Inquiry into Life

Eleventh Edition

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Chapter 12
Lecture Outline

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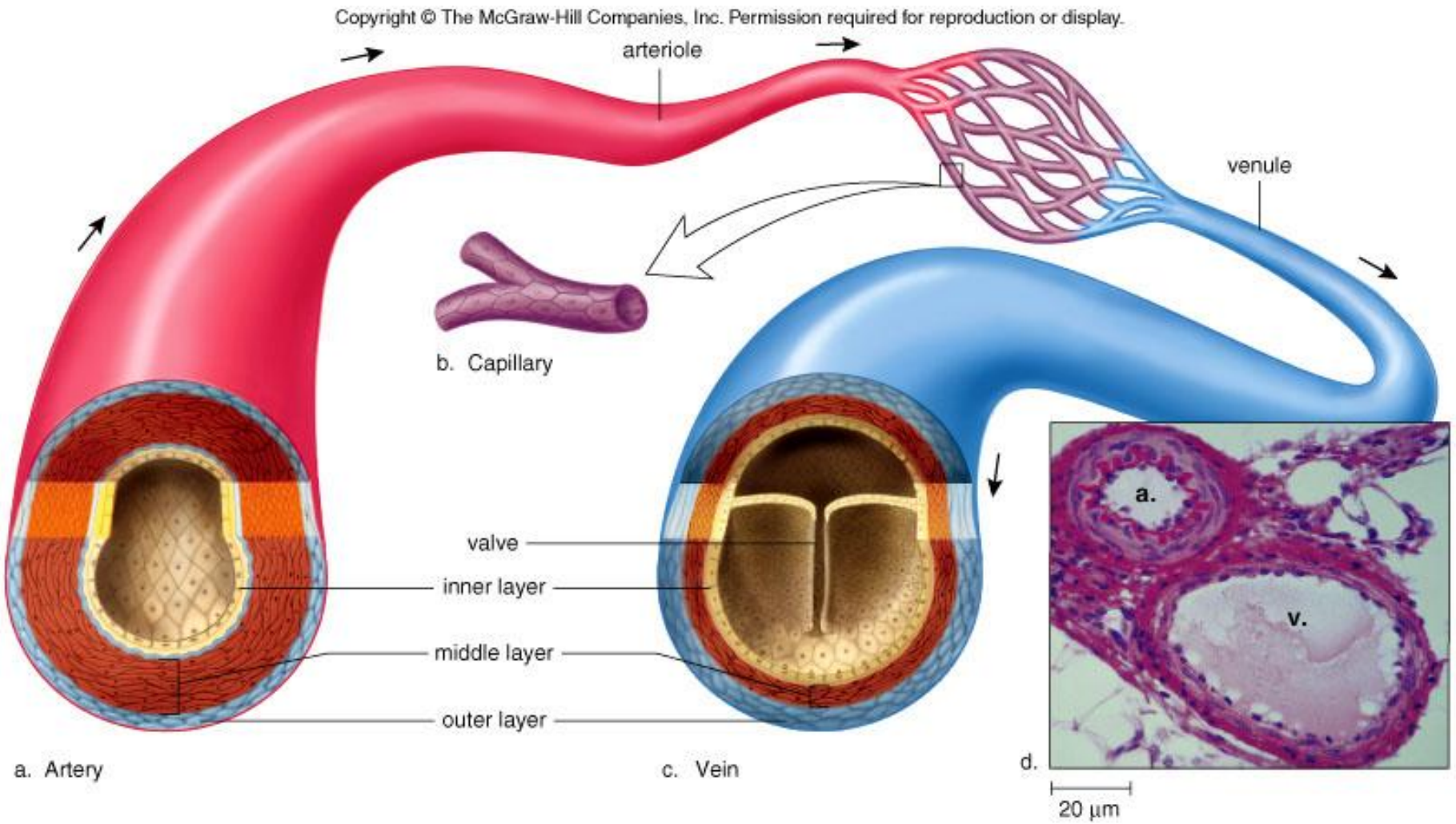
12.1 The blood vessels

- Overview
  - Arteries (and arterioles)
    - Carry blood away from the heart to the capillaries
  - Capillaries
    - Exchange of substances between tissues and blood
  - Veins (and venules)
    - Carry blood to the heart
  - Blood vessels require oxygen and nutrients like all tissues
    - Larger ones have blood supplies of their own

Blood vessels



- Fig 12.1

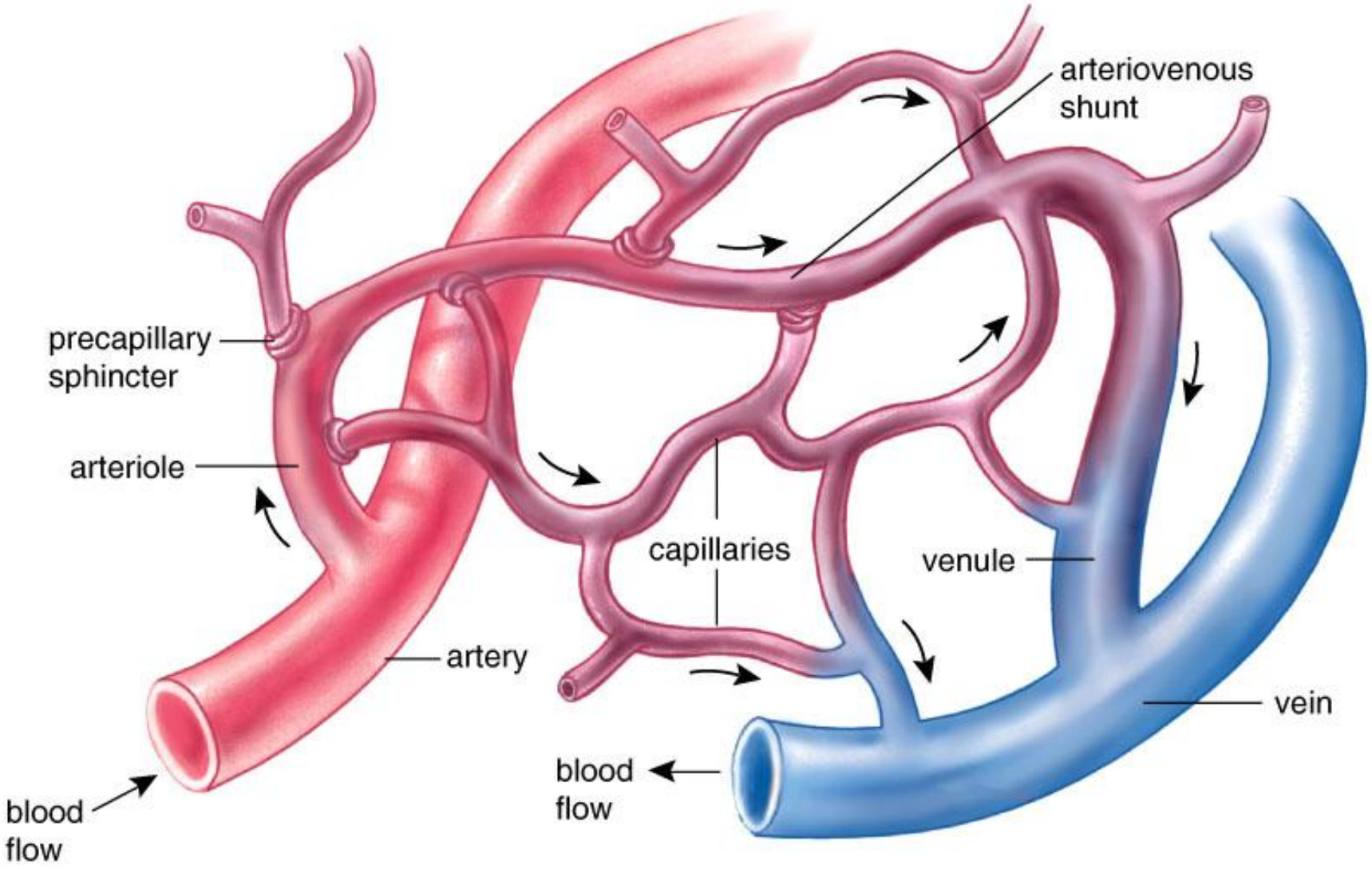
The blood vessels cont'd.

- The arteries
  - Walls have 3 layers
    - Innermost-endothelium
      - Simple squamous epithelium with basement membrane
    - Middle layer- thickest
      - Smooth muscle for regulation of diameter
      - Elastic connective tissue in larger arteries
    - Outer layer
      - Fibrous connective tissue
  - Largest artery is the aorta
  - Arteries branch into the smaller arterioles
    - Middle layer of wall is mostly smooth muscle
    - Important in control of blood pressure

The blood vessels cont'd.

- Capillaries
  - Join arterioles to venules
  - Walls consist of single layer of endothelium
  - Allows for exchange of substances
    - Oxygen, carbon dioxide, nutrients, wastes
  - Total surface area of capillary beds in body is 6000 square meters!
  - Not all capillary beds are open at any one time
    - Each has an arteriovenous shunt which allows capillaries to be bypassed

