Chapter 15
The Cardiovascular System: Blood Vessels and Hemodynamics

- Structure and function of blood vessels
- Hemodynamics
  - forces involved in circulating blood
- Major circulatory routes

Anatomy of Blood Vessels

- Closed system of tubes that carries blood
- Arteries carry blood from heart to tissues
  - elastic arteries
  - muscular arteries
  - arterioles
- Capillaries are thin enough to allow exchange
- Venules merge to form veins that bring blood back to the heart
- Vasa vasorum is vessels in walls of large vessel

Comparative Structure of a Blood Vessel (Fig. 15.1)
Arteries

- Tunica interna (intima)
  - simple squamous epithelium known as endothelium
  - basement membrane
  - internal elastic lamina
- Tunica media
  - circular smooth muscle & elastic fibers
- Tunica externa
  - elastic & collagen fibers
Elastic Arteries

- Largest-diameter arteries have a lot of elastic fibers in the tunica media.
- Help propel blood onward despite ventricular relaxation (stretch and recoil -- pressure reservoir).
Muscular Arteries

- Medium-sized arteries with more muscle than elastic fibers in tunica media
- Capable of greater vasoconstriction and vasodilation to adjust rate of flow
  - walls are relatively thick
  - called distributing arteries because they direct blood flow

Arterioles

- Small arteries delivering blood to capillaries
  - tunica media containing few layers of muscle
- Metarterioles form branches into capillary bed
  - to bypass capillary bed, precapillary sphincters close & blood flows out of bed in thoroughfare channel
  - vasomotion is intermittent contraction & relaxation of sphincters that allow filling of capillary bed 5-10 times/minute

Capillaries form Microcirculation

- Microscopic vessels that connect arterioles to venules
- Found near every cell in the body but more extensive in highly active tissue (muscles, liver, kidneys & brain)
  - entire capillary bed fills with blood when tissue is active
  - lacking in epithelia, cornea and lens of eye & cartilage
- Function is exchange of nutrients & wastes between blood and tissue fluid
- Structure is single layer of simple squamous epithelium and its basement membrane
Types of Capillaries

- Continuous capillaries
  - intercellular clefts are gaps between neighboring cells
  - skeletal & smooth, connective tissue and lungs
- Fenestrated capillaries
  - plasma membranes have many holes
  - kidneys, small intestine, choroid plexuses, ciliary process & endocrine glands
- Sinusoids
  - very large fenestrations
  - incomplete basement membrane
  - liver, bone marrow, spleen, anterior pituitary, & parathyroid gland

Venules

- Small veins collecting blood from capillaries
- Tunica media contains only a few smooth muscle cells & scattered fibroblasts
  - very porous endothelium allows for escape of many phagocytic white blood cells
- Venules that approach size of veins more closely resemble structure of vein
Veins

- Proportionally thinner walls than same diameter artery
  - tunica media less muscle
  - lack external & internal elastic lamina
- Still adaptable to variations in volume & pressure
- Valves are thin folds of tunica interna designed to prevent backflow
- Venous sinus has no muscle at all
  - coronary sinus or dural venous sinuses

Varicose Veins

- Twisted, dilated superficial veins
  - caused by leaky venous valves
    - congenital or mechanically stressed from prolonged standing or pregnancy
  - allow backflow and pooling of blood
    - extra pressure forces fluids into surrounding tissues
    - nearby tissue is inflamed and tender
- Deeper veins not susceptible because of support of surrounding muscles

Anastomoses

- Union of 2 or more arteries supplying the same body region
  - blockage of only one pathway has no effect
    - circle of willis underneath brain
    - coronary circulation of heart
- Alternate route of blood flow through an anastomosis is known as collateral circulation
  - can occur in veins and venules as well
- Alternate routes to a region can also be supplied by nonanastomosing vessels
Blood Distribution

- 60% of blood volume at rest is in systemic veins and venules
  - function as blood reservoir
    - veins of skin & abdominal organs
  - blood is diverted from it in times of need
    - increased muscular activity produces venoconstriction
    - hemorrhage causes venoconstriction to help maintain blood pressure
- 15% of blood volume in arteries & arterioles

