Online Physiology 2130 – Vasculature

Introduction

Hey! Thanks for opening up this Physiology 2130 resource, and welcome. The education team at WebStraw has put together comprehensive review sheets for you that cover all the major learning outcomes for **Vasculature of Physiology 2130**.

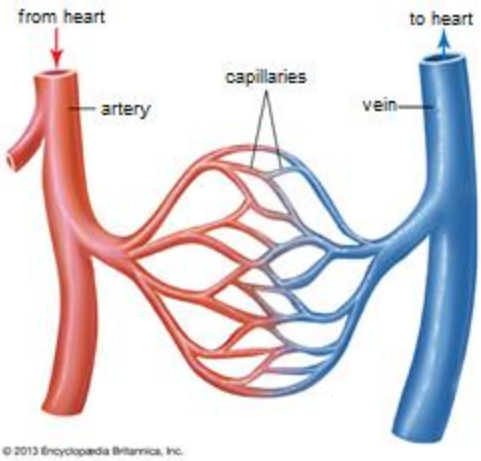
Members of our team have taken the course in previous years, and we understand better than anyone else what specific ideas and concepts tend to trip students up throughout the course. **We are able to essentially offer you the key takeaways from the course after having completed the course ourselves**. We also have representatives currently enrolled in the course as well to keep us up to date on specific topic coverage.

Before you read further, also keep in mind that **these resources are not meant to be a tool for you to learn the course from scratch**. The content presented below was designed with the assumption that you already have a preliminary understanding of the course content. Our goal is to provide you with **a resource in order to quickly review key concepts and easily refer to course content**. We have added a few questions for each module in order to give you some practice and a feel for exam type questions. Please refer to the course material provided by your instructors if there are any discrepancies between the content found in these review sheets and the course content.

With that said, best of luck in your studying! Remember to make good use of your time, but to also take breaks as well.

The WebStraw Education Team

Module 9 - Vasculature



Principal Functions

- Pumps blood and distributes it to all areas of the body
- Uses a closed system of tubes (blood vessels) & central pump (the heart)

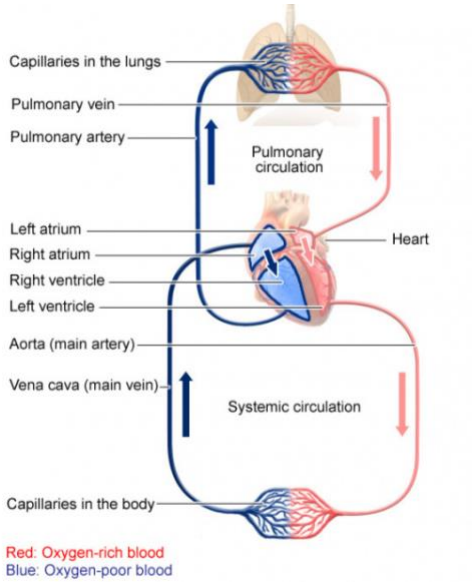
Blood Vessels

Arteries and **Arterioles** – transport blood away from the heart
Venules and **Veins** - return blood back to the heart

Two Distinct Loops:

Pulmonary Circulation
Blood Flow: RS heart → arteries → lungs (pulmonary capillaries) → venules → veins → LS heart

- Starts at the RS of the heart and sends blood to the lungs
- Gas exchange occurs at pulmonary capillaries: oxygen diffuses into blood and CO_2 diffuses out
- Blood enters venules then veins to return to the LS of the heart



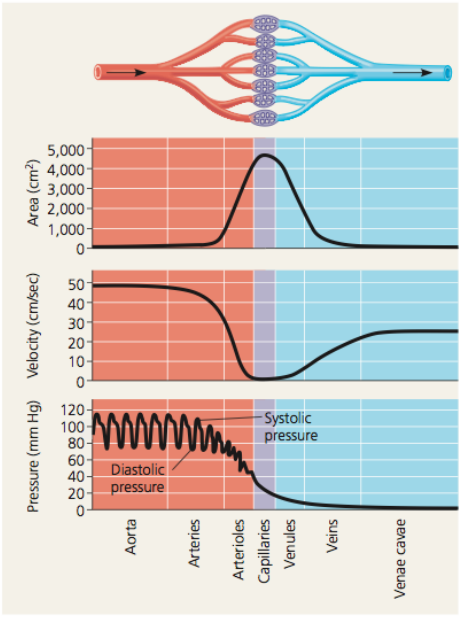
Systemic Circulation
Blood Flow: LS heart → aorta → arteries → arterioles → capillaries → venules → veins → RS heart

- Starts at the LS of heart and sends blood to the rest of the body
- Gas exchange occurs at capillaries: oxygen, nutrients & hormones are delivered to cells and CO_2 & waste are picked up
- Blood enters venules then veins to return to RS of the heart

