Comparative Anatomy of the Vertebrate Circulatory Systems

BIO.A.1.2 – Describe relationships between structure and function at biological levels of organization.

- Focus - Anatomy and Physiology of the circulatory and respiratory systems (strong structure and function approach)
- Focus - Comparative examination of the respiratory and circulatory system in vertebrates
- Focus – Adaptations of the respiratory and circulatory systems within vertebrates
- Describe and interpret relationships between structure and function at various levels of biological organization (i.e. organelles, cells, tissues, organs, organ systems, and multicellular organisms)

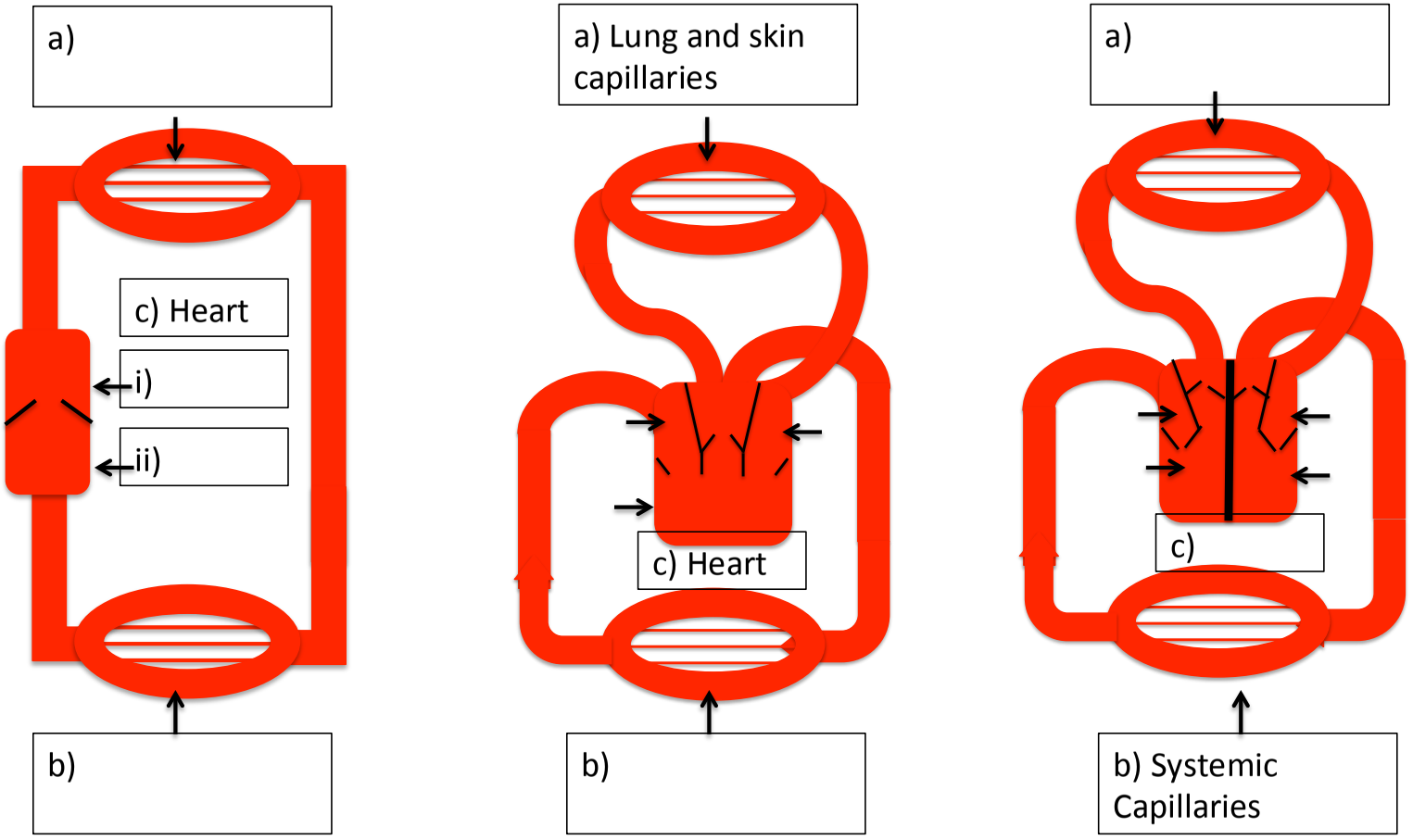
Key terms:

- Heart
- Atrium
- Ventricle
- Blood vessels
- Arteries
- Veins
- Capillaries
- Gill capillaries
- Lung capillaries
- Skin capillaries
- Systemic capillaries
- Gill circulation
- Pulmocutaneous circulation
- Pulmonary circulation
- Systemic circulation

Objectives:

1. Define what a closed circulatory system is and why an organism would need one.
2. Discuss the key circulatory terms and describe the functions of each.
3. Examine the anatomical arrangement of the circulatory systems of fish, amphibians, and mammals.
4. Discuss the advantages and disadvantages of each circulatory system.

Comparative Anatomy of Vertebrate Circulatory Systems



The Mammalian Heart: A Double Pump

Key terms:

- Heart
- Myocardium (cardiac muscle)
- Atrium
- Ventricle
- Right and Left Atrioventricular (AV) valves
- Tricuspid valve
- Bicuspid valve
- Semilunar (SL) valves
- Pulmonary SL valve
- Aortic SL valve
- Blood vessels
- Arteries
- Arterioles
- Veins
- Venules
- Capillaries
- Lung (pulmonary) capillaries
- Systemic capillaries
- Pulmonary circulation
- Systemic circulation

Objectives:

1. Trace the route of travel for a drop of blood from the right atrium, through both the pulmonary and systemic circulations, and back to the right atrium.
2. Identify the structures that ensure unidirectional flow of blood through the heart.
3. Examine the walls of the chambers of the human heart and identify which chamber has the thickest (thinnest) myocardium. Explain the significance of this structural feature.

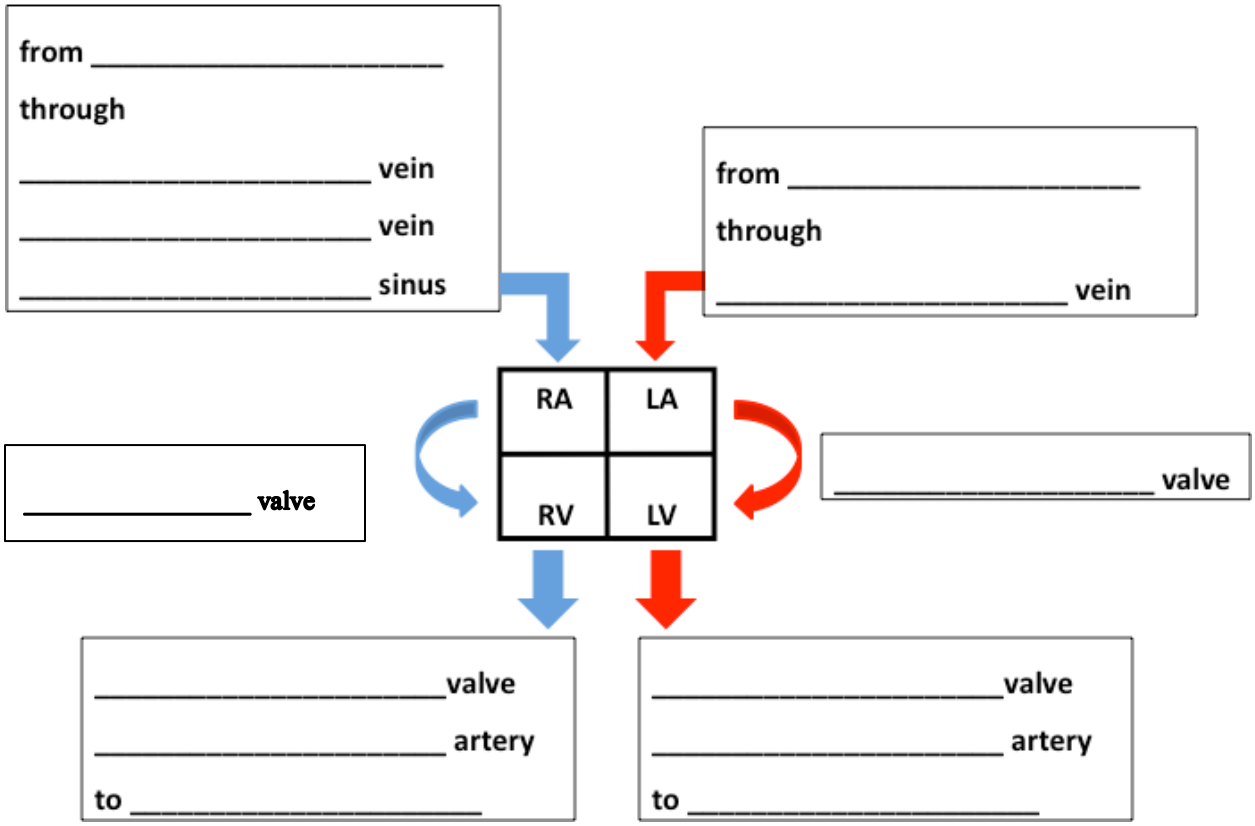
Clinical Discussion Points:

