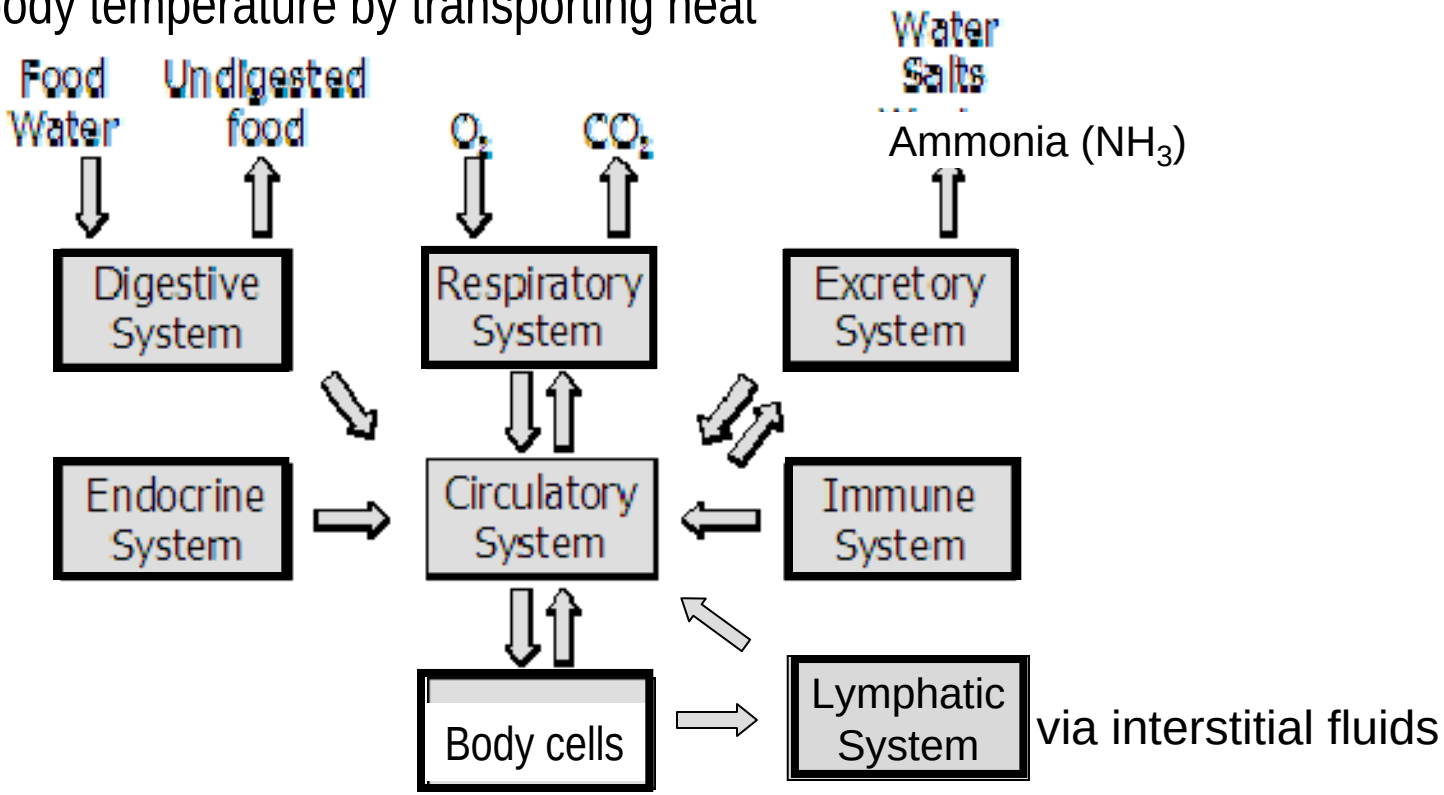
Circulation
Ch 42

2 Functions of Circulatory System

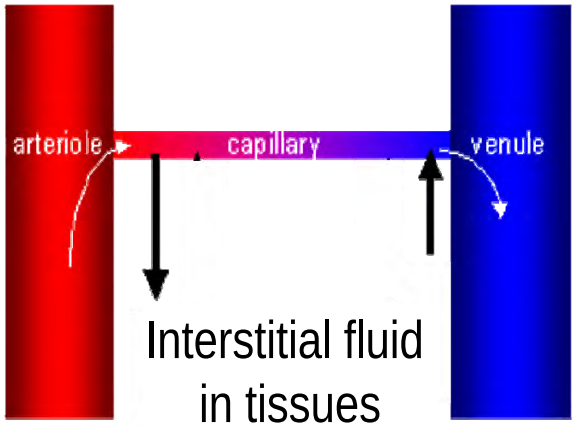
1. Allows all cells to exchange materials w/ the environment
   Gasses (respiratory syst), nutrients (digestive syst), NH_3 water, salt (excretory syst)
2. Allows communication btwn different organs/organ systems (hormones (Endocrine syst))
3. Transport of cells that fight infection, form clots & repair damaged tissue
   WBCs and platelets (Immune system, lymphatic system)
4. Helps stabilize body fluid pH & [ion] (kidneys, brain, pituitary (excretory syst))
5. Helps maintain body temperature by transporting heat



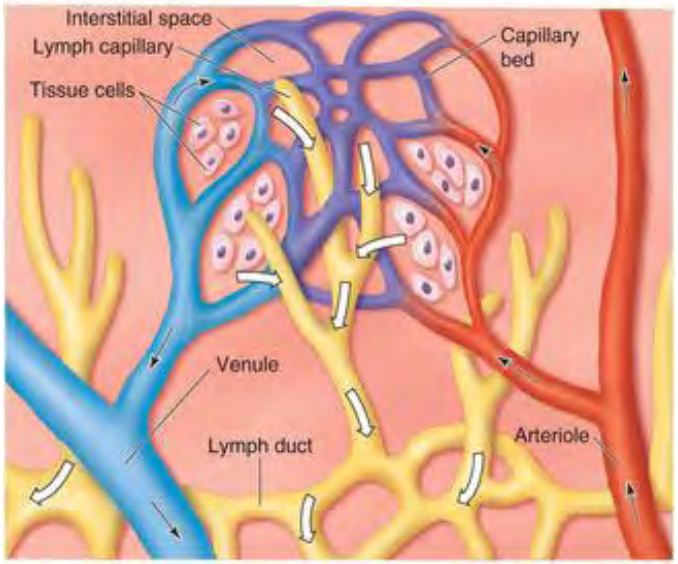
Interstitial fluids (IF)

Fluid between cells

IF Derived from blood plasma



Moves substances btwn cells and circulatory system



- Most IF returns to circ syst directly into capillaries
- Some IF returns to circ syst indirectly via lymph vessels which connect to circ syst

Circulation in Complex Animals

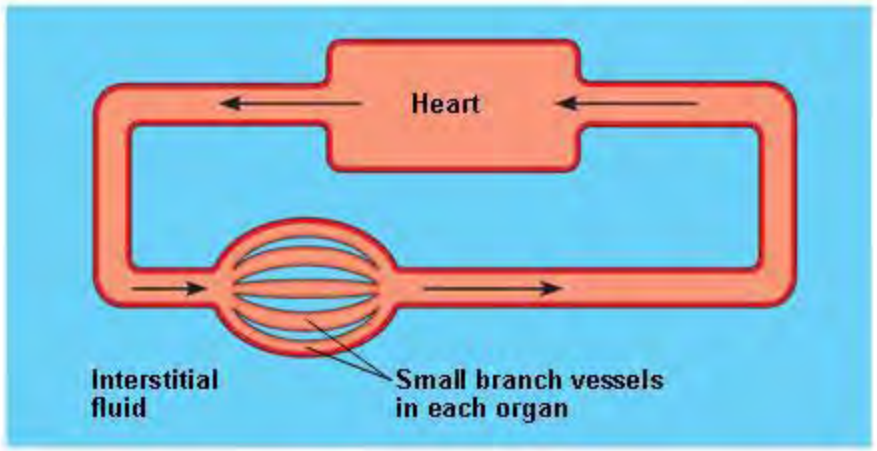
All complex animals have a circulatory system w/ 3 components:

1. Fluid
2. Tubes
3. Pump

8 2 types of Circulation in Complex Animals

Closed Circulation

- Blood never leaves tubes and moves in one direction;
- O_2 rich blood, O_2 poor blood, & waste (NH_3) generally do not mix
- Interstitial fluids move gasses (O_2/CO_2), nutrients, waste (NH_3), btwn blood & cells
- Occurs in some invertebrates & ALL vertebrates.



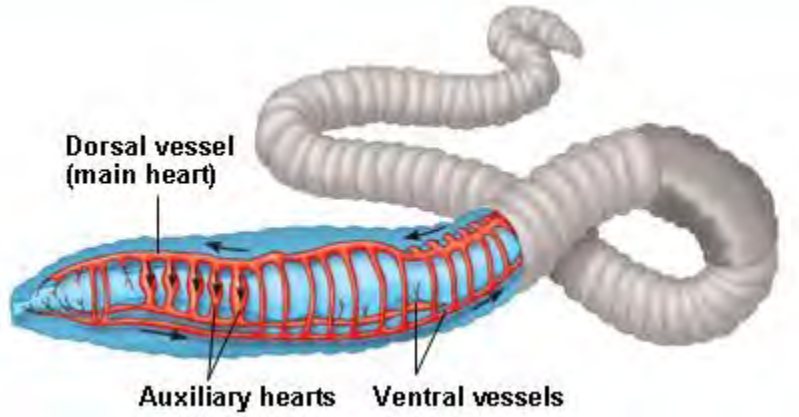
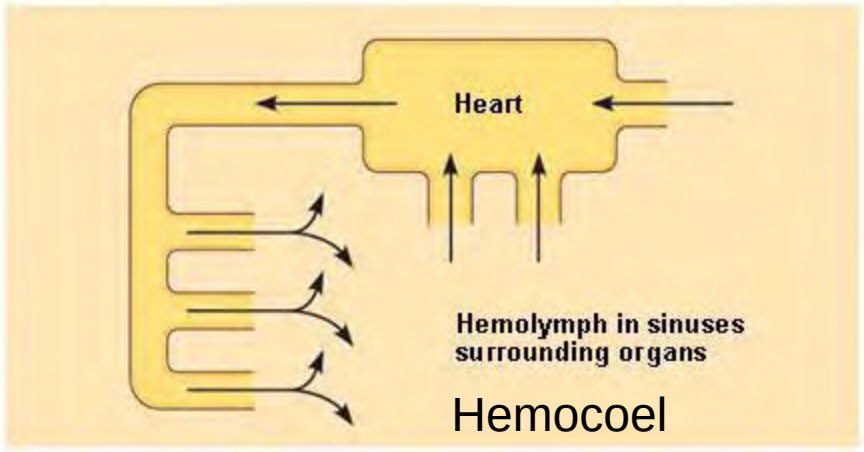


