Chapter 21
Peripheral Circulation and Regulation

Types of Blood Vessels

- **Capillaries**: site of exchange with tissue
- **Arteries**—in dif. Types & sizes
  - Elastic
  - Muscular
  - Arterioles
- **Veins**: thinner walls than arteries, contain less elastic tissue and fewer smooth muscle cells
  - Venules
  - Small veins
  - Medium or large veins
Capillaries

- Capillary wall consists of **endothelial cells** (simple squamous epithelium), basement membrane and a delicate layer of loose C.T.
- Substances move through capillaries by diffusion through
  - Lipid-Soluble and small water-soluble molecules through plasma membrane
  - Larger water-soluble pass through fenestrae or gaps between endothelial cells.

Capillary Network

- Blood flows from arterioles through **metarterioles**, then through capillary network
- Flow through **thoroughfare channel** fairly consistent while flow through arterial capillaries is intermittent
- **Smooth muscle** in arterioles, metarterioles, precapillary sphincters regulates blood flow
Structure of Arteries and Veins

- **Tunica intima**
  - Endothelium
  - Basement membrane
  - Lamina propria (C.T. layer)
  - Internal elastic membrane. Fenestrated layer of elastic fibers.

- **Tunica media**: smooth muscle cells arranged circularly around the blood vessel.
  - **Vasoconstriction**: smooth muscles contract, *decrease* in blood flow
  - **Vasodilation**: smooth muscles relax, *increase* in blood flow

- **Tunica externa (adventitia)**: connective tissue, *varies* from dense regular near the vessel to loose that merges with the surrounding C.T.

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Photomicrograph of Artery and Vein
**Elastic Artery**

- **Elastic or conducting arteries**
  - Largest diameters, pressure high and fluctuates between systolic and diastolic. More elastic tissue than muscle.
  - Relatively thick tunica media, thin tunica intima

**Muscular Artery**

- **Muscular or medium arteries**
  - Smooth muscle allows vessels to regulate blood supply by constricting or dilating
  - (Most of the smaller unnamed arteries)
  - Thick walls due to 25-40 layers of smooth muscle.)
  - Also called distributing arteries because smooth muscle allows vessels to partially regulate blood supply to different regions of the body.
- **Smaller muscular arteries**
  - Adapted for vasodilation and vasoconstriction.
Arterioles

- Transport blood from small arteries to capillaries
- Smallest arteries where the three tunics can be differentiated
- Like small arteries, capable of vasoconstriction and dilation

Medium and Large Veins

- **Medium veins.** Go-between between small veins and large veins.
- **Large veins.** Tunica intima is thin: endothelial cells, relatively thin layer of C.T and a few scattered elastic fibers. Tunica media has circularly arranged smooth muscle cells. Adventitia is predominant layer.
Valves

- Valves found in all veins greater than 2 mm in diameter.
- Folds in intima form two flaps that overlap.
- More valves in veins of lower extremities than in veins of upper extremities.

Nerve Supply

- Small arteries and arterioles innervated to greatest extent
- Some blood vessels innervated by myelinated fibers and act as baroreceptors that monitor stretch and detect changes in blood pressure
Aging of the Arteries

- **Arteriosclerosis**: general term for degeneration changes in arteries making them less elastic
- **Atherosclerosis**: deposition of plaque on walls

Pulmonary Circulation

- From right ventricle into **pulmonary trunk**
- Pulmonary trunk divides into left and right **pulmonary arteries** (TO LUNGS)
- Two **pulmonary veins** exit each lung and enter left atrium (BACK TO HEART)
Systemic Circulation

- **Aorta**: exits left ventricle and is divided into three parts: FROM HERE TO ALL PARTS OF BODY
  - **Ascending aorta**: right and left coronary arteries branch from here
  - **Aortic arch**: arching posteriorly and to the left and has three branches
    - Brachiocephalic artery
    - Left common carotid
    - Left subclavian artery
  - **Descending aorta**
    - **Thoracic aorta**: portion in thorax
    - **Abdominal aorta**: inferior to diaphragm. Ends as two common iliac arteries

Major Arteries--LAB
Head and Neck Arteries

Superficial temporal artery
Posterior auricular artery
Occipital artery
Maxillary artery
Internal carotid artery
External carotid artery
Carotid sinus
Vertebral artery
Common carotid artery
Thyrocvical trunk

Facial artery
Lingual artery
Superior thyroid artery
Subclavian artery
Brachiocephalic artery
Internal thoracic artery