Anatomy of a capillary bed



- Fig 12.2

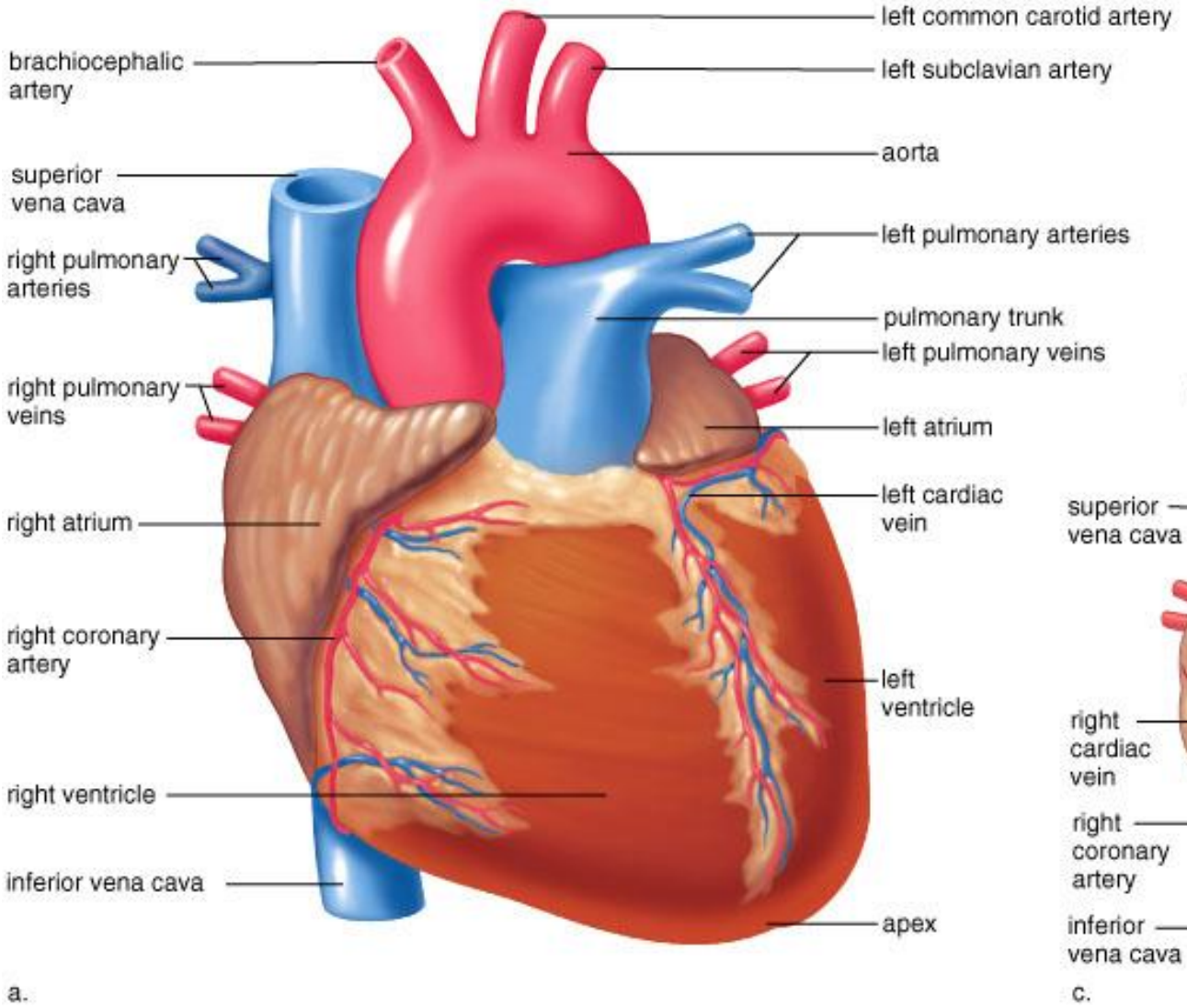
The blood vessels cont'd.

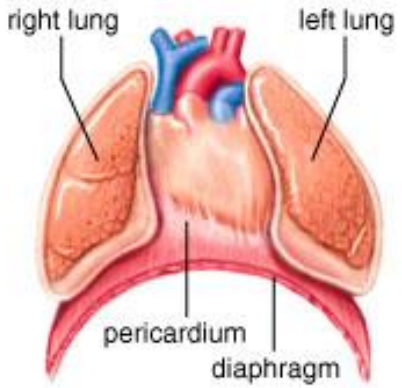
- The veins
  - Veins have less developed muscle and connective tissue layers than arteries
  - Tend to be distensible
    - Can expand to "store" blood
    - Up to 70% of blood is in venous side of the circulation at any one time
  - Veins have valves
    - Prevent backflow of blood
    - Skeletal muscle action squeezes blood upward through valves
  - Largest veins are the vena cavae

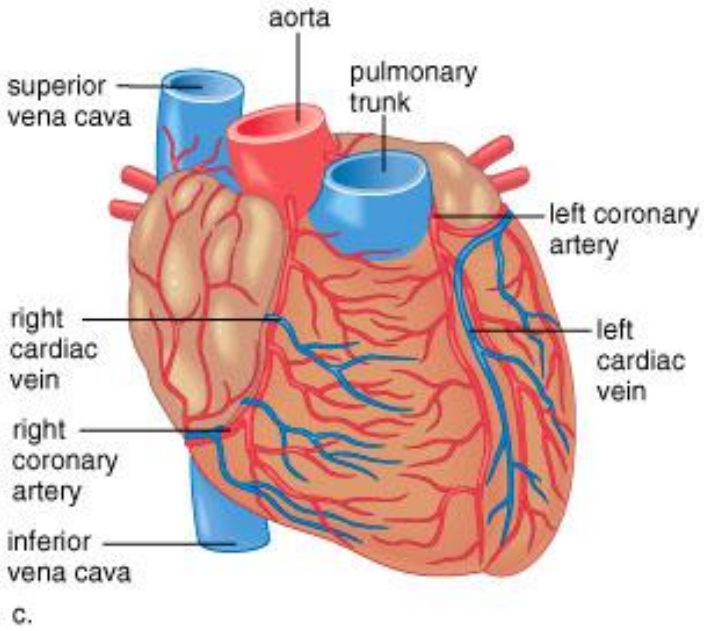
12.2 The heart

- Structure of the heart
  - 4 chambers
    - 2 upper atria
    - 2 lower ventricles
    - Each pair of chambers is separated by a septum
  - Heart wall
    - Major portion is the myocardium-cardiac muscle
    - Inner surfaces lined with endocardium
    - Outer surfaces lined with pericardium

External heart anatomy





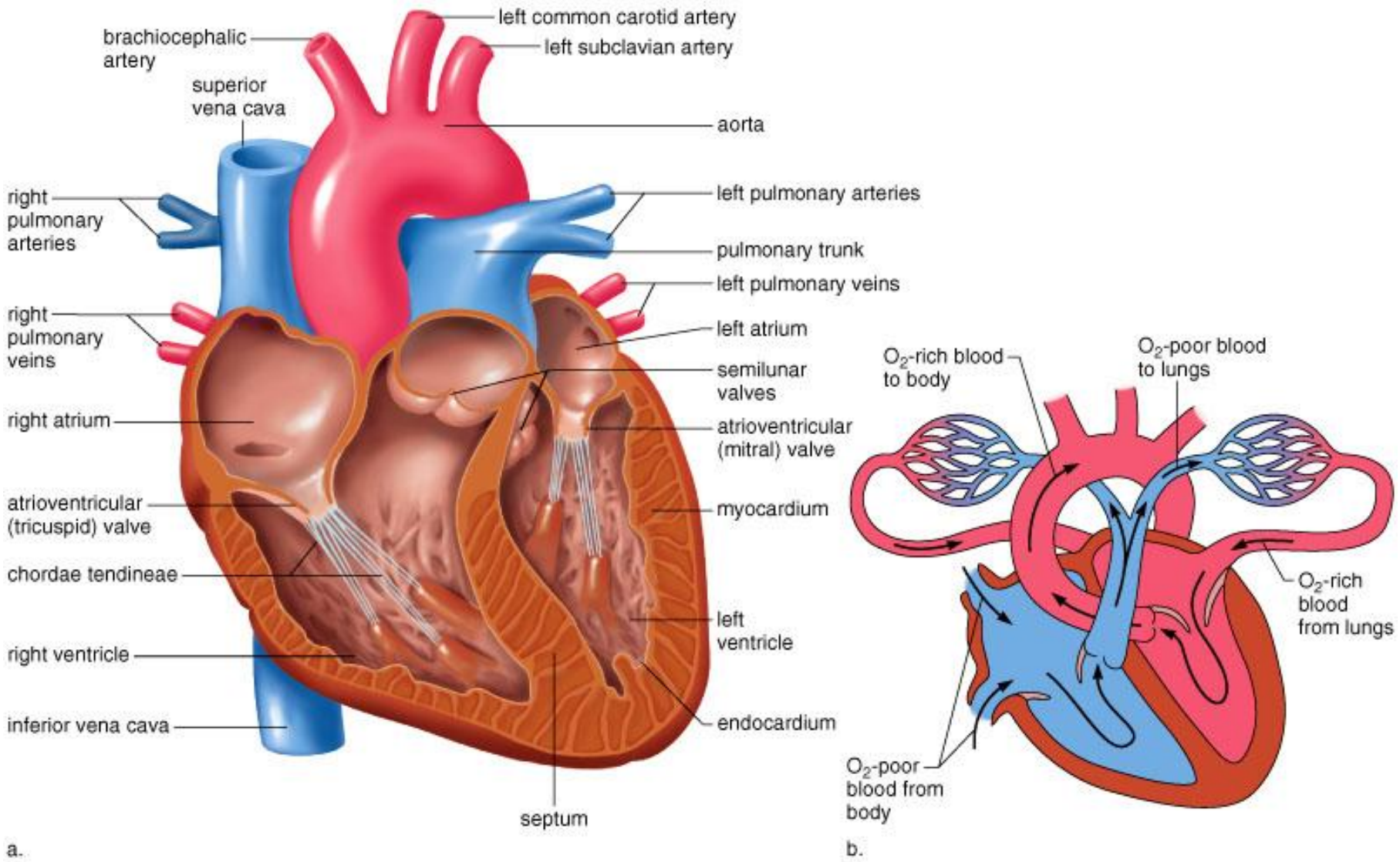


- Fig 12.3

The heart cont'd.

- Heart valves
  - Atrioventricular valves
    - Lie between the atrium and ventricle on each side
    - Mitral valve-between the left atrium and left ventricle
    - Tricuspid valve- between the right atrium and right ventricle
  - Semilunar valves
    - Between the ventricle and great vessel on each side
    - Aortic valve-between the left ventricle and aorta
    - Pulmonary valve-between the right ventricle and the pulmonary artery
  - Valves control the flow of blood through the heart

Internal view of the heart



- Fig 12.4

The heart cont'd.

