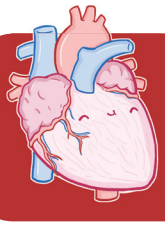

NOTES
SPECIFIC CIRCULATIONS

CEREBRAL CIRCULATION

osms.it/cerebral-circulation

- *Cerebral circulation:* managed almost entirely by local (intrinsic) control (autoregulation; active, reactive hyperemia)
  - ↑ pCO_2 (↑H^+, ↓pH) → arteriolar vasodilation → ↑ blood flow → CO_2 removal (most vasoactive metabolites too big to cross blood-brain barrier → do not affect cerebral tissue
  - Hyperventilation works by same mechanism → ↓ pCO_2 → vasoconstriction (used to reduce swelling in situations of cerebral edema)

CEREBRAL BLOOD SUPPLY SEGMENTATION

- Cerebral blood supply separated into anterior, posterior segments
- Anterior, posterior circulatory segments join via arterial posterior communicating arteries, form circle of Willis
  - Back-up circulation in case of blood vessel occlusion

Anterior segment

- Supplied by internal carotid arteries
- Enter skull in carotid canal, branch out
  - *Ophthalmic arteries:* supply eyes, orbits, forehead, nose
  - *Anterior cerebral artery:* medial part of frontal, parietal lobes; anastomoses with counterpart via anterior communicating artery (part of circle of Willis)
  - *Middle cerebral artery:* supplies lateral sides of temporal, parietal, frontal lobes

Posterior segment

- Supplied by vertebral arteries
- Enter skull through foramen magnum, branch out
  - Right, left vertebral arteries fuse in skull → basilar artery which supplies brainstem, cerebellum, pons
  - *Posterior cerebral arteries:* supply occipital lobes, inferior parts of temporal lobes

CORONARY CIRCULATION

osms.it/coronary-circulation

- *Coronary arteries:* blood vessels delivering oxygenated blood to heart (myocardium)
- *Cardiac veins:* blood vessels retrieving deoxygenated blood from heart

CORONARY ARTERIES

- Two coronary arteries emerge from base of aorta, surround heart in coronary sulcus

Left coronary artery

- Two branches; supplies left atrium, left ventricle, interventricular septum
  - *Circumflex artery:* supplies left atrium, posterior wall of left ventricle
  - *Anterior interventricular artery:* supplies interventricular septum, anterior walls of ventricles

Right coronary artery

- Two branches; supplies right atrium, right ventricle, part of left ventricle, electrical conduction system
  - *Right marginal artery:* supplies lateral right side of heart, superficial parts of ventricle
  - *Posterior interventricular artery:* supplies interventricular septum, posterior walls of ventricles

CORONARY CIRCULATION CONTROL

- Coronary circulation managed primarily by local (intrinsic) control, secondarily by sympathetic nervous system
- ↑ oxygen demand → ↑ blood flow
- Active hyperemia via local (intrinsic) control triggers
  - Hypoxia → build-up of metabolites ADP, AMP → degraded to adenosine (potent vasodilator) → binds to coronary vascular smooth muscle → ↓ calcium influx into cells → vasodilation → ↑ blood flow, oxygen delivery
- Other intrinsic control of vascular tone provided by endothelial factors
  - *Endothelium-derived nitric oxide:* relaxes arterial smooth muscle
  - *Prostacyclin:* vasodilator
  - *Endothelium-derived hyperpolarizing factor (EDHF):* vasodilator
  - *Endothelin 1:* vasoconstrictor
- Reactive hyperemia
  - Brief arterial occlusion period during systole → ↓ blood flow → ↑ O_2 debt → vasodilation during diastole → ↑ blood flow → O_2 demands are met

CONTROL OF BLOOD FLOW CIRCULATION

osms.it/blood-flow

- Blood flow regulation
  - *Intrinsic (local):* humoral, myogenic control
  - *Extrinsic (systemic):* hormonal, neural

LOCAL (INTRINSIC) BLOOD FLOW CONTROL

Mechanisms

- *Humoral:* mediated by vasoactive substances
  - Histamine, nitric oxide (arteriole dilation)
  - Endothelin, serotonin
- *Autoregulation:* maintains constant blood flow via direct control of arterial resistance
  - Present in organs such as kidneys, brain, heart, skeletal muscle (e.g. ↓ coronary artery pressure → compensatory arteriole vasodilation → ↓ vessel resistance → constant blood flow)
- *Active hyperemia:* ↑ blood flow directed to organ/tissue associated with ↑ metabolic activity (e.g. ↑ blood flow in active skeletal muscle)
- *Reactive hyperemia:* temporary ↑ blood flow following ischemia (↓ blood flow) in organ (e.g. arterial occlusion → ↓ blood flow → ↑ O_2 debt → vasodilation, ↑ blood flow)
- Myogenic hypothesis for autoregulation
  - *Focus on arteriolar resistance:* vascular smooth muscle contracts upon stretching (↑ wall tension) and vice versa
  - ↑ blood flow → arteriole stretching → contraction → ↑ resistance → constant blood flow
  - ↓ blood flow → ↓ arteriole stretching → relaxation → ↓ resistance → constant blood flow
  - *Explained by law of Laplace:* ↑ pressure (P) + ↓ radius (r) → tension (T) remains constant ($T=P \times r$)
- Metabolic hypothesis for autoregulation, active, reactive hyperemia
  - O_2 distribution changes in response to O_2 consumption via altering arteriolar resistance
  - ↑ metabolism → ↑ vasodilating metabolites (CO_2, H^+, K^+, lactate, adenosine) → arteriole vasodilation → ↓ resistance → ↑ blood flow, O_2 distribution
  - Certain tissues more susceptible to certain metabolites (coronary circulation—PO_2, adenosine; cerebral circulation—PCO_2)

