* **Digestive System Part 2**
* Accessory digestive organs
	+ Salivary glands
	+ Liver
	+ Gallbladder
	+ Pancreas
* Liver
	+ Functions: performed by hepatocyte
		- Process nutrients in blood
			* Ex: glucose (in blood plasma) <-> glycogen (stored in hepatocytes)
		- Makes blood proteins
		- Stores fat-soluble vitamins
		- Metabolizes poisons and drugs
		- Produces bile = cholesterol, bile salts, bilirubin
			* Excrete bilirubin (from broken down red blood cells)
			* Emulsify fat: keep fats in smaller globs so enzymes can digest them better -> improves fat digestion
	+ Gross Anatomy:
		- Vessels connect on visceral (posterior) side
		- Hepatic veins: carry blood away, back to heart
		- Porta hepatis: region where other vessels connect to liver
			* Vessels at porta hepatis:
				+ Common hepatic duct: carries bile (out of liver)
				+ Hepatic arteries: blood with oxygen (into liver)
				+ Hepatic portal vein: unique! (into liver)
	+ Blood and lymph flow focusing on liver:
		- Sugars and amino acids:
			* Absorbed by blood capillaries
			* Go directly to liver via hepatic portal vein
		- Lipids:
			* Absorbed by lacteals of lymphatic system
			* Bypass liver
			* Enter blood of veins near heart
	+ Microscopic anatomy:
		- Liver lobules:
			* Functional units = hexagonal unit with plates of liver cells (hepatocytes)
			* Each lobule has:
				+ Central vein: delivers blood to hepatic veins

How blood gets to central vein:

Liver sinusoids: leaky capillaries

Fluid (plasma) flows onto hepatocytes by way of fenestrations (holes)

Also contains hepatic macrophages (Kupffer cells)

* + - * + Portal triad: group of 3 vessels

Contains:

Portal arteriole: branch of hepatic artery

Supplies O2 to liver cells

Portal venule: branch of hepatic portal vein

Brings nutrients from digestive tract for storage and processing

Bile duct:

Carries bile (from hepatocytes) out of liver

How bile gets to bile duct:

Bile canaliculi: between hepatocytes

* + Pathology:
		- Jaundice: yellowing of skin and mucosae
			* Due to excess bilirubin throughout body tissues
			* Due to liver failure
				+ Ex: due to hepatitis = inflammation of liver
	+ Summary of pathway of blood flow:
		- From intestines, etc.: hepatic portal vein -> portal venule -> sinusoid -> central vein -> hepatic vein
		- From heart: hepatic artery -> portal arteriole -> sinusoid -> central vein -> hepatic vein
* Gallbladder
	+ General features:
		- On visceral (posterior) surface of liver
		- Stores and concentrates bile
		- Releases bile to duodenum when stimulated
		- Not essential
	+ Pathway of bile flow:
		- Accumulation of bile between meals: liver -> bile ducts -> common hepatic duct -> common bile duct (closed sphincter so backs up) -> cystic duct -> gallbladder
		- Release of stored bile from gallbladder (to emulsify fats – aid digestion): gallbladder -> cystic duct -> common bile duct -> duodenum
	+ Pathology:
		- Gallstones: mainly cholesterol crystals
			* If gallbladder is removed, common bile duct takes over storage function
* Pancreas
	+ Functions:
		- Exocrine secretions: released into lumen of duodenum
			* Acinar cells: secrete most of body’s digestive enzymes
			* Epithelium of small ducts: secrete bicarbonate to neutralize stomach acid
		- Endocrine secretions: released into blood
			* Pancreatic islet cells: secrete insulin and glucagon
				+ Hormones controlling storage of glucose and its release into the blood