- Passage of blood through the heart
  - Superior and inferior vena cavae bring O_2-poor blood to the right atrium
  - Blood flows through tricuspid valve to right ventricle
  - From right ventricle blood passes through the pulmonary valve to the pulmonary artery
  - Blood picks up oxygen in the lungs and returns to the heart through the pulmonary veins
  - Pulmonary veins empty oxygenated blood into the left atrium
  - Blood flows through the mitral valve to the left ventricle
  - From the left ventricle blood flows through the aortic valve to the aorta
  - Aorta carries blood out to the body

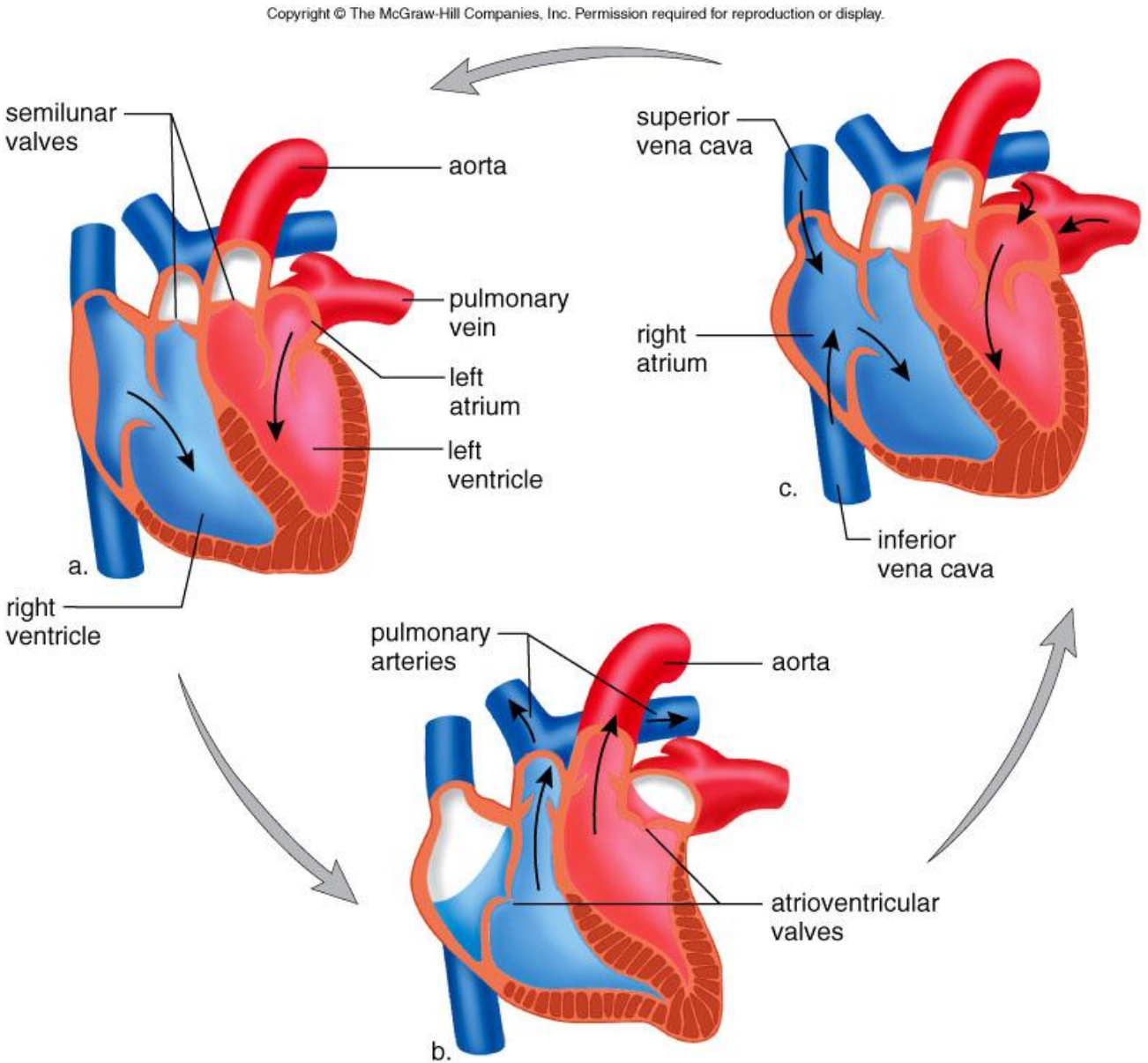
The heart cont'd.

- Blood flow through the heart cont'd.
  - The heart is effectly 2 pumps
    - Right side is the pulmonary pump
      - Pumps deoxygenated blood to pulmonary circuit and lungs
    - Left side is the systemic pump
      - Pumps oxygenated blood out to systemic circulation
  - Note that deoxygenated and oxygenated blood never mix
  - Left ventricle pumps blood under higher pressure
    - Left ventricular wall is more muscular

The heart cont'd.

- The heartbeat
  - The events of each heartbeat are called the cardiac cycle
    - Highly coordinated so that both atria contract together and then both ventricles contract together
    - Systole- contraction of heart muscle
    - Diastole-relaxation of heart muscle
  - Normal heart rate at rest is about 60-80 beats per minute
  - "Lub dup" heart sounds are produced by turbulence and tissue vibration as valves close
    - "lub" sound occurs as atrioventricular valves (AV) close
    - "dup" sound occurs as semilunar valves close
  - Other abnormal sounds are referred to as heart murmurs

Stages in the cardiac cycle



- Fig 12.5

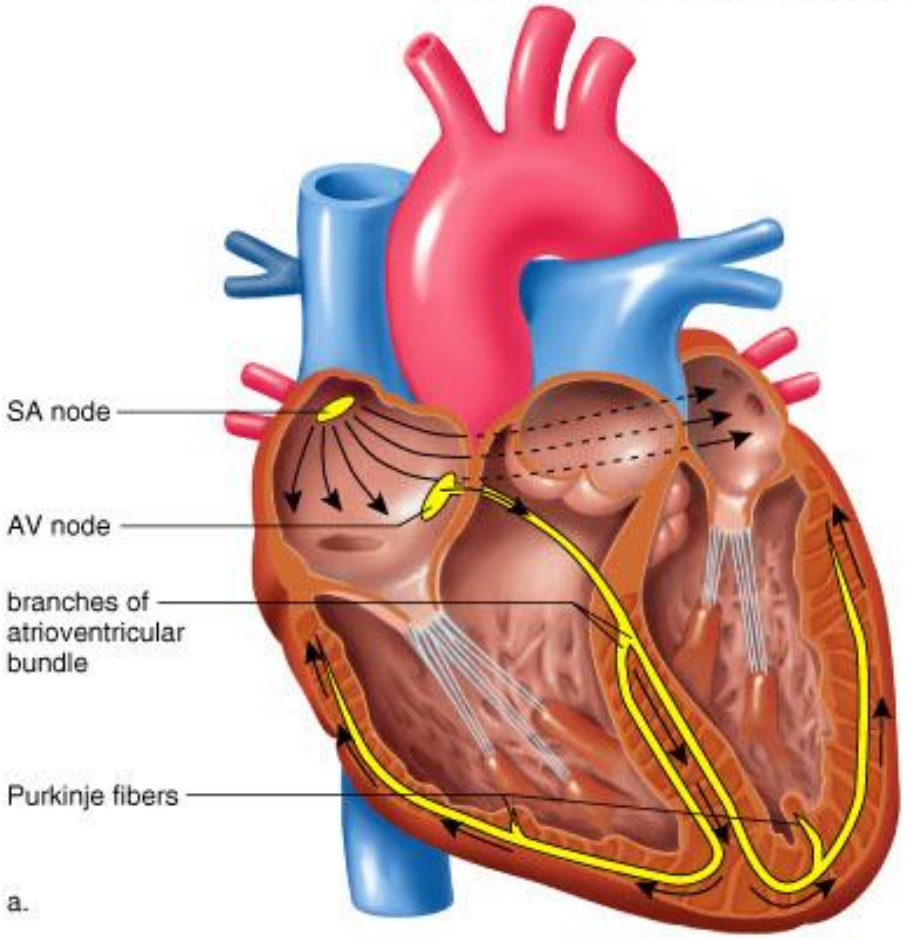
The heart cont'd.

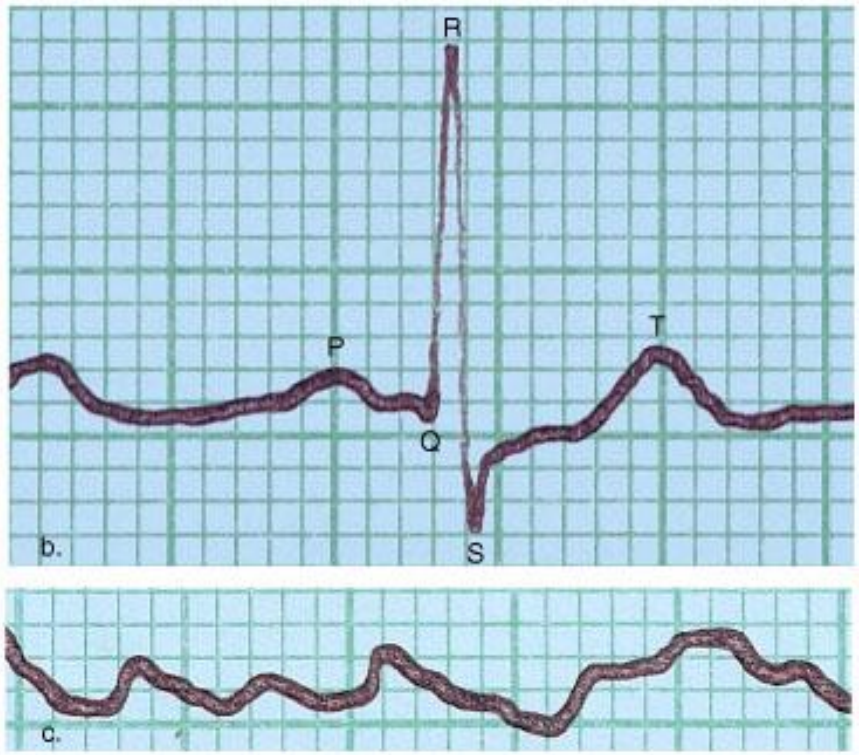
- Intrinsic control of heartbeat
  - Heart has its own intrinsic conduction system
    - Autorhymicity-unlike skeletal muscle, cardiac muscle can contract without neural stimulation
    - The autonomic nervous system does has inputs to the heart and normally regulates rate
  - Nodal tissue-2 areas in the heart
    - Has both muscular and nervous characteristics
    - Can generate action potentials to cause contraction
    - SA node and AV node

The heart cont'd.

- Intrinsic control of the heartbeat cont'd.
  - Normal conduction pathway
    - SA node in right atrium initiates an action potential
    - Action potential spreads throughout atrial muscles
    - Also is conducted to AV node lower in right atrium
    - AV node slows impulse slightly then sends it AV bundle
    - AV bundle conducts impulse down through the interventricular septum
    - Branches into many small purkinje fibers that distribute impulse throughout ventricle
  - Atria contract first, followed by the ventricles

Conduction system of the heart





- Fig 12.6

The heart cont'd.

