Histology and physiology of cardiovascular system
Learning Objectives

• Distinguish among the types of blood vessels.
• Describe fluid and dissolved material transport into and out of the cardiovascular system.
• Describe the factors that influence blood pressure and blood pressure regulation.
• Discuss the mechanisms involved in the movement of fluids between capillaries and interstitial spaces.
Learning Objectives

• Describe how blood flow and pressure in tissues is regulated.

• Identify the principle blood vessels of each circuit and the areas they serve.

• Describe fetal circulation patterns and the changes that occur in these patterns at birth and during aging.
The Anatomy of Blood Vessels

Structure of vessel walls

- Walls of arteries and veins contain three distinct layers
  - Tunic intima
  - Tunica media
  - Tunica externa
A Comparison of a Typical Artery and a Typical Vein
Differences between arteries and veins

- Compared to veins, arteries
  - Have thicker walls
  - Have more smooth muscle and elastic fibers
  - Are more resilient
  - Add Table
Blood flows through the blood vessels from the heart and back to the heart in the following order:

- Elastic Arteries e.g. Aorta, pulmonary artery
- Muscular Arteries
- Arterioles
- Capillaries – the only vessels that allow exchange
- Venules
- Medium Veins
- Large Veins e.g. vena cava, pulmonary vein
As blood flows from the aorta toward the capillaries and from capillaries toward the vena cava:

- Pressure decreases
- Flow decreases
- Resistance increases
Arteries

• Undergo changes in diameter in order to increase or decrease the size of the artery:
  • Vasoconstriction – decreases the size of the lumen
  • Vasodilation – increases the size of the lumen

• Arteries include:
  • Elastic - conducting
  • Muscular – distributes the blood
  • Arteriole - small arteries
Histological Structure of Blood Vessels

- **LARGE VEIN**
  - Tunica externa
  - Tunica media
  - Tunica intima
  - Endothelium

- **ELASTIC ARTERY**
  - Internal elastic layer
  - Endothelium
  - Tunica media
  - Tunica externa

- **MUSCULAR ARTERY**
  - Tunica externa
  - Tunica media
  - Tunica intima
  - Endothelium

- **MEDIUM-SIZED VEIN**
  - Tunica externa
  - Tunica media
  - Tunica intima
  - Endothelium

- **VENULE**
  - Tunica externa
  - Tunica media
  - Tunica intima
  - Endothelium

- **ARTERIOLE**
  - Smooth muscle cells (tunica media)
  - Endothelium
  - Basal lamina

- **FENESTRATED CAPILLARY**
  - Pores
  - Endothelial cells
  - Basal lamina

- **CONTINUOUS CAPILLARY**
  - Endothelial cells
  - Basal lamina
Capillaries

- Capillaries form networks called capillary bed
- Blood flow through the capillary is regulated by pre-capillary sphincter.
- Capillaries allow exchange between interstitial fluid and blood by
  - Active transport
  - Passive transport
    - Osmosis,
    - Diffusion,
    - Filtration,
    - Facilitated Transportation
Capillary Filtration

Capillary hydrostatic pressure (CHP)

- Amino acid
- Blood protein
- Glucose
- Ions

Interstitial fluid

- Water molecule
- Hydrogen bond
- Small solutes
The Organization of a Capillary Bed
Capillaries

• Capillaries have two basic structures
  • Continuous capillaries
    • Have complete lining
    • Supply most region of body
    • Can be found in all tissues except epithelial and cartilage
  • Fenestrated capillaries
    • Contain windows (pores) that span endothelial lining
    • Permit rapid exchange of large solutes as large as peptide
    • Flattened fenestrated capillaries = sinusoids
• Collect blood from all tissues and organs and return it to the heart

• Vein are classified according to their size into:
  • Venules
  • Medium-sized veins
  • Large veins
Venous Valves

- Venules and medium-sized veins contain valves
- Valves prevent backflow of blood
The Function of Valves in the Venous System
The Distribution of Blood in the Cardiovascular System

- Systemic venous system: 64%
- Large veins: 18%
- Large venous networks (liver, bone marrow, skin): 21%
- Venules and medium-sized veins: 25%
- Pulmonary circuit: 9%
- Pulmonary arteries: 3%
- Pulmonary capillaries: 2%
- Pulmonary veins: 4%
- Heart: 7%
- Aorta: 2%
- Elastic arteries: 2%
- Muscular arteries: 4%
- Arterioles: 2%
- Systemic capillaries: 7%
- Systemic arterial system: 13%
Circulatory Pressure

- Circulatory pressure is divided into three components
  - Blood pressure (BP)
  - Capillary hydrostatic pressure (CHP)
  - Venous pressure

- Blood pressure is influenced by:
  - Weight of the person
  - Age of the person
  - Gender of the person
  - Time of the day
Resistance (R)

- Resistance of the cardiovascular system opposes the movement of blood
- For blood to flow, the pressure gradient must overcome total peripheral resistance
  - Peripheral resistance (PR) is the resistance of the arterial system
Arterial blood pressure

- Arterial blood pressure
  - Maintains blood flow through capillary beds
  - Rises during ventricular systole and falls during ventricular diastole
- Pulse is a rhythmic pressure oscillation that accompanies each heartbeat
Forces acting across capillary walls

- Capillary hydrostatic pressure (CHP)
- Blood colloid osmotic pressure (BCOP)
- Interstitial fluid colloid osmotic pressure (ICOP)
- Interstitial fluid hydrostatic pressure (IHP)
Forces Acting across Capillary Walls

KEY

- CHP = Capillary hydrostatic pressure
- BCOP = Blood colloid osmotic pressure
- NFP = Net filtration pressure

