Circulatory System

Presentation by Laurie, Slides by Slidesgo

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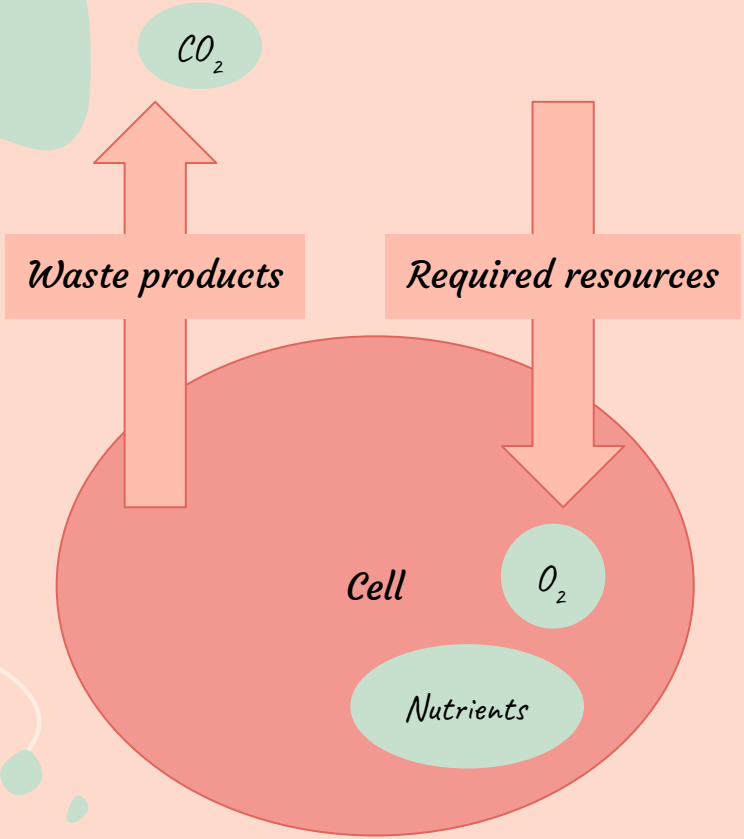
Basics

Exchange happens in every cell



- Small molecules use diffusion
- Diffusion is slow: time is proportional to distance^2
- Unicellular organisms do all exchange through diffusion
- Direct exchange impossible for multicellular organisms

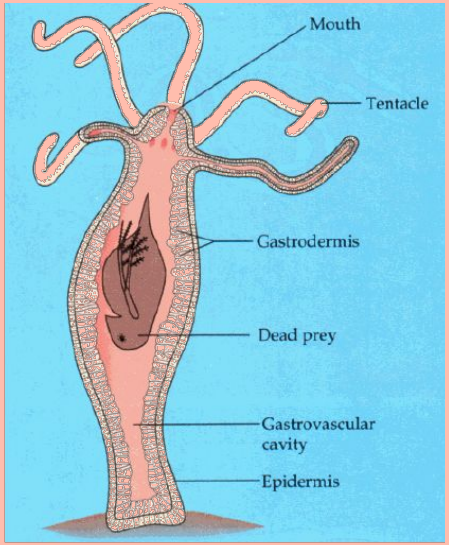
Simple body plan to maximize contact with surface
- Cnidarians
- Flatworms

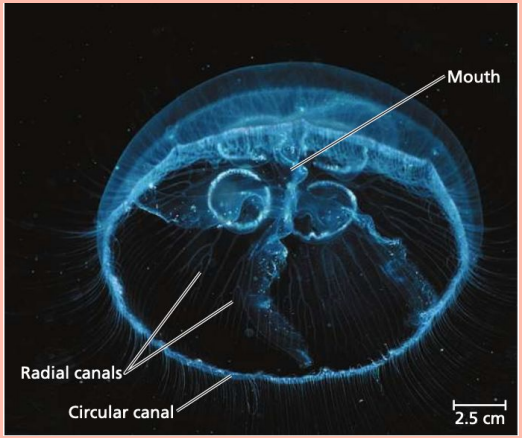
Circulatory system with fluid reaching near every cell
- Linked to gas exchange

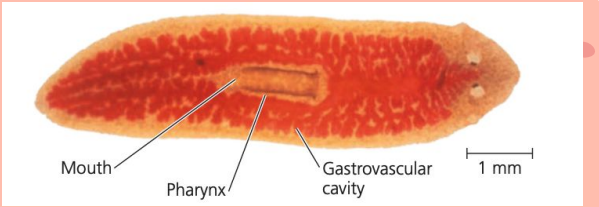
Gastrovascular Cavities

Gastrovascular cavity

- Distributes substances throughout body
- Digestion







https://public.wsu.edu/~rlee/biol103/lect05/img036.gif

Circulatory Systems

Circulatory system

- Circulatory fluid
- Interconnecting vessels
- Muscular pump (heart) to increase hydrostatic pressure

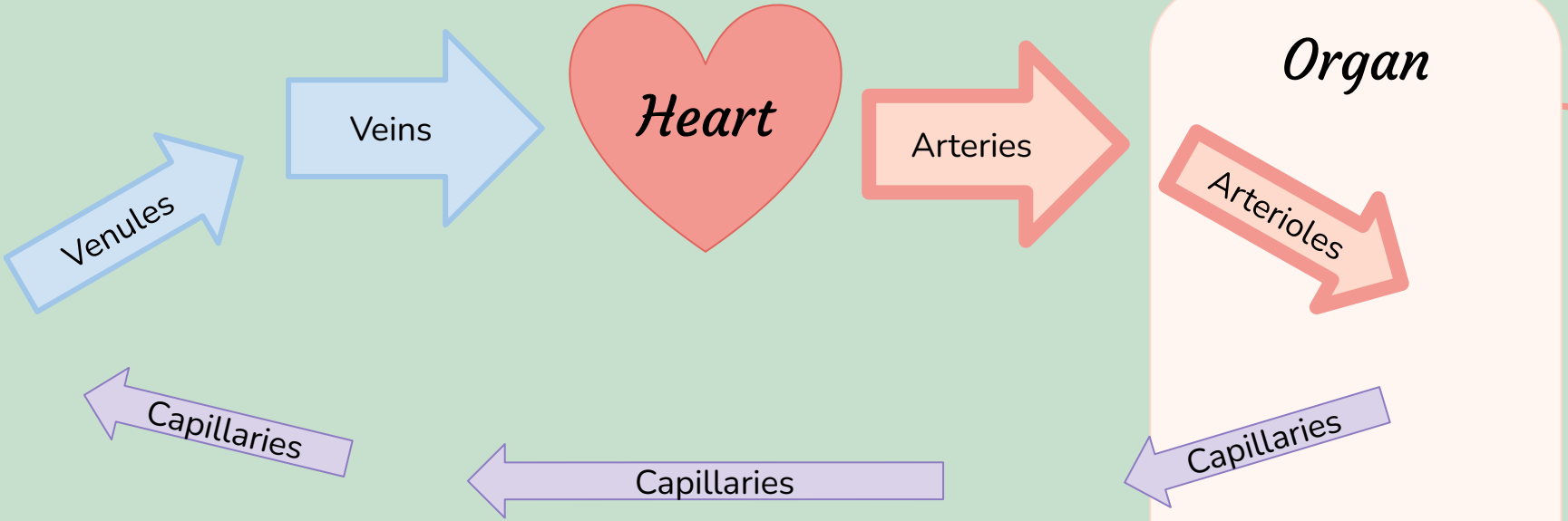
Open Circulatory System

- Hemolymph (also the interstitial fluid)
- Arthropods, some molluscs
- System of sinuses (spaces around organs)
- Crustaceans have more complicated system
- Lower hydrostatic pressure = less energy use
- Can have other functions
    - Spiders use pressure to extend legs