- Extrinsic control of the heartbeat
  - Cardiac control center in the medulla has inputs to heart through the ANS
  - Parasympathetic stimulation causes a decrease in heart rate
  - Sympathetic stimulation causes an increase in heart rate and contractility
  - Hormones also can control heartbeat
    - Epinephrine and norepinephrine cause increased heart rate
    - Occurs during exercise, "fight or flight" response

The heart cont'd.

- The electrocardiogram
  - Records electrical activity of the heart
  - Can give information about heart rate and rhythm
  - Can indicate if conduction pathway is working normally
    - P wave- atrial depolarization
    - QRS complex- ventricular depolarization
    - T wave- ventricular repolarization

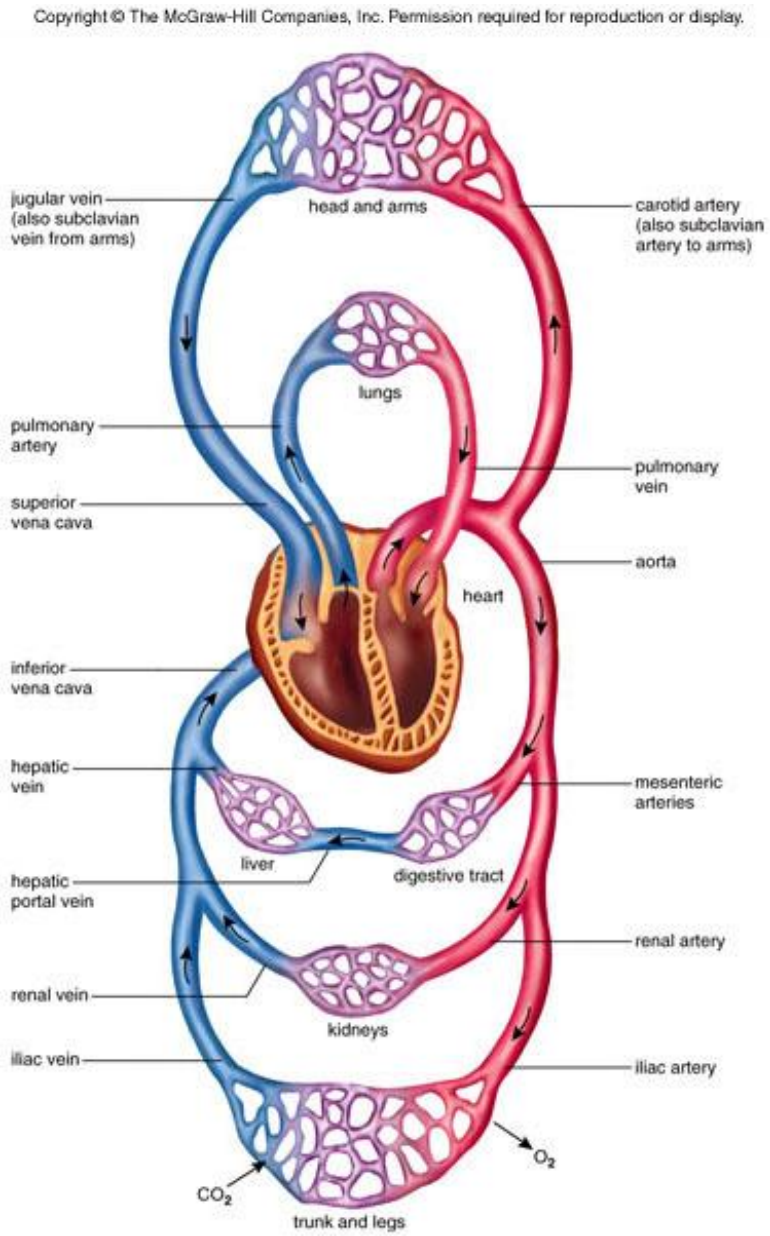
12.3 The vascular pathways

- The pulmonary circuit
  - Right ventricle pumps deoxygenated blood to pulmonary artery
  - Branches into left and right pulmonary arteries that go to the lungs
  - Within the lungs blood is distributed to alveolar capillaries
  - Oxygen diffuses into the blood and carbon dioxide diffuses out
  - Oxygenated blood now travels through pulmonary veins to the left atrium

The vascular pathways cont'd.

- The systemic circuit
  - Oxygenated blood is pumped from the left ventricle to the aorta
  - Aorta distributes blood through the systemic arteries
  - As blood travels through the systemic capillaries it drops off oxygen and picks up carbon dioxide
  - The deoxygenated blood is returned by venules and then veins to the vena cavae
  - The inferior vena cava drains the body below the chest
  - The superior vena cava collects blood from the head, chest, and arms
  - Blood is returned to the right atrium

Cardiovascular system diagram

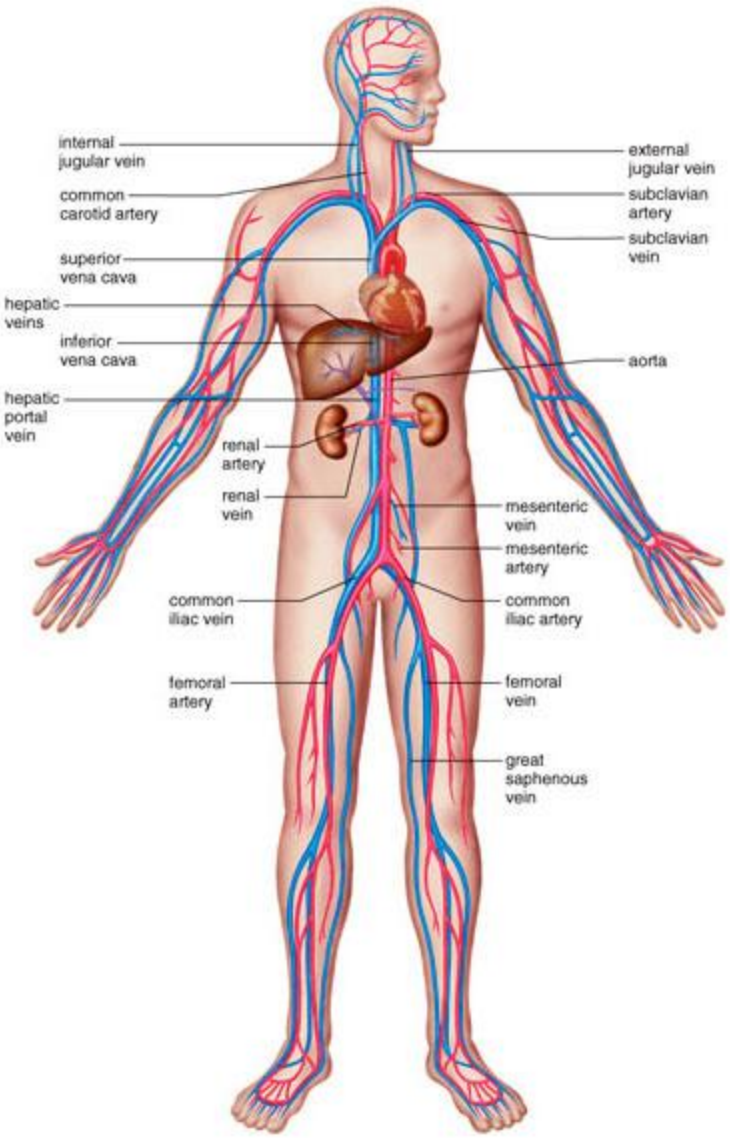


- Fig 12.7

The vascular pathways cont'd.

- Major areas of the systemic circuit
  - Coronary circulation
    - Supplies the heart muscle
    - Coronary arteries are the first branches off the aorta
    - Lie on surface of heart and distribute blood to coronary capillaries in the heart muscle
    - Blood is collected in venules and emptied into coronary veins
    - Coronary veins enter into right atrium
  - Hepatic portal system
    - Collects nutrient-rich blood from digestive tract
    - Blood is carried in the hepatic portal vein to the liver
    - Nutrients are absorbed by the liver
    - Blood is carried out of the liver by hepatic veins to inferior vena cava

Major arteries and veins of the systemic circuit



- Fig 12.8

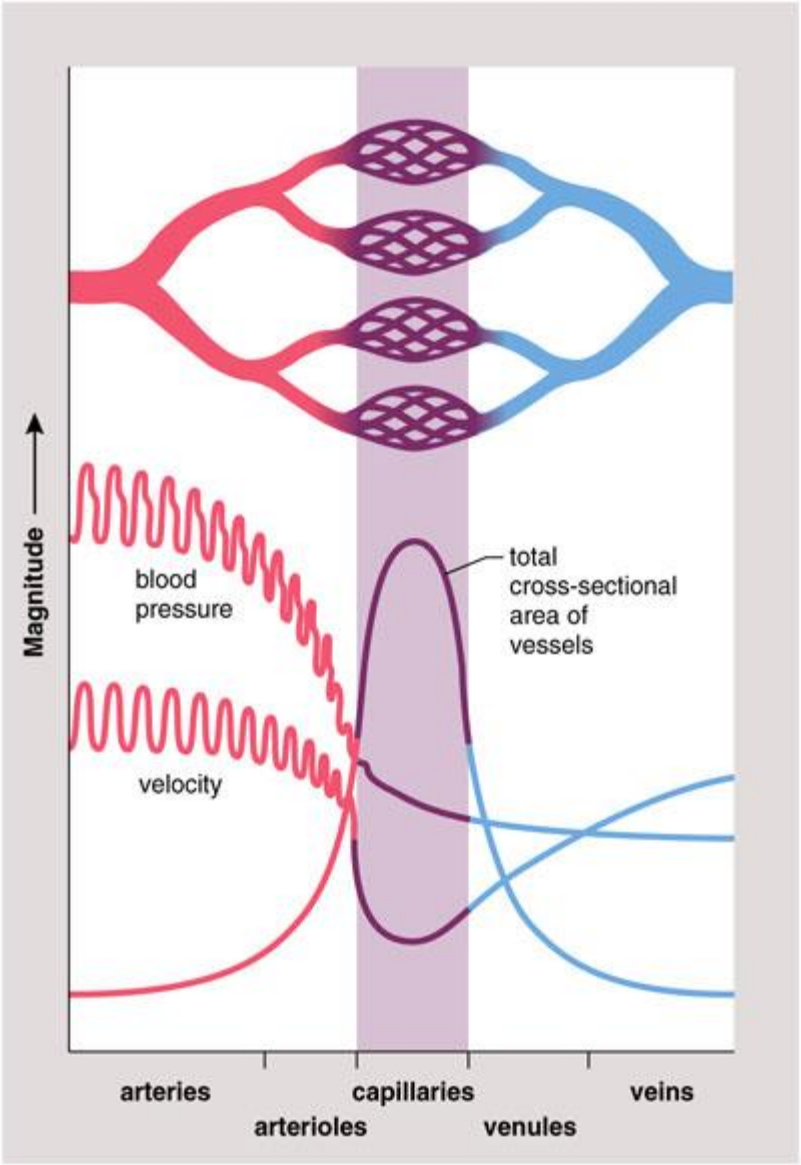
The vascular pathways cont'd.

