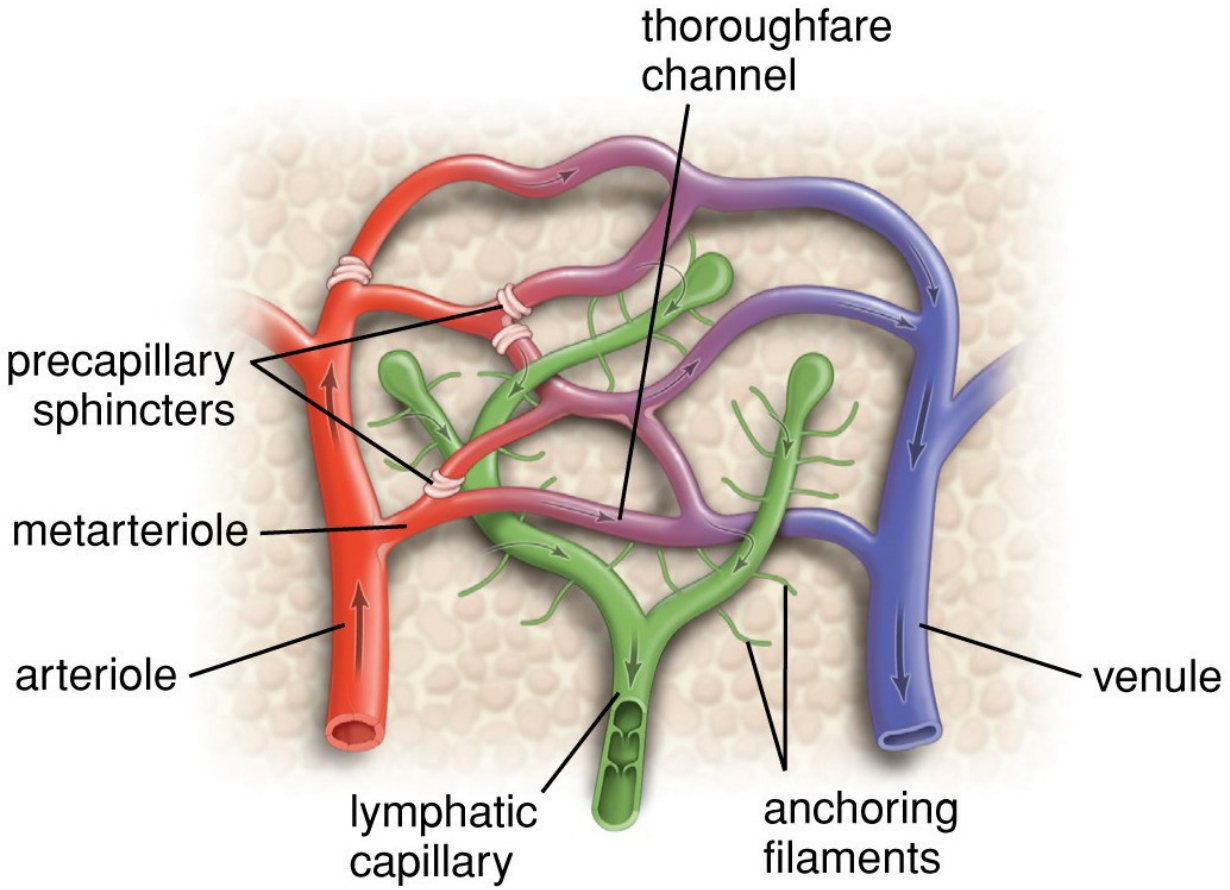


3 Types of capillaries



(a) Continuous capillaries, the most common type, have tight, occluding junctions sealing the intercellular clefts between all the endothelial cells to produce minimal fluid leakage. All molecules exchanged across the endothelium must cross the cells by diffusion or transcytosis.
(b) Fenestrated capillaries also have tight junctions, but perforations (fenestrations) through the endothelial cells allow greater exchange across the endothelium. The basement membrane is continuous in both these capillary types. Fenestrated capillaries are found in organs where molecular exchange with the blood is important, such as endocrine organs, intestinal walls, and choroid plexus.
(c) Sinusoids, or discontinuous capillaries, usually have a wider diameter than the other types and have discontinuities between the endothelial cells, large fenestrations through the cells, and a partial, discontinuous basement membrane. Sinusoids are found in organs where exchange of macromolecules and cells occurs readily between tissue and blood, such as in bone marrow, liver, and spleen.

Venules and small veins



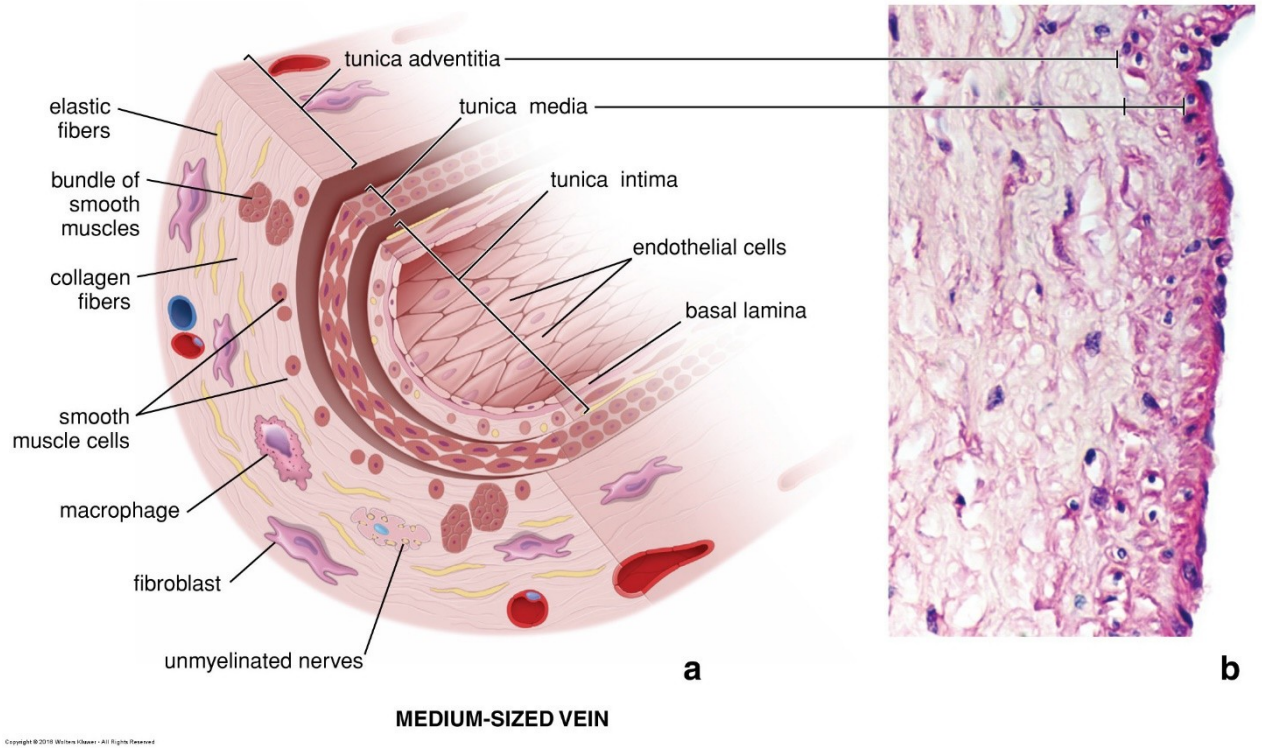
❯❯ MEDICAL APPLICATION

The hyperglycemia (excessive blood sugar) can lead to diabetic microangiopathy, a diffuse thickening of capillary basal laminae and concomitant decrease in metabolic exchange at these vessels, particularly in the kidneys, retina, skeletal muscle, and skin.

❯❯ MEDICAL APPLICATION

Junctions between endothelial cells of postcapillary can clog with leukocytes during inflammation
Loss of fluid here during the inflammatory
response leads to tissue edema.

Medium Veins



MEDIUM-SIZED VEIN

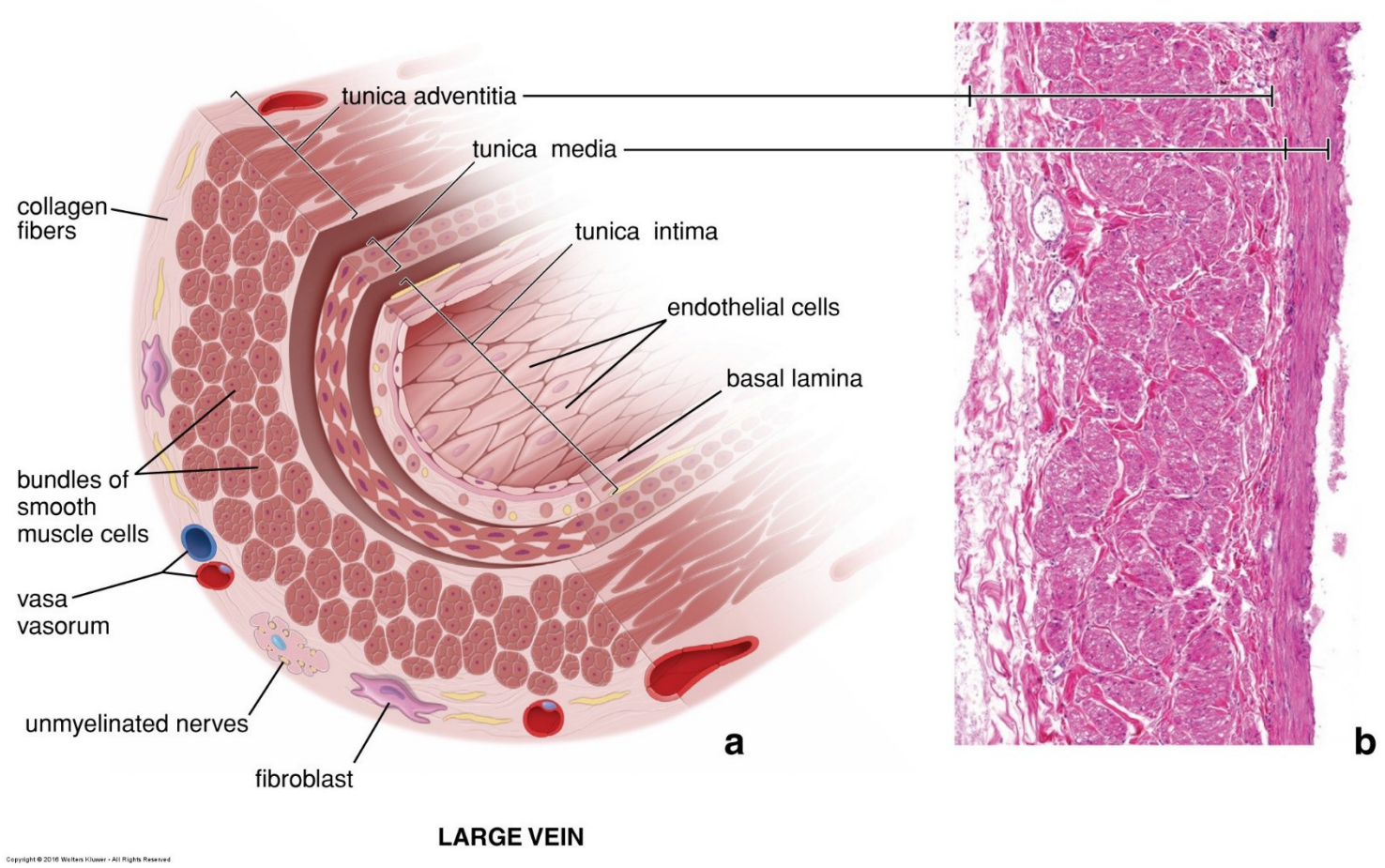
Tunica media: less smooth muscle than similar sized arteries, as flow back to heat is largely passive

Skeletal muscle pump: activity of limb muscles promote flow through one-way valves in medium veins, which prevent blood from flowing back

