Chapter 19

The Cardiovascular System: Blood Vessels: Part A

Blood Vessels

- Delivery system of dynamic structures that begins and ends at heart
  - **Arteries**: carry blood away from heart; oxygenated except for pulmonary circulation and umbilical vessels of fetus
  - **Capillaries**: contact tissue cells; directly serve cellular needs
  - **Veins**: carry blood toward heart

Structure of Blood Vessel Walls

- Lumen
  - Central blood-containing space
- Three wall layers in arteries and veins
  - **Tunica intima, tunica media, and tunica externa**
- Capillaries
  - **Endothelium** with sparse basal lamina

Tunics

- Tunica intima
  - Endothelium lines lumen of all vessels
    - Continuous with endocardium
    - Slick surface reduces friction
  - **Subendothelial layer** in vessels larger than 1 mm; connective tissue basement membrane

Tunics

- Tunica media
  - – Smooth muscle and sheets of elastin
  - – Sympathetic vasomotor nerve fibers control **vasoconstriction** and **vasodilation** of vessels
    - Influence blood flow and blood pressure

Tunics

- Tunica externa (tunica adventitia)
  - – Collagen fibers protect and reinforce; anchor to surrounding structures
  - – Contains nerve fibers, lymphatic vessels
  - – **Vasa vasorum** of larger vessels nourishes external layer

Blood Vessels

- Vessels vary in length, diameter, wall thickness, tissue makeup
- See figure 19.2 for interaction with lymphatic vessels

Arterial System: Elastic Arteries

- Large thick-walled arteries with elastin in all three tunics
- Aorta and its major branches
- Large lumen offers low resistance
- Inactive in vasoconstriction
- Act as pressure reservoirs—expand and recoil as blood

ejected from heart
- Smooth pressure downstream

Arterial System: Muscular Arteries

- Distal to elastic arteries
  - Deliver blood to body organs
- Thick tunica media with more smooth muscle
- Active in vasoconstriction

Arterial System: Arterioles

- Smallest arteries
- Lead to capillary beds
- Control flow into capillary beds via vasodilation and vasoconstriction

Capillaries

- Microscopic blood vessels
- Walls of thin tunica intima
  - In smallest one cell forms entire circumference
- **Pericytes** help stabilize their walls and control permeability
- Diameter allows only single RBC to pass at a time

Capillaries

- In all tissues except for cartilage, epithelia, cornea and lens of eye

- Provide direct access to almost every cell
- Functions
  - Exchange of gases, nutrients, wastes, hormones, etc., between blood and interstitial fluid

Capillaries

- Three structural types
  1. Continuous capillaries
  2. Fenestrated capillaries
  3. Sinusoid capillaries (sinusoids)

Continuous Capillaries

- Abundant in skin and muscles
  - Tight junctions connect endothelial cells
  - Intercellular clefts allow passage of fluids and small solutes
- Continuous capillaries of brain unique
  - Tight junctions complete, forming blood brain barrier

Fenestrated Capillaries

- Some endothelial cells contain pores (fenestrations)
- More permeable than continuous capillaries
- Function in absorption or filtrate formation (small intestines, endocrine glands, and kidneys)

Sinusoid Capillaries

- Fewer tight junctions; usually fenestrated; larger intercellular clefts; large lumens
- Blood flow sluggish – allows modification
  - Large molecules and blood cells pass between blood and surrounding tissues
- Found only in the liver, bone marrow, spleen, adrenal medulla
- Macrophages in lining to destroy bacteria

Capillary Beds

- **Microcirculation**
  - Interwoven networks of capillaries between arterioles and venules
  - **Terminal arteriole → metarteriole**
  - Metarteriole continuous with **thoroughfare channel** (intermediate between capillary and venule)
  - Thoroughfare channel → **postcapillary venule** that drains bed

Capillary Beds: Two Types of Vessels

- **Vascular shunt** (metarteriole—thoroughfare channel)
  - Directly connects terminal arteriole and postcapillary venule
- **True capillaries**
  - 10 to 100 exchange vessels per capillary bed
  - Branch off metarteriole or terminal arteriole

Blood Flow Through Capillary Beds

- True capillaries normally branch from metarteriole and return to thoroughfare channel
- **Precapillary sphincters** regulate blood flow into true capillaries
  - Blood may go into true capillaries or to shunt
- Regulated by local chemical conditions and vasomotor nerves