Blood Volume Distribution | Significance

Total Blood Volume (TBV) of average human = ~5 Liters

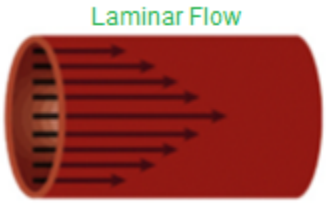
- **Arteries** ~10%
  - Arteries - highest blood pressure (BP) and velocity; very low cross-sectional area
    - Rapidly distribute blood throughout body
  - Arterioles - lower BP and velocity; cross-sectional area is higher.
    - Site of highest resistance in circulation (help regulate blood flow to an organ)
- **Capillaries** ~5%
  - Lowest blood velocity; highest total cross-sectional area in circulation
  - Helps to maximize exchange of substances across BV's
- **Veins** ~70% (sometimes called capacitance vessels or blood "reservoir")
  - BP and cross-sectional area decrease while blood velocity increases in veins/venules
  - Return blood back to heart, while also storing large percentage of TBV
- **Heart & Lungs** ~15%



© Campbell Biology, 10th edition

Pressure, Flow and Resistance

Flow = (P1 – P2) / R



- Driving force behind blood flow is the pressure gradient (P1-P2)
- Higher the resistance the blood encounters → the lower the flow
- Blood flow through a vessel → **Laminar (streamlined) flow** meaning that there are thin "layers" of flow with each layer having a different velocity

Several Factors can Affect Resistance:

1. **Viscosity** (thickness) of the fluid.
   - The thicker the fluid, the higher the resistance
2. **Length** of the vessel (not a major factor)
   - The longer the vessel, the higher the resistance
3. **Diameter/Radius** of blood vessel (major factor)
   - Smaller the inside diameter, the higher the resistance

Resistance = $1 / r^4$

⇨ Flow = $(P1 – P2) * r^4$

where r is radius of blood vessel

Small changes in the radius of the blood vessel result in a ***large*** change in blood flow. ***Large*** change in pressure is required to get a ***large*** change in blood flow.

Control of Blood Flow in the Body

Two ways the body can alter blood flow:

- Changing either **pressure gradient** or **radius** of the vessel.
- Since BP is kept relatively constant, *best way* to regulate blood flow is ***changing the radius*** of the vessels

Why Control Blood Flow?

- After eating a meal, blood flow is diverted away from the muscle to the intestine to help with digestion.
- When exercising, blood is diverted away from intestine to muscles to provide oxygen/nutrients while removing CO_2.

Blood Pressure Below and Above a Constriction

- Area above the constriction would increase in pressure as more blood accumulates
- Area below the constriction has less blood flowing through it, resulting in a lower blood pressure

Arteries & Veins

Outer Layer — **Tunica Externa** – outermost later, mostly of fibrous connective tissue

Tunica Media – smooth muscle and elastic tissue

Inner Layer — **Tunica Interna** – composed of endothelial cells

Blood Vessel	Structure
Arteries	• Larger proportion of elastic tissue to withstand/absorb large pulsatile pressure changes during heart contractions
Veins	• Thinner walls than arteries • Contain some smooth muscle and little elastic tissue • More flexible and stretchable (to hold 70% of TBV) • Has valves to ensure that blood flow is unidirectional and small amount of muscle tissue constrict and push blood to the heart
Arterioles	• Mostly smooth muscle • Able to constrict or dilate to redirect blood flow
Venules	• No smooth muscle or elastic tissue since blood pressure is low
Capillaries	• Contain a thin layer of epithelial cells to allow substances to diffuse in and out of blood • Movement enhanced by thin endothelial cells, clefts & fenestrations

Movement of Dissolved Substances Across the Capillary

Diffusion

- The oxygen & nutrient concentrations are high in the blood → diffuse into interstitial fluid
- The CO_2 & waste concentrations are high in the tissues → diffuse into the blood

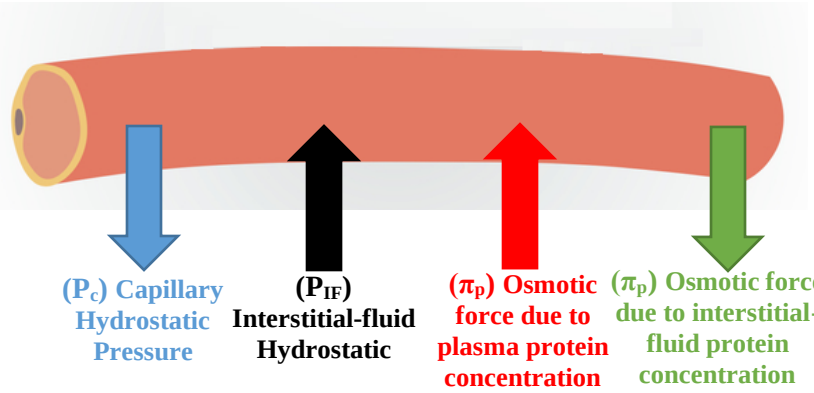
Filtration

Movement of fluid from the capillary into the interstitial space

Reabsorption

Movement of fluid from interstitial space back into the capillary.

Starling Forces – determine whether filtration or reabsorption occurs



Net Filtration Pressure:

$$NFP = (P_C - P_{IF}) - (\pi_p - \pi_{IF})$$

If NFP > 0: **filtration**
If NFP < 0: **reabsorption**

- Filtration and reabsorption do not need to be balanced.
- Can have excess filtration from capillaries causing accumulation in the interstitial space.