Low venous return shock: not enough blood returning to heart e.g., from hemorrhage

Venus pooling: Blood accumulated in lower body E.g., immune reactions causing vasodilation. E.g., standing too long so skeletal pump is not working may lead to fainting

Large veins: Thin tunica media, thick tunica adventitia



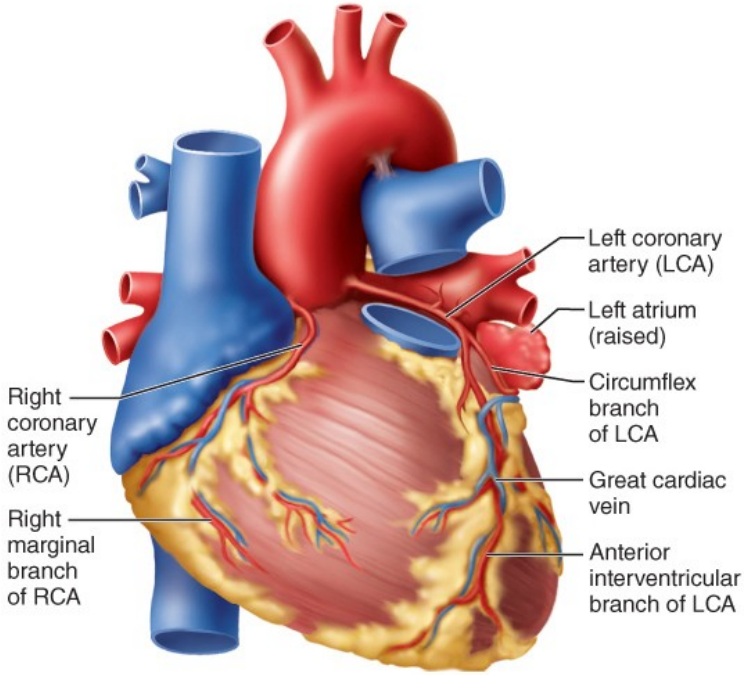
Thick layer of smooth muscle cells in vessels nearest to heart may participate in initiating atrial fibrillation.

Coronary Circulation: Receives disproportionate amount of blood supply which increases dramatically during exercise

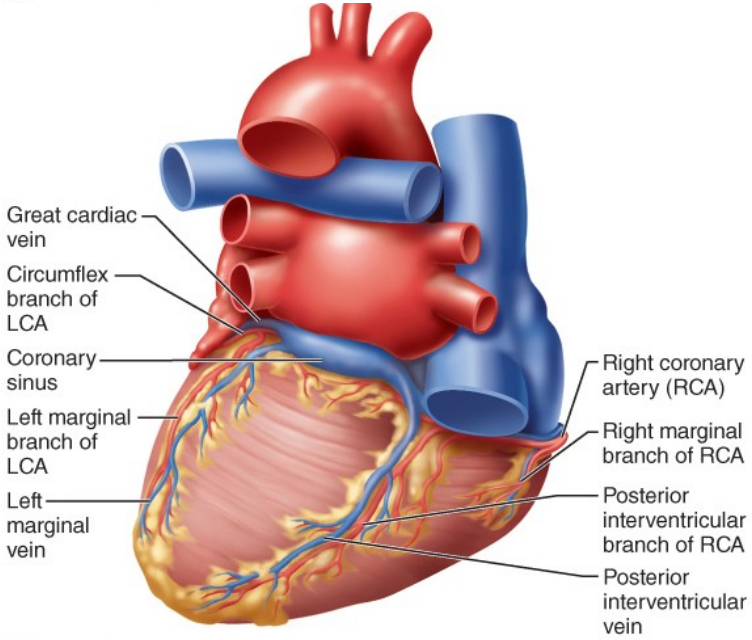
Left coronary artery (LCA)
- **Anterior interventricular branch** (left anterior descending)
- **Circumflex branch**

Right coronary artery (RCA)
- **Right marginal branch**
- **Posterior interventricular branch**

Venous drainage of heart: **Coronary sinus**
- **Posterior interventricular vein**
- **Left marginal vein**
- **Great cardiac vein**

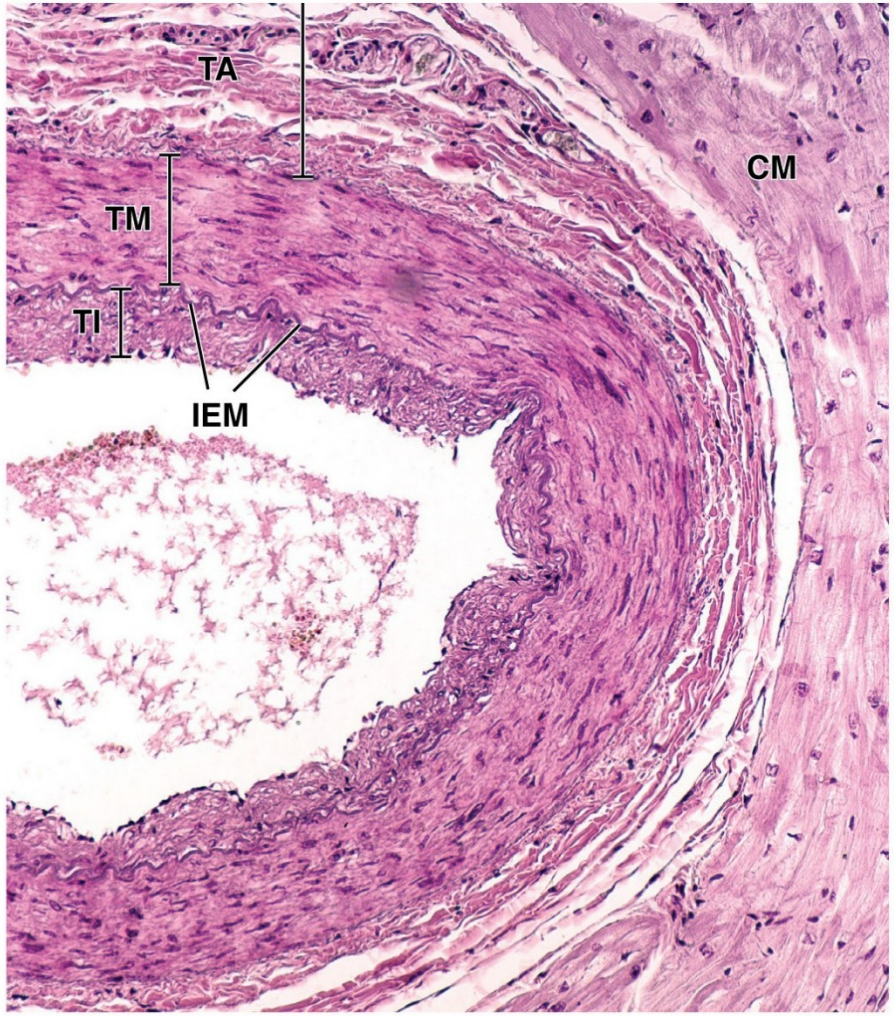


(a) Anterior view



(b) Posterior view

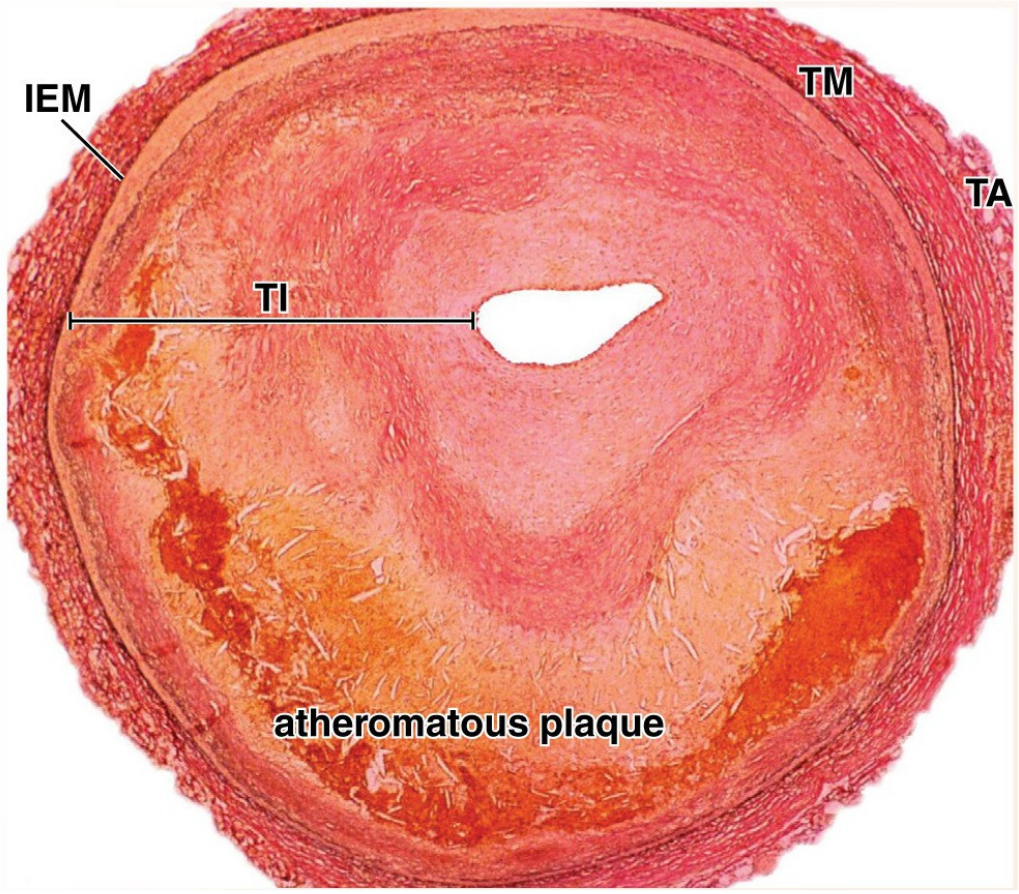
The Coronary artey: medium muscular arteries



tunica media: large amounts of circular smooth muscle **tunica intima**: of younger people is inconspicuous, but it progressively thickens by increasing amounts of smooth muscle cell and fibroelastic tissue with aging

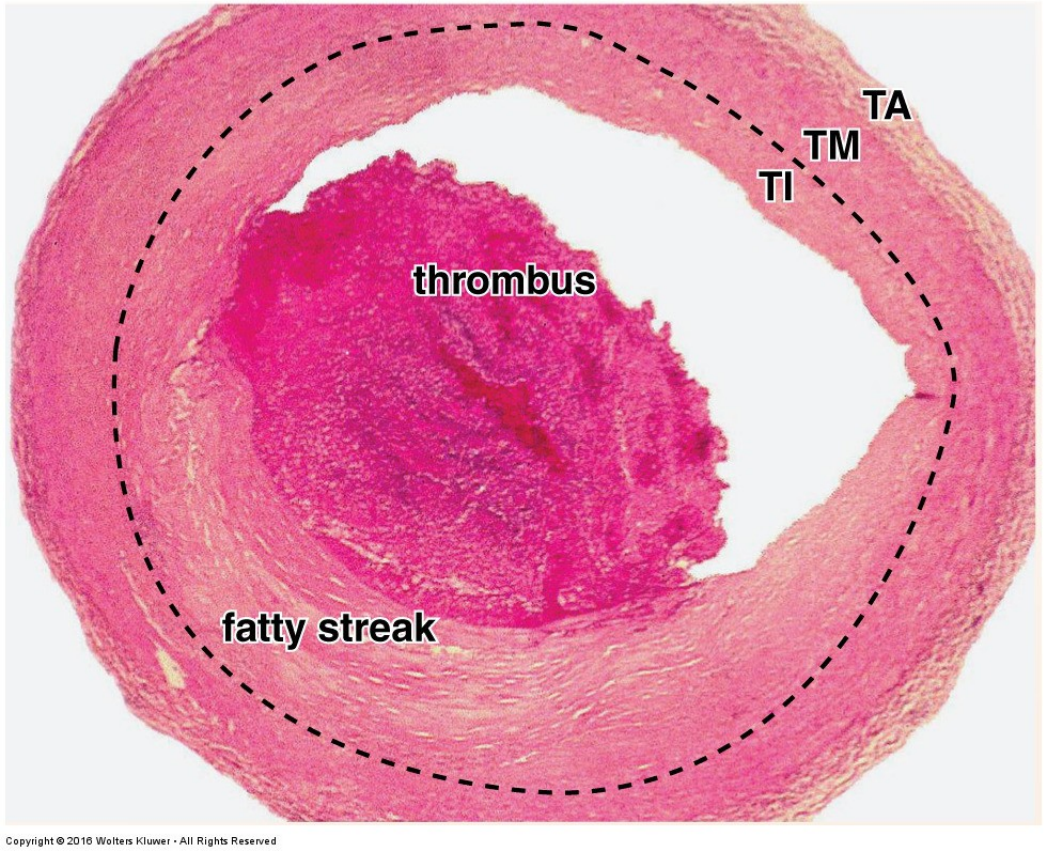
Atherosclerotic changes in coronary arteries that restrict blood flow and oxygen supply to cardiac muscle leads to **ischemic heart disease**

A plaque in the coronary artery



Plaques are formed by intracellular and extracellular lipid deposition, smooth muscle proliferation, and increased synthesis of proteoglycans and collagen within the intima of the vessel wall.