1. Discuss the impact that a valve disorder (won't open fully or won't close fully) would have on the normal flow of blood.
2. Discuss the impact that a hole in the interventricular septum (as some babies are born with), would have on the oxygenation of blood leaving the heart for the systemic circulation.

Listen:

http://youtu.be/SvAVu-7E2gA (Bruno Mars' Grenade)
http://youtu.be/mDSFxcf2UgQ (Carly Rae Jepsen's Call Me Maybe)
http://youtu.be/5tTkxYeNF9Q (Schoolhouse Rock - do the circulation)

Route of Blood Flow Through the Heart



Blood Pressure and Blood Flow

Key terms:

- Heart
- Atrium
- Ventricle
- Blood vessels
- Arteries
- Aorta
- Arterioles
- Capillaries
- Venules
- Veins
- Vena cavae
- Systolic Pressure
- Diastolic Pressure
- Vascular Resistance
- Pressure gradient
- Sphygmomanometer

Objectives:

1. To define hydrostatic pressure.
2. To identify the factors that influence blood pressure.
3. To understand why blood pressure changes in the vasculature as the distance from the left ventricle increases.
4. To understand how resistance changes as blood passes from the arteries, arterioles, and into the capillaries.
5. To discuss how resistance alters the rate of blood flow.

Clinical Discussion Points:

1. Discuss the impact that hemorrhage or severe dehydration would have on blood pressure.
2. Discuss the impact that atherosclerosis would have on the flow of blood through the body.
3. Discuss the impact that hypertension would have on the effort needed for the heart to contract.

To Do:

1. Observe blood pressure being measured with a sphygmomanometer (I referenced Tortora and Derrickson's Principles of Anatomy and Physiology for these steps).
    a. Place a blood pressure cuff around the subject's arm (best if arm is hanging at side or resting on a table top).
    b. Inflate the cuff in order to compress the brachial artery and stop blood flow.
    c. Place a stethoscope over the brachial artery (in the antecubital region).
    d. Gradually deflate the cuff.
        i. When you hear the first sound (corresponds to the pressure dropping below the pressure in the brachial artery and blood flowing through), this is the systolic blood pressure.
        ii. When the sounds become faint, this corresponds to the diastolic pressure, and when sounds disappear, pressure is lower than the diastolic pressure.