Figure 42.3 (Campbell 9th ed)

9 2 types of Circulation in Complex Animals

Open Circulation

- Tubes open-ended;
- Tissues/organs in hemocoel bathe in hemolymph
  - Hemolymph: analogous to blood + interstitial fluid
- O_2 rich hemolymph + O_2 poor hemolymph + waste (NH_3) mix in hemocoel
- Occurs in arthropods & mollusks (except cephalopods)



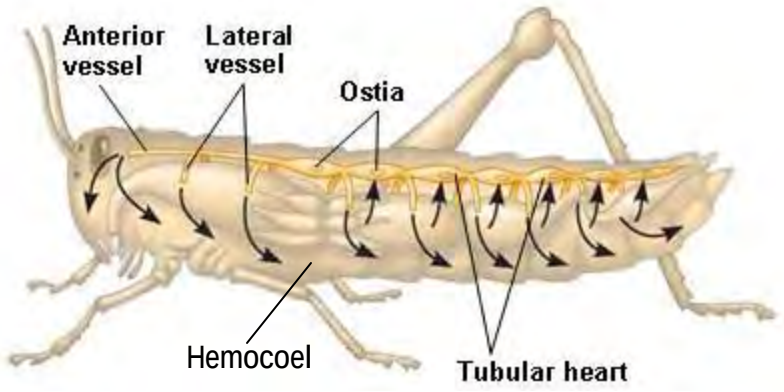


Figure 42.3 (Campbell 9th ed)

Advantages / Disadvantages

Closed circulatory system

-Higher pressure allows:

- rapid delivery and removal
- distant delivery (i.e. bigger bodies)

-Allows for a design in which oxygenated and deoxygenated blood is not mixed

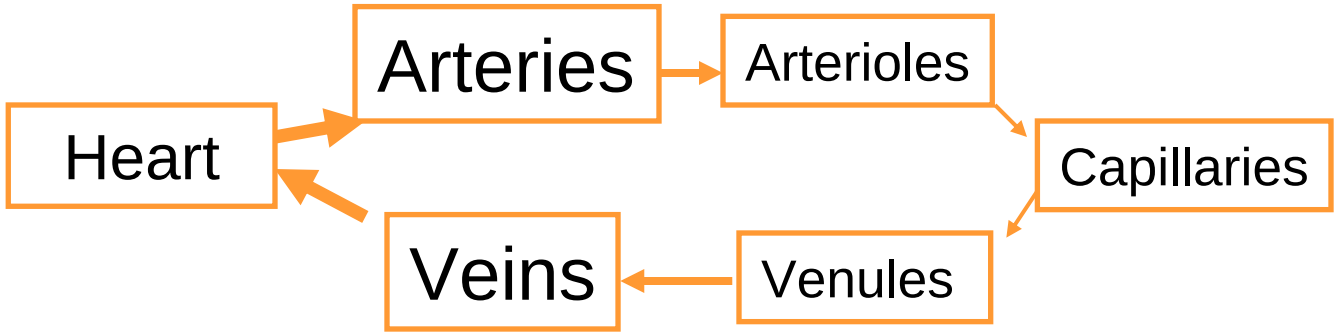
Open circulatory system

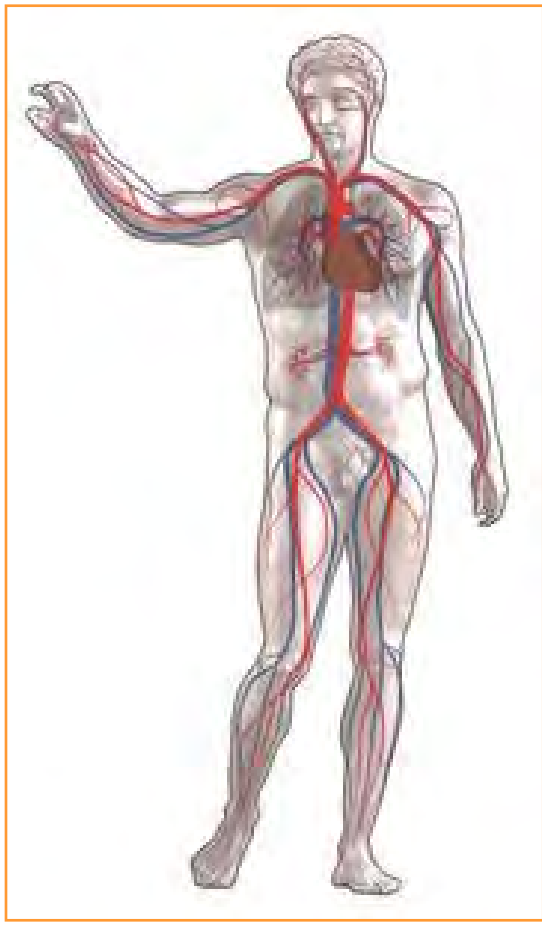
-Lower pressure so requires less energy

Closed Circulatory System

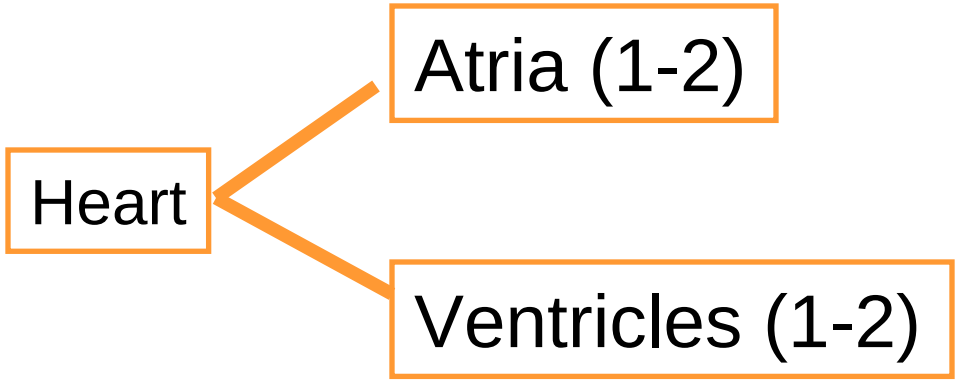
Consists of **blood vessels** and a 2 to 4 chambered **heart**

Blood Vessels:



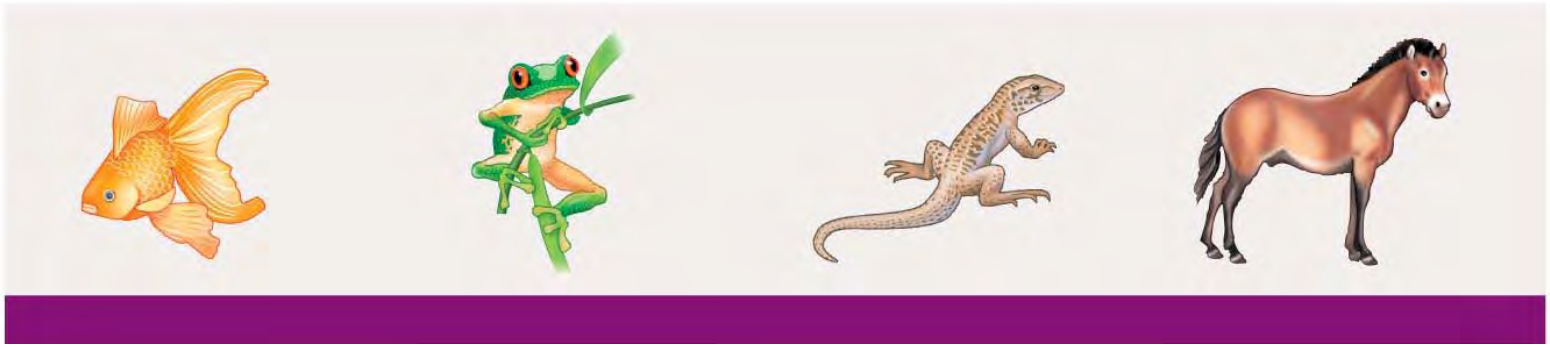


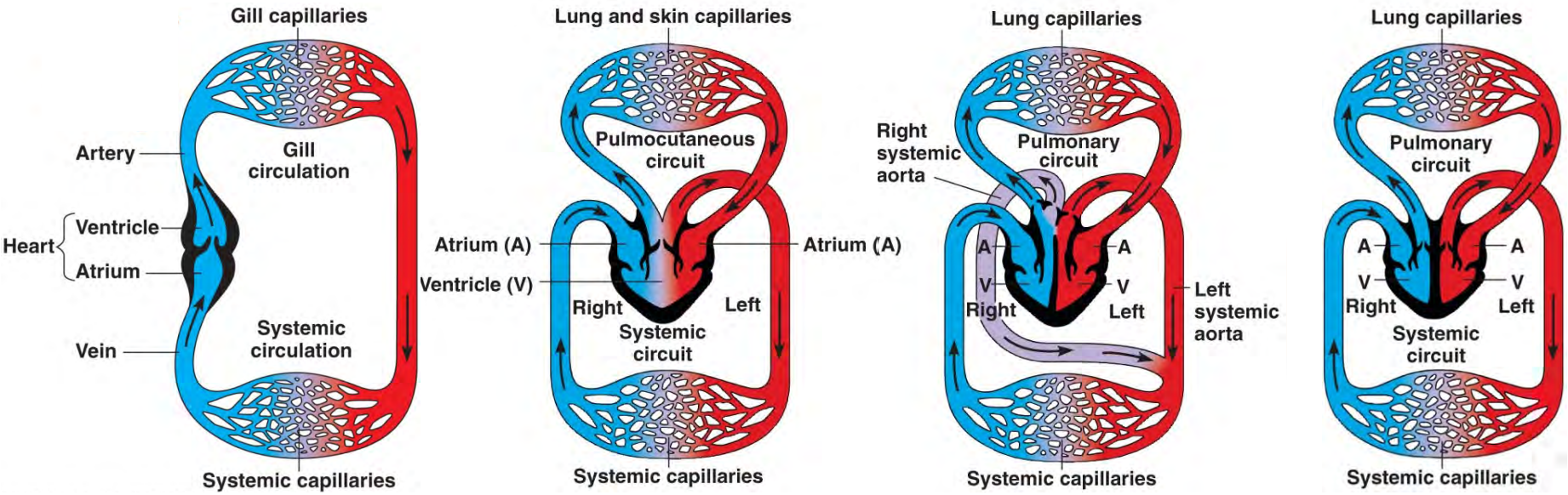
Heart Chambers:



12

Vertebrate Circulatory Systems





- 2-chambers (1A, 1V)
- Single circulation

- 3-chambers (2A, 1V)
- Double circulation
- Some O_2 rich/poor blood mixes but ridge keeps most separate
- When diving, O_2 poor blood diverted from lungs but not skin (i.e. cutaneous respiration)

- TSL: 3-chambers (2A, 1V)
- Double circulation
- Partial septum in ventricle keeps almost all O_2 rich/poor blood separate
- Crocs: 4-chambers (2A, 2V)
- TWO systemic aortas in TSL & C
- When diving, O_2 poor blood diverted from lungs in some reptiles

- 4-chambers (2A, 2V)
- Double circulation

Figure 42.4 and 42.5 (Campbell 9th ed)

Mammalian Circulation Pattern

1. R atrium to R ventricle
2. to pulmonary arteries (O_2 poor)
3. to capillaries of lungs
4. to pulmonary vein (O_2 rich)
5. to L atrium to L venticle
6. to aorta
7. to arteries/ capillaries of the head, limbs and organs & coronary arteries of heart
8. to anterior and posterior vena cava
9. to R atrium

Know **order** of vessels and heart chambers

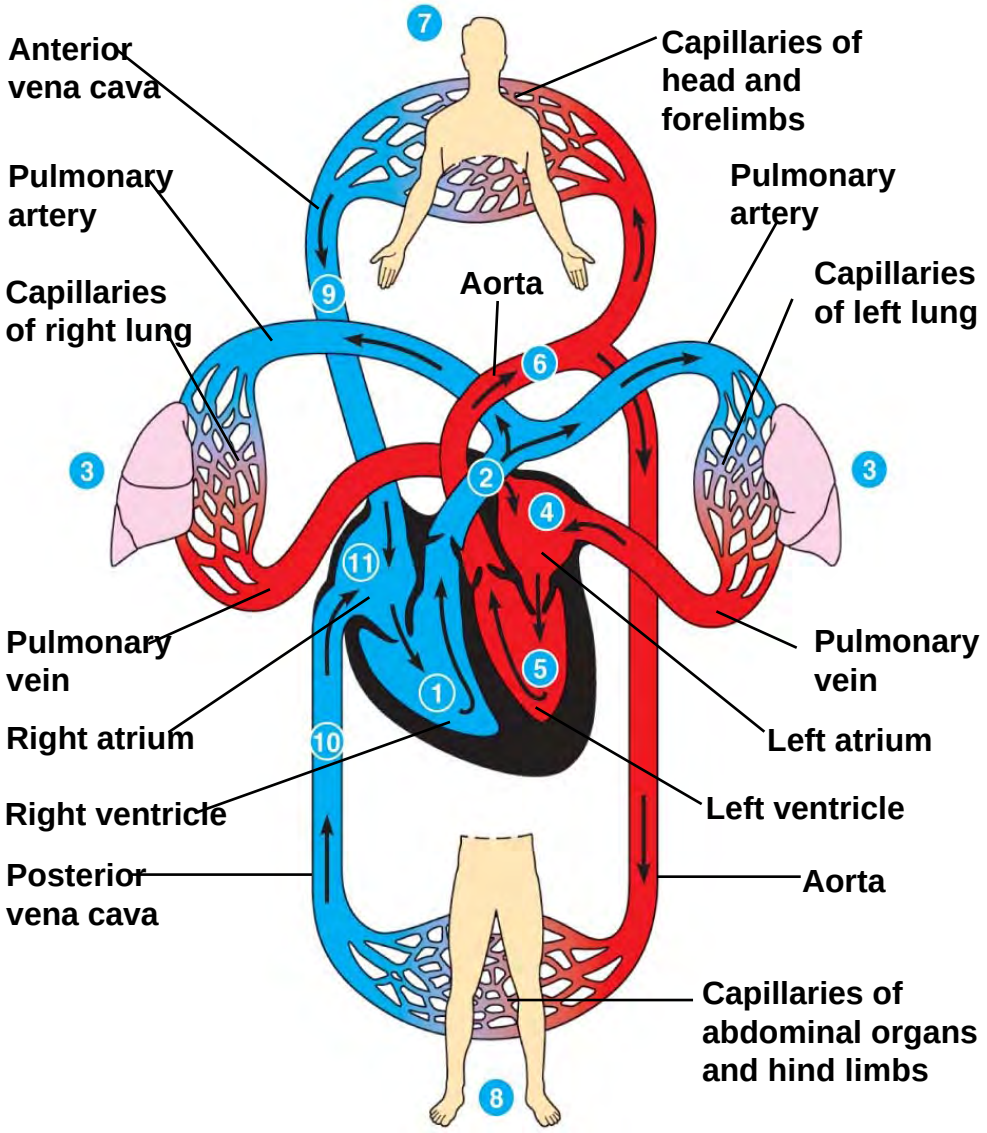
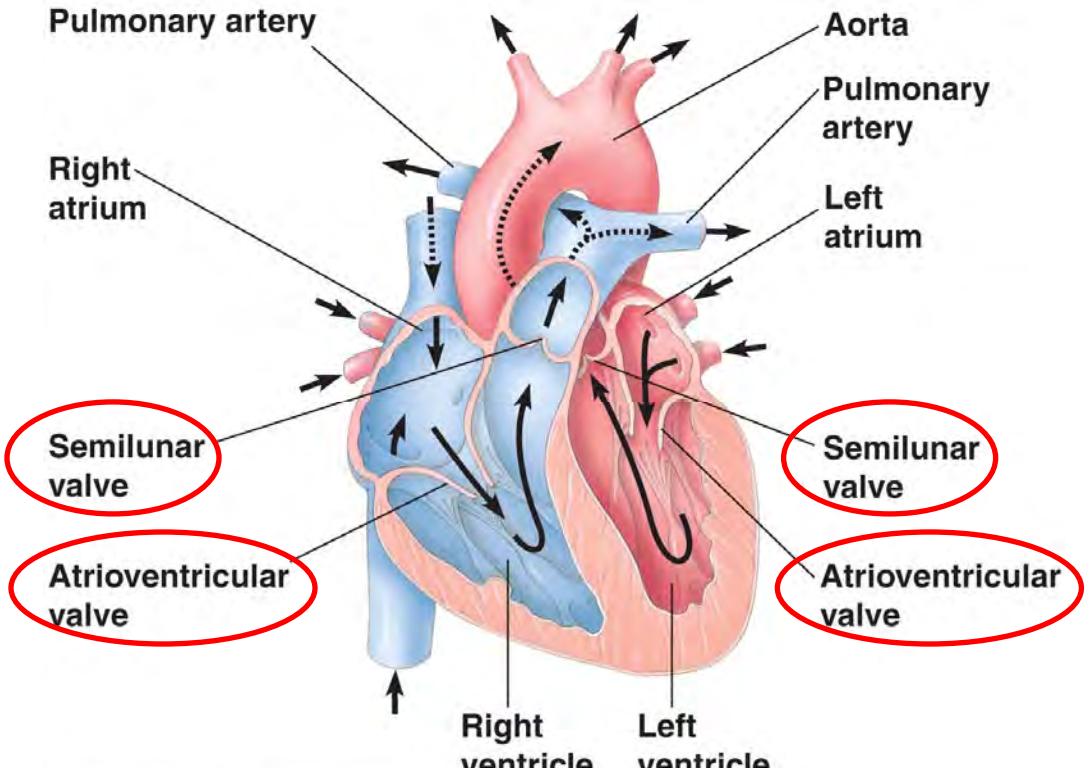


Figure 42.6 (Campbell 9th ed)

Anatomy of the Mammalian Heart



Walls:

a. Ventricles need greater pressure thus have thicker walls

- Left ventricle thicker than right

Valves prevent backflow:

a. Atrioventricular – from ventricles back into atria

b. Semilunar – from aorta/pulmonary arteries back into ventricle

Heart Pumping

Cardiac cycle - The sequence of contraction and relaxation that makes up the heartbeat.