Thrombus (blood clot) in the coronary artery



Blood flow becomes critical when it is reduced by 90% or more. Sudden occlusion of the narrowed lumen by a thrombus (blood clot) released from the surface of an plaque precipitates an acute ischemic event.

Ischemic events are characterized by anginal pain associated with loss of oxygenated blood flow to the region of the heart supplied by the affected coronary vessel. **Coronary artery thrombosis** usually precedes and precipitates a **myocardial infarct** (insufficiency of blood causing muscle cell death). **Mural thrombus** may develop and is usually associated with dysfunctional or ruptured endothelium overlying plaque.

Chapter 12 & 13 Blood and Hemopoiesis
Key Points

1. Blood is a fluid connective tissue that circulates through the cardiovascular system. It consists of protein-rich liquid extracellular matrix called **plasma** and **formed elements** (white blood cells, red blood cells, and platelets).
2. Plasma proteins consist of plasma proteins are secreted by the liver and serum
3. **Leukocytes** are subclassified into two groups based on the presence or absence of specific granules in the cytoplasm: **granulocytes (neutrophils, eosinophils, basophils)** or **granulocytes (lymphocytes, monocytes)**.
4. **Erythrocytes** are anucleate, bicon-cave discs (7.8 μm in diameter) that are packed with hemoglobin and are designed to withstand shear forces experienced during circulation.
5. **Thrombocytes** are small, membrane-bounded, anucleate cytoplasmic fragments derived from megakaryocytes
6. **Hemopoiesis (hematopoiesis)** is initiated in early embryonic development and includes erythropoiesis (development of red blood cells), leukopoiesis (development of white blood cells), and thrombopoiesis (development of platelets).

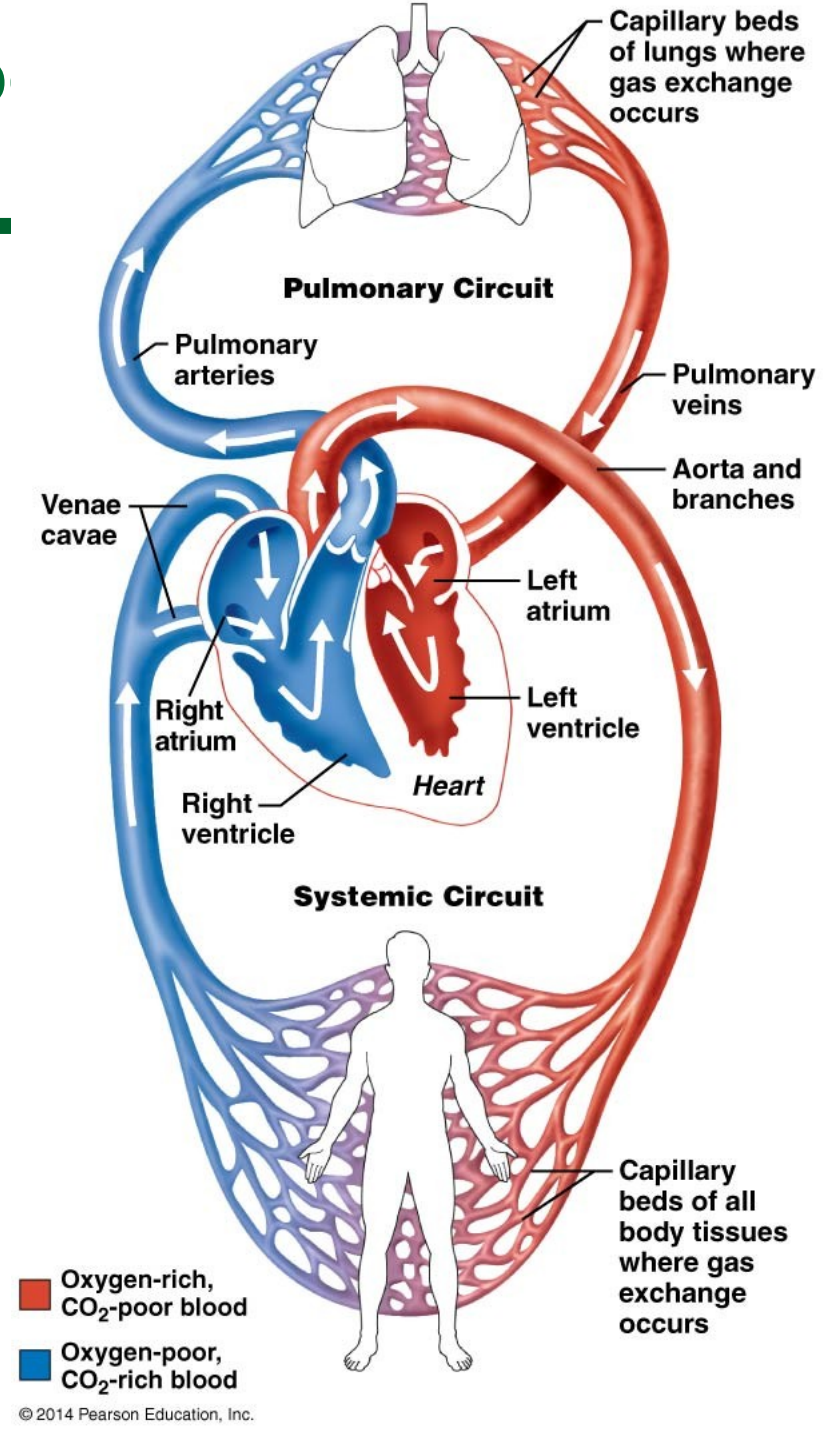
Circulatory system consists of the heart, blo vessels, and blood

Functions of circulatory system

- **Transport:** O_2, CO_2, nutrients, wastes, hormones, and stem cells
- **Protection:** Inflammation, limit spread of infection, destroy microorganisms and cancer cells, neutralize toxins, and initiate clotting
- **Regulation:** Fluid balance, stabilizes pH of ECF, and temperature control

- **Cardiovascular system** refers only to the heart and blood vessels
- **Hematology:** the study of blood

http://ed.ted.com/lessons/oxygen-s-surprisingly-complex-journey-through-your-body-enda-butler

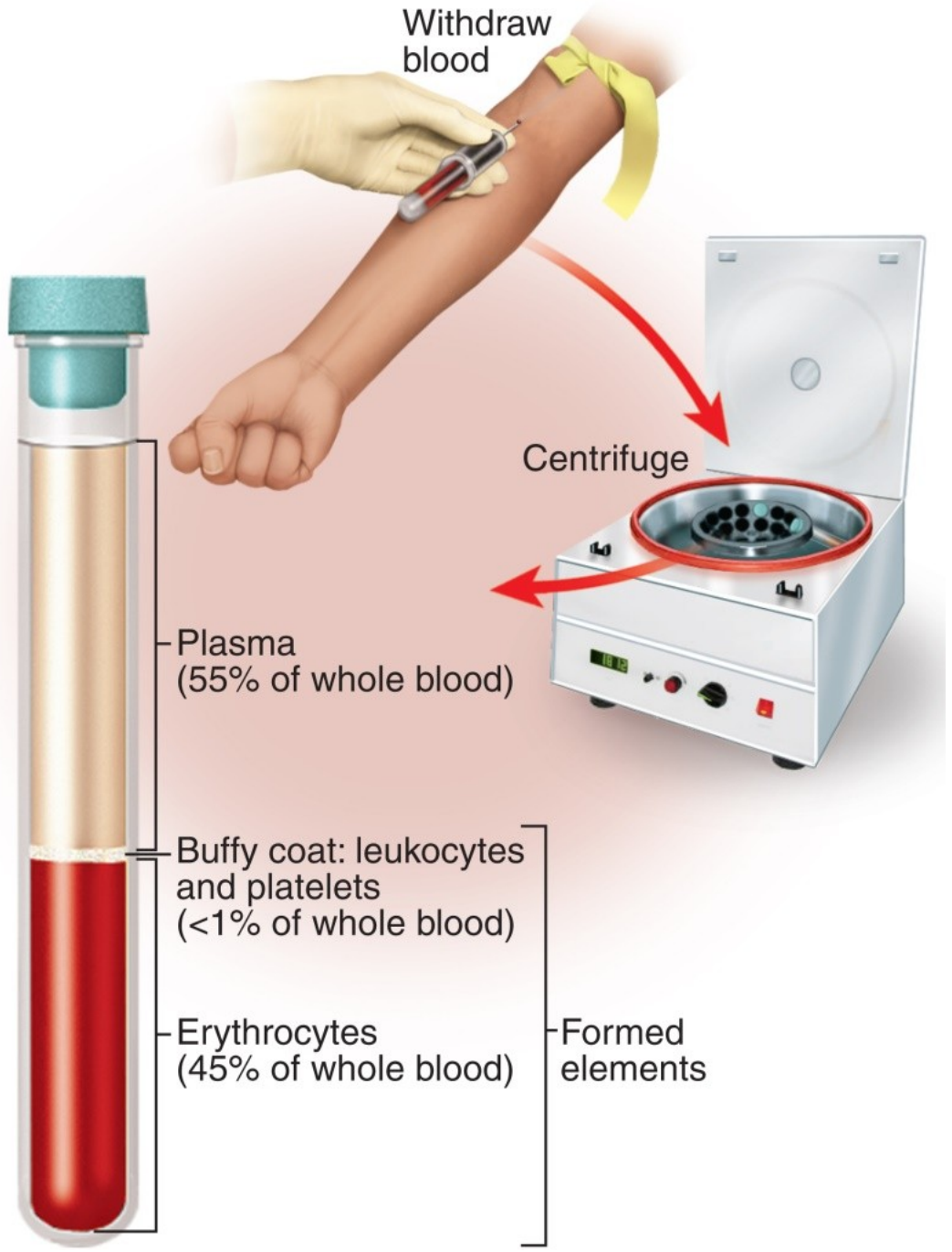


Components and General Properties of Blood

Adults have 4 to 6 L of blood
Blood is a liquid connective tissue consisting of cells and extracellular matrix