Venous System: Venules

- Formed when capillary beds unite
  - Smallest postcapillary venules
  - Very porous; allow fluids and WBCs into tissues
  - Consist of endothelium and a few pericytes
- Larger venules have one or two layers of smooth muscle cells

Veins

- Formed when venules converge
- Have thinner walls, larger lumens compared with corresponding arteries
- Blood pressure lower than in arteries
- Thin tunica media; thick tunica externa of collagen fibers and elastic networks
- Called **capacitance vessels** (blood reservoirs); contain up to 65% of blood supply

Veins

- Adaptations ensure return of blood to heart despite low pressure
  - Large-diameter lumens offer little resistance
  - **Venous valves** prevent backflow of blood
    - Most abundant in veins of limbs
  - **Venous sinuses**: flattened veins with extremely thin walls (e.g., coronary sinus of the heart and dural sinuses of the brain)

Vascular Anastomoses

- Interconnections of blood vessels
- **Arterial anastomoses** provide alternate pathways (**collateral channels**) to given body region
  - Common at joints, in abdominal organs, brain, and heart; none in retina, kidneys, spleen
- Vascular shunts of capillaries are examples of arteriovenous anastomoses
- **Venous anastomoses** are common

Physiology of Circulation: Definition of Terms

- **Blood flow**
  - Volume of blood flowing through vessel, organ, or entire circulation in given period
    - Measured as ml/min
    - Equivalent to cardiac output (CO) for entire vascular system
    - Relatively constant when at rest
    - Varies widely through individual organs, based on needs

Physiology of Circulation: Definition of Terms

- **Blood pressure** (BP)
  - – Force per unit area exerted on wall of blood vessel by blood
    - Expressed in mm Hg
    - Measured as systemic arterial BP in large arteries near heart
  - – Pressure gradient provides driving force that keeps blood moving from higher to lower pressure areas

Physiology of Circulation: Definition of Terms

- **Resistance** (peripheral resistance)
  - – Opposition to flow
  - – Measure of amount of friction blood encounters with vessel walls, generally in peripheral (systemic) circulation
- Three important sources of resistance
  - – Blood viscosity
  - – Total blood vessel length
  - – Blood vessel diameter

Resistance

- Factors that remain relatively constant:
  - – Blood viscosity
    - The "stickiness" of blood due to formed elements and plasma proteins
    - Increased viscosity = increased resistance
  - – Blood vessel length
    - Longer vessel = greater resistance encountered

Resistance

- Blood vessel diameter
  - Greatest influence on resistance
- Frequent changes alter peripheral resistance
- Varies inversely with fourth power of vessel radius
  - E.g., if radius is doubled, the resistance is 1/16 as much
  - E.g., Vasoconstriction → increased resistance

Resistance

- Small-diameter arterioles major determinants of peripheral resistance
- Abrupt changes in diameter or fatty plaques from atherosclerosis dramatically increase resistance
  - Disrupt laminar flow and cause turbulent flow
    - Irregular fluid motion → increased resistance

Relationship Between Blood Flow, Blood Pressure, and Resistance

- Blood flow (F) directly proportional to blood pressure gradient (ΔP)
  - If ΔP increases, blood flow speeds up
- Blood flow inversely proportional to peripheral resistance (R)
  - If R increases, blood flow decreases:

    $F = \Delta P/R$

- R more important in influencing local blood flow because easily changed by altering blood vessel diameter

Systemic Blood Pressure

- Pumping action of heart generates blood flow
- Pressure results when flow is opposed by resistance
- Systemic pressure
  - Highest in aorta
  - Declines throughout pathway
  - 0 mm Hg in right atrium
- Steepest drop occurs in arterioles

Arterial Blood Pressure

- Reflects two factors of arteries close to heart
  - Elasticity (compliance or distensibility)
  - Volume of blood forced into them at any time
- Blood pressure near heart is **pulsatile**

Arterial Blood Pressure

- **Systolic pressure**: pressure exerted in aorta during ventricular contraction
  - Averages 120 mm Hg in normal adult
- **Diastolic pressure**: lowest level of aortic pressure
- **Pulse pressure** = difference between systolic and diastolic pressure
  - Throbbing of arteries (pulse)

Arterial Blood Pressure

- Mean arterial pressure (MAP): pressure that propels blood to tissues
- MAP = diastolic pressure + 1/3 pulse pressure
- Pulse pressure and MAP both decline with increasing distance from heart
- Ex. BP = 120/80; MAP = 93 mm Hg