- **A. Diastole** - relaxation
- **B. Systole** - contraction

Cardiac output

– Blood volume pumped/ minute

Depends on:

- **A. Heart rate** - beats/ minute
- **B. Stroke volume**
  - Amount of blood pumped from ventricle per contraction

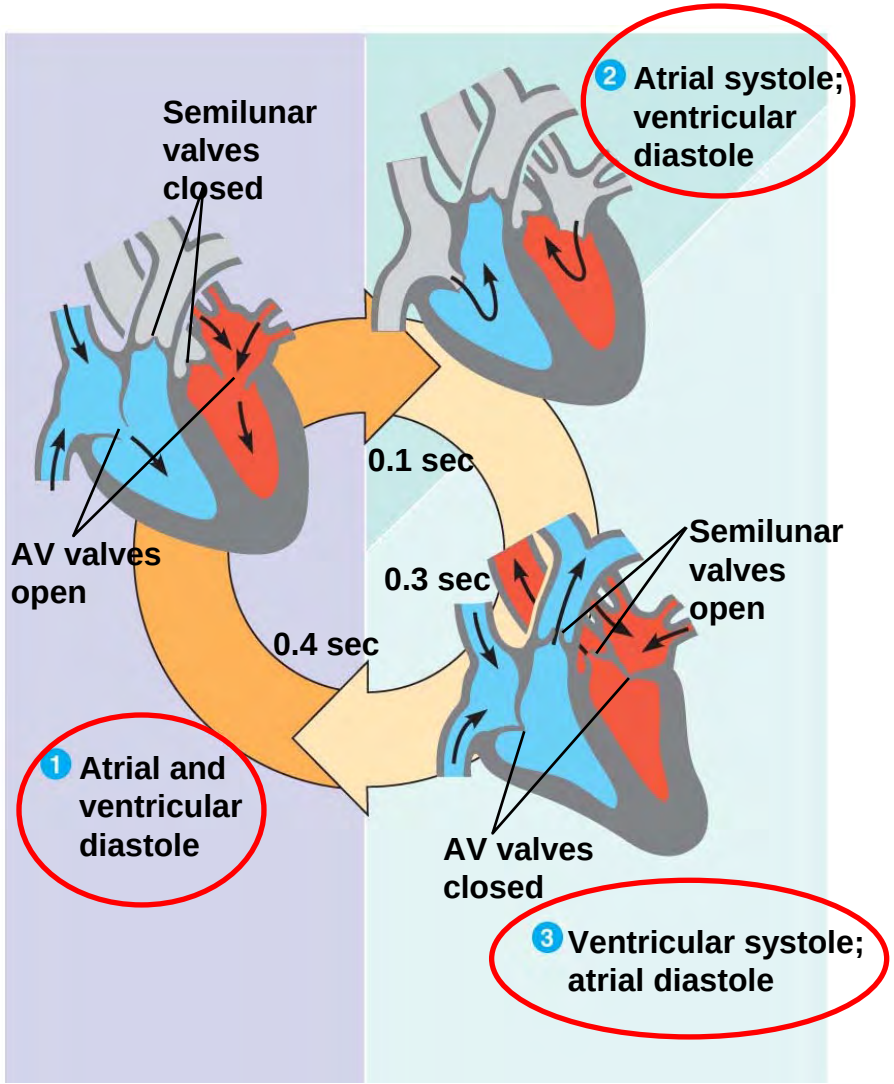
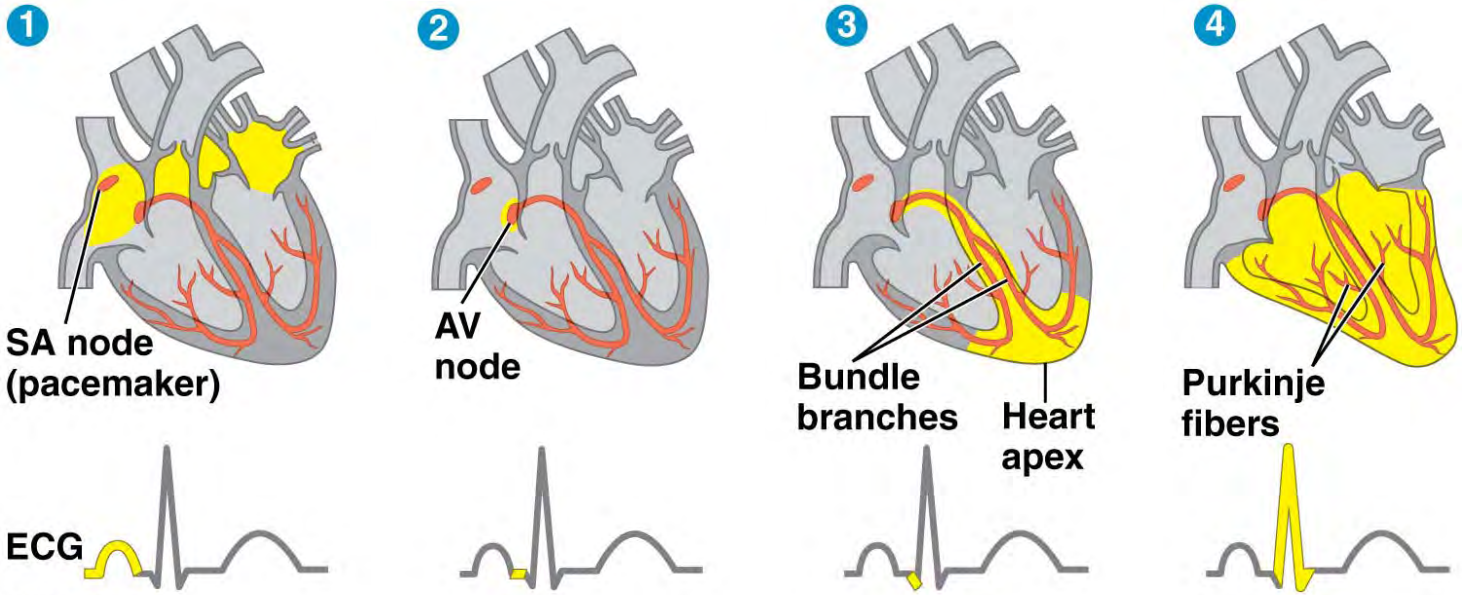


Figure 42.8 (Campbell 9th ed)

Control of Heart Rhythm

1. Sinoatrial node generates signal causing both atria to contract
2. Signal delayed at atrioventricular node to let atria empty
3. AV node passes signal to heart apex
4. Signal spreads throughout ventricle walls



Sinoatrial node (SA):
= Group of autorhythmic cells in wall of RA
a. Sets contraction rate and timing
b. Regulated by signals from nervous & endocrine (hormones) systems

Atrioventricular Node (AV):
= Autorhythmic cells in wall btwn RA and LA

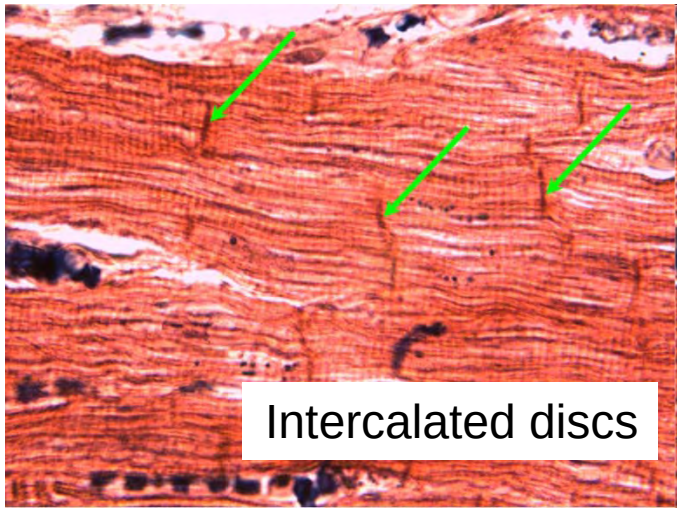
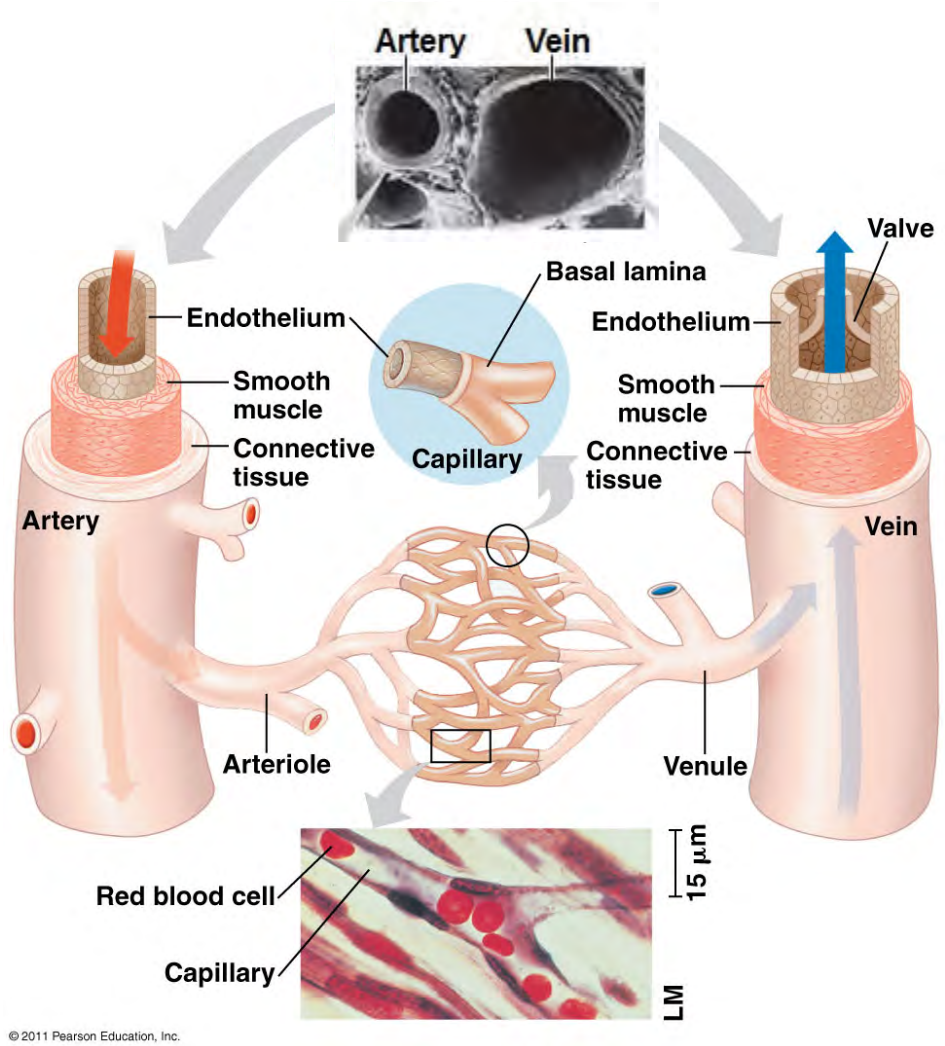


Figure 42.9 (Campbell 9th ed)

Vessel Architecture

A. Veins vs Arteries structure

- Both with <u>three</u> tissue layers
  1. Outer connective tissue
     - Thicker in arteries
  2. Middle smooth muscle
     - Thicker in arteries
  3. Inner epithelium (endothelium)
     - Similar in arteries and veins
- Lumen
  - Larger in veins
- Valves
  - Only in veins (Why?)