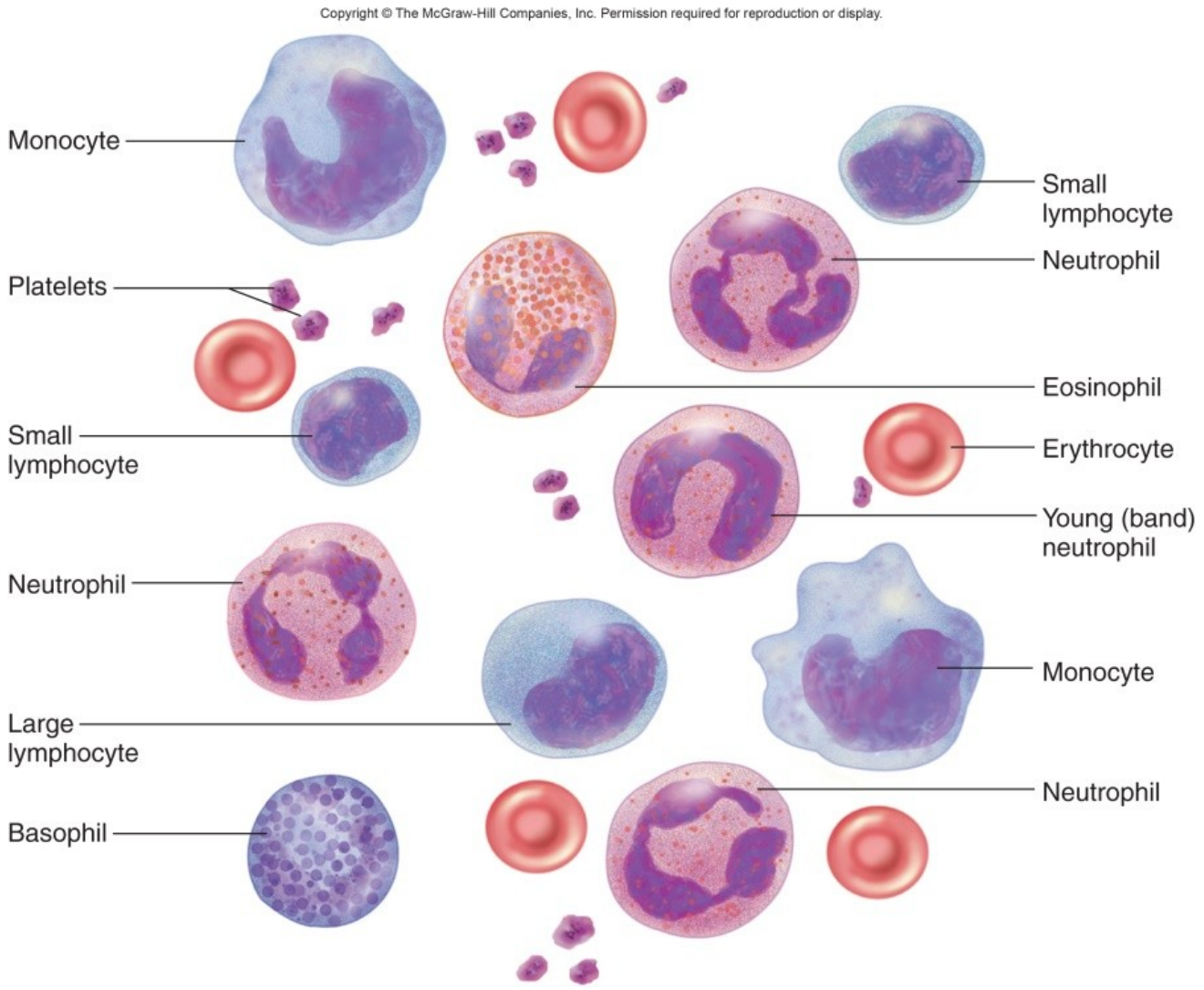
- **Plasma**: matrix of blood. Clear, light yellow fluid
- **Formed elements**: blood cells and cell fragments
  - Red blood cells, white blood cells, and platelets

Hematocrit (packed cell volume): percentage of whole blood volume composed of RBCs



Seven kinds of formed elements

1) **Erythrocytes:** red blood cells (RBCs)
2) **Platelets:** Cell fragments from special cell in bone marrow
3) **Leukocytes:** white blood cells (WBCs)
   Five leukocyte types divided into two categories
   Granulocytes (with granules)
      1)Neutrophils
      2)Eosinophils
      3)Basophils
   Agranulocytes (without granules)
      4)Lymphocytes
      5)Monocytes

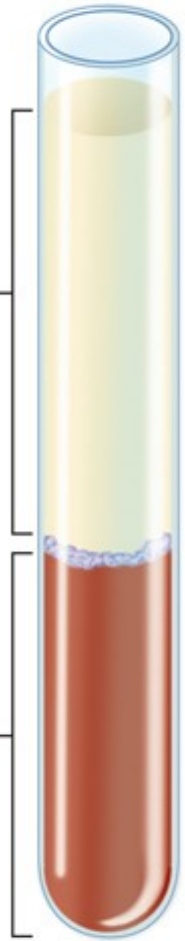


Plasma

Water	Proteins	Other solutes
92% by weight	7% by weight	1% by weight
	Albumins 58%	Electrolytes
	Globulins 37%	Nutrients
	Fibrinogen 4%	Respiratory gases
	Regulatory proteins 1%	Waste products

Erythrocytes

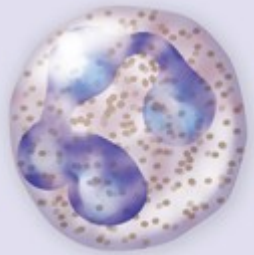
Erythrocytes
3.5-5.5 million/mm^3



Buffy Coat

Platelets
150,000-400,000/mm^3

Leukocytes
4500-11,000/mm^3



Neutrophils
54%-62%

Lymphocytes
25%-33%

Monocytes 3%-7%

Eosinophils
1%-3%

Basophils
0%-0.75%

Blood Plasma

Plasma: liquid portion of blood

- **Serum**: remaining fluid when blood clots and the solids are removed
  - Identical to plasma except for the absence of fibrinogen

Three major categories of plasma proteins

1) Albumins: smallest and most abundant,
  - Contribute to viscosity and osmolarity; influence blood pressure, flow, and fluid balance

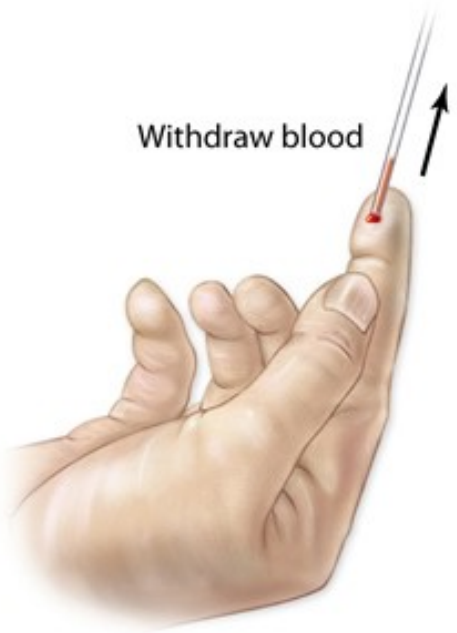
2) Globulins (antibodies): Provide immune system functions
  - Alpha, beta, and gamma globulins

3) Fibrinogen: Precursor of fibrin threads that help form blood clots

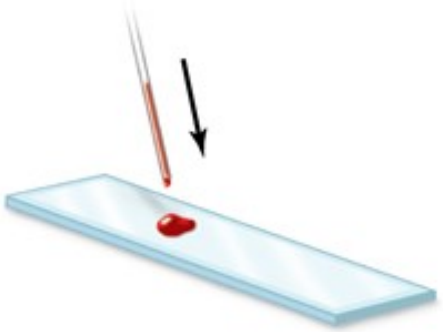
TABLE 10.2 Composition of Blood Plasma

Component	%
Water	91–92
Protein (albumin, globulins, fibrinogen)	7–8
Other solutes:	1–2
Electrolytes (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO^{3-}, PO_4^{3-}, SO_4^{2-})	
Nonprotein nitrogen substances (urea, uric acid, creatine, creatinine, ammonium salts)	
Nutrients (glucose, lipids, amino acids)	
Blood gases (oxygen, carbon dioxide, nitrogen)	
Regulatory substances (hormones, enzymes)	

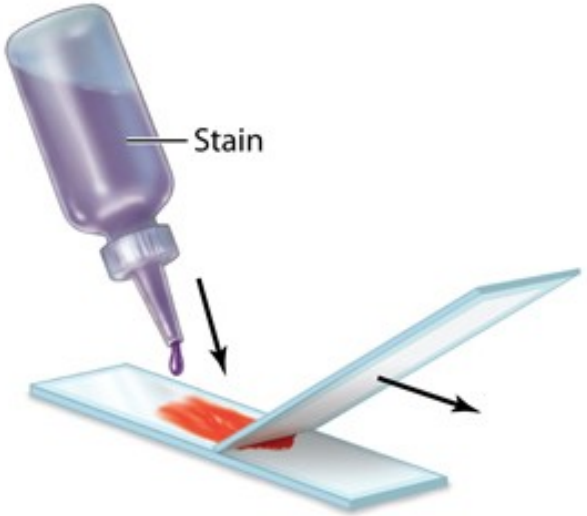
Examination of blood cells requires special preparation and staining.



(1) Prick finger and collect a small amount of blood using a micropipette.

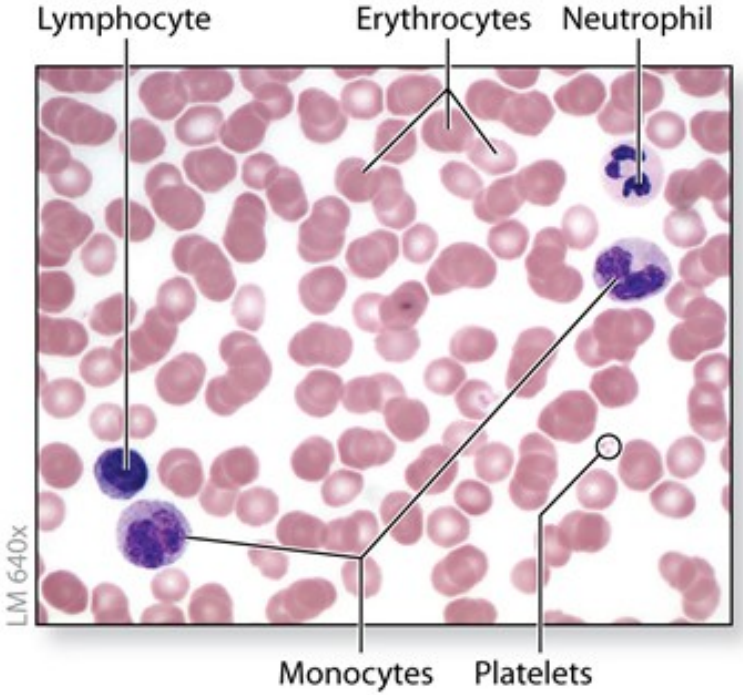


(2) Place a drop of blood on a slide.



(3a) Using a second slide, pull the drop of blood across the first slide's surface, leaving a thin layer of blood on the slide.

(3b) After the blood dries, apply a stain briefly and rinse. Place a coverslip on top.

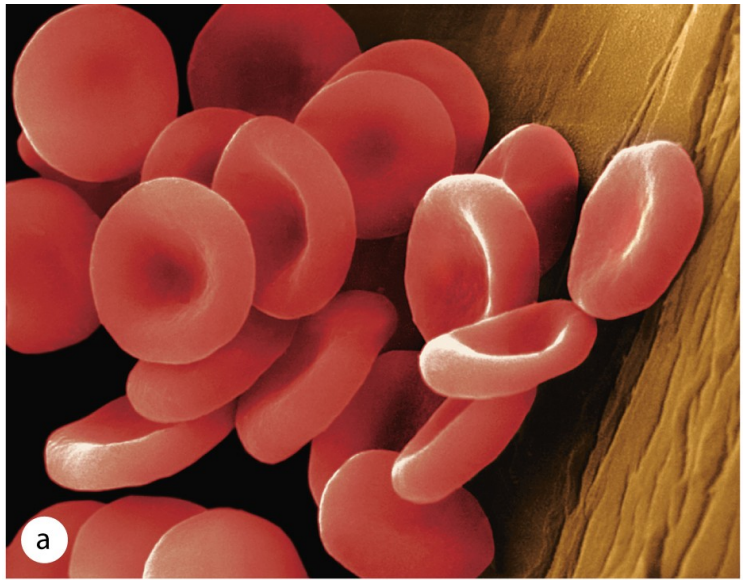


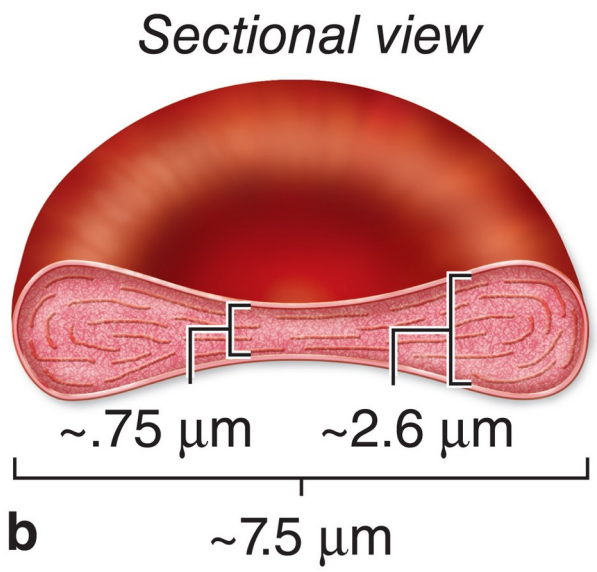
(4) When viewed under the microscope, blood smear reveals the components of the formed elements.