Capillary Exchange

- Movement of materials in & out of a capillary
  - diffusion (most important method)
    - substances move down concentration gradient
    - all plasma solutes except large proteins pass freely across
      - through lipid bilayer, fenestrations or intercellular clefs
      - blood brain barrier does not allow diffusion of water-soluble materials (nonfenestrated epithelium with tight junctions)
  - transcytosis
    - passage of material across endothelium in tiny vesicles by endocytosis and exocytosis
      - large, lipid-insoluble molecules such as insulin or maternal antibodies passing through placental circulation to fetus
    - bulk flow see next slide

Venous Return

- Volume of blood flowing back to the heart from the systemic veins
  - depends on pressure difference from venules (16 mm Hg) to right atrium (0 mm Hg)
  - tricuspid valve leaky and buildup of blood on venous side of circulation
- Skeletal muscle pump
  - contraction of muscles & presence of valves
- Respiratory pump
  - decreased thoracic pressure and increased abdominal pressure during inhalation, moves blood into thoracic veins and the right atrium
Syncope

- Fainting or a sudden, temporary loss of consciousness not due to trauma
  - due to cerebral ischemia or lack of blood flow to the brain
- Causes
  - vasodepressor syncope = sudden emotional stress
  - situational syncope = pressure stress of coughing, defecation, or urination
  - drug-induced syncope = antihypertensives, diuretics, vasodilators and tranquilizers
  - orthostatic hypotension = decrease in BP upon standing

Pulse Points

- The circulatory routes for blood flow are parallel.
- Each organ receives its own supply of freshly oxygenated blood.

The two basic routes for blood flow:

- The systemic circulation includes all the arteries and arterioles that carry oxygenated blood from the left ventricle to systemic capillaries.
- The pulmonary circulation carries deoxygenated blood from the right ventricle to the air sacs within the lungs and returns oxygenated blood from the air sacs to the left atrium.
Systemic Circulation

- All systemic arteries branch from the aorta
- All systemic veins drain into the superior or inferior vena cava or coronary sinus to return to the right-side of heart

Arterial Branches of Systemic Circulation

- All are branches from aorta supplying arms, head, lower limbs and all viscera with O2 from the lungs
- Aorta arises from left ventricle (thickest chamber)
  - 4 major divisions of aorta
    - ascending aorta
    - arch of aorta
    - thoracic aorta
    - abdominal aorta
Aorta and Its Superior Branches

- Aorta is largest artery of the body
  - ascending aorta
    - 2 coronary arteries supply myocardium
  - arch of aorta – branches to the arms & head
    - brachiocephalic trunk branches into right common carotid and right subclavian
    - left subclavian & left carotid arise independently
  - thoracic aorta supplies branches to pericardium, esophagus, bronchi, diaphragm, intercostal & chest muscles, mammary gland, skin, vertebrae and spinal cord
Coronary Circulation

- Right & left coronary arteries branch to supply heart muscle
  - anterior & posterior interventricular aa.

Subclavian Branches

- Subclavian aa. pass superior to the 1st rib
  - gives rise to vertebral a. that supplies blood to the Circle of Willis on the base of the brain
- Become the axillary artery in the armpit
- Become the brachial in the arm
- Divide into radial and ulnar branches in the forearm

Common Carotid Branches

- External carotid arteries
  - supplies structures external to skull as branches of maxillary and superficial temporal branches
- Internal carotid arteries (contribute to Circle of Willis)
  - supply eyeballs and parts of brain
Abdominal Aorta and Its Branches

- Supplies abdominal & pelvic viscera & lower extremities
  - celiac aa. supplies liver, stomach, spleen & pancreas
  - superior & inferior mesenteric aa. supply intestines
  - renal aa supply kidneys
  - gonadal aa. supply ovaries and testes
- Splits into common iliac aa at 4th lumbar vertebrae
  - external iliac aa supply lower extremity
  - internal iliac aa supply pelvic viscera

Abdominal Aorta

- The abdominal aorta ends by dividing into the right and left common iliac arteries.
- These, divide into the internal and external iliac arteries.
- The external iliacs become the femoral arteries in the thighs, the popliteal arteries posterior to the knee, and the anterior and posterior tibial arteries in the legs.

Visceral Branches off Abdominal Aorta

- Celiac artery is first branch inferior to diaphragm
  - left gastric artery, splenic artery, common hepatic artery
- Superior mesenteric artery lies in mesentery
  - pancreaticoduodenal, jejunal, ileocolic, ascending & middle colic aa.
- Inferior mesenteric artery
  - descending colon, sigmoid colon & rectal aa
Arteries of the Lower Extremity

- External iliac artery becomes femoral artery when it passes under the inguinal ligament & into the thigh
  - Femoral artery becomes popliteal artery behind the knee.