Middle cerebral artery
Part of temporal lobe removed to reveal branches of the middle cerebral artery
Pituitary gland (attachment site)
Posterior cerebral artery
Basilar artery
Vertebral artery
Part of cerebellum removed to reveal branches of the posterior cerebral artery

Anterior communicating artery
Anterior cerebral artery
Internal carotid artery
Posterior communicating artery
Posterior cerebral artery
Superior cerebellar artery
Anterior inferior cerebellar artery
Posterior inferior cerebellar artery
Cerebral arterial circle (circle of Willis)

Inferior view
Arteries of Upper Limb and Shoulder

Arteries of Abdomen
Systemic Circulation: Veins

- Return blood from body to right atrium
- Major veins
  - Coronary sinus (heart)
  - Superior vena cava (head, neck, thorax, upper limbs)
  - Inferior vena cava (abdomen, pelvis, lower limbs)
- Types of veins
  - Superficial, deep, sinuses
Major Veins

Venous Sinuses Associated with the Brain -- FYI
Veins of Head and Neck

Veins of Shoulder and Upper Limb
Inferior Vena Cava and Its Tributaries

Hepatic Portal System

- **Portal system**: vascular system that begins and ends at a capillary bed with no pumping mechanism in between.
- (Hepatic portal, renal portal, and portal between hypothalamus and pituitary)
- Blood entering the hepatic portal vein is rich with nutrients collected from the intestines, but may also contain toxic substances. Both nutrients and toxic substances will be regulated by the liver
  - (Nutrients: either taken up and stored or modified chemically and used by other parts of the body
  - **Biotransformation**: Toxic substances can be broken down by hepatocytes or can be made water soluble. To be transported in blood and excreted by the kidneys.)
Veins of Pelvis and Lower Limb

Dynamics of Blood Circulation

- Interrelationships between
  - Pressure
  - Flow
  - Resistance
  - Control mechanisms that regulate blood pressure and blood flow
Laminar and Turbulent Flow

- **Laminar flow**
  - Streamlined: interior of blood vessel is smooth and of equal diameter along its length
  - Outermost layer moving slowest and center moving fastest

- **Turbulent flow**
  - Interrupted
  - Fluid passes a constriction, sharp turn, rough surface
  - Sounds due to turbulence not normal in arteries; increases the probability of thrombosis

Blood Pressure

- Measure of force exerted by blood against the wall
- Blood moves through vessels because of blood pressure
- Measured by listening for Korotkoff sounds produced by turbulent flow in arteries as pressure released from blood pressure cuff
Blood Flow

- Rate of flow through a tube is expressed as the volume that passes a specific point per unit of time. E.g., cardiac output at rest is 5L/min, thus blood flow through the aorta is 5L/min
- Flow = \( P_1 - P_2/R \)
- Resistance is directly related to B.V. diameter
- \( P_1 \) and \( P_2 \) are pressures in the vessel at points one and two; \( R \) is the resistance to flow
- Directly proportional to pressure differences, inversely proportional to resistance
- Flow decreases when resistance increase and vice versa
- During exercise the flow can increase 5 times!

Viscosity

- A Measure of resistance of liquid to flow
- (Resistance proportionate to flow)
- As viscosity increases, pressure required to flow increases
- Viscosity influenced largely by hematocrit (percentage of RBC)
- Dehydration and/or uncontrolled production of RBCs can lead to increased viscosity which increases the workload on the heart.
Cross-Sectional Area

- As diameter of vessels decreases, the total cross-sectional area increases and velocity of blood flow decreases.
- Much like a stream that flows rapidly through a narrow gorge but flows slowly through a broad plane
- Millions of capillaries—slow there—a good thing BECAUSE…..?

Pressure and Resistance

- Blood pressure averages 100 mm Hg in aorta and drops to 0 mm Hg by the time the blood gets to the right atrium.
- Greatest drop in pressure occurs in arterioles which regulate blood flow through tissues
- No large fluctuations in capillaries and veins
- Muscular arteries regulate flow into a region of the body; arterioles regulate flow into a specific tissue.
Pulse Pressure

• Difference between systolic and diastolic pressures
• Increases when stroke volume increases or vascular compliance decreases.
• Pulse pressure can be used to take a pulse to determine heart rate and rhythmicity
• Most frequent site used to measure pulse rate is in the carpus with the radial artery - the radial pulse.