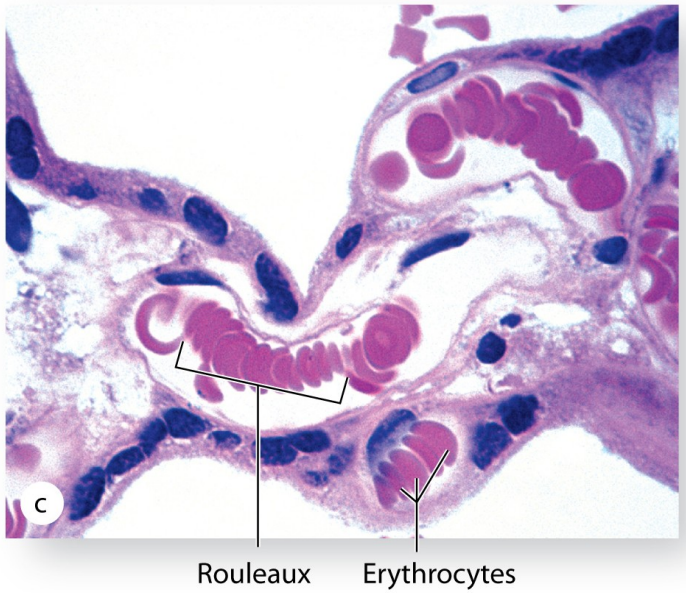
Erythrocytes

- Two principal functions
  - Carry oxygen from lungs to cell tissues
  - Pick up CO_2 from tissues and bring to lungs

- Insufficient RBCs may kill in minutes due to lack of oxygen to tissues

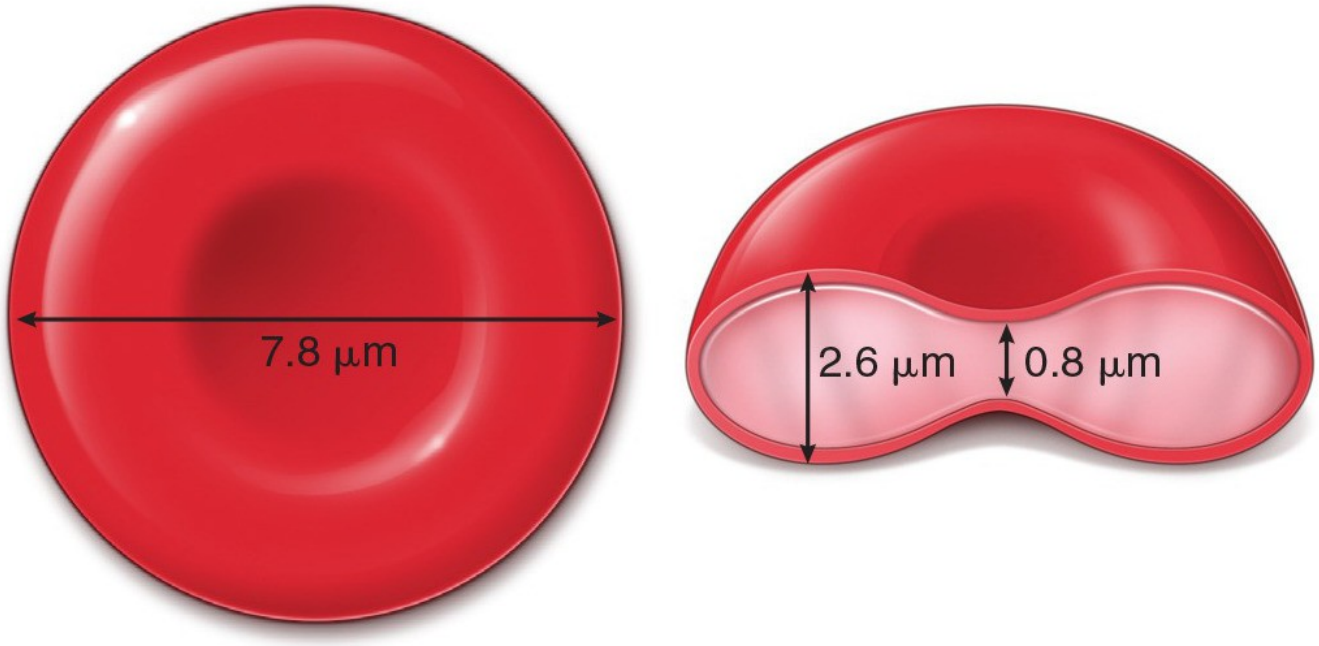




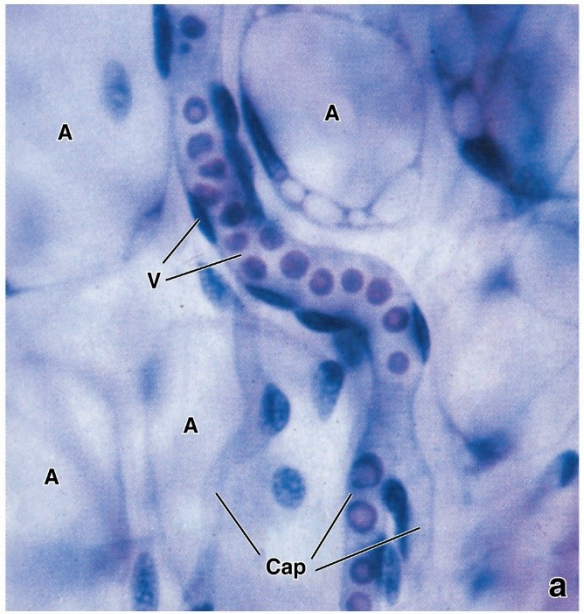


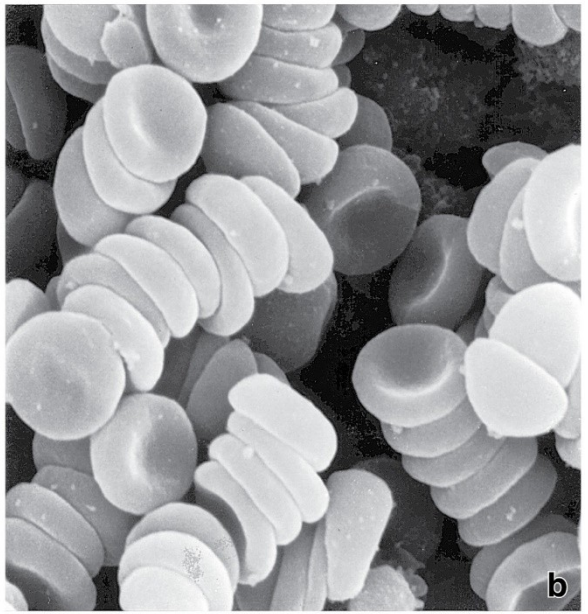
Form and Function

- Disc-shaped cell with thick rim
  - 7.8 μm diameter and 2.0 μm thick at rim
  - Lose nearly all organelles during development
  - Lack mitochondria, use anaerobic fermentation to produce ATP
  - Lack of nucleus and DNA, no protein synthesis or mitosis



Erythrocyte Morphology





Hypoxia "Reading between the genes“: https://www.youtube.com/watch?v=djpTeVtMO-M

❯❯ MEDICAL APPLICATION

Anemia is the condition of having a concentration of erythrocytes below the normal range. With fewer RBCs per milliliter of blood, tissues are unable to receive adequate O_2. Symptoms of anemia include lethargy, shortness of breath, fatigue, skin pallor, and heart palpitations. Anemia may result from insufficient red cell production, due, for example, to iron deficiency, or from blood loss with a stomach ulcer or excessive menses.

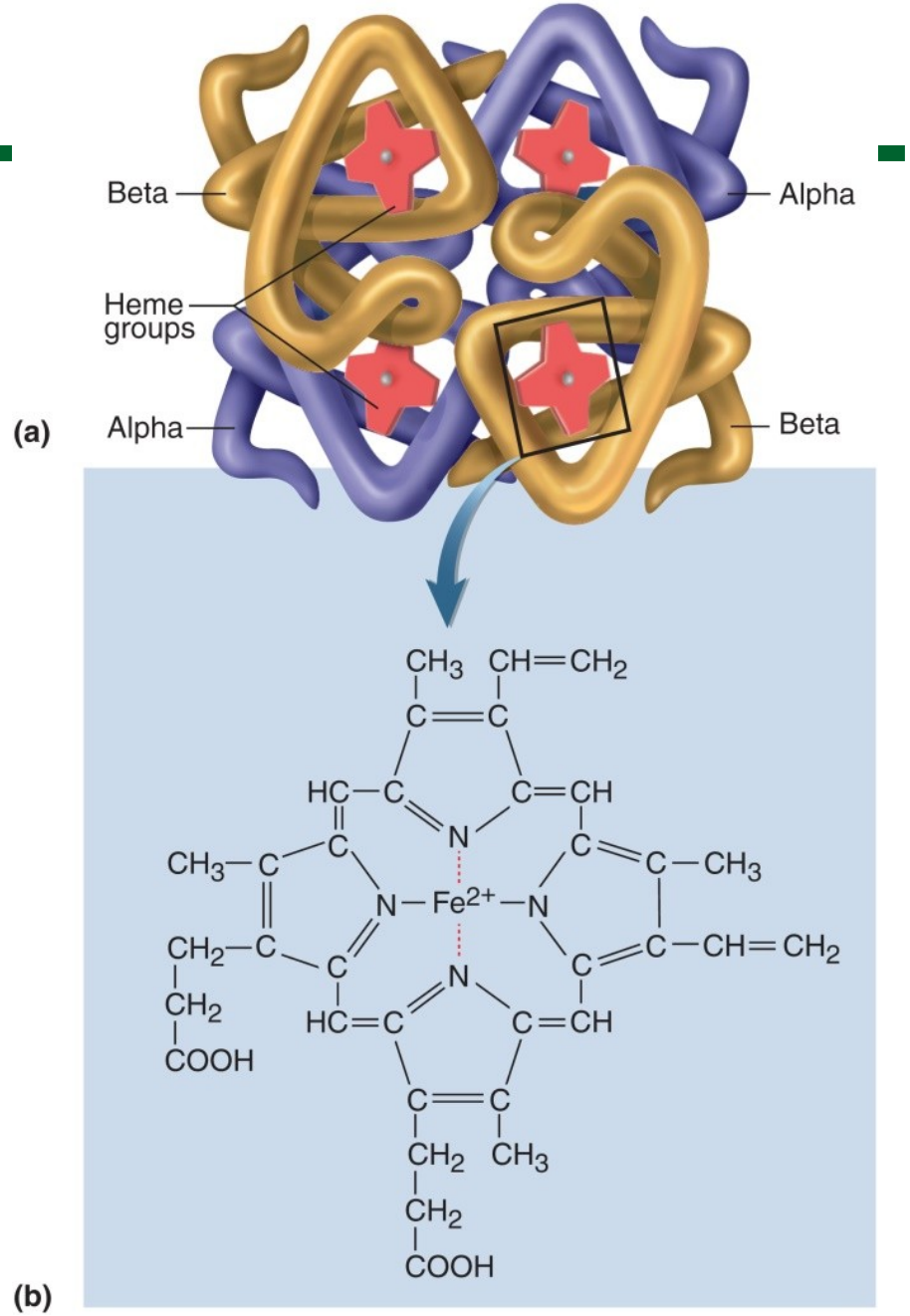
An increased concentration of erythrocytes in blood (**erythrocytosis**, or **polycythemia**) may be a physiologic Adaptation found, for example, in individuals who live at high altitudes, where O_2 is low. Elevated hematocrit increases blood viscosity, putting strain on the heart, and, if severe, can impair circulation through the capillaries.