- Blood flow
  - Blood flow in the arteries
    - Blood pressure- pressure of blood against vessel walls
    - Highest pressure-systolic pressure
    - Lowest pressure-diatolic pressure
    - Normally 120/80mmHg
    - Blood pressure accounts for flow through arteries and arterioles
      - Decreases as blood distributes throughout system
      - Highest in aorta
      - Lowest in vena cavae

The vascular pathways cont'd.

- Blood flow in capillaries
  - Extensive number of capillaries
  - Blood moves slowly through capillaries
    - Allows time for exchange of substances
- Blood flow in veins
  - Blood pressure is low in veins
  - Venous return depends on
    - Skeletal muscle movements
    - Valves to prevent backflow
    - Respiratory movements
      - Inhalation-intrathoracic pressure drops
      - This "sucks" blood upward

Cross-sectional area as it relates to blood pressure and blood velocity



- Fig 12.9

The vascular pathways cont'd.

- Flow through veins cont'd.
  - Varicose veins
    - From weakened valves
    - Develop due to backward pressure of blood
  - Phlebitis
    - Inflammation of a vein
    - Can lead to blood clots

12.4 Blood

- Composition
  - Formed elements
    - Cells-white blood cells and red blood cells
    - Platelets- cell fragments
  - Plasma
    - Liquid portion of blood

Composition of blood

FORMED ELEMENTS	Function and Description	Source
Red Blood Cells (erythrocytes)  4 million–6 million per mm^3 blood	Transport O_2 and help transport CO_2 7–8 μm in diameter Bright-red to dark-purple biconcave disks without nuclei	Red bone marrow
White Blood Cells (leukocytes) 5,000–11,000 per mm^3 blood	Fight infection	Red bone marrow
Granular leukocytes		
• Neutrophils  40–70%	10–14 μm in diameter Spherical cells with multilobed nuclei; fine, pink granules in cytoplasm; phagocytize pathogens	
• Eosinophils  1–4%	10–14 μm in diameter Spherical cells with bilobed nuclei; coarse, deep-red, uniformly sized granules in cytoplasm; phagocytize antigen-antibody complexes and allergens	
• Basophils  0–1%	10–12 μm in diameter Spherical cells with lobed nuclei; large, irregularly shaped, deep-blue granules in cytoplasm; release histamine, which promotes blood flow to injured tissues	
Agranular leukocytes		
• Lymphocytes  20–45%	5–17 μm in diameter (average 9–10 μm) Spherical cells with large round nuclei; responsible for specific immunity	
• Monocytes  4–8%	10–24 μm in diameter Large spherical cells with kidney-shaped, round, or lobed nuclei; become macrophages that phagocytize pathogens and cellular debris	
Platelets (thrombocytes)  150,000–300,000 per mm^3 blood	Aid clotting 2–4 μm in diameter Disk-shaped cell fragments with no nuclei; purple granules in cytoplasm	Red bone marrow

PLASMA	Function	Source
Water (90–92% of plasma)	Maintains blood volume; transports molecules	Absorbed from intestine
Plasma proteins (7–8% of plasma)	Maintain blood osmotic pressure and pH	Liver
Albumins	Maintain blood volume and pressure	
Globulins	Transport; fight infection	
Fibrinogen	Clotting	
Salts (less than 1% of plasma)	Maintain blood osmotic pressure and pH; aid metabolism	Absorbed from intestine
Gases		
Oxygen Carbon dioxide	Cellular respiration End product of metabolism	Lungs Tissues
Nutrients	Food for cells	Absorbed from intestine
Lipids Glucose Amino acids		
Nitrogenous wastes	Excretion by kidneys	Liver
Urea Uric acid		
Other		
Hormones, vitamins, etc.	Aid metabolism	Varied

• Appearance with Wright's stain.

- Fig 12.10

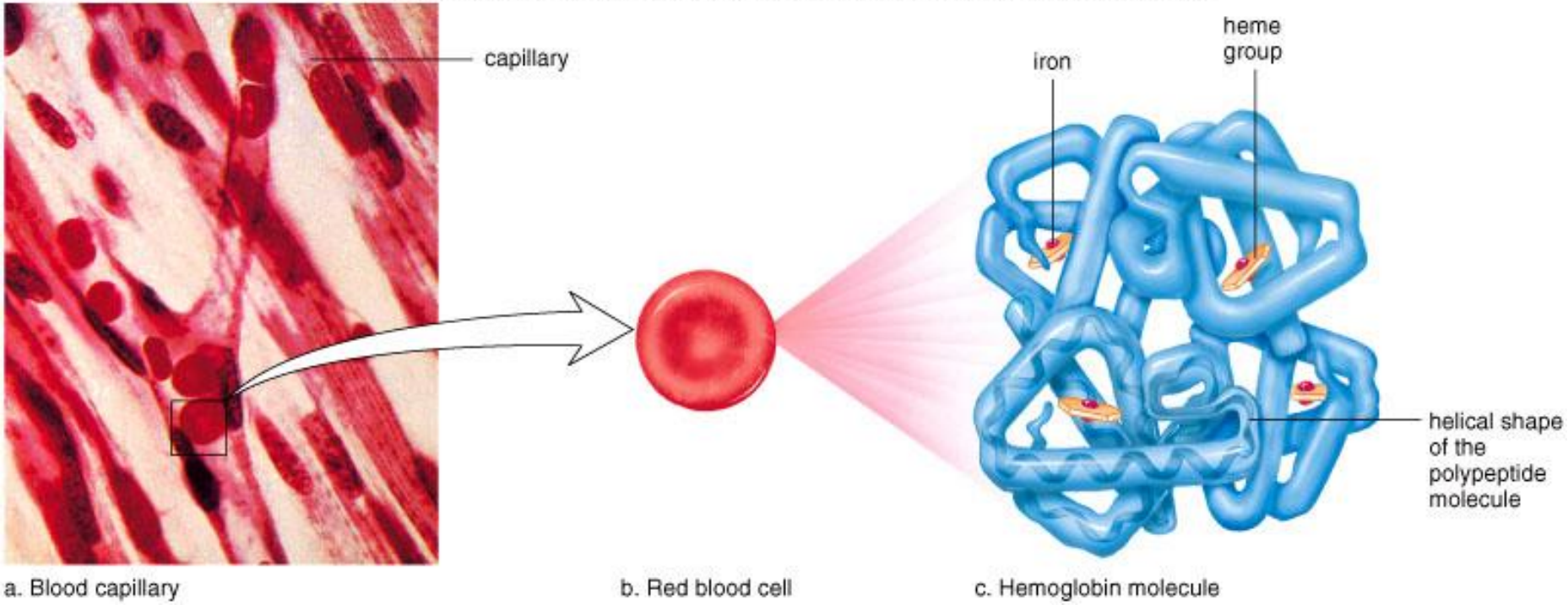
The blood cont'd.

- Plasma
  - Plasma proteins
    - Maintain blood volume by contributing to osmotic pressure
    - Fibrinogen-blood clotting
    - Immunoglobulins-immunity
    - Albumins-transport
    - Many others
  - Inorganic and organic substances
  - Blood gases-in dissolved molecular form

The blood cont'd.

- Red blood cells
  - Manufactured in red bone marrow
  - 4-6 million per mm^3 of whole blood
  - Lack a nucleus-lose it as they mature
  - Biconcave disks- shape allows greater surface area
  - Contain hemoglobin
    - Red iron-containing pigment
    - Heme portion binds oxygen
    - Carries 20 ml oxygen per 100 ml of blood
    - carbon monoxide can also bind at heme sites
      - more strongly than oxygen
      - Carbon monoxide poisoning

Physiology of red blood cells



- Fig. 12.11

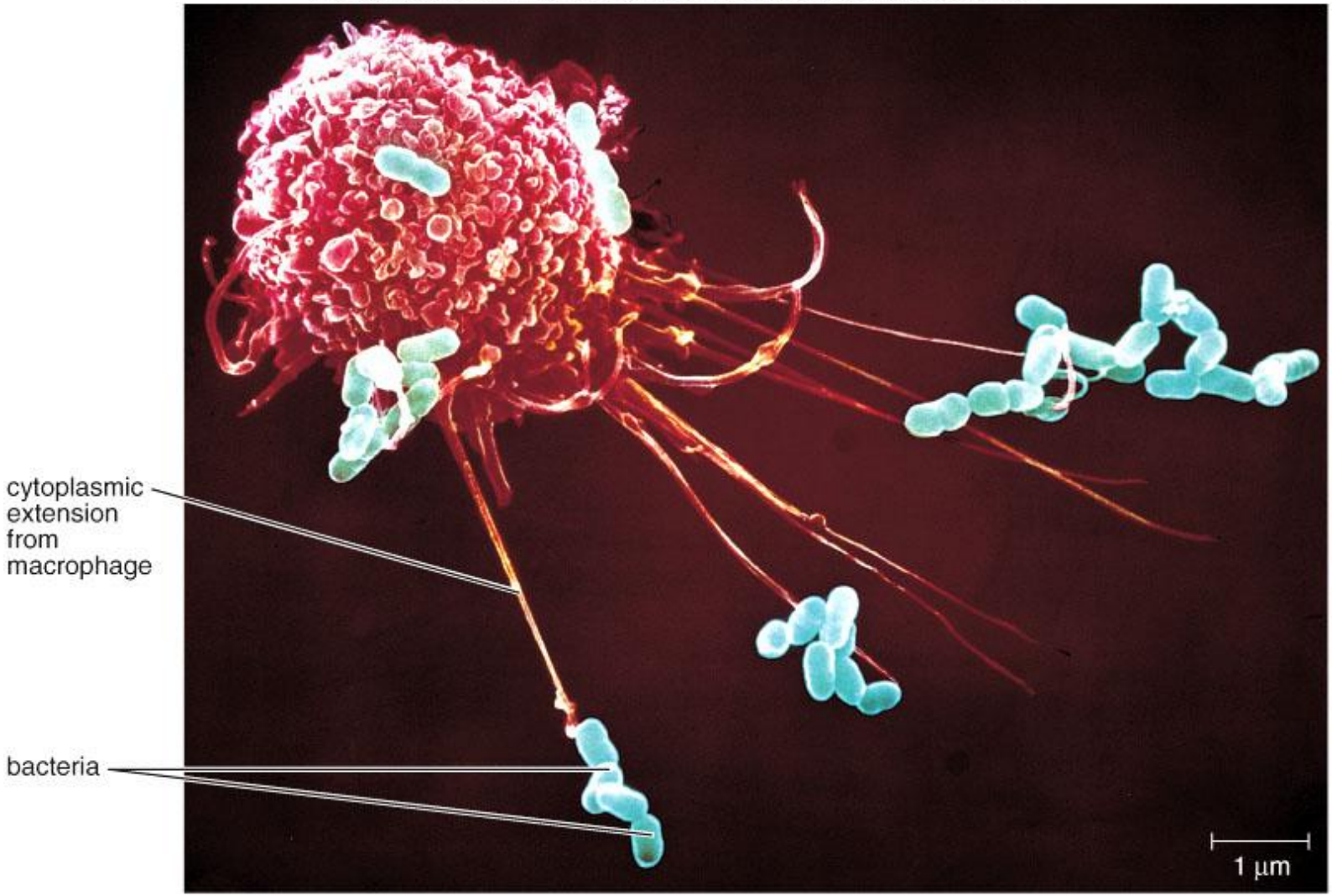
The blood cont'd.