Closed Circulatory System

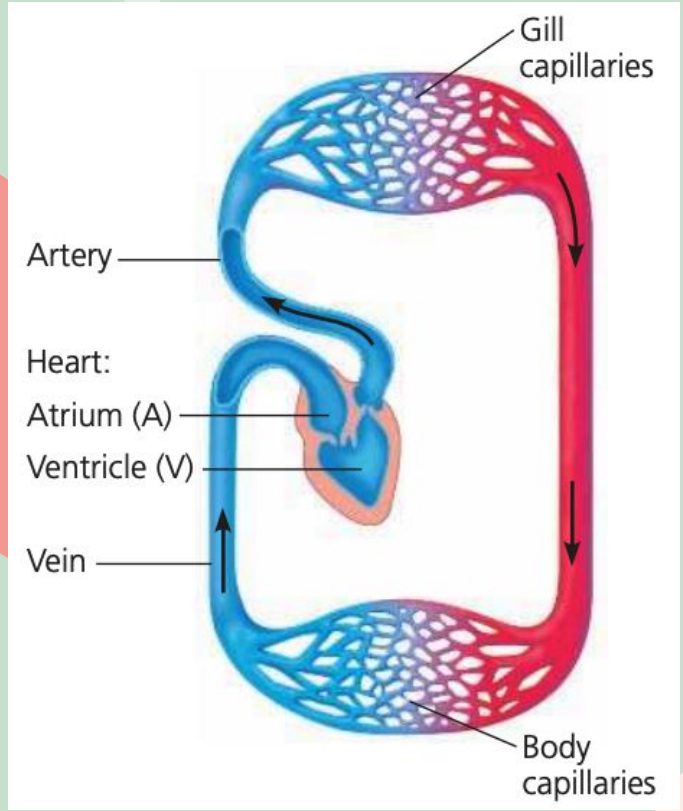
- Blood (not the interstitial fluid)
- Annelids, cephalopods, vertebrates
- Vessels go into tissues and organs
- High blood pressure = good for big and active animals
    - Most active molluscs
- Blood distribution better regulated

Cardiovascular System (Vertebrates)



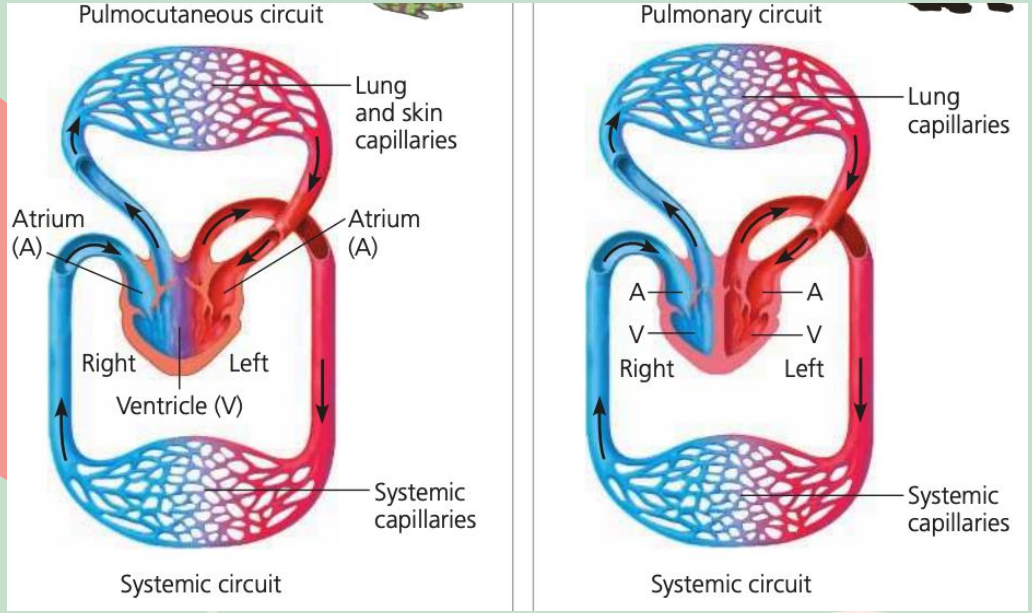
- Arteries + veins differ by direction they carry blood
- Portal veins = capillary bed to capillary bed
- Heart chambers
  - Atria = receive blood
  - Ventricles = pump blood

Single Circulation



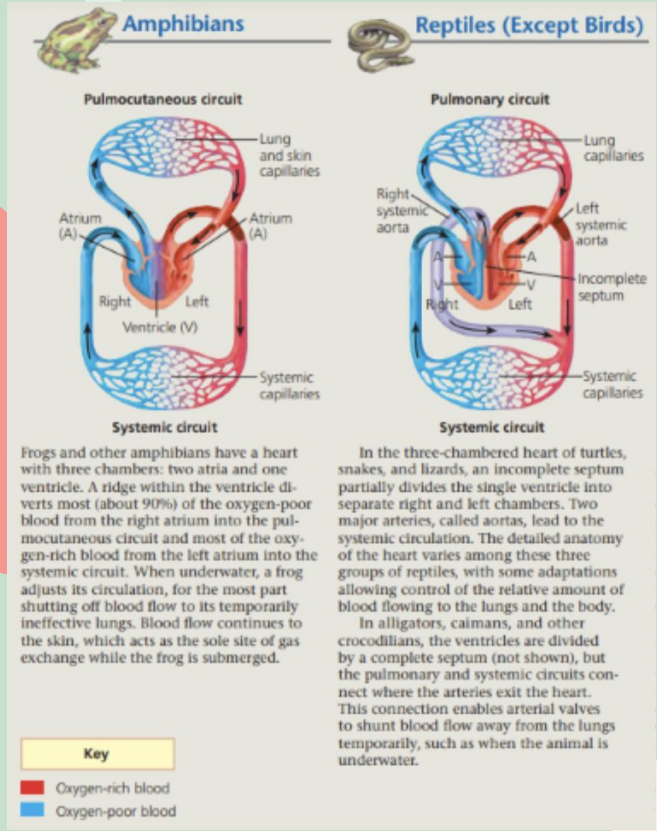
- Sharks, rays, bony fishes
- Sluggish flow
  - Muscle movements help move blood around