Hemoglobin

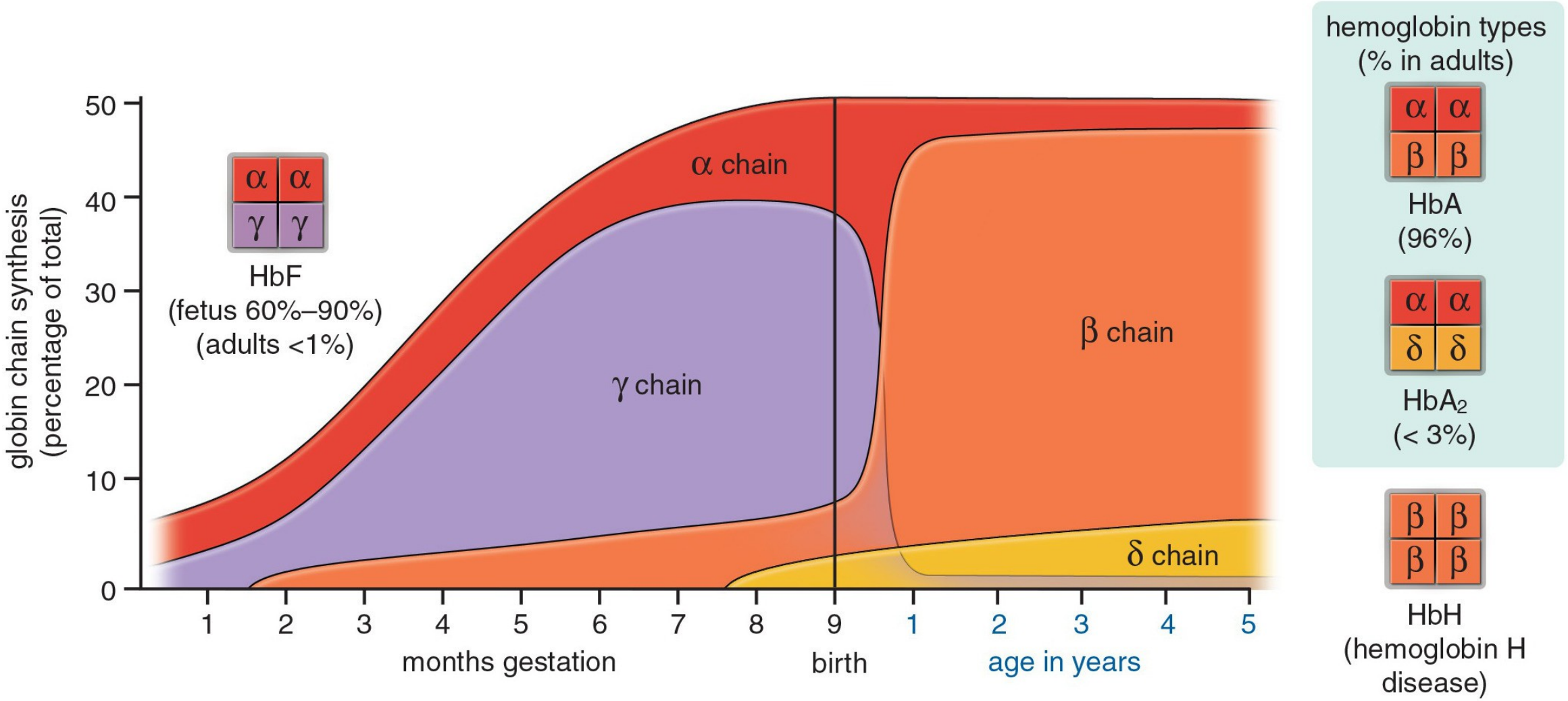
- Each Hb molecule consists of:
  - Four protein chains—globins
  - Four heme groups

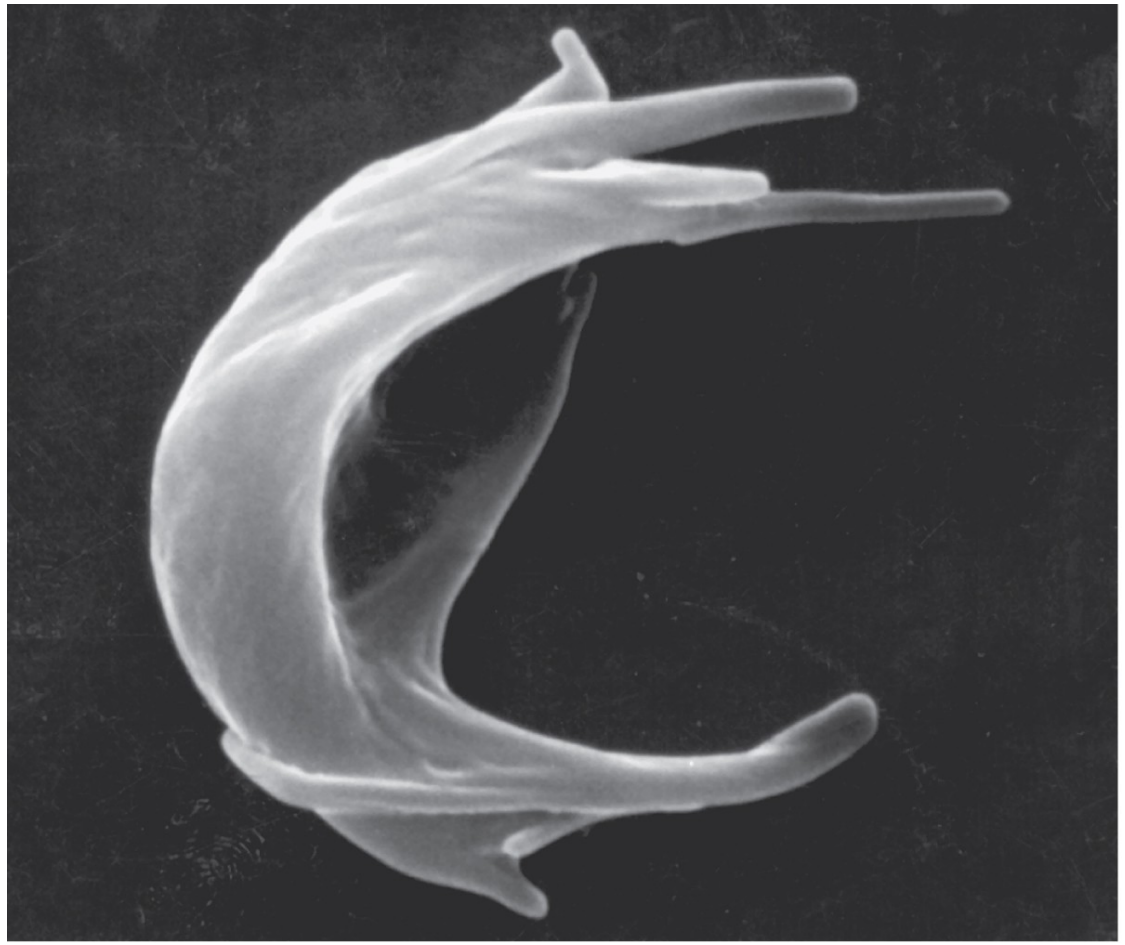
- Heme groups
  - Nonprotein moiety that binds O_2 to ferrous ion (Fe^{2+}) at its center

- RBC count and hemoglobin concentration indicate amount of O_2 blood can carry
  - **Hematocrit (packed cell volume):** percentage of whole blood volume composed of RBCs



Major globin chain synthesis and hemoglobin composition in prenatal and postnatal periods.





Sickle cell erythrocyte

A single nucleotide substitute in the hemoglobin gene produces a version of the protein that polymerizes to form rigid aggregates, leading to greatly misshapen cells with reduced flexibility. In individuals homozygous for the mutated *HbS* gene, this can lead to greater blood viscosity,- and poor microvascular circulation, both - features of sickle cell disease

Leukocytes

Leukocytes (white blood cells, WBCs)

- Protect us from pathogens
- Spend only few hours in bloodstream
  - migrate through capillaries
  - spend rest of lives in connective tissue

Leukocyte characteristics

- Vary in form and function
- Retain organelles throughout life
  - include instruments of protein synthesis
  - proteins needed for wide variety of function
  - e.g., digestive enzymes enabling pathogen digestion