Endothelium = A smooth simple squamous epithelium

Figure 42.10 (Campbell 9th ed)

Vessel Architecture

A. Veins vs Arteries structure

B. Capillary structure

- One tissue layer
  - Epithelium (endothelium)
    - Includes outer basement membrane
- Lumen – thickness of 1 RBC

Thus capillaries are more permeable to substances than arteries/veins

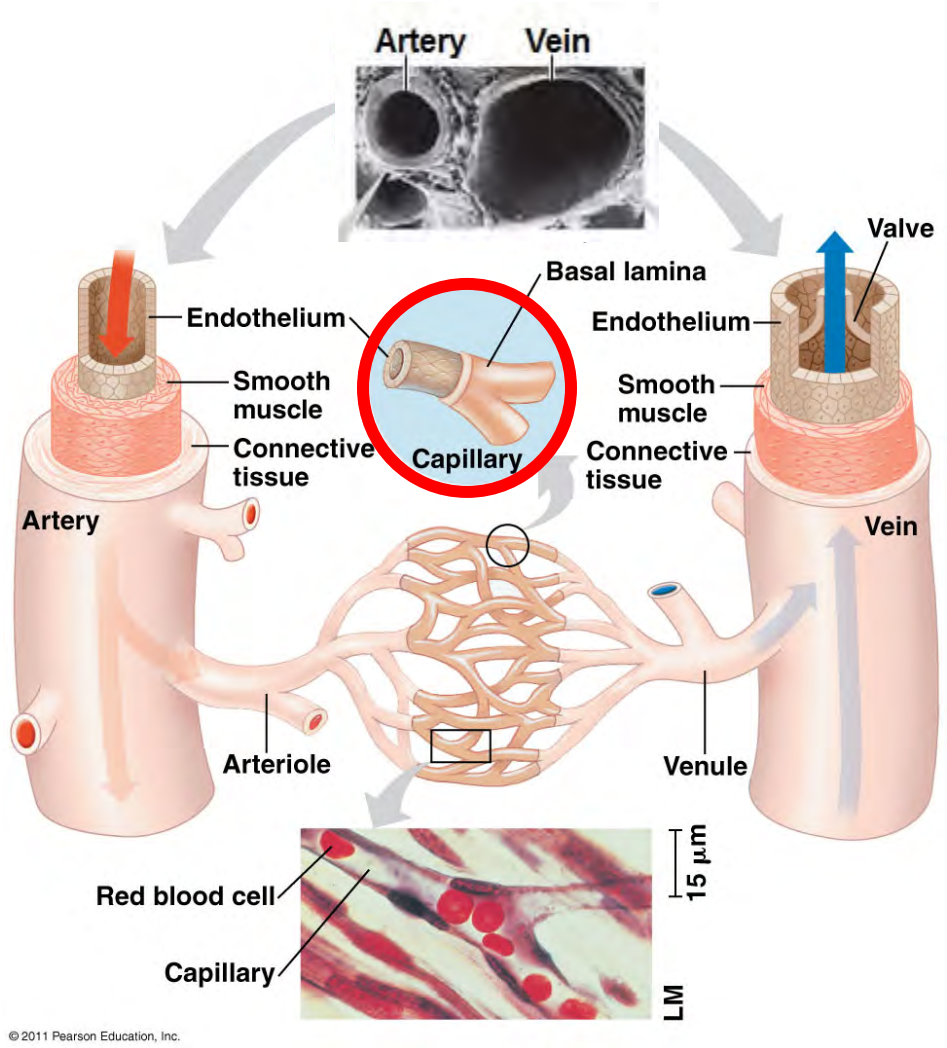


Figure 42.10 (Campbell 9th ed)

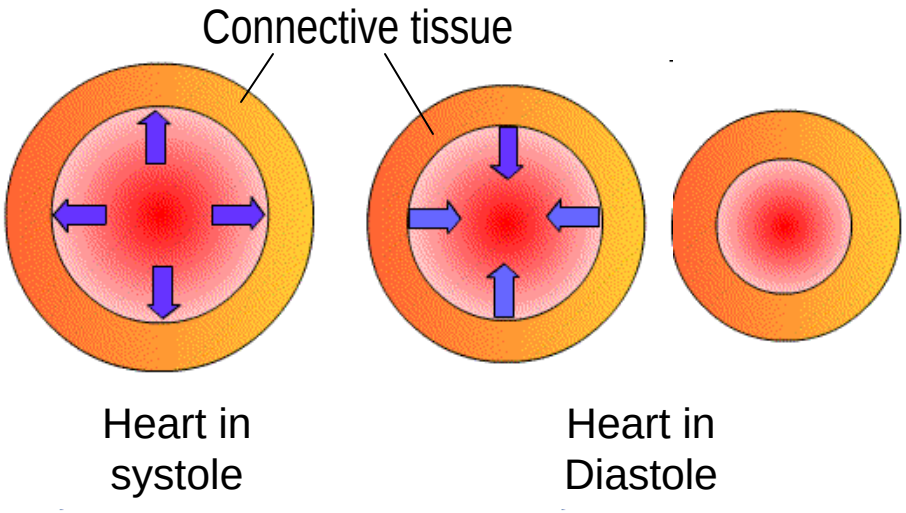
What causes blood to flow?

Arteries

A. Heart pumping

B. Contraction of thick smooth muscle

C. Recoil of thick elastic connective tissue



Veins

A. Contraction of smooth muscle

B. Contraction of abutting skeletal muscle

C. Expansion due to pressure change during inhalation (veins near heart only)

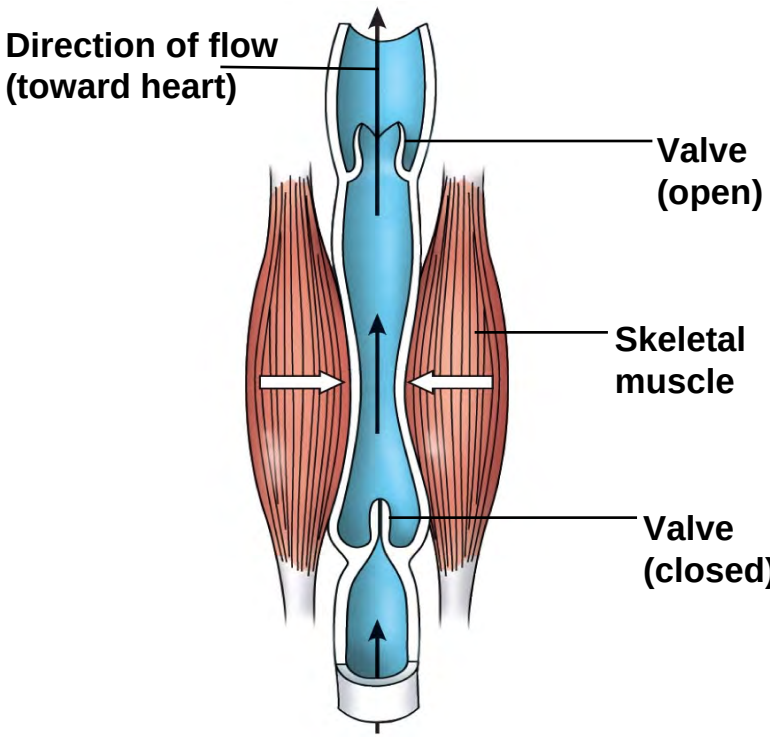


Figure 42.13 (Campbell 9th ed)

Blood Pressure

Blood velocity decreases as it goes from thick arteries into thin capillaries. Why?

Area:

Velocity: High Low Medium

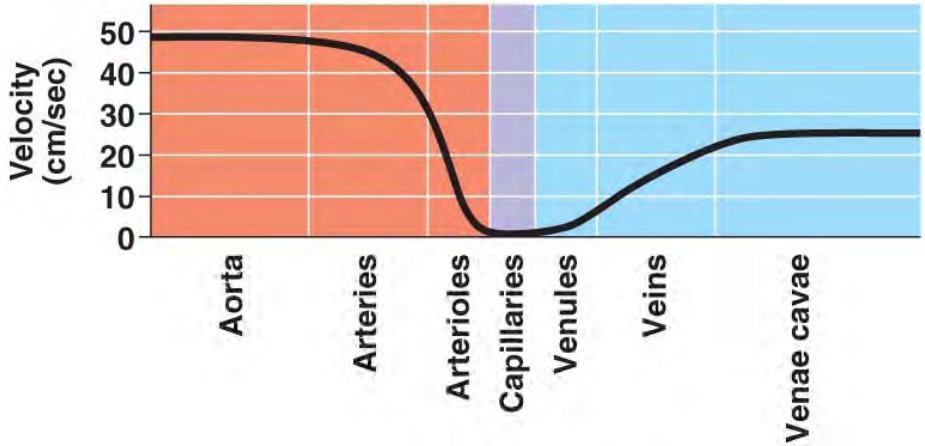


Figure 42.11 (Campbell 9th ed)

Blood Pressure

Blood velocity decreases as it goes from thick arteries into thin capillaries. Why?

Though small, there are many capillaries so their total volume is high and far exceeds the arteries.

Low area in the arteries → high pressure.
High area in capillaries → low pressure.