Double Circulation



- Amphibians, reptiles, mammals
- Pulmonary circuit/pulmocutaneous circuit
  - Right side pumps oxygen-poor blood to gas exchange tissues
  - Some amphibians/reptiles are intermittent breathers
- Systemic circuit
  - Left side pumps oxygen-rich blood to body
- More vigorous circulation than single circuit, higher blood pressure

Adaptations for Intermittent Breathers



- Amphibians
  - Pulmocutaneous circuit
  - Ventricular ridge – ~90% of blood goes where it “should”
  - Stops most blood flow to lungs underwater
- Turtles, snakes, lizards
  - Incomplete septum divides ventricle
  - 2 aortas (major arteries) lead to systemic circulation
  - Allows for control over how much blood goes to lungs and body
- Alligators, caimans, crocodilians
  - Complete septum
  - Pulmonary and systemic circuits connect where arteries exit heart – blood flow can be diverted from lungs when underwater

Birds and mammals are endotherms = 10x more energy needed – powerful hearts

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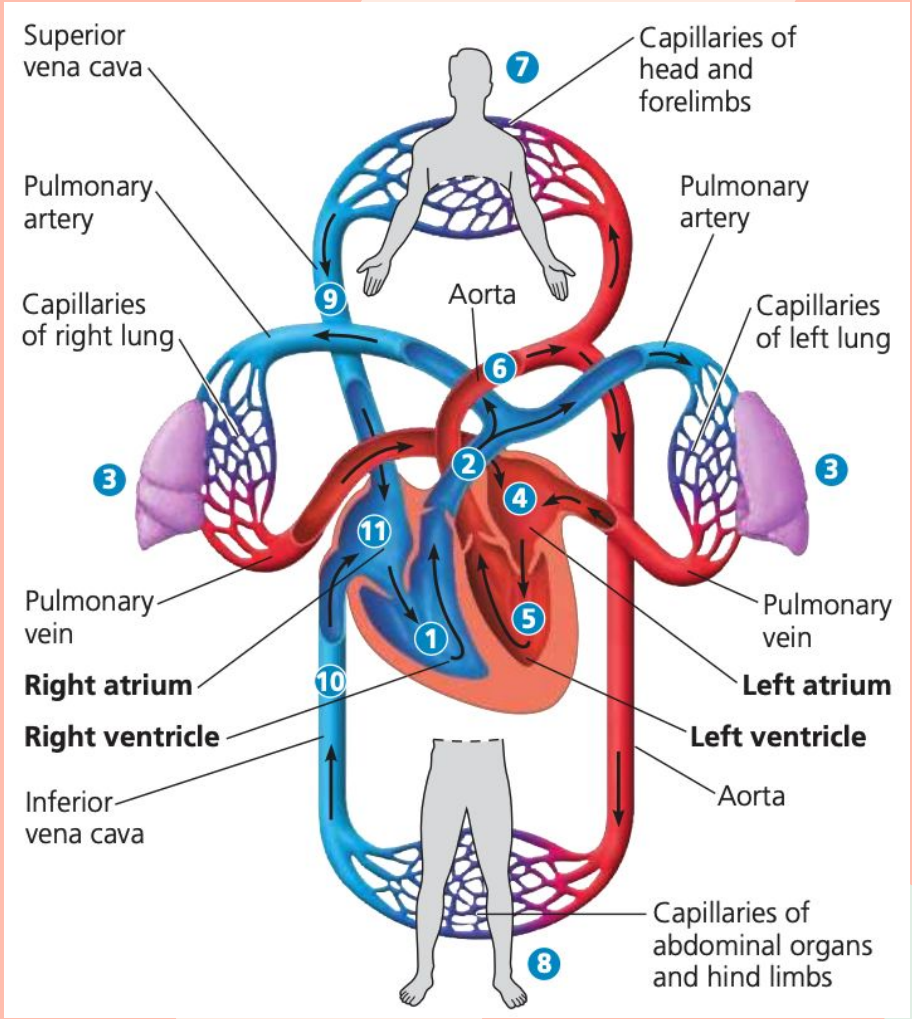
Mammals


Superior vena cava
Capillaries of head and forelimbs
Pulmonary artery
Pulmonary artery
Capillaries of right lung
Aorta
Capillaries of left lung
Pulmonary vein
Pulmonary vein
Right atrium
Left atrium
Right ventricle
Left ventricle
Inferior vena cava
Aorta
Capillaries of abdominal organs and hind limbs
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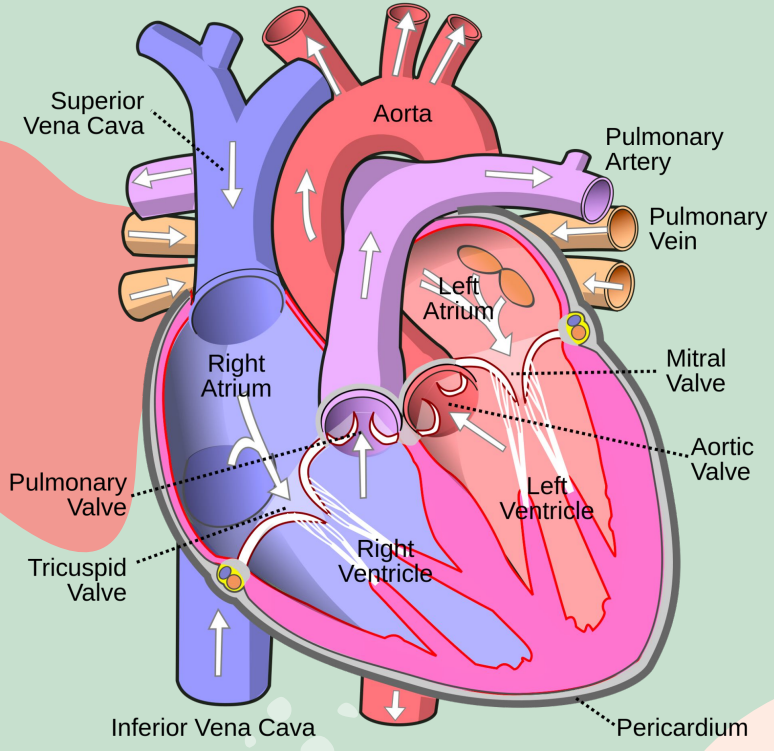
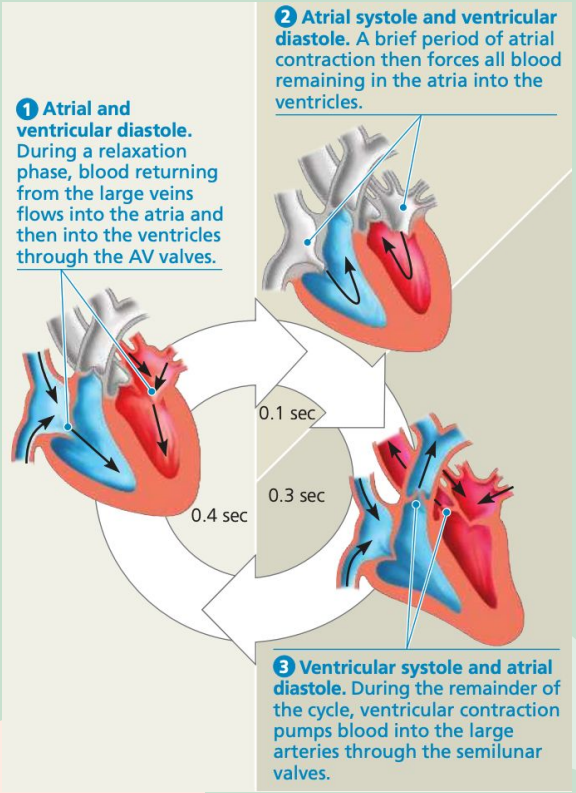
11