Fluid Exchange Across Capillary Walls

• Net filtration pressure (NFP) - force responsible for moving fluid across capillary walls. Two forces affect
  • Hydrostatic pressure: physical pressure of blood flowing through the vessels or of fluid in interstitial spaces
  • Osmotic pressure: movement of solutes (plasma or tissue fluid) through a membrane (plasma membrane) in the presence of a non-diffusible solute (large proteins).
Pressure Involved

- **NFP** = Net hydrostatic pressure minus net osmotic pressure
- **Net hydrostatic pressure** = BP-IFP
- **Net osmotic pressure** = BCOP-ICOP where
  - BP = blood pressure
  - IFP = interstitial fluid pressure (lymphatic vessels are pulling in tissue fluid)
  - BCOP = blood colloid osmotic pressure
  - ICOP = interstitial fluid colloid osmotic pressure

Fluid Exchange Across the Walls of Capillaries
Edema and Capillary Exchange

• If capillaries become more permeable, proteins can leak into the interstitial fluid. More fluid moves from the capillaries into the interstitial fluid: edema.
  – Chemicals of inflammation increase permeability
  – Decreases in plasma concentration of protein reduces BCOP; more fluid moves into interstitial fluid
    • Liver disease resulting in fewer plasma proteins
    • Loss of plasma proteins through the kidneys
    • Protein starvation
  – Blockage of veins increases capillary BP;
  – Blockage or removal of lymphatic vessels (blockage: elephantiasis; removal: cancer)

Control of Blood Flow in Tissues

• Local control: in most tissues, blood flow is proportional to metabolic needs of tissues
• Nervous System: responsible for routing blood flow and maintaining blood pressure
• Hormonal Control: sympathetic action potentials stimulate epinephrine and norepinephrine
Local Control of Blood Flow by Tissues

Nervous Regulation of Blood Vessels

- Important in minute-to-minute regulation of local circulation
- Provides a means by which blood can be shunted
- Sympathetic division most important. Innervates all vessels except capillaries
- Vasomotor center in lower pons and upper medulla oblongata.
  - Excitatory part is tonically active. Causes vasomotor tone. Norepinephrine
  - Inhibitory part can cause vasodilation by decreasing sympathetic output
- Sympathetic stimulation of adrenal medulla causes output of norepinephrine and epinephrine
Regulation of Mean Arterial Pressure

- Mechanisms that maintain arterial blood pressure within a normal range of values

- Mean arterial pressure (MAP): slightly less than the average of systolic and diastolic pressures because diastole lasts longer than systole.

- (70 mmHg at birth, 100 mmHg from adolescence to middle age, 110 mmHg in healthy older individuals.)

- MAP = CO(PR), MAP = HR(SV)(PR)
- If any of these go up-- so does MAP.

Short-Term Regulation of Blood Pressure

- **Baroreceptor reflexes**: change peripheral resistance, heart rate, and stroke volume in response to changes in blood pressure

- **Chemoreceptor reflexes**: sensory receptors sensitive to oxygen, carbon dioxide, and pH levels of blood

- **Central nervous system ischemic response**: results from high carbon dioxide or low pH levels in medulla and increases peripheral resistance
Baroreceptor Reflex Control

Adrenal Medullary Mechanism

- Adrenal releases epinephrine and norepinephrine
- Hormones mimic sympathetic stimulation of heart and blood vessels.
CNS Ischemic Response

- Elevation of BP in response to a lack of blood flow to the medulla oblongata.
- Functions in response to emergency situations and BP falls below 50 mmHg
- Neurons of vasomotor center strongly stimulated; increases blood flow to brain if vessels are intact but at the same time, decreases oxygenation of blood because blood does not go to lungs.
- Lack of oxygen causes vasomotor center to become inactive; extensive vasodilation follows with concomitant drop in BP. Death if CNS ischemic response lasts longer than a few minutes.
Long-Term Regulation of Blood Pressure

- Renin-angiotensin-aldosterone mechanism
- Vasopressin (ADH) mechanism
- Atrial natriuretic mechanism
- Fluid shift mechanism
- Stress-relaxation response

Renin-Angiotensin-Aldosterone Mechanism
Vasopressin (ADH) Mechanism

Long-term Mechanisms

- **Atrial natriuretic hormone**: released from cardiac muscle cells when atrial blood pressure increases, simulating an increase in urinary production, causing a decrease in blood volume and blood pressure.
- **Fluid shift**: movement of fluid from interstitial spaces into capillaries in response to decrease in blood pressure to maintain blood volume and vice versa.
- **Stress-relaxation response**: adjustment of blood vessel smooth muscle to respond to change in blood volume. (When blood volume suddenly declines and pressure drops, smooth muscles contract and vice versa.)