- Red blood cells cont'd.
  - Lifespan- 120 days
  - Destroyed in liver by fixed macrophages
    - Hemoglobin is broken down
      - Iron is recycled-taken to bone marrow
      - Heme portion is degraded and excreted as bile pigments
  - Anemia- decreased red blood cells
    - Most common type comes from iron deficiency
  - Production of red blood cells is stimulated by erythropoietin
    - From kidney
    - In response to decreased oxygen in blood

The blood cont'd.

- White blood cells
  - Less numerous than RBC's- 4000-11000 per mm^3 of whole blood
  - Larger cells, nucleated
  - Fight infection and play a role in immunity
  - Granulocytes-have visible granules in cytoplasm
    - Neutrophils- most abundant WBC, phagocytic
    - Basophils-granules stain deep blue and release histamine
    - Eosinophils-granules stain red, phagocytize allergens
  - Agranulocytes- lack visible granules
    - Lymphocytes-T and B cells, play roles in immunity
    - Monocytes-largest WBC's, phagocytic
      - Differentiate into macrophages and dendritic cells

Macrophage engulfing bacteria



- Fig. 12.12

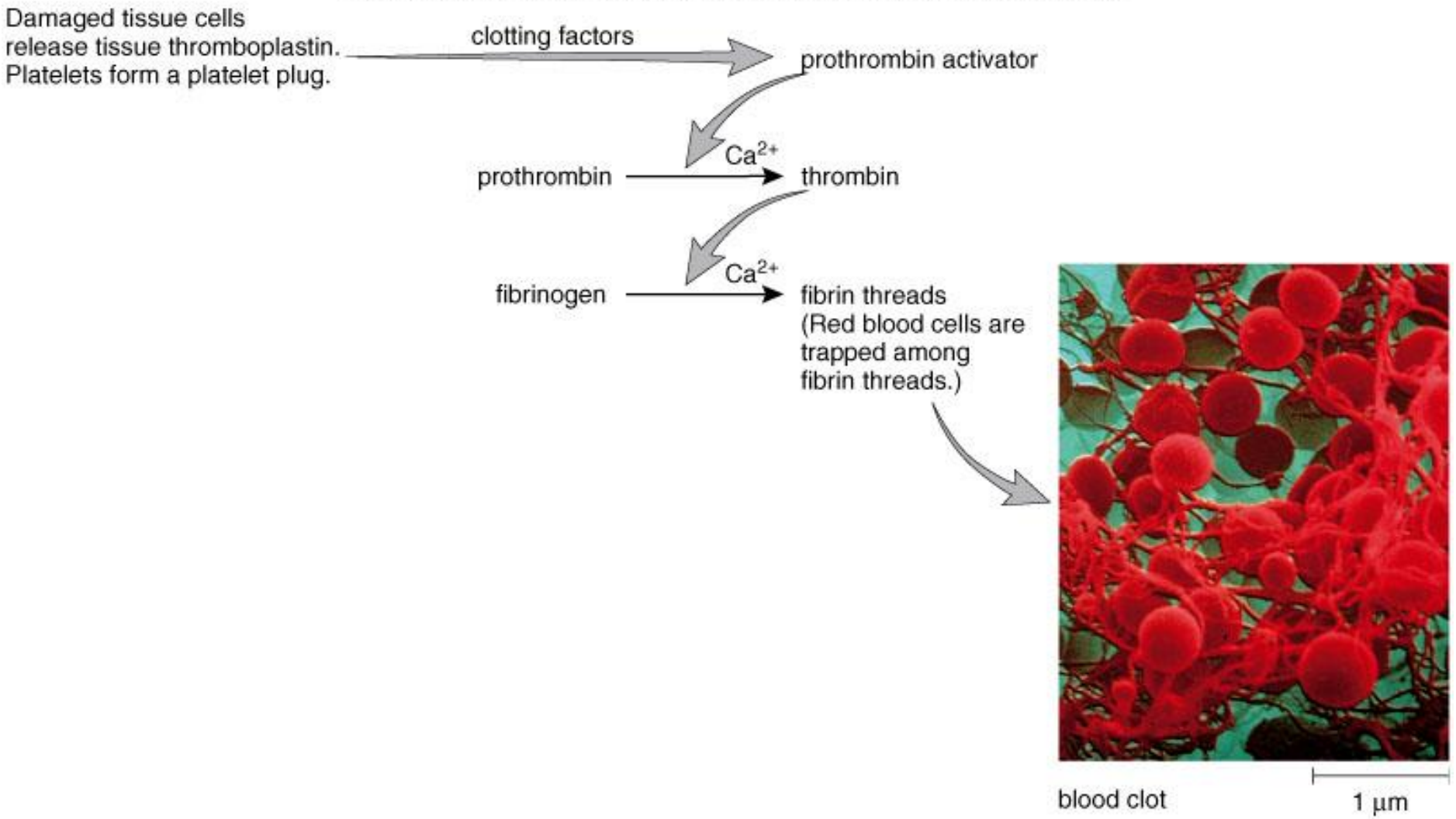
The blood cont'd.

- White blood cells cont'd.
  - A change in numbers may indicate disease
    - Infectious mononucleosis-caused by Epstein-Barr virus
      - Increased number of B lymphocytes
    - AIDS- caused by HIV
      - Decreased number of T lymphocytes
    - Leukemia- form of cancer
      - Uncontrolled numbers of WBC's
  - Lifespan
    - Different types live different lengths of time
    - Some live only a few days-die combating invading pathogens
    - Some live months or years

The blood cont'd.

- The platelets
  - fragmentation of large cells called megakaryocytes
  - 150000-300000 per mm^3 of whole blood
  - Involved in the process of clotting
- Blood clotting
  - Platelets form a plug for immediate stoppage of bleeding
  - Vessels release prothrombin activator and injured tissues release thromboplastin
    - Thromboplastin stimulates further release of prothrombin activator
    - Requires calcium
  - Prothrombin activator activates a plasma protein prothrombin to thrombin
  - Thrombin activates fibrinogen to fibrin which forms a clot

Blood clotting



- Fig 12.13

The blood cont'd.

- Clotting cont'd.
  - Clot is composed of network of fibrin threads and trapped cells
  - As damage heals, plasmin breaks down the clot
  - If blood is allowed to clot in a test tube, serum develops
    - Serum-plasma without fibrinogen
- Hemophilia
  - Inherited clotting disorder
  - Caused by a deficiency of a clotting factor
  - Small injuries cause uncontrolled bleeding

Body fluids related to blood

TABLE 12.1 BODY FLUIDS RELATED TO BLOOD

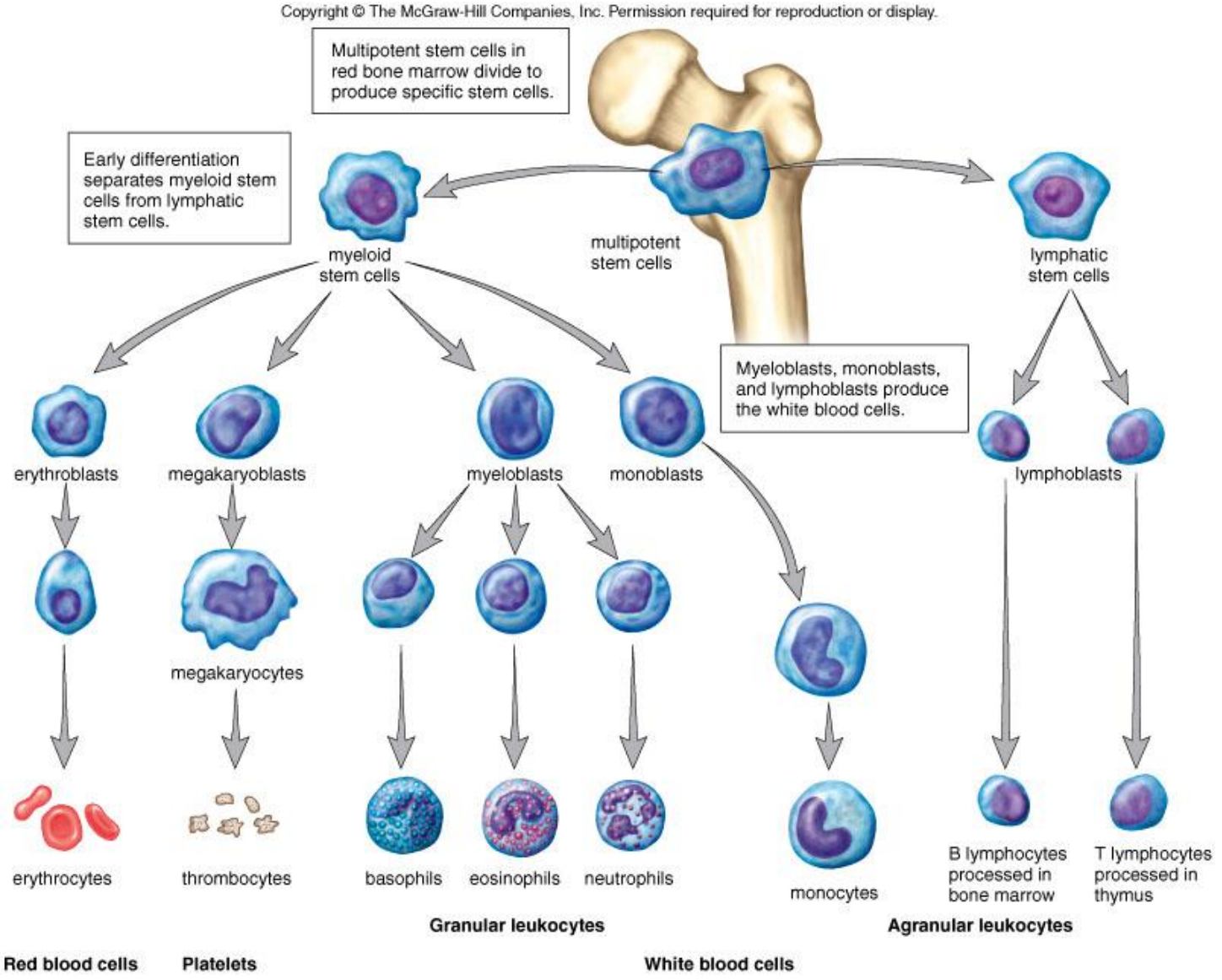
Name	Composition
Blood	Formed elements and plasma
Plasma	Liquid portion of blood
Serum	Plasma minus fibrinogen
Tissue fluid	Plasma minus most proteins
Lymph	Tissue fluid within lymphatic vessels