The Heart





Atrioventricular (AV) valves = tricuspid + mitral (bicuspid)

Semilunar valves = pulmonary + aortic valves

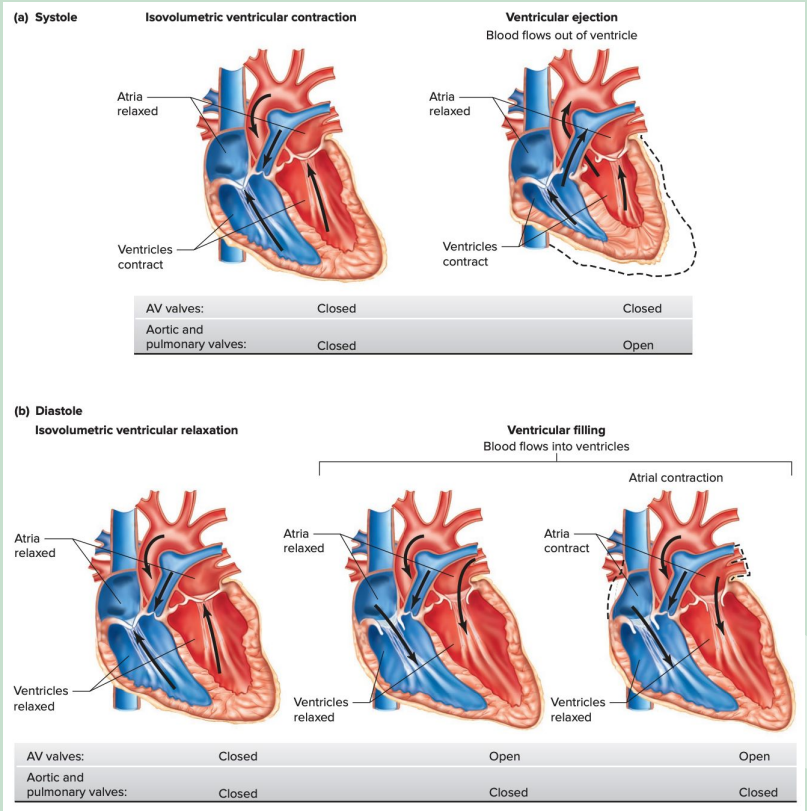
Cardiac output = heart rate * stroke volume

Lub-dub sound

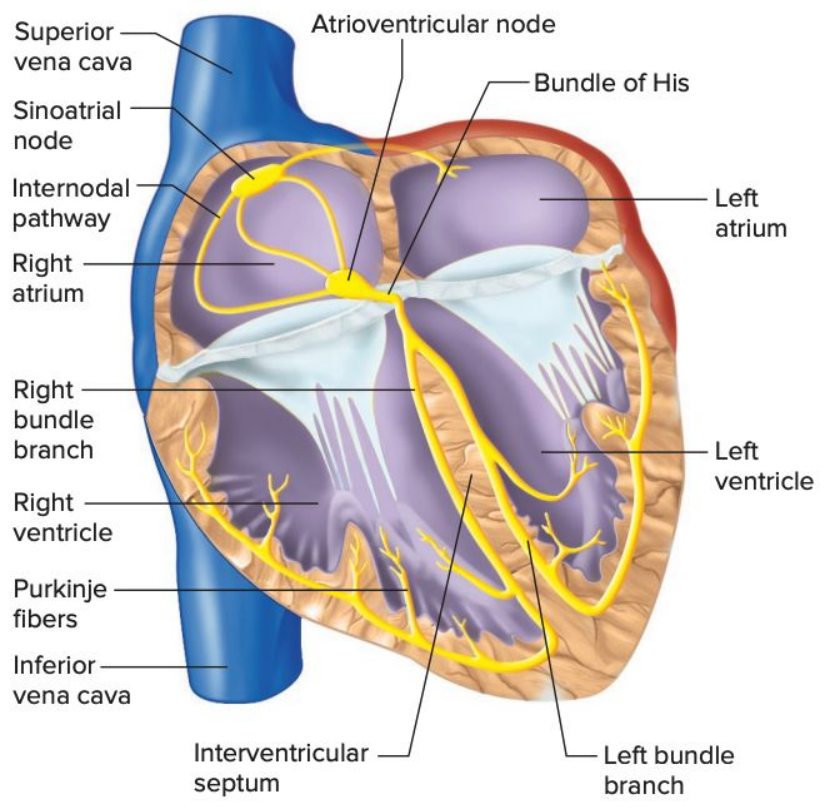
- Lub = recoil against AV valves
- Dub = closing of semilunar valves
- **Heart murmur** – blood goes backwards through a valve

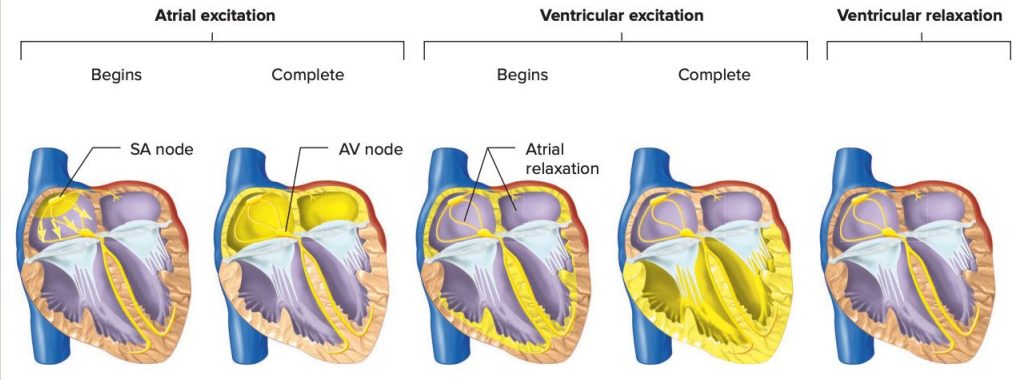
https://upload.wikimedia.org/wikipedia/commons/thumb/e/e5/Diagram_of_the_human_heart_%28cropped%29.svg/2086px-Diagram_of_the_human_heart_%28cropped%29.svg.png