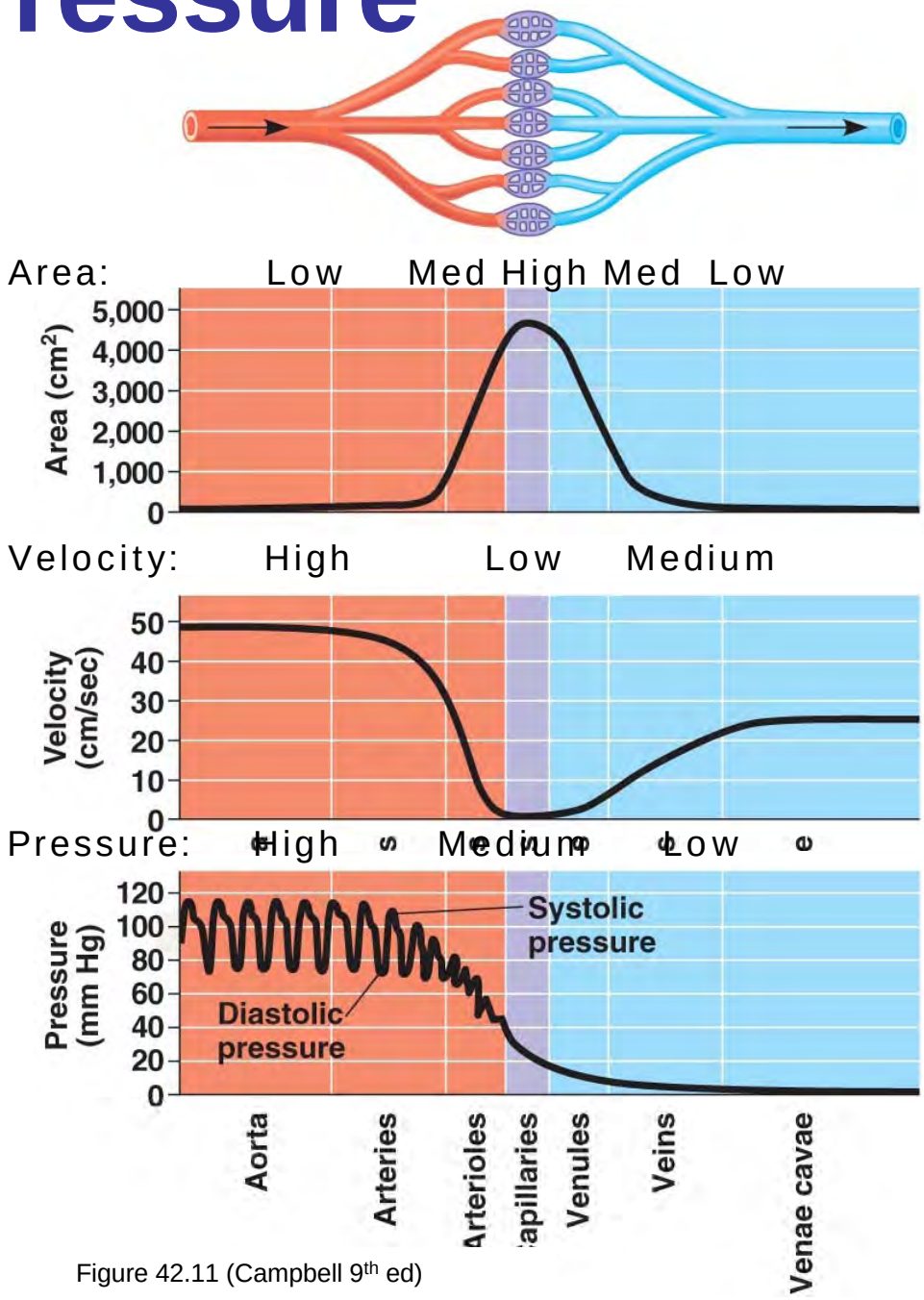


Figure 42.11 (Campbell 9th ed)

Blood Pressure

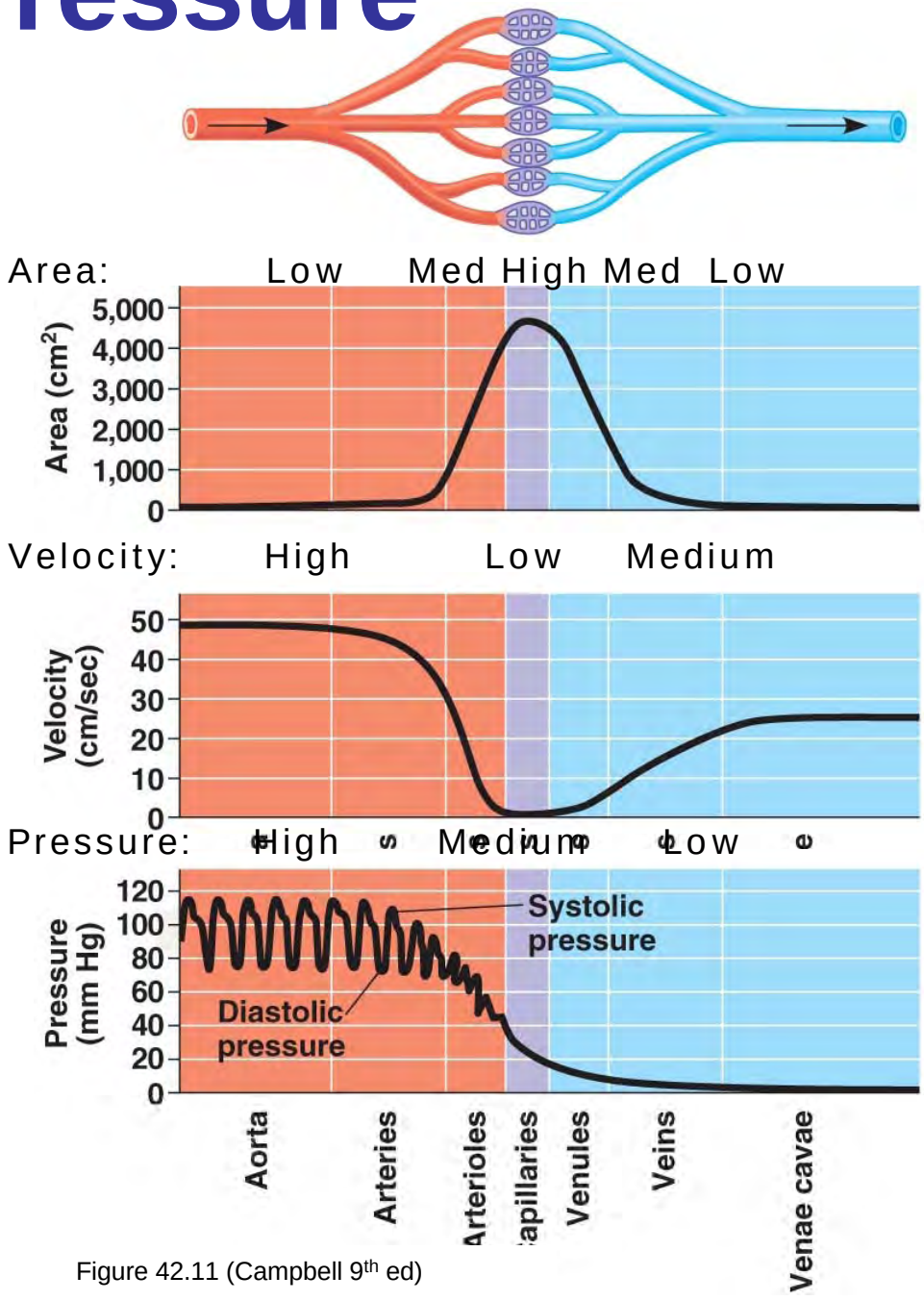


Figure 42.11 (Campbell 9th ed)

Blood Pressure

Pressure must be low in **capillaries** since they must be **thin** to transmit substances between the blood and interstitial fluids.

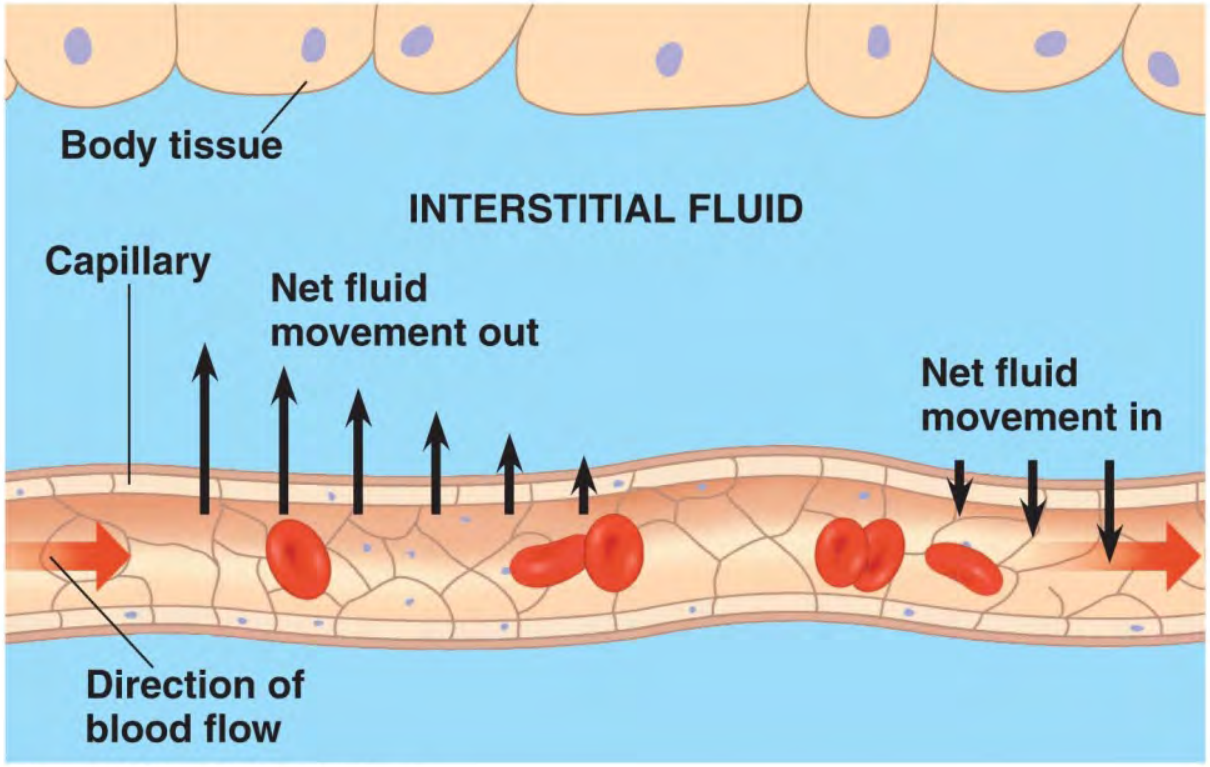


Figure 42.11 (Campbell 9th ed)