Veins of the Systemic Circulation

- Drain blood from entire body & return it to right side of heart
- Deep veins parallel the arteries in the region
- Superficial veins are found just beneath the skin
- All venous blood drains to either superior or inferior vena cava or coronary sinus

Major Systemic Veins

- All empty into the right atrium of the heart
  - Superior vena cava drains the head and upper extremities
  - Inferior vena cava drains the abdomen, pelvis & lower limbs
  - Coronary sinus is large vein draining the heart muscle back into the heart
Veins of the Head and Neck

- External and Internal jugular veins drain the head and neck into the superior vena cava
- Dural venous sinuses empty into internal jugular vein

Superficial and Deep Venous Return from Upper Body

- **Superficial veins** are located just deep to the skin and are often visible.
- Deep veins are located deep in the body. They usually accompany arteries and have the same names as the corresponding arteries.
- Both superficial and deep veins have valves, but valves are more numerous in the deep veins.

Veins of Right Upper Limb

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Veins of the Thorax

- The brachiocephalic veins drain most thoracic structures by a network of veins, called the **azygos system**, that runs on either side of the vertebral column.
- The system consists of three veins—the **azygos**, **hemiazygos**, and **accessory hemiazygos veins**.
- Ultimately they empty into the superior vena cava.

Veins of the Thorax, Abdomen and Pelvis

Venous return via the Inferior Vena Cava

- Many small veins enter the inferior vena cava.
- The inferior vena cava does not receive veins directly from the gastrointestinal tract, spleen, pancreas, and gallbladder.
- These organs pass their blood into the **hepatic portal vein**.
- The **superior mesenteric** and splenic veins unite to form the hepatic portal vein.
Venous flow from the lower Limbs

- Blood from the lower limbs is drained by both superficial and deep veins.
- The superficial veins often anastomose with one another and with deep veins along their length.
- Deep veins have the same names as corresponding arteries.
- All veins of the lower limbs have valves, which are more numerous than in veins of the upper limbs.

Venipuncture

- Venipuncture is normally performed at cubital fossa, dorsum of the hand or great saphenous vein in infants

Circulatory Routes

- Systemic circulation is left side heart to body & back to heart
- Hepatic Portal circulation is capillaries of GI tract to capillaries in liver
- Pulmonary circulation is right-side heart to lungs & back to heart
- Fetal circulation is from fetal heart through umbilical cord to placenta & back
Hepatic Portal System

- Subdivision of systemic circulation
- Detours venous blood from GI tract to liver on its way to the heart
- liver stores or modifies nutrients
- Formed by union of splenic, superior mesenteric & hepatic veins

Arterial Supply and Venous Drainage of Liver

Pulmonary Circulation

- Carries deoxygenated blood from right ventricle to air sacs in the lungs and returns it to the left atria
- Vessels include pulmonary trunk, arteries and veins
- Differences from systemic circulation
  - pulmonary aa. are larger, thinner with less elastic tissue
  - resistance to is low & pulmonary blood pressure is reduced
Fetal Circulation

- Oxygen from placenta reaches heart via fetal veins in umbilical cord.
  - bypasses liver
- Heart pumps oxygenated blood to capillaries in all fetal tissues including lungs.
- Umbilical aa. Branch off iliac aa. to return blood to placenta.

Lung Bypasses in Fetal Circulation

- Ductus arteriosus is shortcut from pulmonary trunk to aorta bypassing the lungs.
- Foramen ovale is shortcut from right atria to left atria bypassing the lungs.

Developmental Anatomy of Blood Vessels

- Begins at 15 days in yolk sac, chorion & body stalk
- Masses of mesenchyme called blood islands develop a “lumen”
- Mesenchymal cells give rise to endothelial lining and muscle
- Growth & fusion form vascular networks
- Plasma & cells develop from endothelium
### Aging and the Cardiovascular System

- General changes associated with aging
  - decreased compliance of aorta
  - reduction in cardiac muscle fiber size
  - reduced cardiac output & maximum heart rate
  - increase in systolic pressure
- Total cholesterol & LDL increases, HDL decreases
- Congestive heart failure, coronary artery disease and atherosclerosis more likely