Cardiac Cycle



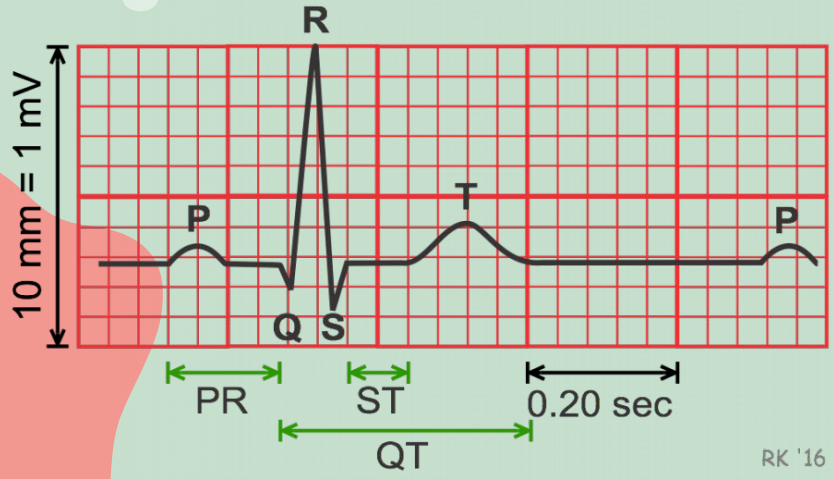
Conduction/Heartbeats





- Signals sent through gap junctions
- SA node = “pacemaker”
- AV node contraction is slow to delay ventricular contraction
- Toothpaste-like effect

EKGs/ECGs



- P wave – atrial depolarization, <.11s
- QRS – ventricular depolarization, <.1s
  - Coincides with atrial repolarization
- Q wave – septum activated
- R wave – ventricular free walls activated
- S wave – everything else
- T wave – bigger than P, ventricular repolarization
- ST segment – should be straight, if elevated by >1mm = early ventricular repolarization
- PR Interval – conduction time of AV node, usually between .12 and .20
- QT Interval – Total ventricular depolarization and repolarization, .32-.4s

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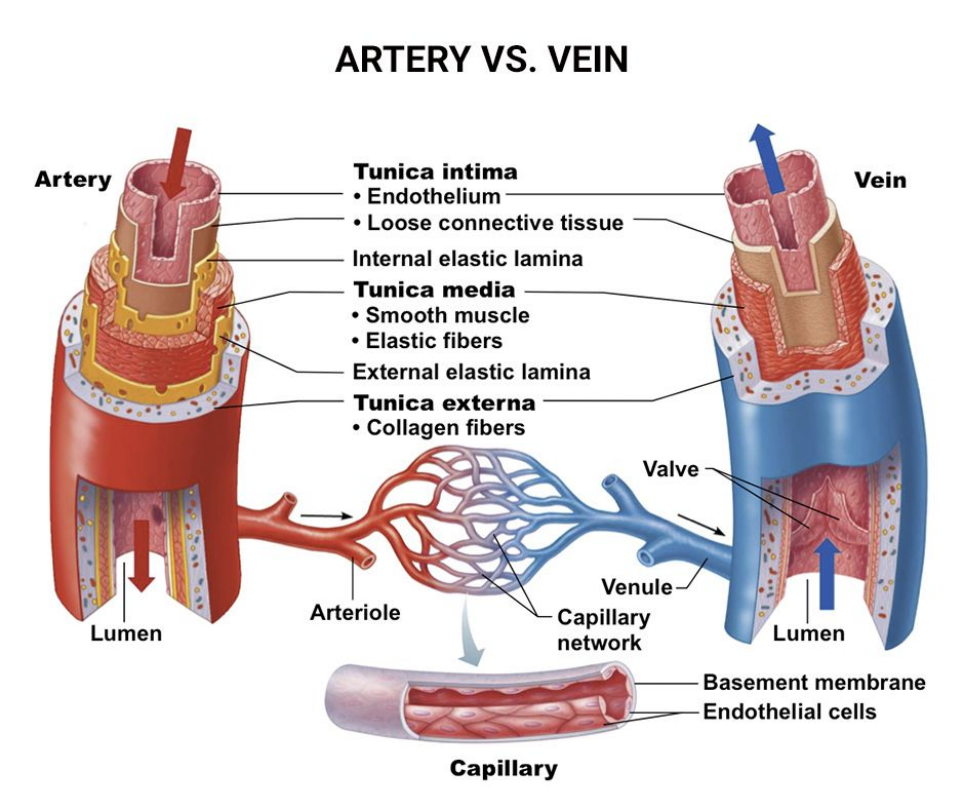
Blood Vessels

Wall Compositions

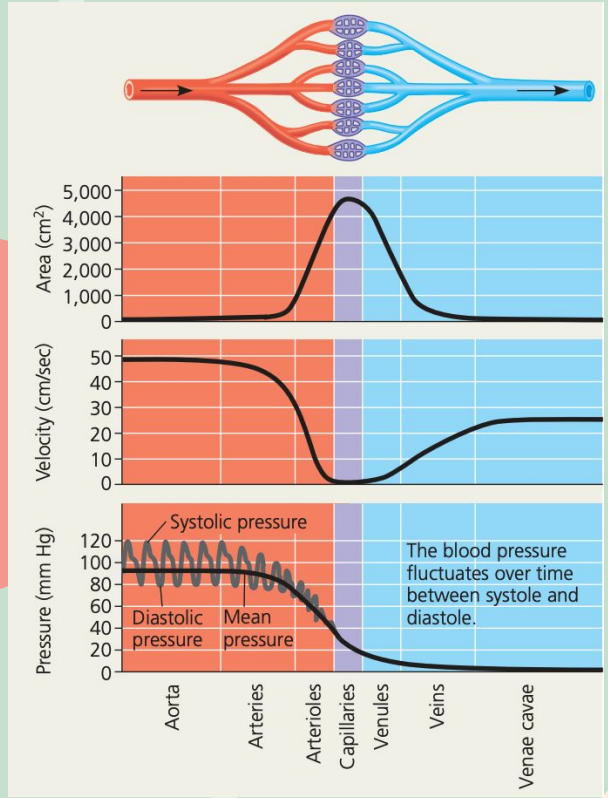
- 3x thicker walls than veins
- Very elastic and strong
  - Elastin in tunica media