Capillary exchange

1. Osmotic pressure (OP) and blood pressure (BP) affect fluid exchange btwn capillaries and interstitial fluid

2. Venous end of capillary bed:
   a) BP low (far from heart).
   b) OP high due to large proteins & RBCs in blood making [solute] higher than interstitial fluids.
   c) Since OP>BP, interstitial fluid (H_2O) + waste (CO_2, NH_3) flow from tissues <u>into</u> capillary due to osmosis

3. Arteriole end of capillary bed:
   a) BP>OP
   b) Net flow of H_2O, nutrients, O_2 <u>out</u> of capillary into tissue

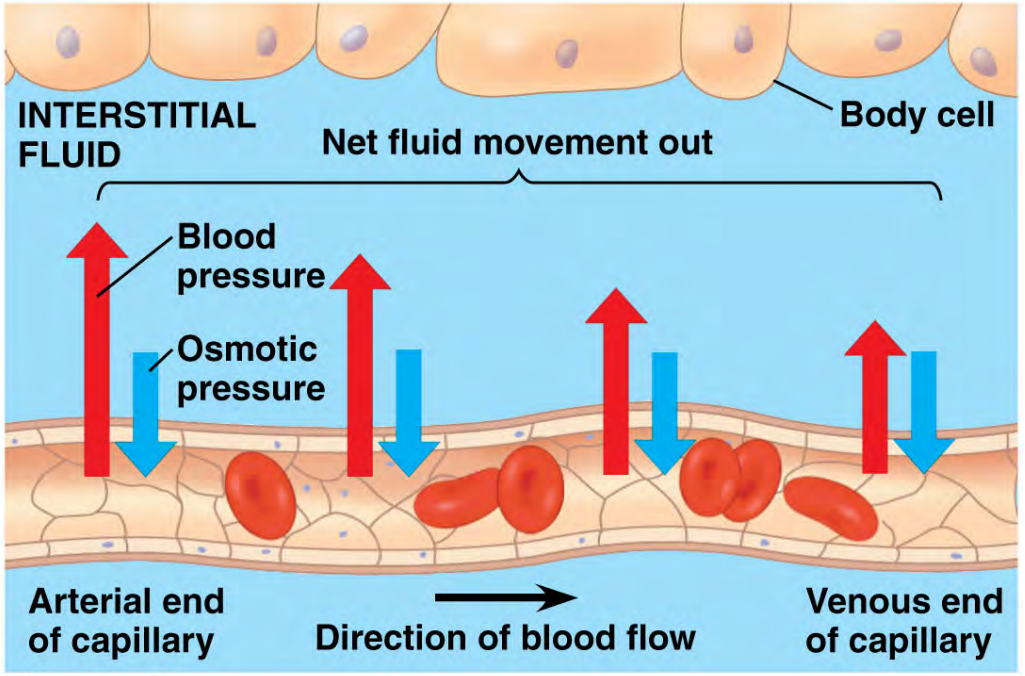
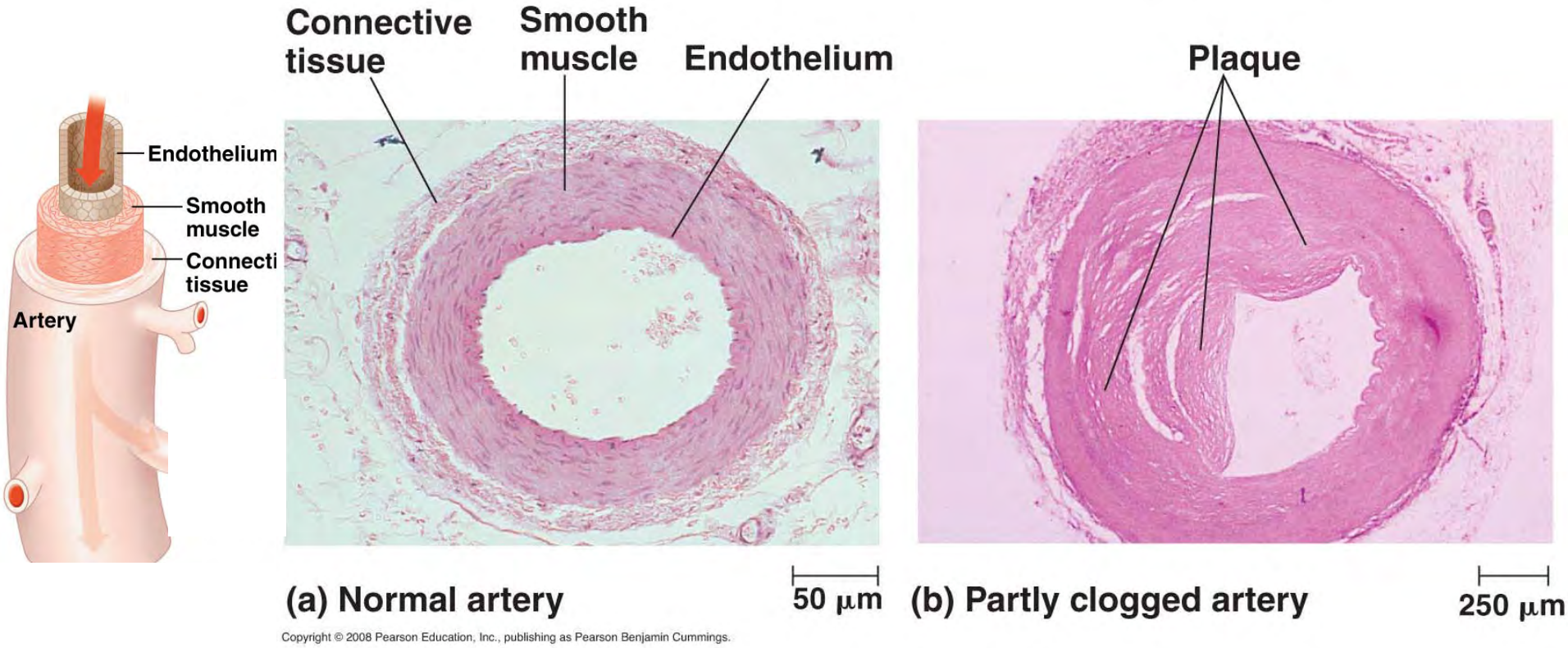


Figure 42.15 (Campbell 8th ed)

4. H_20 etc also returned to blood via lymphatic system

Atherosclerosis
aka ‘Hardening of the arteries’

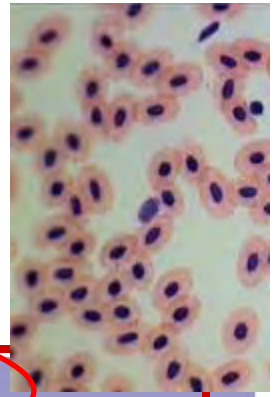


1. Vitamin C needed to make connective tissue collagen fibers.
2. Deficiency damages connective tissue and leukocytes move in to repair damage.
3. Leukocytes take up lipids, primarily cholesterol, which joins with fibers.
4. Altered fibers make CT stiff causing higher blood pressure.

Figure 42.20 (Campbell 9th ed)

Blood Composition

Blood = cells suspended in liquid called plasma

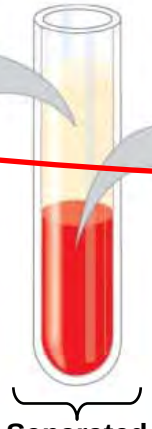


Plasma 55%

Constituent		Major functions
Water	90% of plasma	Solvent for carrying other substances
Ions (blood electrolytes)		
Sodium		Osmotic balance, pH buffering, and regulation of membrane permeability
Potassium		
Calcium		
Magnesium		
Chloride		
Bicarbonate		
Plasma proteins		
•Albumin		Osmotic balance, pH buffering
•Fibrinogen		Clotting
•Immunoglobulins (antibodies)		Defense

Substances transported by blood

- •Nutrients (such as glucose, fatty acids, vitamins)
- •Waste products of metabolism
- •Respiratory gases (O_2 and CO_2)
- •Hormones



Separated blood elements

Cellular elements 45%

Cell type	Number per µL (mm^3) of blood	Functions
Erythrocytes (red blood cells)	5–6 million	Transport oxygen and help transport carbon dioxide
Leukocytes (white blood cells)	5,000–10,000	Defense and immunity
Platelets	250,000–400,000	Blood clotting

