The Cardiovascular System: Blood Vessels and Circulation

The Structure of Blood Vessels

Blood Vessel Review

- **Arteries** carry blood away from the heart
  - Pulmonary trunk to lungs
  - Aorta to everything else
- Microcirculation is where exchange occurs
  - **Arterioles** to feed the capillaries
  - **Capillaries** exchange with the tissues
  - **Venules** to receive capillary blood
- **Veins** bring it back to the heart

The Structure of Blood Vessels

A Comparison of a Typical Artery and a Typical Vein

The Structure of Blood Vessels

Arteries and Veins Have Three Layers

- **Tunica interna**
  - Innermost layer (*endothelium*) in contact with blood
- **Tunica media**
  - Middle layer of smooth muscle
    - *Vasoconstrict* or *vasodilate*
- **Tunica externa**
  - Outer layer of loose connective tissue

The Structure of Blood Vessels

Types of Arteries

- **Elastic** arteries
  - Largest
  - Closest to heart
  - Stretch during systole
  - Recoil during diastole
- **Muscular** arteries
- **Arterioles**
The Structure of Blood Vessels
The Structure of the Various Types of Blood Vessels

The Structure of Blood Vessels
Properties of Capillaries
- Tiny branches of small arteries
- Feeders of capillary networks

The Structure of Blood Vessels
The Structure of the Various Types of Blood Vessels

The Structure of Blood Vessels
Properties of Capillaries
- Where exchange between blood and cells takes place
- Organized into interconnected capillary beds
- Vasomotion of precapillary sphincters (bands of smooth muscle) controls flow

The Structure of Blood Vessels
The Organization of a Capillary Bed

The Structure of Blood Vessels
The Organization of a Capillary Bed

The Structure of Blood Vessels
Properties of Veins
- Collect blood from capillaries
- Merge into medium-sized veins
- Merge then into large veins
  - Blood pressure is low here
  - Valves keep blood flowing toward the heart

The Structure of Blood Vessels
The Function of Valves in the Venous System

Circulatory Physiology
Factors Affecting Blood Flow
- Pressure
  - Flow goes up as pressure difference goes up
  - Flow goes from higher to lower pressure
  - Regulated by nervous and endocrine systems

Circulatory Physiology
Factors Affecting Blood Flow
- Peripheral resistance
  - Flow goes down as resistance goes up

Circulatory Physiology
Control of Peripheral Resistance
- Consists of three components:
  - Vascular resistance
    - Goes up as diameter is reduced
    - Arteriole diameter dominates
• Viscosity of blood
  • Depends on hematocrit
• Turbulence
  • Cause of pathological sounds

**Circulatory Physiology**

**Pressures in the Systemic Circuit**
• Arterial pressure
  • Overcomes peripheral resistance to maintain flow to the organs
• Capillary pressure
  • Excessive pressure causes edema
• Venous pressure
  • Low pressure that drives venous return
  • Affects cardiac output and peripheral flow

**Circulatory Physiology**

**Arterial Pressure**
• Rises during ventricular systole
• Falls during ventricular diastole
• *Pulse pressure* is difference between systolic pressure and diastolic pressure
  • Lessens with distance from heart

**Circulatory Physiology**

**Pressures Within the Circulatory System**

**Circulatory Physiology**

**Checking the Pulse and Blood Pressure**

**Circulatory Physiology**

**Functions of Capillary Exchange**
• Maintain communication between plasma and interstitial fluid
• Speed the distribution of nutrients, hormones, and dissolved gases
• Flush antigens to lymphoid tissue
• Aid movement of proteins

**Circulatory Physiology**

**Dynamics of Capillary Exchange**
• Small molecules diffuse across endothelium
• Water follows osmotically
• Balance of forces determines
direction of filtration
  • Capillary pressure forces fluid out
  • Protein osmotic pressure pulls fluid in

Circulatory Physiology
Forces Acting Across Capillary Walls

Circulatory Physiology
Factors Assisting Venous Return
  • Low venous resistance
  • Valves in veins
  • Compression of veins by muscular contraction
  • Respiratory pump pulls blood into thorax

Circulatory Physiology
Key Note
Blood flow is the goal. Total peripheral blood flow is equal to cardiac output. Blood pressure is needed to overcome friction to sustain blood flow. If blood pressure is too low, vessels collapse, blood flow stops, and tissues die; if too high, vessel walls stiffen and capillary beds may rupture.

