Chapter 14 The Cardiovascular System: Blood Vessels, Blood Flow and Blood Pressure (I)

- **Chapter Outline**
  - Physical Laws Governing Blood Flow and Blood Pressure
  - Overview of the Vasculature
  - Arteries
  - Arterioles

14.1 Physical Laws Governing Blood Flow and Blood Pressure

- **Pressure** = force exerted by blood
- Heart creates pressure gradient for bulk flow of blood
- The pressure gradient \( \Delta P \) = \( P \) at one end of a blood vessel - \( P \) at the other end of a blood vessel

- **Flow Rule**
  - Driving force: \( \Delta P \) drives the blood flow in circulatory system.
  - Flow direction: from high pressure to low pressure
  - Factors that affect the blood flow in the cardiovascular system: Resistance (R) and \( \Delta P \)
  - Flow rate = \( \Delta P / R \)

- **Pressure Gradient across Systemic Circuit (Figure 14.2)**
  - Pressure in aorta = mean arterial pressure (MAP)
  - Pressure in vena cava = central venous pressure (CVP)
  - The driving force in systemic circuit \( \Delta P = MAP - CVP = 85 \text{ mmHg} \)

- **Pressure Gradient across Pulmonary Circuit**
  - Pressure gradient = pressure in pulmonary arteries minus pressure in pulmonary veins
  - Pulmonary arterial pressure = 15 mm Hg
  - Pulmonary venous pressure = 0 mm Hg
  - Pressure gradient = 15 – 0 = 15 mm Hg
  - The driving force in pulmonary circuit = \( \text{Pressure} \)

- **Pressures of the Pulmonary and Systemic Circuit (Figure 14.3)**
  - The average pressure \( \Delta P \) is higher in (systemic circuit or pulmonary circuit).
  - These blood vessels have the highest average BP _________
  - These blood vessels have the biggest drop in the average BP drops __________
  - These blood vessels have the lowest average BP ________.

**Factors Affecting Resistance of Individual Blood Vessels**

- **Poiseuille’s Law**
  - Radius (r) of vessel, in arterioles (and small arteries) - can regulate radius
  - Length of vessel (L)
  - Viscosity of fluid = \( \eta \) Blood viscosity dependent on the amount of RBCs and proteins contain in blood

\[
R = \frac{8 \eta L}{\pi r^4} \quad \text{Flow rate} = \frac{\Delta P}{R} = \frac{\Delta P \pi r^4}{8 \eta L}
\]
Resistance of Blood Vessel Network: Total Peripheral Resistance (TPR) = Combined resistance of all blood vessels within the systemic circuit.
  - Vasoconstriction in network → increase resistance → decrease flow
  - Vasodilation in network → decrease resistance → increase flow

Relating Pressure Gradients and Resistance in the Systemic Circulation
  - Flow rate= the volume of blood flows through the systemic circuit per minute = cardiac output (CO)
    - ∆P = mean arterial pressure (MAP)
    - R = total peripheral resistance (TPR)
    - Cardiac output (CO) = \________/\________

14.2 Overview of the Vasculature (Figure 14.5)
- Arteries and larger arterioles—carry blood away from heart
- Microcirculation: arterioles; capillaries—site of exchange; and venules
- Veins—return blood to heart
- Figure 14.6 Structural characteristics of the five blood vessel types

14.3 Arteries (Figure 14.7)
- Structure
  - Three layered muscular thick elastic arterial walls
  - Low compliance
- Function: Storage site for __________ to maintain blood flow
- Compliance
  - Compliance is a change in volume per unit change in distending pressure = ∆V/∆P
  - Low compliance (arteries): Harder to expand
  - High compliance (veins)
- Arterial Blood Pressure
  - Pressure in the aorta
  - Varies with cardiac cycle
  - Systolic blood pressure (SP) = maximum pressure; due to ejection of blood into aorta
  - Diastolic blood pressure (DP) = minimum pressure; not zero due to ______ ______ of blood vessels
- Blood Pressure Measurement (Figure 14.8)
- Example of Blood Pressure Determinations
  - SP / DP; example: 110 / 70
  - ______ Pressure = SP – DP = 110 – 70 = 40 mm Hg
  - ______ = (SP + (2 x DP)) / 3 = (110 + 140) / 3 = 83.3 mm Hg

14.4 Arterioles and Resistance to Blood Flow
- Arterioles = __________ vessels
- Arterioles provide greatest resistance to blood flow (> 60% of TPR). They are muscular and well innervated.
- Largest pressure drop in vasculature (90 mm Hg to 40 mm Hg Figure 14.9)
- Main Function
  - Controlling blood flow to individual capillary beds
  - Regulating mean arterial pressure
• Resistance to Blood Flow: Changes in Arteriole Radius (Figure 14.10)
  o The contractile state of smooth muscle is affected by both intrinsic and extrinsic factors

• Intrinsic Control of Blood Flow Distribution to Organs
  o Regulation of blood flow to organs is based on need by varying resistance
  o Organ blood flow = MAP / organ resistance
  o Organ blood flow driving force = Arterial pressure (AP) – Venous pressure (VP)

• Arteriole Radius and Blood Flow (Figure 14.11)
  o Assuming $\Delta P$ is the same, flow varies due to differences in resistance, which organ has the lowest resistance? ____
  o Blood flow changes when resistance changed in B, Cardiac Output (CO) of organ A and C increased

• Intrinsic Regulation in Response to Changes in Metabolic Activity
  o Increased metabolic activity generally cause vasodilation
    ▪ Vasodilators: Carbon dioxide, potassium and hydrogen ions
  o Decreased metabolic activity generally cause vasoconstriction
    ▪ Vasoconstrictor: oxygen

• Intrinsic Control of Blood Flow Distribution to Organs (Figure 14.12-13)
  o Active hyperemia: increased blood flow in response to increased metabolic activity
  o Reactive hyperemia: increased blood flow in response to a previous reduction in blood flow
  o Myogenic response (Figure 14.14)
    ▪ Change in vascular resistance in response to stretch of blood vessels in absence of any external factors
    ▪ Perfusion pressure = $\Delta P$ that drives blood flow through an organ or tissue
  o (Table 14.1) Within the human body, the nitroglycerin is converted to nitric oxide. Why is nitroglycerin used to release chest pain in patients?

• Extrinsic Control of Arteriole Radius and Mean Arterial Pressure
  Flow = $\Delta P/R \rightarrow CO = MAP / TPR \rightarrow MAP = CO \times TPR$
  o MAP depends on TPR
  o TPR depends on radius of arterioles
  o Radius of arterioles regulated by extrinsic mechanisms to control MAP (Table 14.2)
    ▪ Sympathetic activity → vaso______ →↓ or ↑ MAP
    ▪ Hormone: ___________ ↑ or ↓ MAP (dominant);
    ▪ Hormones ___________ and ______ increase MAP

• Independent Regulation of Blood Flow (at rest and during Exercise Page 406)