Arteriole

- 24 l/day moves out of capillaries
- 35 mm Hg

NFP = +10 mm Hg

Fluid forced out of capillary

Venule

- 20.4 l/day reabsorbed into lymphatic capillaries
- 25 mm Hg

NFP = 0

No net fluid movement

- 25 mm Hg

- 18 mm Hg

NFP = -7 mm Hg

Fluid moves into capillary

Return to circulation
Cardiovascular Regulation

- Autoregulation
- Neural mechanisms
- Endocrine mechanisms
Autoregulation of blood flow within tissues

- Local vasodilators accelerate blood flow in response to:
  - Decreased tissue $O_2$ levels or increased $CO_2$ levels
  - Generation of lactic acid
  - Release of nitric acid
  - Rising $K^+$ or $H^+$ concentrations in interstitial fluid
  - Local inflammation
  - Elevated temperature
Hormones and cardiovascular regulation

- Low Blood pressure stimulates release of renin by juxtaglomerular cells
  - Renin converts Angiotensin to Angiotensin I
  - Angiotensin I is converted into Angiotensin II at the lungs
- Angiotensin II stimulate:
  - Release of Antidiuretic hormone
  - Thirst
    - Increased thirst promotes water absorption across the digestive tract
  - Secretion of aldosterone by adrenal gland
- Aldosterone and ADH promote fluid retention
Hormones and cardiovascular regulation

- Erythropoietin – released if BP falls or O$_2$ levels are abnormally low
  - Erythropoietin ultimately increases blood volume and improves O$_2$ delivery
- Natriuretic peptides – released in response to excessive right atrial stretch i.e. when BP is high
The Regulation of Blood Pressure and Blood Volume

- **HOMEOSTASIS**
  - Normal blood pressure and volume

- **HOMEOSTASIS DISTURBED**
  - Decreased blood pressure and volume

- **Sympathetic activation**
  - Increased cardiac output and peripheral vasoconstriction

- **Increased blood pressure**
  - Increased blood volume

- **Renin release leads to angiotensin II activation**
  - Erythropoietin released

- **Antidiuretic hormone released**
  - Aldosterone secreted

- **Thirst stimulated**
  - Increased red blood cell formation
The Regulation of Blood Pressure and Blood Volume

HOMEOSTASIS
Normal blood pressure and volume

HOMEOSTASIS DISTURBED
Increased blood pressure and volume

Natriuretic peptides released by the heart

Increased Na⁺ losses in urine

Increased water losses in urine

Reduced thirst

Blockage of ADH, aldosterone, epinephrine, and norepinephrine release

Peripheral vasodilation

Reduced blood volume

Reduced blood pressure
Patterns of Cardiovascular Response

Exercise and the Cardiovascular System

• Light exercise results in
  • Extensive vasodilation
  • Increased venous return
  • A rise in cardiac output

• Heavy exercise results in
  • Increased blood flow to skeletal muscles
  • Restriction of blood flow to nonessential organs
  • Increases venous return
Special circulation

• The brain
  • Four arteries which anastomose insuring constant blood flow

• The heart
  • Coronary arteries arising from the ascending aorta

• The lungs
  • Pulmonary circuit, regulated by local responses to O\textsubscript{2} levels
    • Opposite other tissues (declines in O\textsubscript{2} cause vasodilation)
An Overview of the Patterns of Circulation
The Pulmonary Circuit

Pulmonary circuit consists of pulmonary vessels

- Arteries which deliver blood to the lungs
- Capillaries in the lungs where gas exchange occurs
- Veins which deliver blood to the left atrium
The Pulmonary Circuit

Animation: See tutorial/Lab
The Systemic Circuit

Systemic arteries

• Ascending aorta
  • Right and left coronary arteries originate from base of aortic sinus
• Aortic arch and branches
  • Brachiocephalic
  • Left common carotid
  • Left subclavian arteries
• Descending aorta and its branches
  • Thoracic and abdominal aortas
Systemic Veins

- Superior vena cava
  - Drains blood from the head and neck
- Inferior vena cava
  - Drains blood from the remainder of the body
Hepatic Portal System

- Contains substance absorbed by the stomach and intestines
- Delivers these compounds to the liver for
  - Storage
  - Metabolic conversion
  - Excretion
- Nutrients from the digestive tract enter the hepatic portal vein
The Hepatic Portal System
Fetal Circulation

Placental Supply

- Fetal blood flow to the placenta is supplied via paired umbilical arteries
- A single umbilical vein drains from the placenta to the ductus venosus
  - Collects blood from umbilical vein and liver
  - Empties into the inferior vena cava
Fetal Circulation of the Heart and Great Vessels

- No need for pulmonary function in the fetus
- Two shunts bypass the pulmonary circuit
  - Foramen ovale
  - Ductus arteriosus
Cardiovascular Changes at Birth

- Lungs and pulmonary vessels expand
- Ductus arteriosus constricts and becomes ligamentum arteriosum
- A valvular flap closes the foramen ovale
Age-related changes in blood may include

- Decreased hematocrit
- Constriction or blockage of peripheral veins by a thrombus
- Pooling of blood in the veins of the legs
- Vessels are less elastic, prone to Ca^{2+} deposits and thrombi formation

The aging heart has reduced output, decreased activity, and scarring
You should now be familiar with:

• The types of blood vessels
• Fluid and dissolved material transport into and out of the cardiovascular system
• The factors that influence blood pressure and blood pressure regulation
• The mechanisms involved in the movement of fluids between capillaries and interstitial spaces
You should now be familiar with:

- How blood flow and pressure in tissues is regulated
- The principle blood vessels of each circuit and the areas they serve
- Fetal circulation patterns and the changes that occur in these patterns at birth and during aging