Lymphatic System

- A large network of capillaries and vessels that returns excess fluid back into the systemic circulation
- Process:
  1. Excess fluid passes through openings on small blind-ended lymphatic capillaries
  2. Fluid is returned to larger collecting vessels that pass through lymph nodes
  3. Lymph nodes filter & screen fluid for foreign particles
  4. Fluid is sent back to venous circulation through collecting ducts

Edema – accumulation of fluid in the interstitial space causing swelling
Factors:

- An increase in the capillary hydrostatic pressure (P_C) caused by increased blood pressure → can occur during weight lifting
- Decrease in the plasma osmotic force (π_P) → can occur with severe malnutrition
- Blockage or disruption of the lymphatic system → can occur after radical mastectomy

Control and Regulation of the Cardiovascular System

1. Local control mechanisms in the organs themselves
   a. **Autoregulation** - capillary beds maintain relatively constant blood flow when moderate changes occur in blood pressure
      i. **Myogenic Theory** - change in blood flow produced by contraction & relaxation of smooth muscle in blood vessel walls → protects capillary network in vital organs from sudden pressure changes
      ii. **Metabolic Theory** - vasodilation and increased blood flow that occurs due to changes in metabolic activity of an organ →metabolic by-products CO_2, lactic acid, and adenosine cause vasodilation
2. Humoral mechanisms that rely on chemicals in the blood
   a. Use of **vasoconstrictors** & **vasodilators** to regulate blood flow
3. The **autonomic nervous system (ANS),** which alters cardiac output & blood flow to organs
   a. **Sympathetic Nervous System (SNS)** → fight or flight
      i. Releases norepinephrine to cause vasoconstriction of blood vessel smooth muscle
      ii. Releases Ach onto skeletal muscle blood vessels, causing vasodilation
      iii. Redirects blood away from digestive system, kidneys, and spleen towards muscle
   b. **Parasympathetic Nervous System (PNS)** → rest and relaxation
      i. Does not strongly innervate smooth muscle of blood vessels, but where does innervate, it releases ACh and produces a vasodilation of the blood vessels

Vasoconstrictors	Vasodilators
• Epinephrine (binds to alpha receptors) • Angiotensin II • Vasopressin	• Epinephrine (binds to β receptors) • Kinins • Histamine • Atrial Natriuretic Factor (ANF)

Baroreceptor Reflex – negative feedback loop that returns blood pressure to normal if it goes too high

- Baroreceptors in aortic arch and carotid sinus stretch; sends signal to cardioregulatory & vasomotor center in brain stem to decrease blood pressure back to normal

$$BP = CO * TPR$$

Total peripheral resistance (TPR): the sum of all the resistance in all the blood vessels in the body
Cardiac output (CO) is the amount of blood pumped by each ventricle in one minute.
Recall: **CO = HR * SV**

Review Questions

1. Which of the following blood vessel(s) has the lowest resistance to blood flow?
    a. Aorta
    b. Large Arteries
    c. Arterioles
    d. Capillaries

2. Which of the following statements is correct?
    a. Veins in the pulmonary circulation contain more oxygen than veins in systemic circulation
    b. Arteries in the systemic circulation contain more blood than veins in systemic circulation
    c. Most of the vascular beds in the systemic circulation are in series with one another, which reduces the workload in the heart
    d. Being the smallest diameter vessels in the body, the capillaries have the highest resistance to blood flow.

3. As blood flows from the aorta to the arterioles, all the following trends occur EXCEPT
    a. Mean blood velocity decreases
    b. Total cross-sectional area increases
    c. Average blood pressure decreases
    d. Vascular resistance increases
    e. Total blood flow at each level decreases

4. Which of the following is not a factor causing edema?
    a. Increase in the capillary hydrostatic pressure (P_C)
    b. Decrease in the plasma osmotic force (π_P)
    c. Increase in the interstitial fluid hydrostatic pressure (P_{IF})
    d. Disruption of the lymphatic system

5. Which of the following can act as both a vasoconstricting and vasodilating agent, depending on which blood vessels it affects?
    a. Vasopressin
    b. Epinephrine
    c. Atrial Naturietic Factor (ANF)
    d. Kinins

6. Which of the following blood vessels does not have any smooth muscle?
    a. Arteries
    b. Veins
    c. Arterioles
    d. Venules
    e. None of the above

7. Given the following data, calculate the net fluid movement across the capillary
        Capillary hydrostatic pressure (P_c) . = +20 mmHg
        Plasma osmotic pressure (π_p) = +10 mmHg
        Interstitial-fluid hydrostatic pressure (P_{IF}) = -9 mmHg
        Interstitial osmotic pressure (π_{IF}) = +6 mmHg
    a. +25 mmHg favouring filtration
    b. +25 mmHg favouring reabsorption
    c. -5 mmHg favouring filtration
    d. -5 mmHg favouring reabsorption

Answer Key:
1. D 2. A 3. E 4. C 5. B 6. D 7. A