- Valves

https://www.downtownveinvascular.com/wp-content/uploads/2023/10/artery-vs-vein.jpg

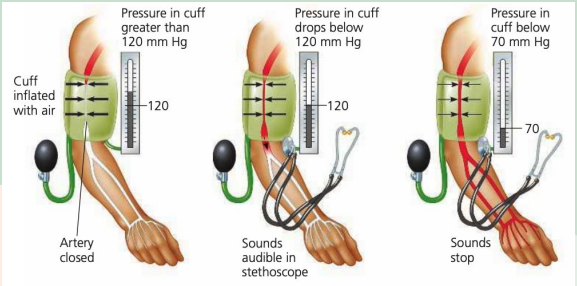
Velocity & Pressure



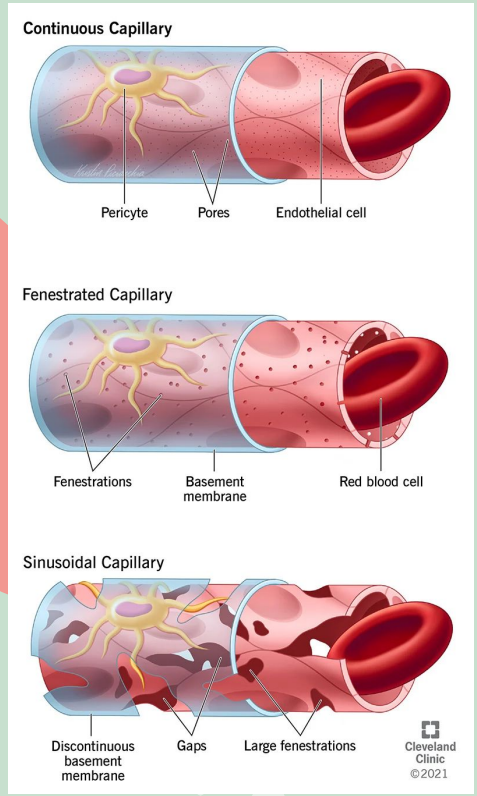
- Equation of continuity
  - $A_1V_1 = A_2V_2$

Pulse = systolic pressure
Diastolic pressure = artery walls snap back

Blood pressure = systolic/diastolic
Vasoconstriction (arterioles narrow) – endothelin
Vasodilation (arterioles dilate) – nitric oxide
Gravity affects blood pressure!

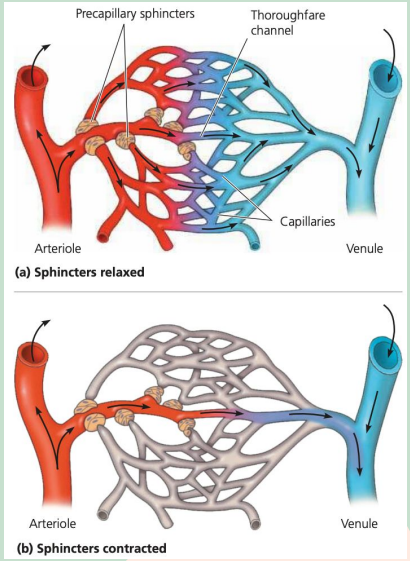


Capillaries

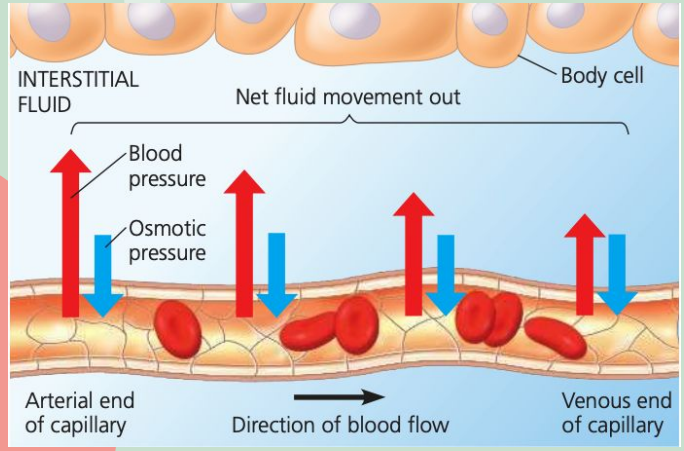


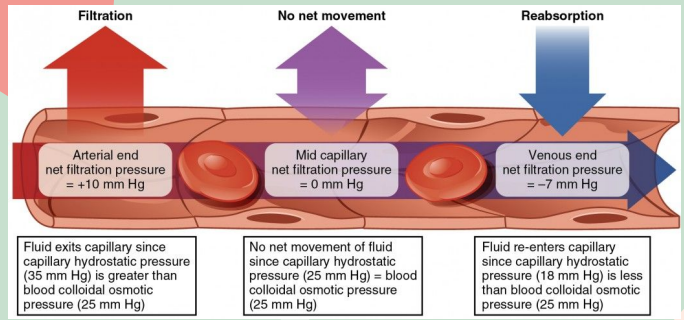
Only ~5 to 10% of capillaries are in use at a time
Vasoconstriction/vasodilation and precapillary sphincters help regulate

- Vasodilation at injury site (histamines)
- Increased blood flow to intestines after meal



Capillaries & Lymph





Starling Forces

- Hydrostatic = pushing out
- Oncotic = pulling

Maintained by plasma proteins like albumin

Blood pressure > osmotic pressure

- Lost fluid recovered by lymphatic system

https://s3-us-west-2.amazonaws.com/courses-images-archive-read-only/wp-content/uploads/sites/403/2015/04/21031434/2108_Capillary_ExchangeN.jpg

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Blood

Blood

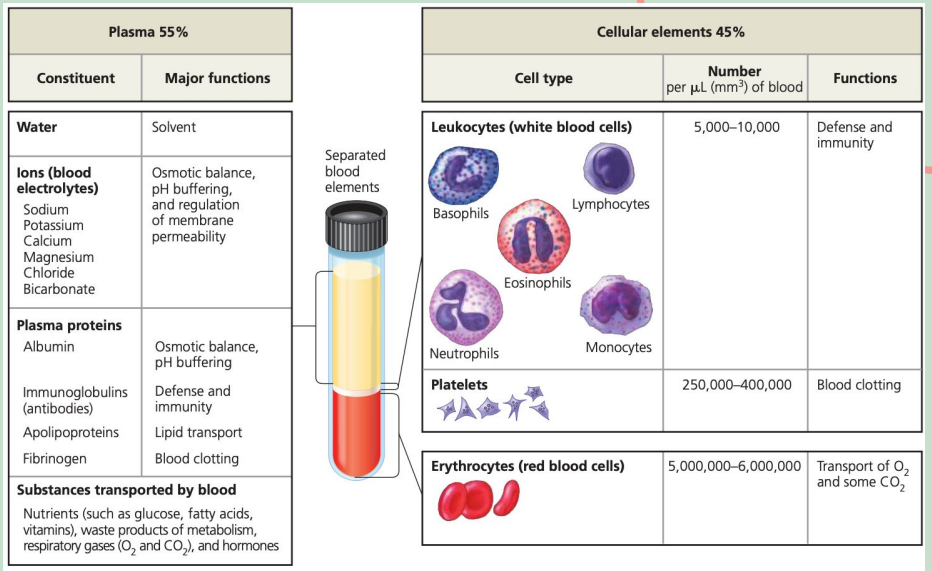
Formed elements (cells and cell fragments) in plasma