- Table 12.1

The blood cont'd.

- Bone marrow stem cells
  - Cell which is capable of dividing and differentiating into particular cell types
    - Red and white blood cells
    - Some may even be able to give rise to liver, bone, fat, cartilage, heart, and nerve cells
    - May provide solutions for diseases such as Alzheimer's and Parkinson's
  - Many researchers prefer to work with embryonic stem cells
    - Totipotent-can become any cell type
    - Ethical issues

Blood cell formation in red bone marrow



- Fig. 12.14

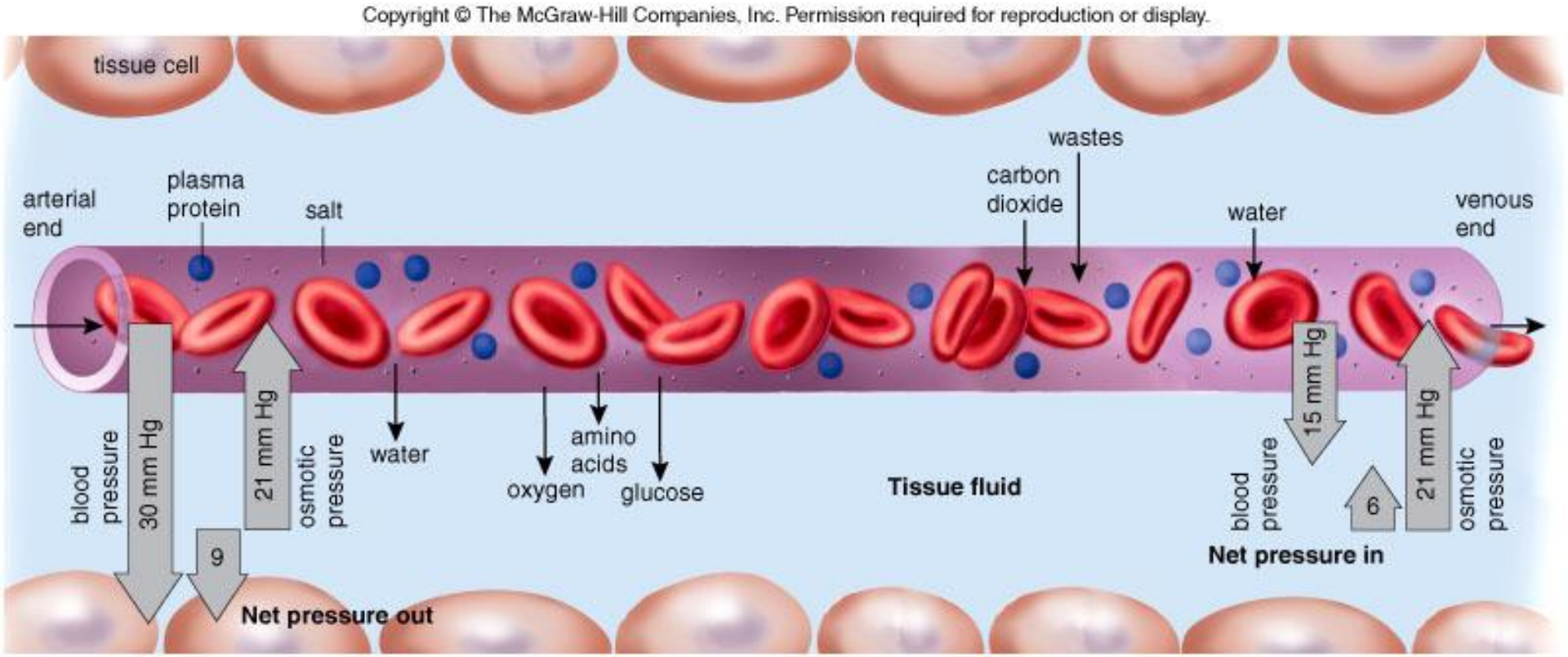
The blood cont'd.

- Capillary exchange
  - 2 forces control movement through capillary wall
    - Osmotic pressure-tends to cause water to move from tissues to blood; due to presence of plasma proteins and salts
    - Hydrostatic pressure (blood pressure)-tends to cause water to move from blood to tissues
  - At arterial end of capillary hydrostatic pressure is higher so water moves out-contributes to tissue fluids
  - Midway through capillary these forces are equalized so no net movement of water
    - Solutes now move down their gradients
  - At venous end osmotic pressure is greater than hydrostatic so water moves into capillary

The blood cont'd.

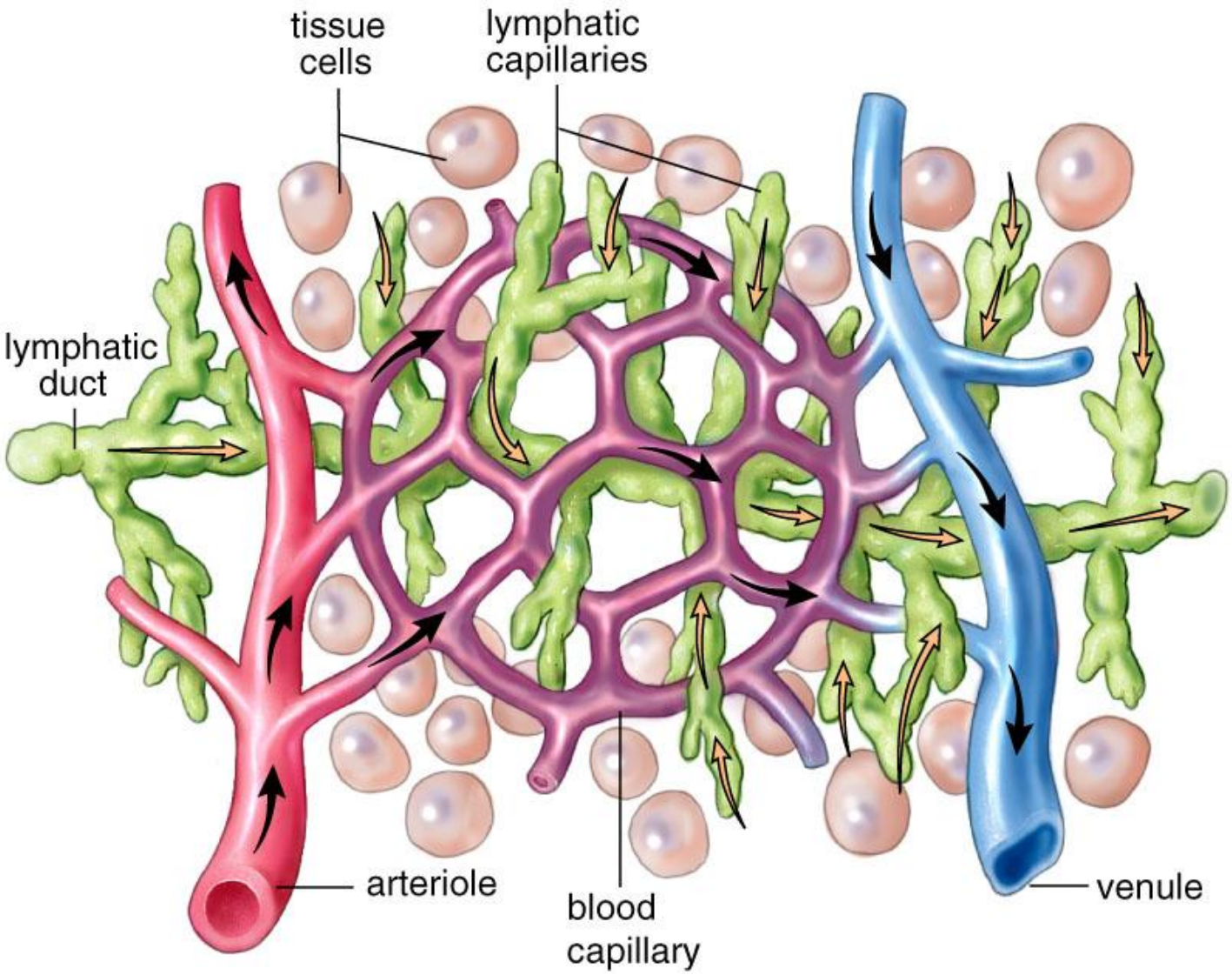
- Capillary exchange cont'd.
  - Almost the same about of water gets reabsorbed that left it at the arterial end
  - The small amount remaining behind can be absorbed by lymphatic vessels- lymph