Capillary Blood Pressure

- Ranges from 17 to 35 mm Hg
- Low capillary pressure is desirable
  - High BP would rupture fragile, thin-walled capillaries
  - Most very permeable, so low pressure forces filtrate into interstitial spaces

Venous Blood Pressure

- Changes little during cardiac cycle
- Small pressure gradient; about 15 mm Hg
- Low pressure due to cumulative effects of peripheral resistance
  - Energy of blood pressure lost as heat during each circuit

Factors Aiding Venous Return

1. **Muscular pump**: contraction of skeletal muscles "milks" blood toward heart; valves prevent backflow
2. **Respiratory pump**: pressure changes during breathing move blood toward heart by squeezing abdominal veins as thoracic veins expand
3. **Venoconstriction** under sympathetic control pushes blood toward heart

Maintaining Blood Pressure

- Requires
  - Cooperation of heart, blood vessels, and kidneys
  - Supervision by brain
- Main factors influencing blood pressure
  - Cardiac output (CO)
  - Peripheral resistance (PR)
  - Blood volume

Maintaining Blood Pressure

- $F = \Delta P/R$; $CO = \Delta P/R$; $\Delta P = CO \times R$
- Blood pressure = CO × PR (and CO depends on blood volume)
- Blood pressure varies directly with CO, PR, and blood volume
- Changes in one variable quickly compensated for by changes in other variables

Cardiac Output (CO)

- CO = SV × HR; normal = 5.0-5.5 L/min
- Determined by venous return, and neural and hormonal controls
- Resting heart rate maintained by cardioinhibitory center via parasympathetic vagus nerves
- Stroke volume controlled by venous return (EDV)

Cardiac Output (CO)

- During stress, cardioacceleratory center increases heart rate and stroke volume via sympathetic stimulation
  - ESV decreases and MAP increases

Control of Blood Pressure

- Short-term neural and hormonal controls
  - Counteract fluctuations in blood pressure by altering peripheral resistance and CO
- Long-term renal regulation
  - Counteracts fluctuations in blood pressure by altering blood volume

Short-term Mechanisms: Neural Controls

- Neural controls of peripheral resistance
  - Maintain MAP by altering blood vessel diameter
    - If low blood volume all vessels constricted except those to heart and brain
  - Alter blood distribution to organs in response to specific

demands

Short-term Mechanisms: Neural Controls

- Neural controls operate via **reflex arcs** that involve
  - **Baroreceptors**
  - Cardiovascular center of medulla
  - Vasomotor fibers to heart and vascular smooth muscle
  - Sometimes input from chemoreceptors and higher brain centers

The Cardiovascular Center

- Clusters of sympathetic neurons in medulla oversee changes in CO and blood vessel diameter
- Consists of cardiac centers and vasomotor center
- Vasomotor center sends steady impulses via sympathetic efferents to blood vessels → moderate constriction called **vasomotor tone**
- Receives inputs from baroreceptors, chemoreceptors, and higher brain centers

Short-term Mechanisms: Baroreceptor Reflexes

- **Baroreceptors** located in
  - Carotid sinuses
  - Aortic arch
  - Walls of large arteries of neck and thorax

Short-term Mechanisms: Baroreceptor Reflexes

- Increased blood pressure stimulates baroreceptors to increase input to vasomotor center
  - Inhibits vasomotor and cardioacceleratory centers, causing arteriolar dilation and venodilation
  - Stimulates cardioinhibitory center
  - → decreased blood pressure

Short-term Mechanisms: Baroreceptor Reflexes

- Decrease in blood pressure due to
  - Arteriolar vasodilation
  - Venodilation
  - Decreased cardiac output

Short-term Mechanisms: Baroreceptor Reflexes

- If MAP low
  - → Reflex vasoconstriction → increased CO → increased blood pressure
  - Ex. Upon standing baroreceptors of **carotid sinus reflex** protect blood to brain; in systemic circuit as whole **aortic reflex** maintains blood pressure
- Baroreceptors ineffective if altered blood pressure sustained

Short-term Mechanisms: Chemoreceptor Reflexes

- Chemoreceptors in aortic arch and large arteries of neck detect increase in CO_2, or drop in pH or O_2
- Cause increased blood pressure by
  - Signaling cardioacceleratory center → increase CO
  - Signaling vasomotor center → increase vasoconstriction