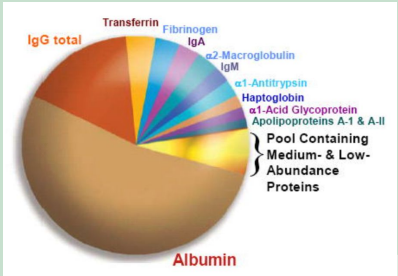
Plasma

- Proteins, nutrients, metabolic wastes, electrolytes
- Plasma proteins
  - Albumins
  - Immunoglobulins
  - Apolipoproteins
  - Fibrinogen
  - Hormone Transporting Plasma Proteins (HTTP)
  - Transferrin
- Serum = plasma without clotting proteins

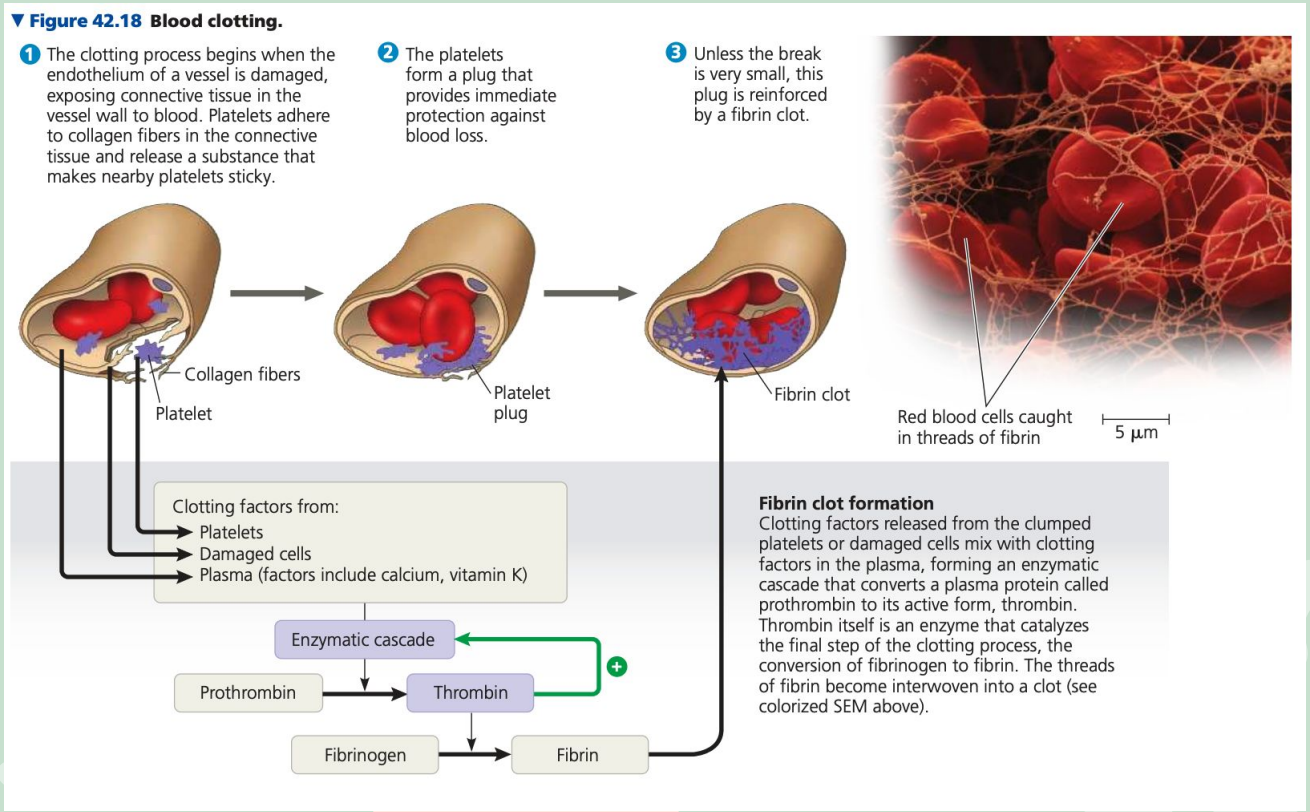
Cells

- Erythrocytes/red blood cells
- Platelets
- Leukocytes/white blood cells





Blood Clotting



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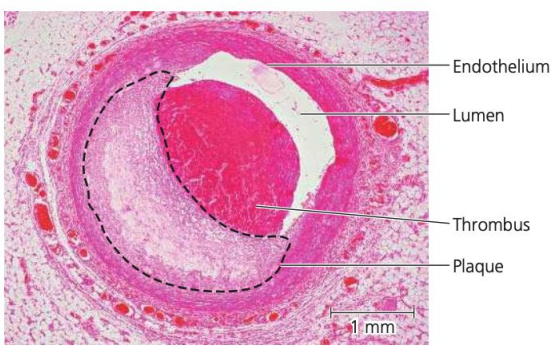
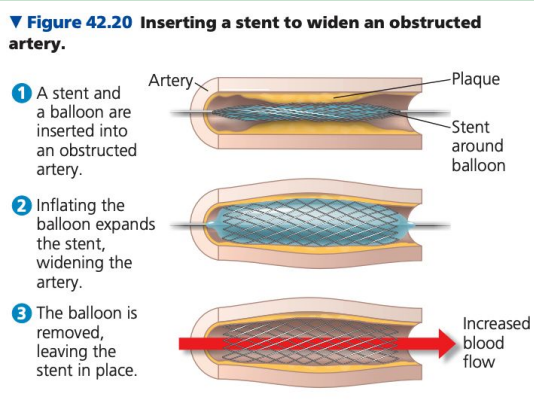
Diseases

Diseases

- Atherosclerosis
  - Arteries harden because of plaque (fatty deposits)
  - Cholesterol
    - LDL delivers cholesterol
    - HDL picks up cholesterol and returns to liver
  - Thrombus can form
  - Angina pectoris is a symptom
- Heart Attack/Myocardial Infarction (MI)
  - Coronary arteries are blocked
  - Heart muscle dies due to lack of O_2
- Stroke
  - Nervous tissue dies due to lack of O_2