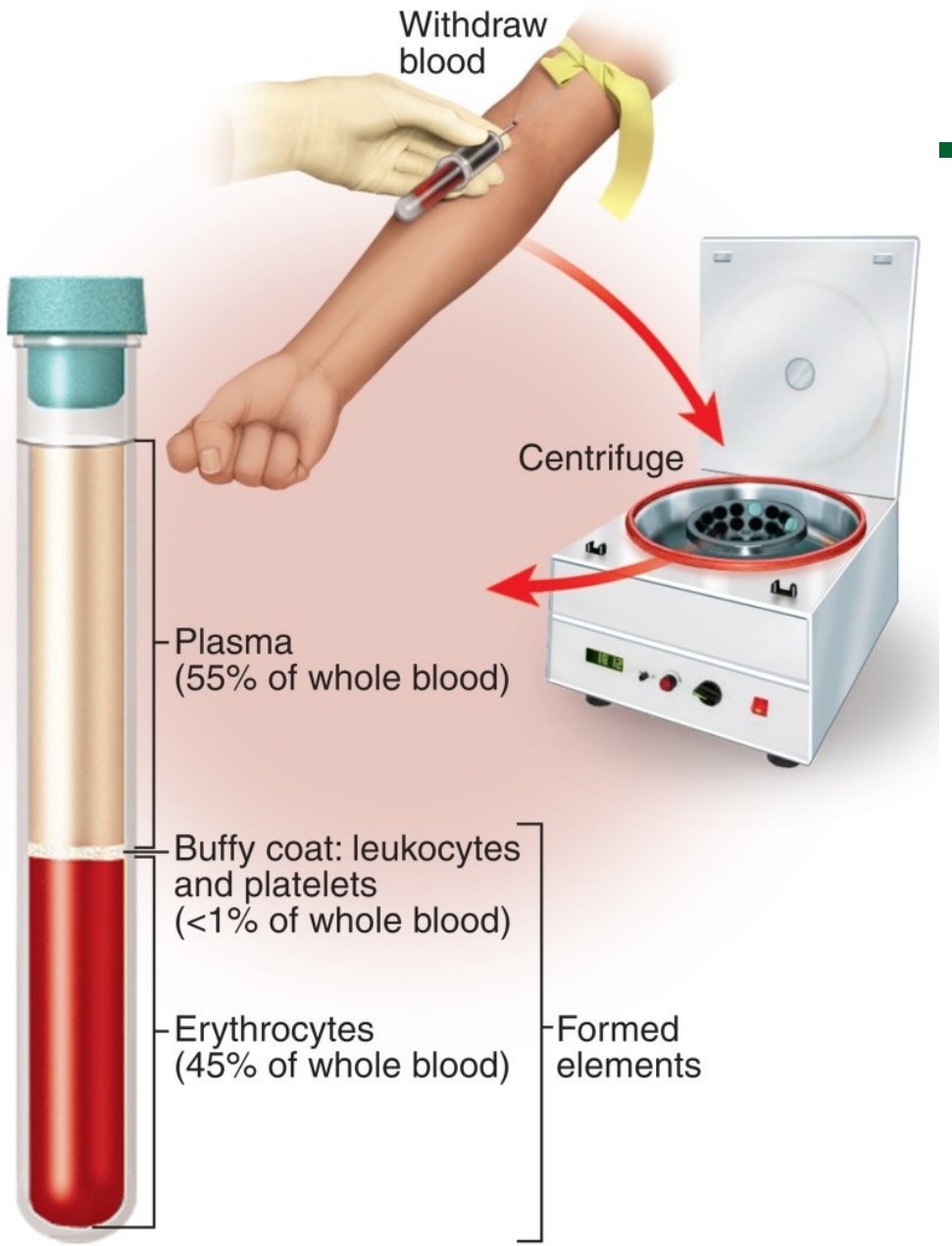
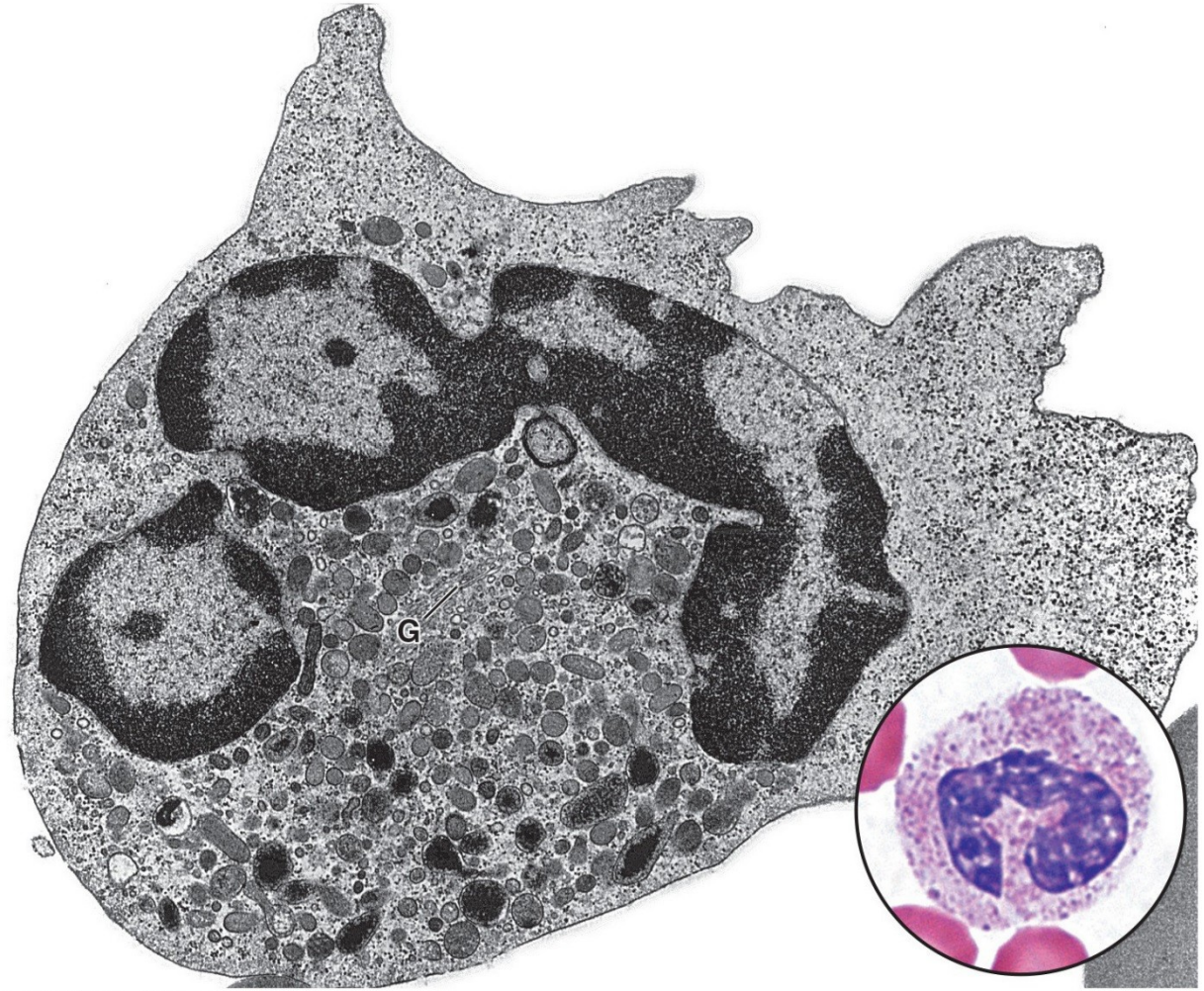


Table 29.1 Summary of Formed Elements of the Blood

Cell type	Illustration	Description*	Cells/mm3 (µl) of blood	Duration of development (D) and life span (LS)	Function
Erythrocytes (red blood cells, RBCs)		Biconcave, anucleate disc; salmon-colored; diameter 7–8 µm	4–6 million	D: about 15 days LS: 100–120 days	Transport oxygen and carbon dioxide
Leukocytes (white blood cells, WBCs)		Spherical, nucleated cells	4800–10,800		
Granulocytes Neutrophil		Nucleus multilobed; inconspicuous cytoplasmic granules; diameter 10–12 µm	3000–7000	D: about 14 days LS: 6 hours to a few days	Phagocytize bacteria
Eosinophil		Nucleus bilobed; red cytoplasmic granules; diameter 10–14 µm	100–400	D: about 14 days LS: about 5 days	Kill parasitic worms; complex role in allergy and asthma
Basophil		Nucleus lobed; large blue-purple cytoplasmic granules; diameter 10–14 µm	20–50	D: 1–7 days LS: a few hours to a few days	Release histamine and other mediators of inflammation; contain heparin, an anticoagulant
Agranulocytes Lymphocyte		Nucleus spherical or indented; pale blue cytoplasm; diameter 5–17 µm	1500–3000	D: days to weeks LS: hours to years	Mount immune response by direct cell attack or via antibodies
Monocyte		Nucleus U- or kidney-shaped; gray-blue cytoplasm; diameter 14–24 µm	100–700	D: 2–3 days LS: months	Phagocytosis; develop into macrophages in tissues
Platelets		Discoid cytoplasmic fragments containing granules; stain deep purple; diameter 2–4 µm	150,000–400,000	D: 4–5 days LS: 5–10 days	Seal small tears in blood vessels; instrumental in blood clotting

*Appearance when stained with Wright's stain.

Electron micrograph of a human mature neutrophil.

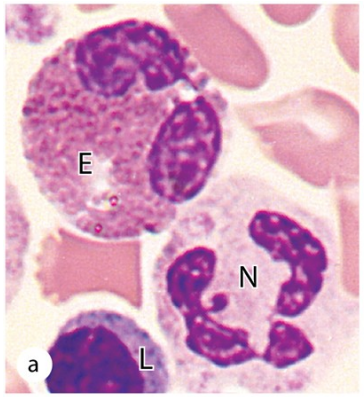


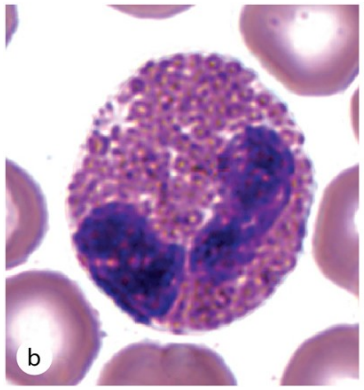
The nucleus shows the typical multilobed configuration with the heterochromatin at the periphery and the euchromatin more centrally located.

Granules contain lysosomes and enzymes

- Motile cells that leave circulation and migrate to their site of action in the connective tissue.
- Active phagocytes that utilize a variety of surface receptors to recognize bacteria and other infectious agents at the site of inflammation

Eosinophils are about the same size as neutrophils but have bilobed nuclei and more abundant coarse cytoplasmic granules



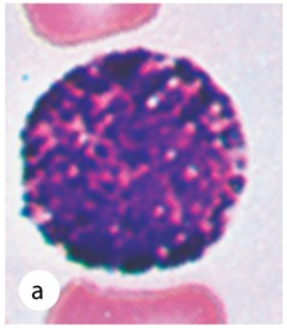


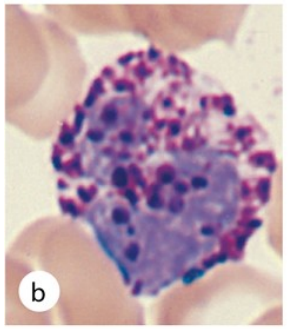
Eosinophils are associated with allergic reactions, parasitic infections, and chronic inflammation.

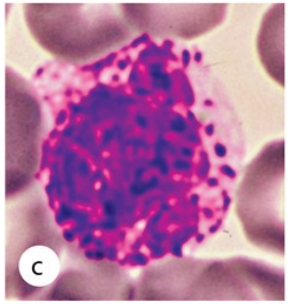
❯❯ MEDICAL APPLICATION

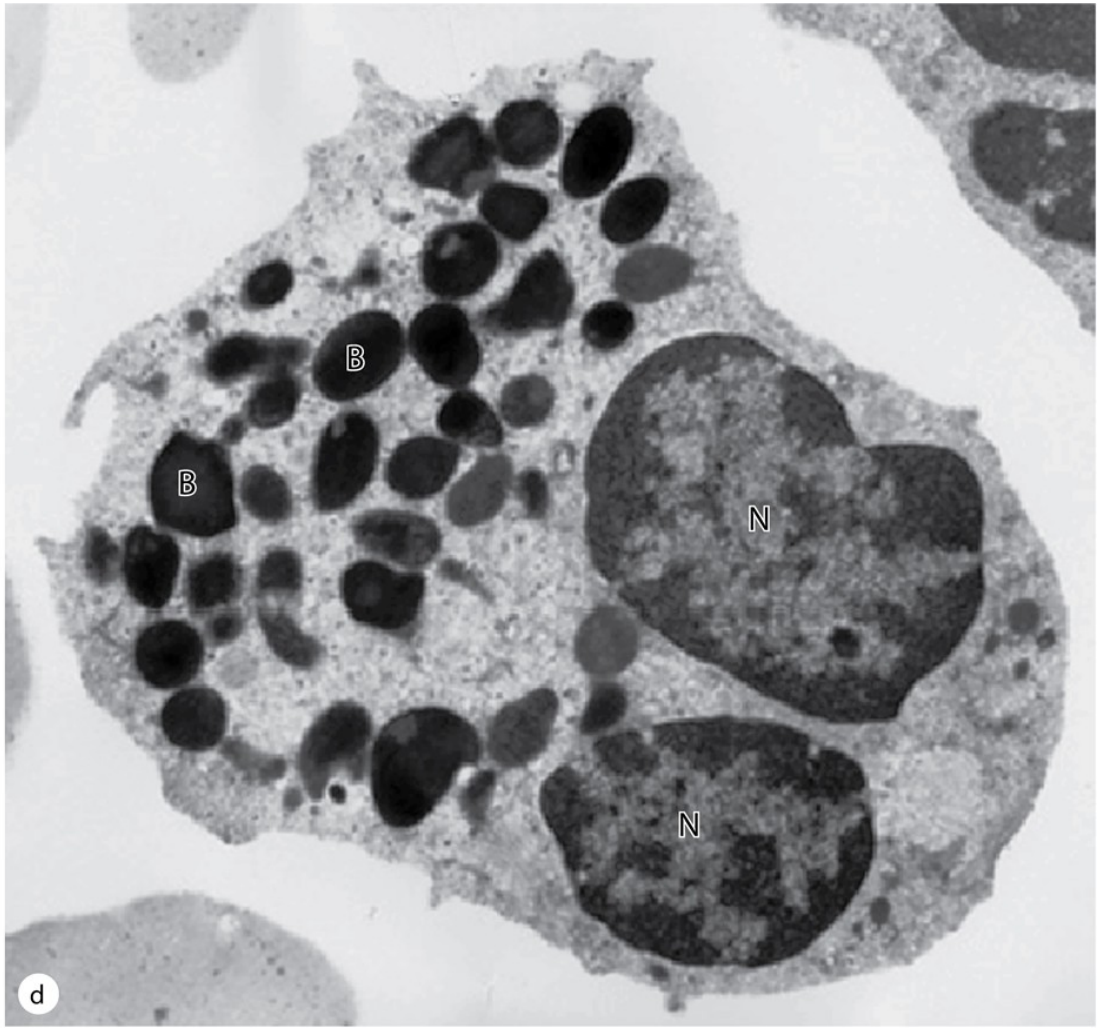
An increase in the number of eosinophils in blood (eosinophilia) is associated with allergic reactions and helminth parasitic infections. In patients with such conditions, eosinophils are found in the connective tissues underlying epithelia of the bronchi, gastrointestinal tract, uterus, and vagina, and surrounding any parasitic worms present.