NEURAL & HORMONAL (EXTRINSIC) CONTROL

- *Neural:* sympathetic nervous system acts on vascular smooth muscle
  - *α1*: vasoconstriction → skin, intestines
  - *β2*: vasodilation → lungs, skeletal muscles
- *Hormonal:* vasopressin released from anterior pituitary → vasoconstriction

MICROCIRCULATION & STARLING FORCES

osms.it/microcirculation-starling-forces

- *Microcirculation:* vascular network involving capillaries, lymphatic vessels

Capillaries

- *Vessels:* thin walls lined with endothelial cells
- Arterioles → metarterioles → capillaries → venules → veins
  - Metarterioles end in precapillary sphincters → smooth muscle ring controls blood flow/capillary exchange rate by constricting/relaxing
  - Capillary blood flow regulated by intrinsic (local), extrinsic (systemic) control

CAPILLARY EXCHANGE

- *Capillaries:* exchange sites for nutrients, waste, fluids between interstitial, vascular space
  - *Afferent blood:* capillaries → interstitial space → tissue
  - *Efferent blood:* tissue → interstitial space → capillaries

Capillary exchange types

- *Simple diffusion:* substance exchange through lipid bilayer/between capillary wall's epithelial cells
  - Depends on driving force (partial pressure gradient), available diffusion area
  - *Driving force:* substances move across their own partial pressure gradient (towards ↓ concentration area)
  - Lipid soluble substances (O_2, CO_2) pass through lipid bilayer
  - Water soluble substances (ions, glucose, amino acids) pass between endothelial cells through fluid-filled intercellular clefts/fenestrations
- *Vesicular transport:* large molecule exchange (proteins) via pinocytic vesicles (caveolae)
  - In some tissues (kidney, intestine) proteins pass through capillary fenestrations
- *Osmosis:* if capillary wall has aqueous pores, pressure gradient across membrane, driven by Starling forces

STARLING FORCES

- Capillary filtration/absorption depend on Starling forces: hydrostatic, colloid osmotic (oncotic) pressure
  - *Filtration:* fluid movement from capillaries → interstitium
  - *Absorption:* fluid movement from interstitium → capillaries

Hydrostatic pressure

- Pressure exerted by fluid against capillary wall
- Capillary hydrostatic pressure (P_c)
  - *Favors filtration:* tends to move fluid out of capillaries
  - Blood pressure ↓ throughout capillary beds → arterial (37mmHg) > venous (17mmHg) pressure
- Interstitial fluid hydrostatic pressure (P_i)
  - *Opposes filtration:* pressure exerted outside capillary wall
  - Tends to move fluid into capillary
  - Contains very little fluid → P_i considered zero, slightly positive/slightly negative (1mmHg)

Colloid osmotic pressure (oncotic pressure)

- *Pressure gradient:* large non-diffusible molecules (e.g. plasma proteins)
  - *Capillary oncotic pressure (π_c) (25mmHg):* created by plasma proteins (primarily albumin; reflection coefficient = 1.0); opposes filtration

- *Interstitial oncotic pressure (π_i) (0mmHg):* contains very little protein; favors filtration

Flow direction

- Arterial end of capillary
  - Blood pressure's outward driving force > inwardly directed oncotic pressure force → fluid moves out of vessel
- Venous end of capillary
  - Oncotic pressure inward driving force > outwardly directed hydrostatic pressure → fluid moves into vessel
- Most fluid leaving capillary at arterial end reenters capillary before leaving venous end
- Fluid remaining in interstitial space recovered by lymphatic vessels
- Fluid movement through capillary wall is dependent on Starling force

Starling equation

- $J_v = K_f [(P_c - P_i) - (\pi_c - \pi_i)]$
  - J_v = fluid movement (mL/min)
  - K_f = hydraulic conductance (wall to water permeability; depends on tissue, wall structure—e.g. fenestrated, non-fenestrated)

LYMPH

- Lymphatic capillaries drain excess fluid + some proteins from interstitial space into venous system
  - Lymphatic capillaries → lymphatic vessels → thoracic duct/right lymphatic duct → subclavian vein
  - One way valves → unidirectional flow

Edema

- Abnormal buildup of fluid in interstitial space
- Causes
  - Imbalance of Starling forces
  - ↑ hydrostatic capillary pressure (↑ volume—e.g. heart failure; obstruction; e.g. thrombosis)
  - ↓ oncotic capillary pressure (↓ plasma protein —e.g. liver failure, malnourishment, nephrotic syndrome
  - ↑ capillary permeability (burns/ inflammation)
  - Impaired drainage (immobility; lack of/ irradiated lymphatic nodes; parasitic infections of lymphatic nodes—e.g. filariasis)