

Circulatory System

Chapter 14

- Functions:
 - Transport material to the cells -
 - Transport material away from cells -
 - Regulation of body systems –
 - Homeostasis
 - Thermoregulation
 - Biochemical control
 - Immunological control
 - Tissue repair

- Components:
 - Muscular pump
 - Arteries
 - Capillaries
 - Veins
 - Blood

- Blood as a Tissue
 - Highly specialized connective tissue
 - Living cells (RBCs, WBCs & others) embedded within a non-living matrix (plasma)
 - Plasma:
 - Water
 - Albumins
 - Globulins
 - Fibrinogen
 - Dissolved/suspended salts, etc.

- Blood cells
 - Erythrocytes (RBCs)
 - Leucocytes (WBCs)
 - Nongranular (mononuclear) leukocytes
 - Granular leukocytes
 - Neutrophils
 - Eosinophils
 - Basophils
 - Thrombocytes
 - Spindle cells
 - Platelets

- Circulatory vessels – derived from embryonic mesenchyme
- All contain endothelium –
 - single layer of specialized epithelium
 - no porous openings
 - regulates passage of all material into and out of blood
 - Capillaries – smallest division of circulatory vessels
 - represent the functional unit of the circulatory system
 - lumen wide enough for single cell passage
 - highly branched & highly invasive
 - # may increase or decrease depending on need

- Capillaries represent the functional part of the circulatory system
- Specialized capillaries:
 - Rete Mirabile – specialized capillary network with function other than circulatory
 - Red organ
 - Glomeruli of kidney
 - Heat sensing organ of pit vipers

- Arteries – carry blood away from heart under high pressure
 - thick wall, narrow lumen
 - endothelium + 3 tunics
 - tunica intima – fibrous elastic tissue
 - tunica media – smooth muscle; concentric
 - tunica adventitia – loose connective tissue
- Veins – carry blood towards heart under very little pressure
 - thin walls, large lumen
 - endothelium + less well developed tunics
 - may contain one-way valves to prevent backflow

- Aortic Arch Evolution (Afferent/Efferent Branchial Arteries)
 - Primitive pattern:
 - Heart → ventral aorta → gills (capillary bed) → dorsal aorta → body
 - Land vertebrates lost gills, but still develop aortic arch system
 - One of the best examples of the Biogenetic Law
 - Aortic arches designated by roman numerals:
 - I = anterior → VI = posterior

- Primitive Jawless Vertebrate - Hypothetical Ancestor to Jawed Vertebrates
 - Ventral Aorta splits into 6 pairs of aortic arches
 - (6 pairs develop embryologically in all gnathosomes)
 - After leaving gills these arches join to form the Dorsal Aorta
 - branched anteriorly
 - portion leading toward head = carotid artery
 - portion leading toward body join to form true dorsal aorta

- Major Subdivisions of Systemic Circulation
 - Somatic Branches:
 - Subclavian & Iliac
 - Visceral Branches:
 - Gastrointestinal tract = celiac, superior & inferior mesenteric
 - Kidneys = renal arteries
 - Body wall = intersegmental arteries
 - Gonads = ovarian/testicular (genital) arteries

- Venous System
 - 4 subsystems:
 - 1) Subintestinal System - connects gut to liver
 - hepatic portal system - similar in all vertebrates
 - collects blood from intestinal capillaries
 - allows liver to collect digested materials
 - insures proper regulation of metabolites
 - hepatic veins - collect blood from liver for transport to the heart
 - fish - drains directly into sinus venosus
 - tetrapods - becomes involved with posterior vena cava

- Venous System
 - 4 subsystems:
 - 2) Cardinal System - dorsal portion of body & head
 - posterior cardinal system - develops as paired vessels in all vertebrates
 - fish - Renal Portal System
 - » carries blood first to the kidneys (no filtration)
 - » exit from kidneys forms posterior cardinal veins
 - tetrapods - Posterior Vena Cava
 - » develops as an extension of the hepatic veins
 - » eventually takes over as renal portal system degenerates
 - » only remnant of posterior cardinals in mammals are the azygous and hemizygous veins
 - anterior cardinal system - paired vessels draining head
 - fish - dump directly into sinus venosus
 - tetrapods - become modified into Jugular system
 - » join with subclavians to form brachiocephalic
 - » involved in formation of superior vena cava