Short-term Mechanisms: Influence of Higher Brain Centers

- Reflexes in medulla
- Hypothalamus and cerebral cortex can modify arterial pressure via relays to medulla
- Hypothalamus increases blood pressure during stress
- Hypothalamus mediates redistribution of blood flow during exercise and changes in body temperature

Short-term Mechanisms: Hormonal Controls

- Short term regulation via changes in peripheral resistance
- Long term regulation via changes in blood volume

Short-term Mechanisms: Hormonal Controls

- Cause increased blood pressure
  - Epinephrine and norepinephrine from adrenal gland → increased

CO and vasoconstriction
  - Angiotensin II stimulates vasoconstriction
  - High ADH levels cause vasoconstriction
- Cause lowered blood pressure
  - Atrial natriuretic peptide causes decreased blood volume by antagonizing aldosterone

Long-term Mechanisms: Renal Regulation

- Baroreceptors quickly adapt to chronic high or low BP so are ineffective
- Long-term mechanisms control BP by altering blood volume via kidneys
- Kidneys regulate arterial blood pressure
  1. Direct renal mechanism
  2. Indirect renal (renin-angiotensin-aldosterone) mechanism

Direct Renal Mechanism

- Alters blood volume independently of hormones
  - Increased BP or blood volume causes elimination of more urine, thus reducing BP
  - Decreased BP or blood volume causes kidneys to conserve water, and BP rises

Indirect Mechanism

- The renin-angiotensin-aldosterone mechanism
  - ↓ Arterial blood pressure → release of renin
  - Renin catalyzes conversion of angiotensinogen from liver to

angiotensin I
  - Angiotensin converting enzyme, especially from lungs, converts angiotensin I to angiotensin II

Functions of Angiotensin II

- Increases blood volume
  - Stimulates aldosterone secretion
  - Causes ADH release
  - Triggers hypothalamic thirst center
- Causes vasoconstriction directly increasing blood pressure

Chapter 19

The Cardiovascular System: Blood Vessels: Part B

Monitoring Circulatory Efficiency

- **Vital signs**: pulse and blood pressure, along with respiratory rate and body temperature
- **Pulse**: pressure wave caused by expansion and recoil of arteries
- **Radial pulse** (taken at the wrist) routinely used
- **Pressure points** where arteries close to body surface
  - Can be compressed to stop blood flow

Measuring Blood Pressure

- Systemic arterial BP
  - Measured indirectly by **auscultatory method** using a **sphygmomanometer**
  - Pressure increased in cuff until it exceeds systolic pressure in brachial artery
  - Pressure released slowly and examiner listens for **sounds of Korotkoff** with a stethoscope

Measuring Blood Pressure

- **Systolic pressure**, normally less than 120 mm Hg, is pressure when sounds first occur as blood starts to spurt through artery
- **Diastolic pressure**, normally less than 80 mm Hg, is

pressure when sounds disappear because artery no longer constricted; blood flowing freely

Variations in Blood Pressure

- Transient elevations occur during changes in posture, physical exertion, emotional upset, fever.
- Age, sex, weight, race, mood, and posture may cause BP to vary

Alterations in Blood Pressure

- **Hypertension**: high blood pressure
  - Sustained elevated arterial pressure of 140/90 or higher
  - **Prehypertension** if values elevated but not yet in hypertension range
    - May be transient adaptations during fever, physical exertion, and emotional upset
    - Often persistent in obese people

Homeostatic Imbalance: Hypertension

- Prolonged hypertension major cause of heart failure, vascular disease, renal failure, and stroke
  - Heart must work harder → myocardium enlarges, weakens, becomes flabby
  - Also accelerates atherosclerosis

Primary or Essential Hypertension

- 90% of hypertensive conditions
- No underlying cause identified
  - Risk factors include heredity, diet, obesity, age, diabetes mellitus, stress, and smoking
- No cure but can be controlled
  - Restrict salt, fat, cholesterol intake
  - Increase exercise, lose weight, stop smoking
  - Antihypertensive drugs

Homeostatic Imbalance: Hypertension

- **Secondary hypertension** less common
  - Due to identifiable disorders including obstructed renal arteries, kidney disease, and endocrine disorders such as hyperthyroidism and Cushing's syndrome
  - Treatment focuses on correcting underlying cause

Alterations in Blood Pressure

- **Hypotension**: low blood pressure
  - Blood pressure below 90/60 mm Hg
  - Usually not a concern
    - Only if leads to inadequate blood flow to tissues
  - Often associated with long life and lack of cardiovascular illness