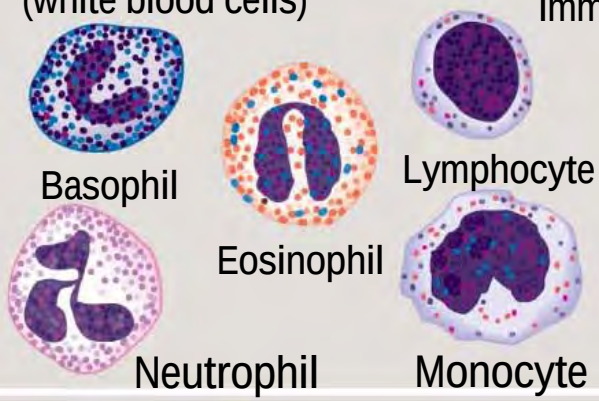


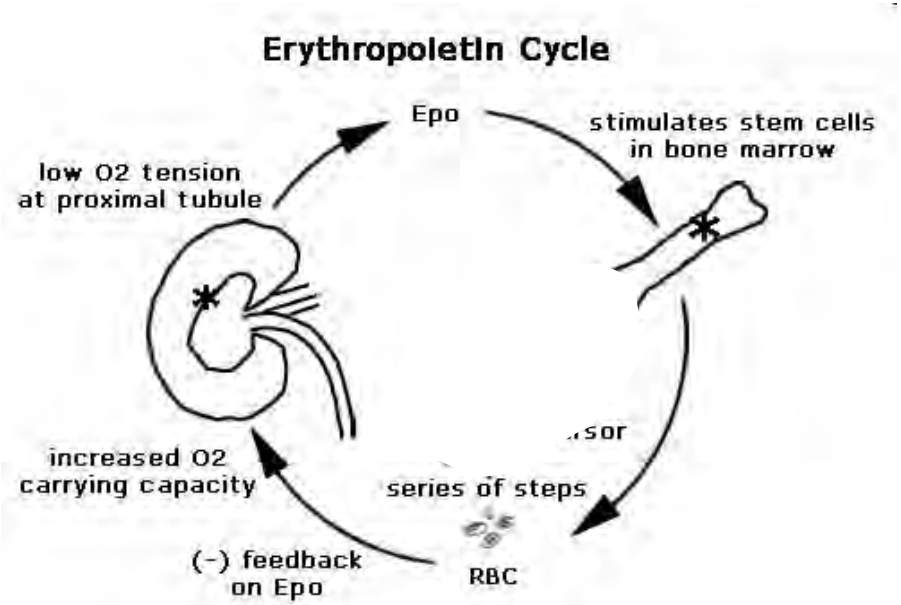
Figure 42.17 (Campbell 9th ed)

38 Regulation of Red Blood Cell Production

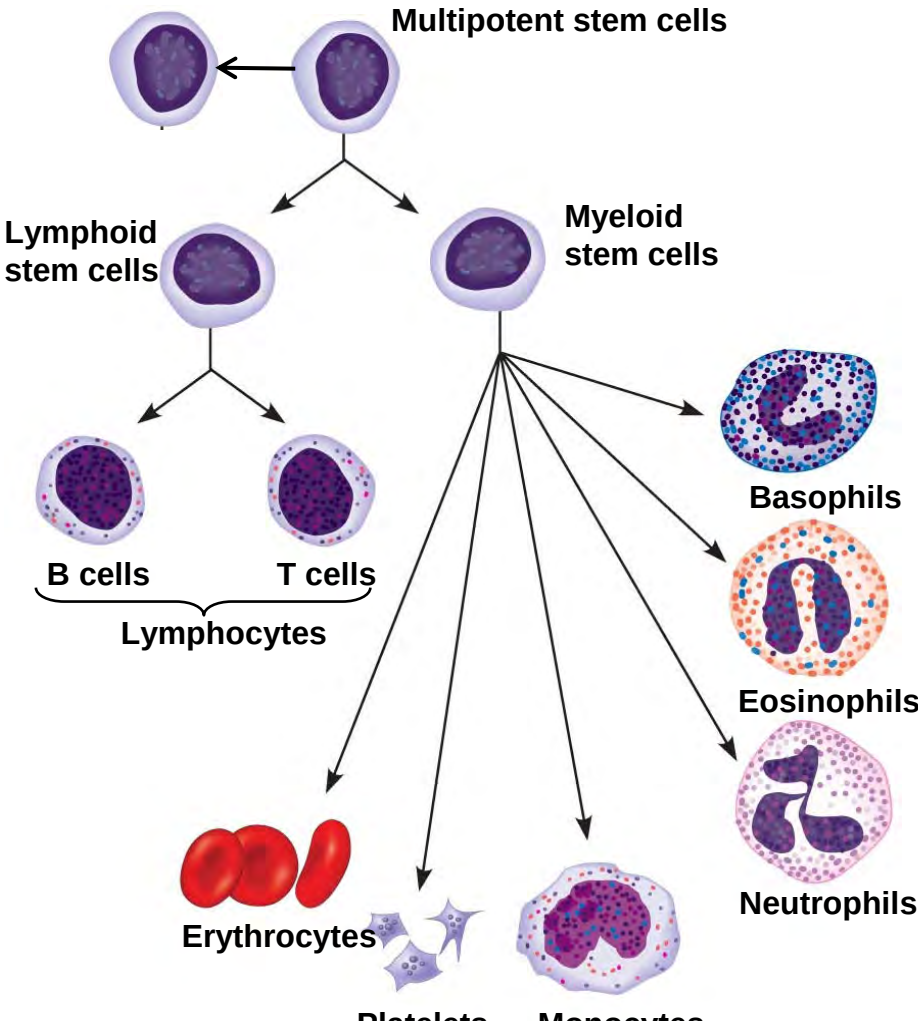
- Erythrocyte production controlled via negative feedback

- Low O_2 signal in kidney causes release of hormone erythropoietin which acts on stem cells to increase RBCs

- High O_2 stops release of erythropoietin



- Stem cells found in red bone marrow (ribs, vertebrae, sternum, pelvis)



http://www.lifesciencesfoundation.org/content/media/2011/07/17/1983_Erythropoietin__Cycle_allaboutim.webs.com.jpg

Figure 42.19 (Campbell 9th ed)

Blood Clotting

1. Endothelium of vessel is damaged, exposing connective tissue; platelets adhere
2. Platelets form a plug & release clotting factor that begins enzyme cascade
3. Fibrin, formed from fibrinogen in blood, forms clot to reinforce plug

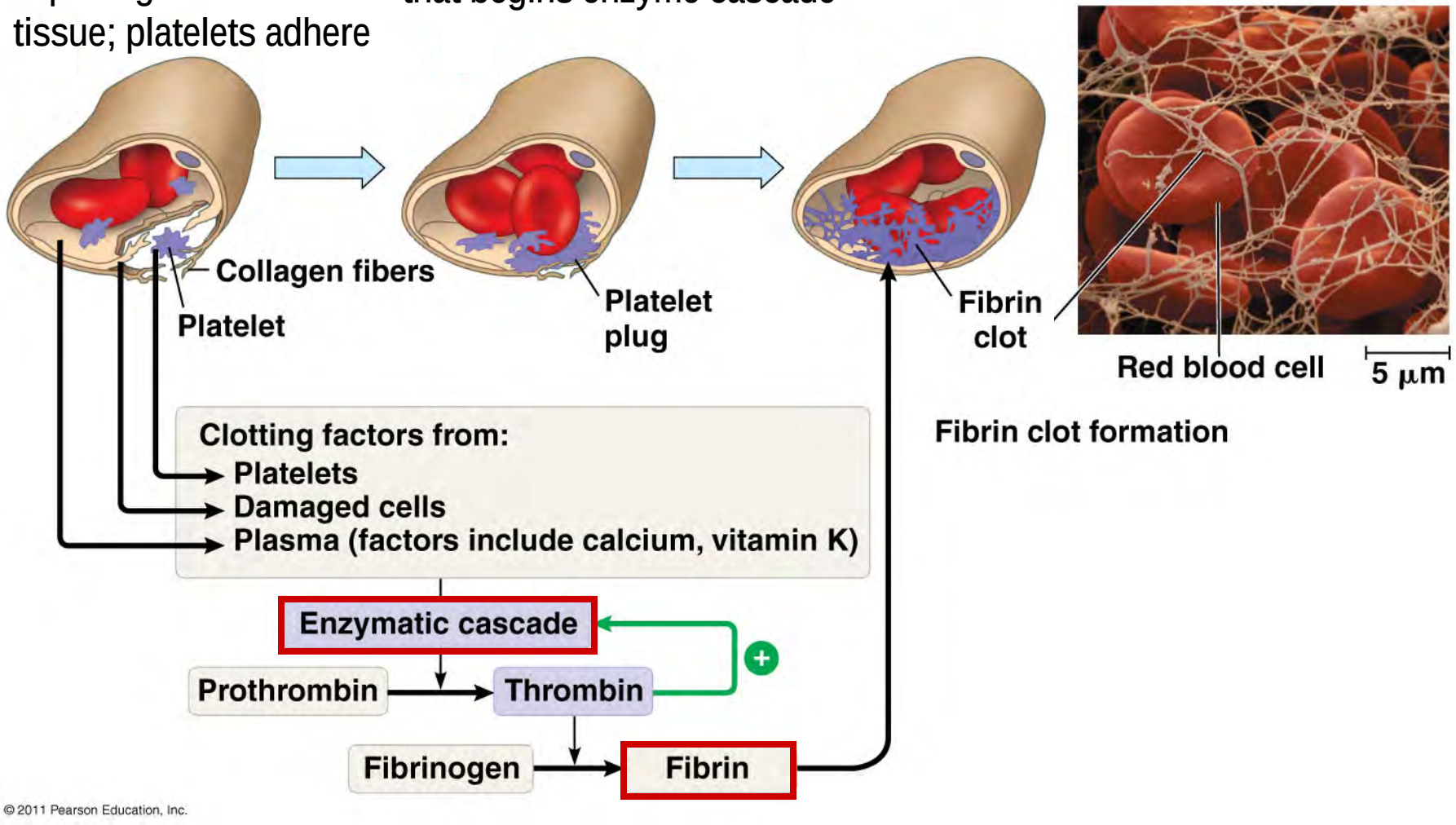


Figure 42.18 (Campbell 9th ed)

Readings on which you will NOT be tested

- Figure 42.12 (907)
- Heart attacks (914)
- Risk factors and Treatment (914-915)
- Figure 42.21 (914)
- Sections 42.5 to 42.7 (915-926)

In general:

- You are NOT responsible for definitions of terms or sections included in the text but which were not discussed in lecture
- You are not responsible for the details of examples used in the text but not discussed in lecture. HOWEVER, these additional examples will help your understanding of concepts discussed and may be used on exams to test if you understand the general concepts.
- You ARE responsible for material covered in lecture but not included in the readings

Next Lecture

- Immune System – Chapter 43