Cardiovascular Regulation
Factors Affecting Tissue Blood Flow
  • Cardiac output
  • Peripheral resistance
  • Blood pressure

Cardiovascular Regulation
Homeostasis of Tissue Perfusion
  • Autoregulation
    • Local control of pre-capillary sphincters
  • CNS control
    • Responds to blood pressure, blood gases
  • Hormone control
    • Short-term adjustments
      • Blood pressure
      • Peripheral resistance
    • Long-term adjustments
      • Blood volume

Cardiovascular Regulation
Local, Neural, and Endocrine Adjustments That Maintain Blood Pressure and Blood Flow

Cardiovascular Regulation
Neural Control of Blood Flow and Pressure
- **Baroreceptor reflexes**
  - Adjust cardiac output and peripheral resistance to maintain normal blood pressure
  - Driven by baroreceptors
    - Aortic sinus
    - Carotid sinus
    - Atrial baroreceptors

**Cardiovascular Regulation**
Neural Control of Blood Flow and Pressure
- **Chemoreceptor reflexes**
  - Respond to changes in CO$_2$, O$_2$ and pH
  - Sense blood and cerebrospinal fluid
  - Impact cardioacceleratory, cardioinhibitory and vasomotor centers

**Cardiovascular Regulation**
The Hormonal Regulation of Blood Pressure and Blood Volume
**Cardiovascular Regulation**
The Hormonal Regulation of Blood Pressure and Blood Volume
**Cardiovascular Regulation**
Hormonal CV Regulation
- Short-term regulation
  - Epinephrine from adrenal medulla
  - Cardiac output and peripheral resistance
- Long-term regulation
  - Antidiuretic Hormone (ADH)
  - Angiotensin II
  - Erythropoietin (EPO)
  - Atrial natriuretic peptide (ANP)

**Cardiovascular Regulation**
Hormone Effects on CV Regulation
- ADH, angiotensin II promote vasoconstriction
- ADH, aldosterone promote water, salt retention
- EPO stimulates RBC production
- ANP promotes sodium, water loss

**Cardiovascular Regulation**
**Key Note**
Cardiac output cannot be increased indefinitely, and so blood flow to active tissues must be increased and flow to inactive tissue reduced.
A combination of autoregulation, neural regulation, and hormone release accomplish this.

**Patterns of CV Response**

**Exercise and the Cardiovascular System**

- Cardiac output rises
- Blood flow to skeletal muscle increases
- Flow to non-essential organs falls
- Exercise produces long-term benefits
  - Larger stroke volumes
  - Slower resting heart rates
  - Greater cardiac reserves

**Patterns of CV Response**

**Response to Hemorrhage (Blood Loss)**

- Increase in cardiac output
- Mobilization of venous reserves
- Peripheral vasoconstriction
- Release of hormones that defend blood volume

**The Blood Vessels**

**Vessels of the Pulmonary Circuit**

- Pulmonary trunk
  - From right ventricle to lungs
- Pulmonary arteries (left and right)
- Pulmonary veins (left and right)
  - To left atrium

**The Blood Vessels**

**An Overview of the Pattern of Circulation**

**The Blood Vessels**

**The Pulmonary Circuit**

**The Blood Vessels**

**The Systemic Circulation**

- Ascending aorta
  - From left ventricle
  - Feeds coronary circulation
- Aortic arch
  - Feeds shoulders, neck, head
- Descending aorta
  - Feeds inferior body regions
An Overview of the Arterial System

The Blood Vessels
Arteries of the Chest and Upper Limb

The Blood Vessels
A Flow Chart Showing the Arterial Distribution to the Head, Chest, and Upper Limbs

The Blood Vessels
Arteries of the Neck, Head, and Brain

The Blood Vessels
Major Arteries of the Trunk

The Blood Vessels
Major Arteries of the Trunk

The Blood Vessels
Anatomy of Arterial Supply Contrasts with Venous Drainage

• Major arteries in neck and limbs all lie deep
• Major veins form a dual-venous drainage
  • Are either superficial or deep
  • Serves temperature control needs