Homeostatic Imbalance: Hypotension

- **Orthostatic hypotension**: temporary low BP and dizziness when suddenly rising from sitting or reclining position

- **Chronic hypotension**: hint of poor nutrition and warning sign for Addison's disease or hypothyroidism
- **Acute hypotension**: important sign of circulatory shock; threat for surgical patients and those in ICU

Blood Flow Through Body Tissues

- **Tissue perfusion** involved in
  - Delivery of O_2 and nutrients to, and removal of wastes from, tissue cells
  - Gas exchange (lungs)
  - Absorption of nutrients (digestive tract)
  - Urine formation (kidneys)
- Rate of flow is precisely right amount to provide proper function

Velocity of Blood Flow

- Changes as travels through systemic circulation
- Inversely related to total cross-sectional area
- Fastest in aorta; slowest in capillaries; increases in veins
- Slow capillary flow allows adequate time for exchange between blood and tissues

Autoregulation

- Automatic adjustment of blood flow to each tissue relative to its varying requirements
- Controlled intrinsically by modifying diameter of local arterioles feeding capillaries

- Independent of MAP, which is controlled as needed to maintain constant pressure

- Organs regulate own blood flow by varying resistance of own arterioles

Autoregulation

- Two types of autoregulation
  - Metabolic controls
  - Myogenic controls
- Both determine final autoregulatory response

Metabolic Controls

- Vasodilation of arterioles and relaxation of precapillary sphincters occur in response to
  - Declining tissue O_2
  - Substances from metabolically active tissues (H^+, K^+, adenosine, and prostaglandins) and inflammatory chemicals

Metabolic Controls

- Effects
  - Relaxation of vascular smooth muscle
  - Release of NO (powerful vasodilator) by endothelial cells
- **Endothelins** released from endothelium are potent vasoconstrictors
- NO and endothelins balanced unless blood flow inadequate, then NO wins
- Inflammatory chemicals also cause vasodilation

Myogenic Controls

- Myogenic responses keep tissue perfusion constant despite most fluctuations in systemic pressure
- Vascular smooth muscle responds to stretch
  - Passive stretch (increased intravascular pressure) promotes increased tone and vasoconstriction
  - Reduced stretch promotes vasodilation and increases blood flow to the tissue

Long-term Autoregulation

- Occurs when short-term autoregulation cannot meet tissue nutrient requirements
- **Angiogenesis**
  - Number of vessels to region increases and existing vessels enlarge
  - Common in heart when coronary vessel occluded, or throughout body in people in high-altitude areas

Blood Flow: Skeletal Muscles

- Varies with fiber type and activity
  - At rest, myogenic and general neural mechanisms predominate - maintain ~ 1L /minute
  - During muscle activity
    - **Active or exercise hyperemia** - blood flow increases in direct proportion to metabolic activity
    - Local controls override sympathetic vasoconstriction
    - Muscle blood flow can increase 10×

Blood Flow: Brain

- Blood flow to brain constant as neurons intolerant of ischemia; averages 750 ml/min
- Metabolic controls
  - Decreased pH of increased carbon dioxide cause marked vasodilation
- Myogenic controls
  - Decreased MAP causes cerebral vessels to dilate
  - Increased MAP causes cerebral vessels to constrict

Blood Flow: Brain

- Brain vulnerable under extreme systemic pressure changes
  - MAP below 60 mm Hg can cause **syncope** (fainting)
  - MAP above 160 can result in cerebral edema

Blood Flow: Skin

- Blood flow through skin
  - Supplies nutrients to cells (autoregulation in response to O_2 need)
  - Helps regulate body temperature (neurally controlled) – primary function
  - Provides a blood reservoir (neurally controlled)

Blood Flow: Skin

- Blood flow to venous plexuses below skin surface regulates body temperature
  - Varies from 50 ml/min to 2500 ml/min, depending on body temperature
  - Controlled by sympathetic nervous system reflexes initiated by temperature receptors and central nervous system

Temperature Regulation

- As temperature rises (e.g., heat exposure, fever, vigorous exercise)
  - Hypothalamic signals reduce vasomotor stimulation of skin vessels →
  - Warm blood flushes into capillary beds →
  - Heat radiates from skin

Temperature Regulation

- Sweat also causes vasodilation via **bradykinin** in perspiration
  - Bradykinin stimulates NO release
- As temperature decreases, blood is shunted to deeper, more vital organs