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Practice

Which of the following is most directly responsible for the colloid osmotic pressure in humans that acts to retain fluid in the vascular system:

W) albumin
X) sodium ions
Y) calcium ions
Z) potassium ions

In which of the following locations does human blood have the highest oxygen concentration?
W) Pulmonary artery
X) Pulmonary vein
Y) Right atrium
Z) Capillaries in fingers

Albumins, globulins and fibrinogen are all examples of:
W) Capillary hormones
X) Myocardial antigens
Y) Plasma proteins
Z) White blood cells

2018 Opens

25. Which of the following is most accurate regarding the anatomy and physiology of the vertebrate vascular system?

A. The thin walls of veins are an adaptation that allows the tissues of the vein itself to obtain, via diffusion, sufficient oxygen from oxygen-poor venous blood. Otherwise, the tissue of thick-walled vessels carrying deoxygenated blood would experience inadequate oxygenation and die.
B. Arteries and veins contain valves to prevent backflow of blood.
C. Elastic fibers made of the protein elastin in the tunica media allow arteries to accommodate fluctuating blood pressures. They are almost absent in the tunica media of veins.
D. The larger arteries have a thick layer of smooth muscle, the motion of which helps propel blood forward.
E. Vascular endothelial growth factor (VEGF) is a signaling protein that stimulates branching and growth of capillaries. The gene encoding VEGF is often lost or inhibited in solid tissue cancers.

2017 Opens

27. The Starling equation is a widely used model of the movement of fluid across capillary walls in animals. Essentially, the fluid flux is proportional to the net pressure from oncotic and hydrostatic pressures, and to the permeability of the capillary wall to water. The oncotic pressure is simply the osmotic pressure contributed by proteins in the blood serum like albumin.

$J_v = K_f [(P_c - P_i) - (\pi_c - \pi_i)]$, where

J_v = fluid movement/flux out of the capillary (mL min-1)
K_f = hydraulic conductance (mL min-1 mmHg-1)
P_c = capillary hydrostatic pressure (mmHg)
P_i = interstitial hydrostatic pressure (mmHg)
π_c = capillary oncotic pressure (mmHg)
π_i = interstitial oncotic pressure (mmHg)

Which of the following physiologic changes would increase the fluid volume of the interstitial space of tissues? Select ALL where the change will increase the fluid volume of the interstitial space.

A. Scarring of and decreased albumin synthesis by the liver from chronic alcohol abuse.
B. Constriction of a precapillary smooth muscle sphincter upstream of the capillary bed.
C. The release of histamine and cytokines that increase capillary permeability.
D. Formation of a thrombus downstream of the capillary bed.
E. Severe protein malnourishment, such as in the condition kwashiorkor.

2014 Opens

29. Using the following structures, trace the flow of blood entering from the systemic circulation.

I. Right atrium
II. Left atrium
III. Right ventricle
IV. Left ventricle
V. Vena cavae
VI. Aorta
VII. Pulmonary artery
VIII. Pulmonary veins

A. I,II,VII,VIII,III,IV,VI,V.
B. I,VII,III,XIII,II,IV,VI,V.
C. V,I,III,VII,VIII,II,IV,VI.
D. V,I,III,VIII,VII,II,IV,VI.
E. V,III,I,VII,VIII,IV,II,VI.

2013 Opens

26. Which of the following is important for the coordinated rhythmic nature of heart contraction?

A. Acetylcholine transmission between cardiac myocytes.
B. Desmosomes between cardiac myocytes.
C. Gap junctions between cardiac myocytes.
D. Plasmodesmata between cardiac myocytes.
E. Tight junctions between cardiac myocytes.

2017 Semis

7. Nitroglycerin (the key ingredient in dynamite) is sometimes prescribed for heart disease patients. Within the body, the nitroglycerin is converted to nitric oxide. Why would you expect nitroglycerin to relieve chest pain in these patients based on your knowledge?

A. Nitric acid will stimulate the production of endorphins; thus you will perceive less pain.
B. Nitric acid will depolarize neurons and the neurons will no longer be able to send any signals.
C. Nitric acid will decrease the activity of pain receptors (mechanoreceptors) specifically near the heart; thus you will perceive less pain.
D. Vasodilation promoted by nitric oxide from nitroglycerin increases blood flow, providing the heart muscle with additional oxygen and thus relieving the pain.
E. Vasoconstriction promoted by nitric oxide from nitroglycerin decreases blood flow, providing the heart muscle with less oxygen and thus relieving the pain.

2017 Semis

82. A 1973 *Washington Post* quote about a gun shooting follows: "*The most serious wound, which at the onset many thought would cost the victim his life was just above the belt-line on the left side. It affected the pancreas, colon and portal vein, which supplies blood to the stomach. The vein was almost severed in two.*" There is a biological error in this excerpt. Select the error from the responses below:

A. The colon is nowhere near the indicated wound site.
B. The pancreas is on the left side of the body.
C. The portal vein does not supply blood to the stomach.
D. A single bullet could not have hit both the pancreas and the colon.
E. The listed wounds were not serious enough to endanger life.

2017 Semis

83. At the venule end of the capillary bed

A. The hydrostatic blood pressure is greater than the osmotic pressure of the blood.
B. The hydrostatic blood pressure is higher than it is at the arteriole end.
C. The hydrostatic blood pressure and the osmotic pressure are equal.
D. The osmotic pressure of the blood is greater than the hydrostatic blood pressure.
E. Water and dissolved materials leave the capillary.

2016 Semis

4. Which of the following statements about capillaries is FALSE?

A. They are the blood vessel type with the thinnest walls.
B. They are the vessels with the narrowest diameter.
C. Blood moves through the capillaries at a lower velocity than other vessels.
D. More blood moves through the combined capillaries each minute than through the combined arteries.
E. All of these are true.

2016 Semis

5. Which of the following changes, by itself, would tend to make lymph form more slowly?

A. An increase in capillary blood pressure.
B. An increase in the osmotic concentration of the interstitial fluid.
C. An increase in the osmotic concentration of the blood plasma.
D. Two of the above could both make lymph form more slowly.
E. All of the above could make lymph form more slowly.

2015 Semis

31. Plasma proteins are responsible for a number of physiological functions. Which of the following are examples of plasma protein functions?

I. Protection against bacteria and viruses.
II. Transportation of iron.
III. Transportation of oxygen.
IV. Transportation of fats.
V. Transportation of water-soluble hormones.
VI. Transportation of lipid-soluble hormones.
VII. Protection against blood loss.
VIII. Activation of nuclear receptors.

A. I, II, IV, VI, VII only.
B. I, IV, V, VIII only.
C. II, III, IV, V, VII only.
D. I, III VI, VII only.
E. III, V, VI, VII, VIII only.

Thanks!