The Blood Vessels
Anatomy of Venous Drainage

• Superior vena cava
  • Drains head, neck, shoulders, arms, chest
• Inferior vena cava
  • Drains most of body below diaphragm
• Hepatic portal vein
  • Carries blood draining the digestive system to the liver for purification and storage of absorbed nutrients

The Blood Vessels
An Overview of the Venous System

The Blood Vessels
Major Veins of the Head and Neck

The Blood Vessels
The Venous Drainage of the Abdomen and Chest

The Blood Vessels
A Flow Chart of the Circulation to the Superior and Inferior Venae Cavae

The Blood Vessels
A Flow Chart of the Circulation to the Superior and Inferior Venae Cavae
The Blood Vessels
The Hepatic Portal System

The Blood Vessels
Fetal Circulation
- Placenta
  - Receives two *umbilical arteries* from fetus
  - Drained by one *umbilical vein* to the fetus
    - Joins *ductus venosus* in liver

The Blood Vessels
Fetal Circulation
- Pulmonary bypass
  - Lets blood flow skip the lungs
- *Foramen ovale*
  - Between atria in *interatrial septum*
  - Becomes *fossa ovalis* in adult
- *Ductus arteriosus*
  - Between pulmonary trunk and aorta
  - Both pathways close after birth

The Blood Vessels
Fetal Circulation

Aging and the CV System
Age Related Changes in the Blood
- Decreased *hematocrit*
- Vessel blockage by a *thrombus* (blood clot)
- Pooling in the legs resulting from faulty valves

Aging and the CV System
Age Related Changes in the Heart
- Reduction in maximal cardiac output
- Impaired nodal and conduction function
- Stiffening of *cardiac skeleton*
- Restricted coronary flow due to *atherosclerosis*
- Fibrous replacement of damaged myocardium

Aging and the CV System
Age Related Changes in Blood Vessels
- Embrittlement of arterial walls by *atherosclerosis*
  - Increased risk of aneurism
- Calcium deposits in lumen
• Increased risk of thrombus
• *Thrombus* formation at *atherosclerotic* plaques

**The Integumentary System**
• Stimulation of mast cells produces localized changes in blood flow and capillary permeability
• Delivers immune system cells to injury sites; clotting response seals breaks in skin surface; carries away toxins from sites of infection; provides heat

**The Skeletal System**
• Provides calcium needed for normal cardiac muscle contraction; protects blood cells developing in bone marrow
• Provides calcium and phosphate for bone deposition; delivers EPO to bone marrow, parathyroid hormone, and calcitonin to osteoblasts and osteoclasts

**The Muscular System**
• Skeletal muscle contractions assist in moving blood through veins; protects superficial blood vessels, especially in neck and limbs
• Delivers oxygen and nutrients, removes carbon dioxide, lactic acid, and heat during skeletal muscle activity

**The Nervous System**
• Controls patterns of circulation in peripheral tissues; modifies heart rate and regulates blood pressure; releases ADH
• Endothelial cells maintain blood-brain barrier; help generate CSF

**The Endocrine System**
• Erythropoietin regulates production of RBCs; several hormones elevate blood pressure; epinephrine stimulates cardiac muscle, elevating heart rate and contractile force
• Distributes hormones throughout the body; heart secretes ANP

**The Lymphatic System**
• Defends against pathogens or toxins in blood; fights infections of cardiovascular organs; returns tissue fluid to circulation
• Distributes WBCs; carries antibodies that attack pathogens; clotting response assists in restricting spread of pathogens; granulocytes and lymphocytes produced in bone marrow

**The Respiratory System**
• Provides oxygen to cardiovascular organs and removes carbon dioxide
• RBCs transport oxygen and carbon dioxide between lungs and peripheral tissues

**The Digestive System**
• Provides nutrients to cardiovascular organs; absorbs water and ions essential to maintenance of normal blood volume
• Distributes digestive tract hormones; carries nutrients, water, and ions away from sites of absorption; delivers nutrients and toxins to liver

**The Urinary System**
• Releases renin to elevate blood pressure and erythropoietin to accelerate red blood cell production
• Delivers blood to capillaries, where filtration occurs; accepts fluids and solutes reabsorbed during urine production

**The Reproductive System**
• Sex hormones maintain healthy vessels, estrogen slows development of atherosclerosis
• Distributes reproductive hormones; provides nutrients, oxygen, and waste removal for developing fetus; local blood pressure changes responsible for physical changes during sexual arousal