Blood Flow: Lungs

- Pulmonary circuit unusual
  - Pathway short
  - Arteries/arterioles more like veins/venules (thin walled, with large lumens)
  - Arterial resistance and pressure are low (24/10 mm Hg)

Blood Flow: Lungs

- Autoregulatory mechanism opposite that in most tissues
  - Low O_2 levels cause vasoconstriction; high levels promote vasodilation
    - Allows blood flow to O_2-rich areas of lung

Blood Flow: Heart

- During ventricular systole
  - Coronary vessels are compressed
    - Myocardial blood flow ceases
    - Stored myoglobin supplies sufficient oxygen
- During diastole high aortic pressure forces blood through coronary circulation
- At rest ~ 250 ml/min; control probably myogenic

Blood Flow: Heart

- During strenuous exercise
  - Coronary vessels dilate in response to local accumulation of vasodilators
  - Blood flow may increase three to four times
    - Important–cardiac cells use 65% of O2 delivered so increased blood flow provides more O2

Blood Flow Through Capillaries

- Vasomotion
  - Slow, intermittent flow
  - Reflects on/off opening and closing of precapillary sphincters

Capillary Exchange of Respiratory Gases and Nutrients

- Diffusion down concentration gradients
  - O_2 and nutrients from blood to tissues
  - CO_2 and metabolic wastes from tissues to blood
- Lipid-soluble molecules diffuse directly through endothelial membranes
- Water-soluble solutes pass through clefts and fenestrations
- Larger molecules, such as proteins, are actively transported in pinocytotic vesicles or caveolae

Fluid Movements: Bulk Flow

- Fluid leaves capillaries at arterial end; most returns to blood at venous end
  - Extremely important in determining relative fluid volumes in blood and interstitial space
- Direction and amount of fluid flow depend on two opposing forces: **hydrostatic** and **colloid osmotic pressures**

Hydrostatic Pressures

- **Capillary hydrostatic pressure** (HP_c) (capillary blood pressure)

– Tends to force fluids through capillary walls
– Greater at arterial end (35 mm Hg) of bed than at venule end (17 mm Hg)

- **Interstitial fluid hydrostatic pressure** (HP_{if})
  – Pressure that would push fluid into vessel
  – Usually assumed to be zero because of lymphatic vessels

Colloid Osmotic Pressures

- **Capillary colloid osmotic pressure** (**oncotic pressure**) (OP_c)
  – Created by nondiffusible plasma proteins, which draw water toward themselves
  – ~26 mm Hg
- Interstitial fluid osmotic pressure (OP_{if})
  – Low (~1 mm Hg) due to low protein content

Hydrostatic-osmotic Pressure Interactions: Net Filtration Pressure (NFP)

- NFP—comprises all forces acting on capillary bed
  – $NFP = (HP_c + OP_{if}) – (HP_{if} + OP_c)$
- Net fluid flow out at arterial end
- Net fluid flow in at venous end
- More leaves than is returned
  – Excess fluid returned to blood via lymphatic system

Circulatory Shock

- Any condition in which

- Blood vessels inadequately filled
- Blood cannot circulate normally

- Results in inadequate blood flow to meet tissue needs

Circulatory Shock

- **Hypovolemic shock**: results from large-scale blood loss
- **Vascular shock**: results from extreme vasodilation and decreased peripheral resistance
- **Cardiogenic shock** results when an inefficient heart cannot sustain adequate circulation

Circulatory Pathways: Blood Vessels of the Body

- Two main circulations
  - **Pulmonary circulation**: short loop that runs from heart to lungs and back to heart
  - **Systemic circulation**: long loop to all parts of body and back to heart

Developmental Aspects

- Endothelial lining arises from mesodermal cells in blood islands
- Blood islands form rudimentary vascular tubes, guided by cues
- Vascular endothelial growth factor determines whether vessel becomes artery or vein
- The heart pumps blood by the 4th week of development

Developmental Aspects

- Fetal shunts (foramen ovale and ductus arteriosus) bypass nonfunctional lungs
- Ductus venosus bypasses liver
- Umbilical vein and arteries circulate blood to and from placenta
- Congenital vascular problems rare

Developmental Aspects

- Vessel formation occurs
  - To support body growth
  - For wound healing
  - To rebuild vessels lost during menstrual cycles
- With aging, varicose veins, atherosclerosis, and increased blood pressure may arise