- Venous System
 - 4 subsystems:
 - 3) Lateral Abdominal System - drain ventral body wall
 - 4) Pulmonary System - in lung-breathing vertebrates
 - pulmonary veins returning blood from lungs to heart
 - Blood Supply to Kidneys
 - Agnathans and Mammals
 - entire supply of blood to kidney is arterial (Renal artery)
 - All other vertebrates
 - renal portal system supplies venous blood for reabsorption of water
 - renal arteries supply arterial blood for filtration

- Aortic Arch Evolution
 - Remember, we started out with 6 AAs
 - Chondrichthyan Fish
 - Arch I lost
 - Arch II modified to supply blood to spiracle
 - essentially also becomes the carotid artery
 - Arches III-VI supply dorsal aorta for systemic circulation

- Actinopterygian Fish
 - Arch I lost
 - Arch II retained in some
 - Arches III-VI well developed
 - Internal Carotids comprised of extensions of DA into head
- Sarcopterygian Fish (i.e. lungfish)
 - Arches II-VI retained, but no capillary bed associated with II-IV
 - Arch VI modified on efferent side
 - Goes from gills to lungs = **Pulmonary artery**

- Amphibians
 - Arches I & II lost as adults
 - Arches III - VI always present
 - Arch III - specialized for blood supply to the head
 - Afferent portion of III = **external carotid**
 - Efferent portion of III = **internal carotid**
 - Ventral aorta leading to III = **common carotid**
 - Dorsal aorta between III and IV = **carotid duct**
 - Arch IV = **Systemic** arch
 - Arch V - variable, lost in anurans
 - Arch VI = **Pulmonary artery**
 - **Ductus Arteriosus** = efferent VI (resorbed in most adults)
 - **Pulmocutaneous Artery** = split of pulmonary artery
 - Ventral aorta - split into channels; one for VI, one for III & IV

- Reptiles
 - Ventral aorta split into three trunks
 - (1) pulmonary trunk = AA VI
 - (2) systemic trunk = Left AA IV
 - (3) trunk for right IV and IIIs
 - AA II & V totally lacking
- Birds
 - Derived directly from reptilian system
 - VI = pulmonary
 - Left IV absent
 - Right IV = systemic
 - IIIs = carotid
 - Only two trunks leave the heart - VI and combination of right IV and IIIs

- Mammals
 - Also derived from reptilian, but different group than birds
 - VI = pulmonary
 - Right IV absent
 - Left IV = systemic
 - IIIs = carotid

- Evolution of the Heart

- Primitive Vertebrate Heart = uniflow pump
- 4 successive chambers
 - (1) sinus venosus - receives blood
 - (2) atrium - capable of distension, some muscular action
 - (3) ventricle - highly muscular chamber, major pumping region
 - (4) conus arteriosus - thick walled chamber with small diameter
- Valves
 - Sinoartial valve
 - Atrioventricular valve
 - Semilunar valve
- This basic, single-circuit heart typical of all fish up to lungfish.

- Use of lungs created 4 major changes:

- reduction of sinus venosus
- reduction of conus arteriosus
- development of a septum dividing the atrium
- development of a septum dividing the ventricle
 - Lungfish
 - Atrium - partial septum
 - Ventricle - partial septum
 - Pulmonary vein - enters left side of atrium
 - Ventral Aorta - contains a "spiral valve" to direct blood

- Amphibians

- Atria - complete separation of left and right
 - Left receives oxygenated blood from lungs
 - Right receives deoxygenated blood from body
- Ventricle - no subdivision but large & cavernous (some direction of blood flow)
- Ventral Aorta - spiral valve present

- Reptiles
 - Atria - complete separation
 - Ventricle - incomplete separation in most groups
 - 3 trunks exit the heart
 - VI to lungs from right side of ventricle
 - Left IV has its own exit from right side of ventricle
 - Right IV and IIIs exit from left side of ventricle
 - Crocodilians
 - Have completely separated ventricles
 - Snakes
 - Tendency towards asymmetry
 - Right III absent
 - Left VI (and left lung) absent

- Mammals & Birds
 - Complete 4 chambered hearts
 - VI from right ventricle
 - separate pulmonary circulation
 - IV and III from left ventricle
 - carotid and systemic circulation
 - Note that birds have the right IV, mammals the left IV