Basophils are also approximately the same size as neutrophils and eosinophils







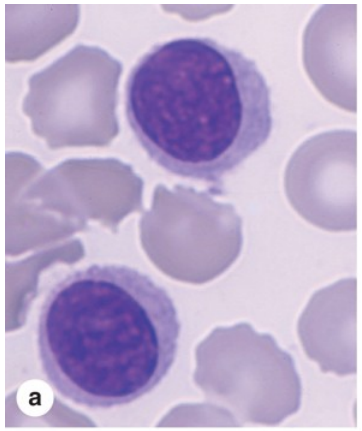


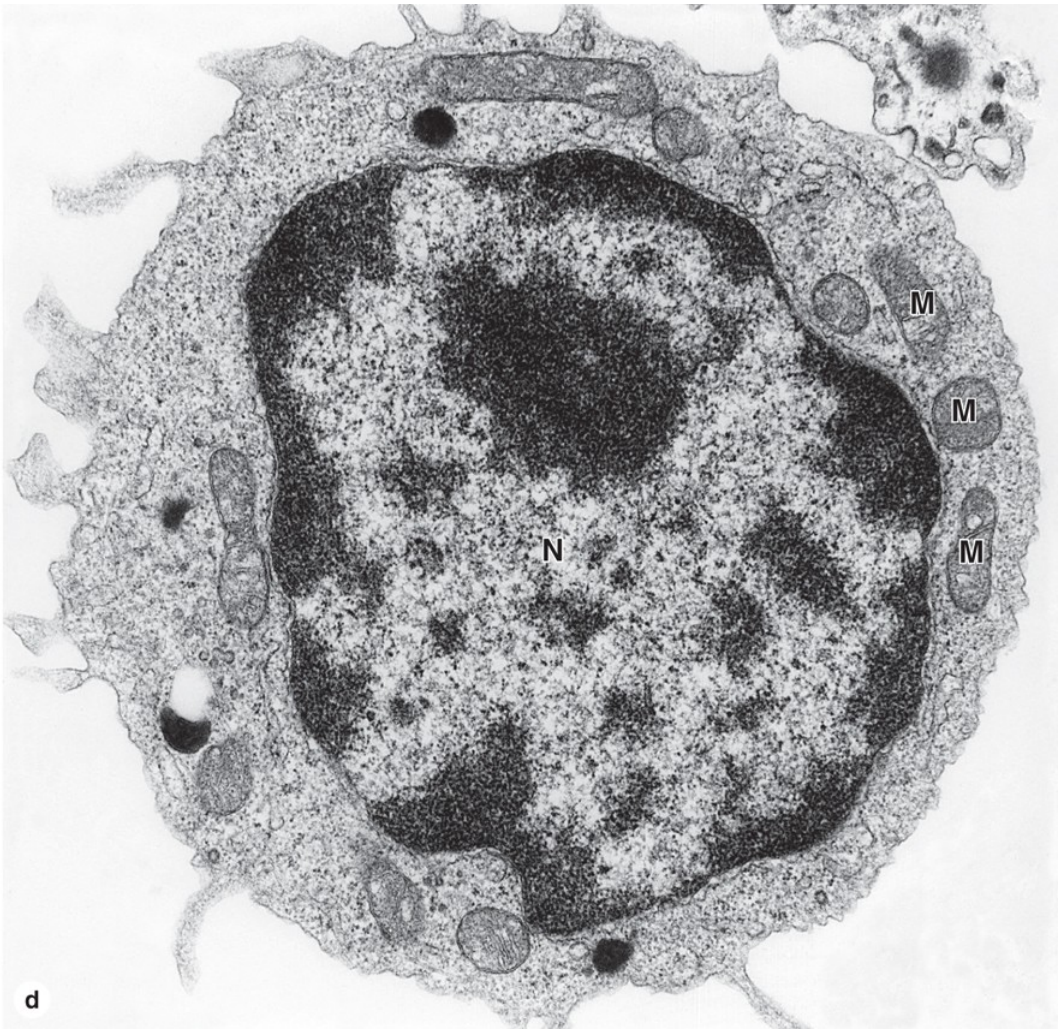
Basophils have large, strongly basophilic specific granules that usually obstruct the appearance of the nucleus which usually has two large irregular lobes

A TEM of a sectioned basophil reveals the single bilobed nucleus (**N**) and the large, electron-dense specific basophilic granules (**B**).

Basophils exert many activities modulating the immune response and inflammation and have many functional similarities with mast cells, which are normal, longer-term residents of connective tissue.

Lymphocytes are agranulocytes and lack the specific granules characteristic of granulocytes





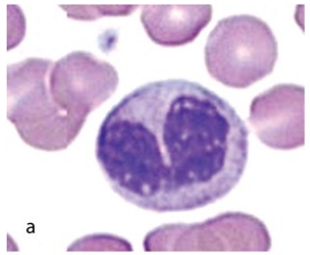
Lymphocytes circulating in blood generally range in size from 6 to 15 µm in diameter

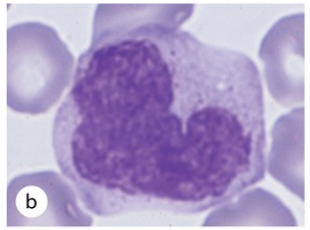
❯❯ MEDICAL APPLICATION

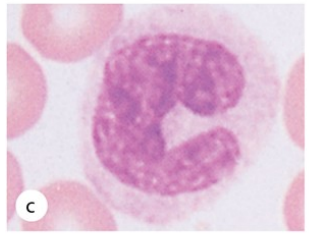
Lymphomas are a group of disorders involving neoplastic proliferation of lymphocytes or the failure of these cells to undergo apoptosis. Although often slow-growing, all lymphomas are considered malignant because they can very easily become widely spread throughout the body.

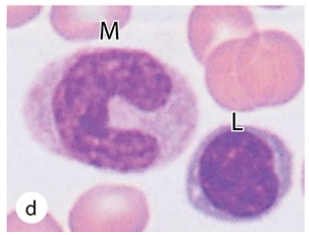
http://ed.ted.com/lessons/what-is-leukemia-danilo-allegra-and-dania-puggioni

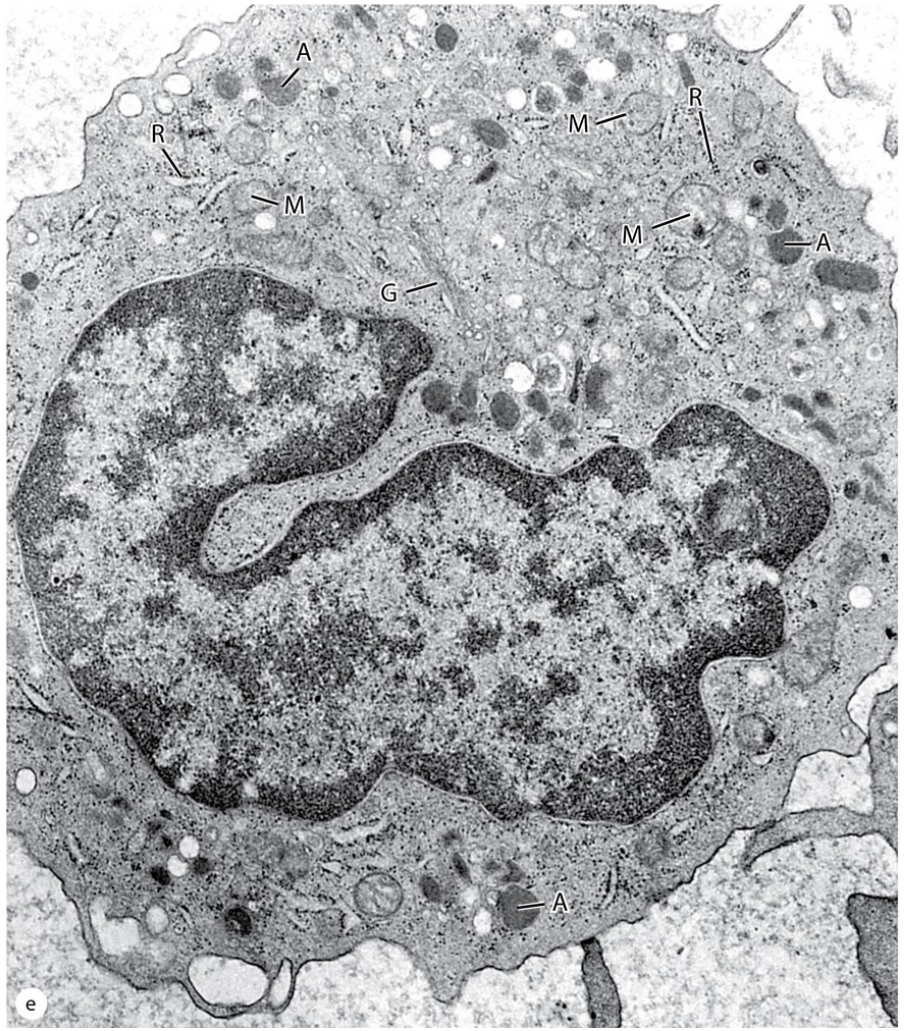
Monocytes are large agranulocytes with diameters from 12 to 20 µm that circulate as precursors to macrophages









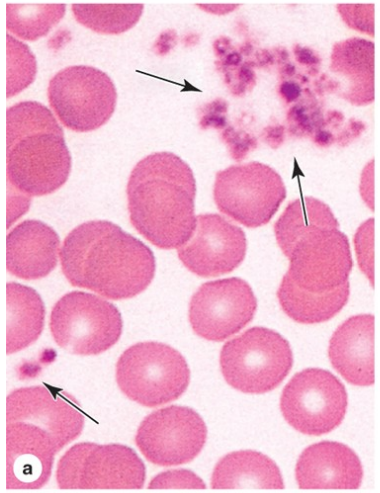


Monocytes have distinctive nuclei which are indented, kidney-shaped, or C-shaped

❯❯ MEDICAL APPLICATION

Accumulation of immigrating monocytes occurs in the early phase of inflammation following tissue injury. Acute inflammation is usually short-lived as macrophages undergo apoptosis or leave the site, but chronic inflammation usually involves the continued recruitment of monocytes. The resulting continuous presence of macrophages can lead to excessive tissue damage that is typical of chronic inflammation.

Platelets (Thrombocytes) are cell fragments 2-4 µm in diameter derived from megakaryocytes of bone marrow



Platelets: release the content of their granules upon contact with collagen (or other materials outside of the endothelium) to begin the process of clot formation and reduce blood loss from the vasculature.

❯❯ MEDICAL APPLICATION

Aspirin and other nonsteroidal anti-inflammatory agents have an inhibitory effect on platelet function and blood coagulation because they block the local prostaglandin synthesis that is needed for platelet aggregation, contraction, and exocytosis at sites of injury. Bleeding disorders result from abnormally slow blood clotting.

How Blood is Produced

Hemopoiesis (hematopoiesis) is initiated in early embryonic development and includes **erythropoiesis** (development of red blood cells), **leukopoiesis** (development of white blood cells), and **thrombopoiesis** (development of platelets).