Capillary exchange



- Fig 12.15

Lymphatic capillaries



- Fig 12.16

12.5 Cardiovascular disorders

- Atherosclerosis
  - Plaque formation in vessels-fats and cholesterol
  - Interferes with blood flow
  - Can be inherited
  - Prevention
    - Diet high in fruits and vegetables
    - Low in saturated fats and cholesterol
  - Plaques can cause clots to form-thrombus
    - If clot breaks lose it becomes a thromboembolism

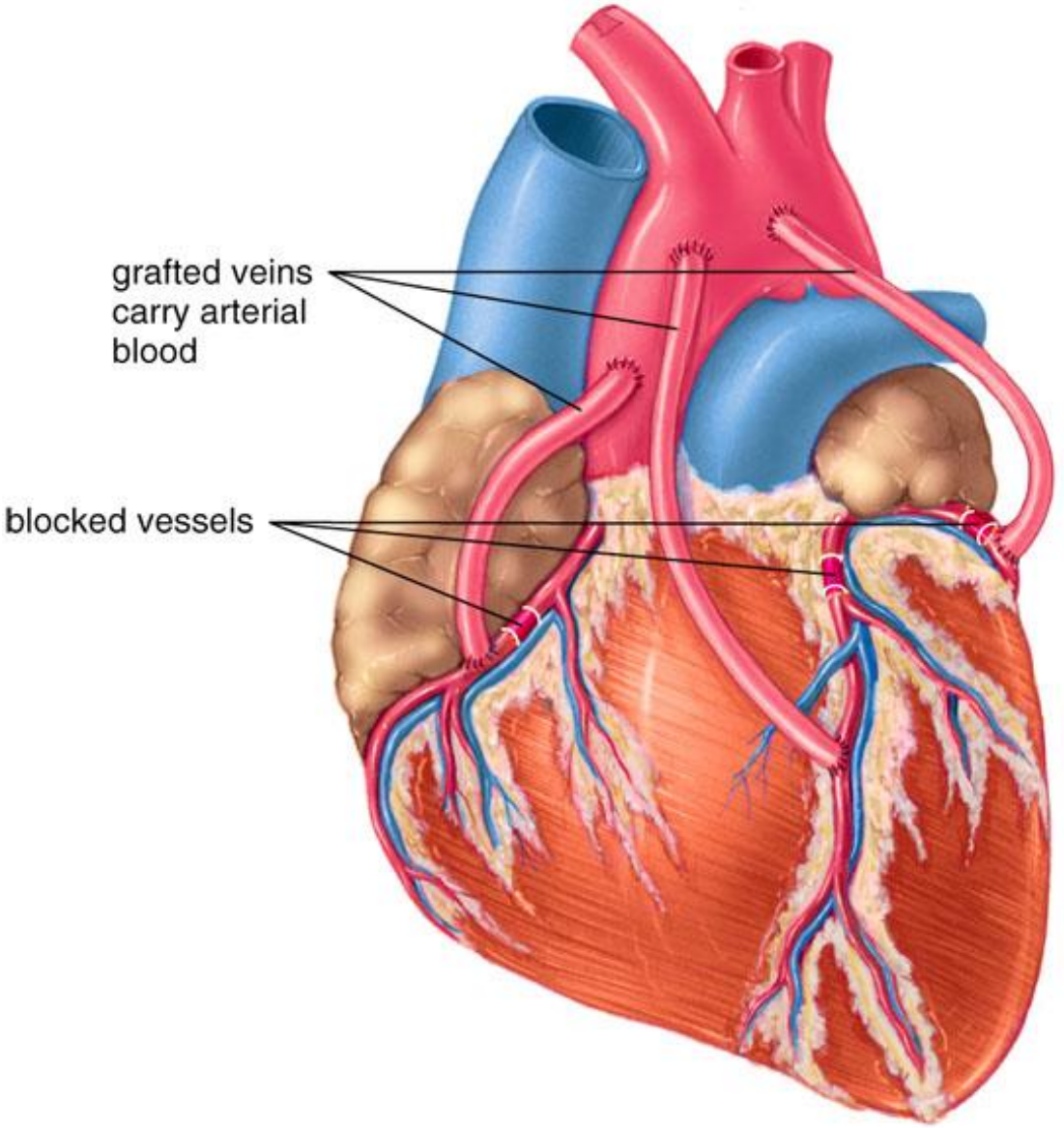
Cardiovascular disorders cont'd.

- Stroke, heart attack, and aneurysm
  - Stroke (CVA)- small cranial arteriole becomes blocked by an embolism
    - Lack of oxygen to brain can cause paralysis or death
    - Warning signs- numbness in hands or face, difficulty speaking, temporary blindness in one eye
  - Heart attack (MI)-portion of the heart muscle deprived of oxygen
    - Angina pectoris-chest pain from partially blocked coronary artery
    - Heart attack occurs when vessel becomes completely blocked
  - Aneurysm- ballooning of a blood vessel
    - Most often in abdomen or brain
    - Athersclerosis and hypertension can weaken walls of vessels leading to an aneurysm
    - Can rupture

Cardiovascular disorders cont'd.

- Coronary bypass operations
  - Bypass blocked areas of coronary arteries
  - Can graft another vessel to the aorta and then to the blocked artery past the point of blockage
  - Gene therapy is sometimes used to grow new vessels

Coronary bypass operation

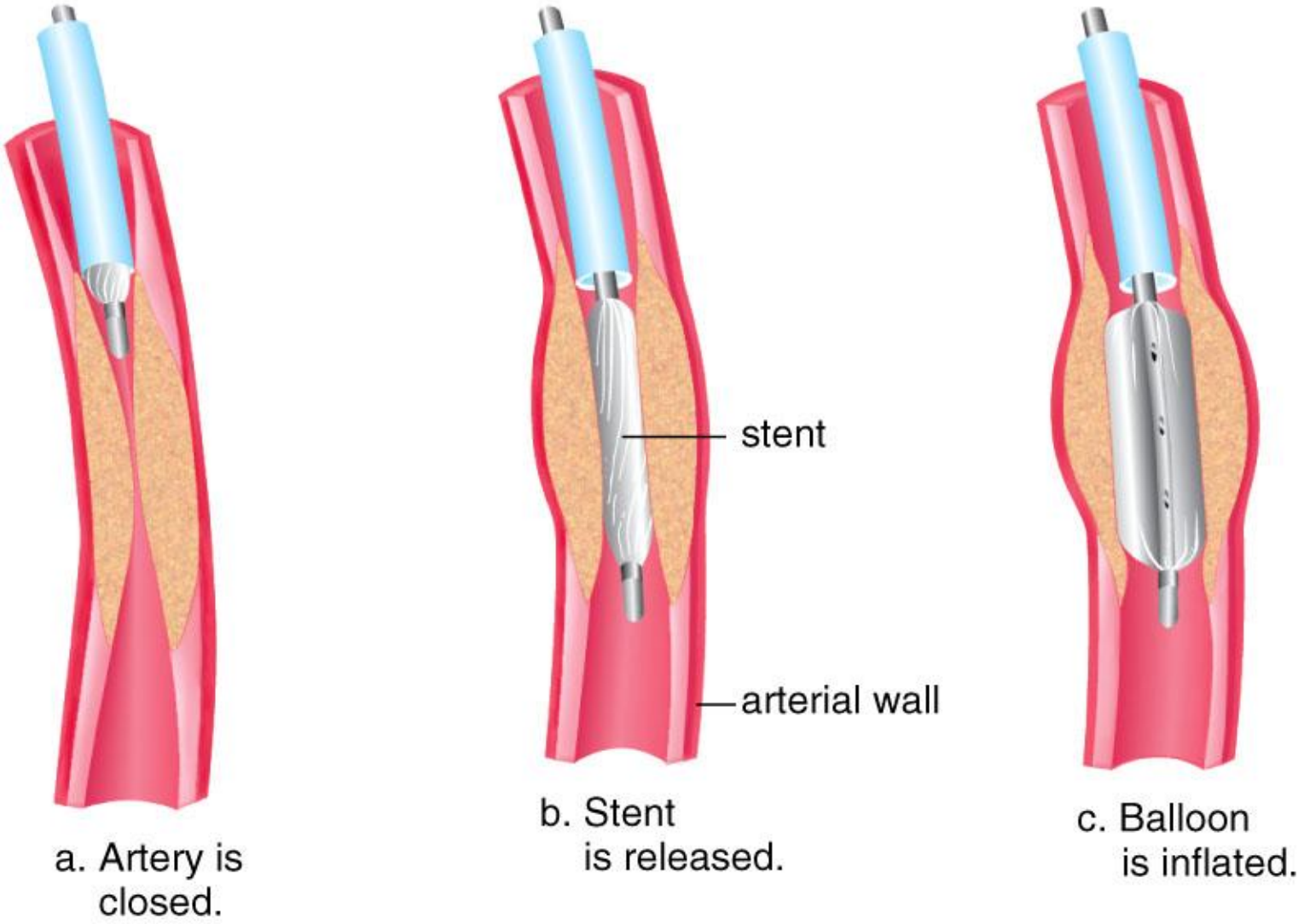


- Fig. 12.17

Cardiovascular disorders cont'd.

- Clearing clogged arteries
  - Angioplasty
    - Catheter is placed in clogged artery
    - Balloon attached to catheter is inflated
    - Increases the lumen of the vessel
    - Stents can be placed to keep vessel open
- Dissolving blood clots
  - Treatment for thromboembolism includes t-PA
  - Converts plasminogen to plasmin
  - Dissolves clot

Angioplasty



- Fig. 12.18

Cardiovascular disorders

- Heart transplants and artificial hearts
  - Usually successful but shortage of donors
  - LVAD-left ventricular assist device
    - Alternative to heart transplant
    - Tube passes blood from left ventricle to the LVAD
    - Blood is pumped to the aorta
  - TAH-total artificial heart
    - Generally only used to very ill patients
    - Survival rates are not good but may be because patients are so ill

Cardiovascular disorders

- Hypertension
  - 20% of Americans have hypertension
  - Atherosclerosis also can cause hypertension by narrowing vessels
  - Silent killer-may not be diagnosed until person has a heart attack or stroke
  - Causes damage to heart, brain, kidneys, and vessels
  - 2 genes may be responsible
    - One is a gene for angiotensinogen- powerful vasoconstrictor
    - The other codes for an enzyme that activates angiotensin
  - Monitor blood pressure and adopt lifestyle that lowers risk