2. Observe changes in blood flow with changes in vessel diameter using cups with different diameter straws. (Please note that this is a Science Buddies activity that I found on the internet).

   Materials needed:
   2- 16 ounce plastic cups
   2 different diameter straws cut to similar length (~ 2")
   Play doh or silly putty
   A glass/clear plastic bin
   Water with food coloring (best if it is coming from 2 separate bottles)

   To do:
   1. Make a hole in each of the cups, near the bottom (make the hole about the same diameter as the straws).
   2. Place the straw through the hole and use the play doh to seal off the opening so that water cannot leak through.
   3. Put both of the cups into the bin.
   4. Simultaneously pour water into the 2 cups.
   5. Observe the difference in the rate in which the 2 cups empty and compare the different diameter straws to the different diameter blood vessels (i.e arteries versus capillaries or normal versus atherosclerotic arteries).

Vessel Structure and Function – A Focus on Capillaries

Key terms:

- Blood vessels
- Arteries
- Arterioles
- Capillaries
- Continuous capillaries
- Fenestrated capillaries
- Sinusoid capillaries
- Venules
- Veins
- Tunica interna
- Lumen
- Endothelium
- Simple squamous epithelial tissue
- Basement membrane
- Exchange vessels
- Diffusion
- Transcytosis
- Bulk flow
- Filtration
- Reabsorption
- Hydrostatic pressure
- Osmotic pressure

Objectives:

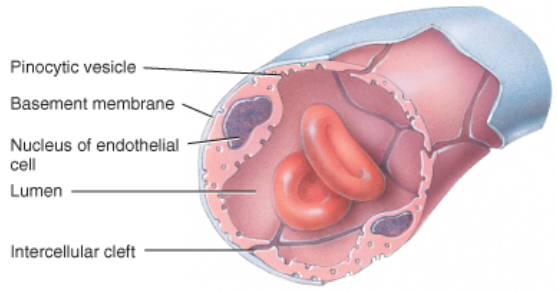
1. To describe the structure of a capillary wall and how this makes the capillary well suited for exchange.
2. To identify the 3 different types of capillaries and explain where in the body you might find them.
3. To identify the three manners in which exchange occurs across the capillary wall.

Clinical Discussion Points:

1. To understand the cause of edema and what situations may result in edema occurring.

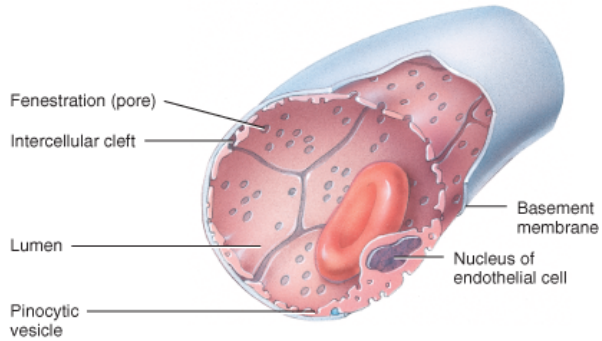
To Do:

1. Examine an image depicting the 3 different types of capillaries and identify locations in the body where these capillaries are found.



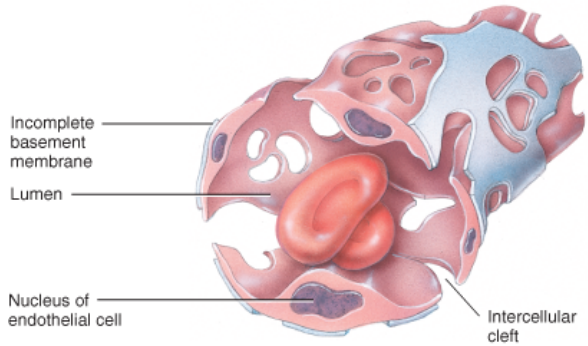
(a) Continuous capillary formed by endothelial cells

Where you would find these capillaries:



(b) Fenestrated capillary

Where you would find these capillaries:

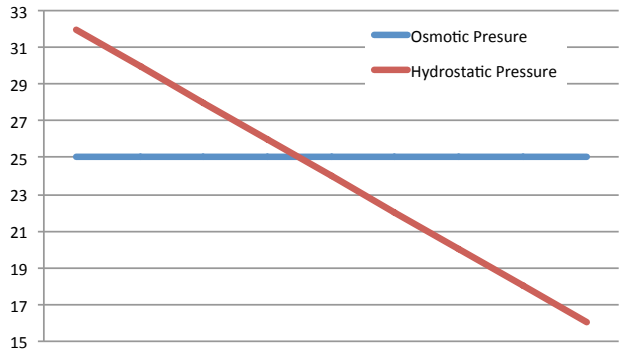


(c) Sinusoid

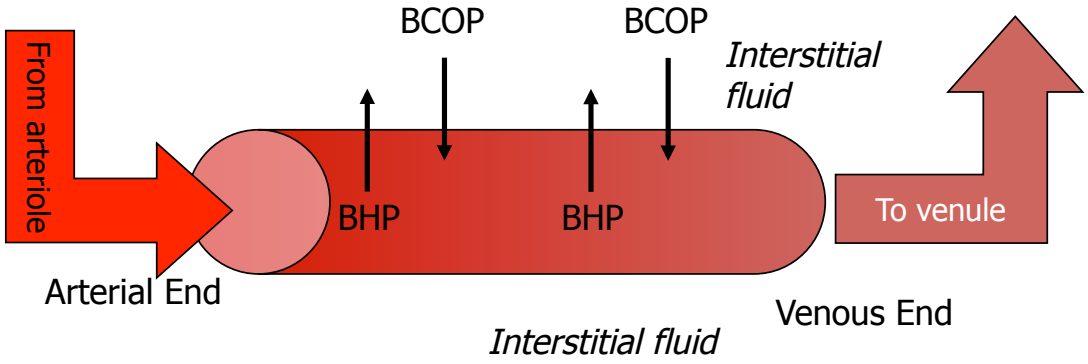
Where you would find these capillaries:

Image from Tortora and Derrickson's Principles of Anatomy and Physiology, 13th edition

2. Gain an understanding of Bulk Flow.



NFP = BHP - BCOP



a. At the arterial end, the net filtration pressure is _____ and _____ occurs.
b. At the venous end, the net filtration pressure is _____ and _____ occurs.

3. Observe a demonstration for transport across a capillary that depicts which components of the blood are filtered and which are not.

The Blood – A Fluid Connective Tissue

Key terms:

- Blood
- Plasma
- Plasma proteins
- Water
- Ions
- Nutrients
- Wastes
- Gases
- Hormones
- Red Blood Cells (Erythrocytes)
- White Blood Cells (Leukocytes)
- Neutrophils
- Lymphocytes
- Monocytes
- Eosinophils
- Basophils
- Platelets
- Viscosity

Objectives:

1. To describe the composition of blood.
2. To discuss the functions of blood.
3. To describe the structure of a red blood cell and discuss the functional significance of this structure.

Clinical Discussion Points:

2. Discuss the impact that dehydration would have on blood viscosity and blood flow.
3. Discuss the impact that an abnormal increase in blood cell number would have on blood.

Activities:

1. Use a breath saver versus a solid disc to examine the bi-concave feature of a red blood cell. and discuss the functional significance of this structural feature.
2. Complete the following activity to model the composition of blood (from Pinterest):
   a. Take a beaker and fill 55% of the way with corn syrup (plasma).
   b. Add red-hot candies until the beaker is almost full (red blood cells).
   c. Add a few mini marshmallows (white blood cells, fewer but larger).
   d. Add some sprinkles (platelets, more numerous than WBCs but very small).

   Note: This is an easy time to show size/abundance relationships. It is also a good time to visually show what would happen if there were less liquid (dehydration) or more red blood cells (blood doping).