For example at the liver

* + Gross anatomy:
		- Located posterior to stomach
		- Pancreatic duct(s): empties into lumen of duodenum
* **Respiratory System**
* Function
	+ Respiration: exchange of gases (oxygen and carbon dioxide) with the environment
		- Consists of 4 processes:
			* Ventilation: move air in/out of lungs (active process)
			* External respiration: gas diffuses between lungs and blood (passive process)
				+ Two above processes are functions of respiratory system
			* Gas transport via blood (active process)
			* Internal respiration: gas diffuses between blood and cells (passive process)
				+ Two above processes are functions of cardiovascular system
* Zones
	+ Conducting zone: passageways for air, no diffusion
		- Ventilation: external nose through most tubes in lungs
	+ Respiratory zone: the anatomical zone where oxygen diffuses into blood
		- External respiration
			* Pulmonary alveoli
			* Respiratory bronchioles
* Walls of conducting zone
	+ Layers: mucosa, submucosa (some organs have other too)
		- Mucosa contains:
			* Epithelium:
				+ Areas exposed to food: nonkeratinized stratified squamous
				+ Most areas: pseudostratified ciliated columnar

Major function: removing debris

* + CT: lamina propria
	+ Glands secrete mucus to trap debris:
		- Goblet cells (1 celled glands): in mucosal epithelium
		- Seromucous glands: in lamina propria and submucosa
* Organs of respiratory system
	+ External nose:
		- External nares: nostrils (entrance/exit)
	+ Nasal cavity:
		- Nasal septum separates left and right nasal cavities
		- Epithelium: pseudostratified ciliated columnar
		- Debris are swept posteriorly to be swallowed
		- Highly vascularized lamina propria: warms and moistens the inspired air
	+ Paranasal sinuses: paired air spaces in the bones of the skull
		- Connect to nasal cavities by drainage ducts
		- Warm and moisten the inspired air
		- Sinusitis: sinus infection
	+ Pharynx: where respiratory/digestive tracts intersect
		- Divisions of pharynx:
			* Nasopharynx: nasal cavity (pseudostratified ciliated columnar)
			* Oropharynx: oral cavity (stratified squamous)
			* Laryngopharynx: larynx and esophagus (stratified squamous)
		- During swallowing soft palate folds upward to seal of nasopharynx
	+ Larynx:
		- Functions:
			* Gateway to the lungs
			* Speech (voicebox)
		- Structures: most are hyaline cartilage
			* Thyroid cartilage:
				+ Laryngeal prominence: Adam’s apple (larger in males)
			* Cricoid cartilage: inferior to thyroid cartilage
			* Arytenoid cartilage: attached to back of cricoid cartilage (A like shape of cartilage)
			* Epiglottis: swallowing elevates the larynx -> epiglottis passively tilts down -> laryngeal inlet (opening) closes
				+ Elastic cartilage
			* Vocal folds: true vocal cords
				+ Vibrated by the air to produce sound
				+ Rima glottides: opening between vocal folds
				+ Glottis: rima glottides + vocal folds
				+ Attached directly to thyroid cartilage (at anterior end) and arytenoid cartilages (at posterior end)

Open/close by moving arytenoid cartilages in transverse plane

* + - * + Control of pitch: cricoid cartilage moves in sagittal plane (around joint between cricoid and thyroid)

Carries arytenoid cartilages along

Increases tension in vocal folds -> higher pitch

* + - * Vestibular folds: false vocal cords
				+ Superior to vocal folds
				+ No direct role in most sound production
				+ Important for holding breath against pressure in the thoracic cavity
			* Epithelium:
				+ Superior larynx: occasional contact with food

Stratified squamous

* + - * + Inferior larynx (below vocal folds):

Pseudostratified ciliated columnar

* + Trachea:
		- Location: in mediastinum
		- Tissues:
			* Epithelium: pseudostratified cilated columnar
			* Rings of hyaline cartilage to prevent collapse
			* Smooth muscle
			* Elastic CT: for elastic recoil (more efficient ventilation)
			* NOTE: Same tissues continue through most of the conducting zone
	+ Primary bronchi:
		- First part of the bronchial tree
		- The only bronchi outside the lungs
		- Location: in mediastinum
	+ Lungs:
		- Contains:
			* Most of bronchial tree (except for primary bronchi): part of the conducting zone
			* Pulmonary alveoli: most of the respiratory zone
		- Pleurae: serous membranes surrounding the lungs (superficial to deep)
			* Parietal pleura (outer pleura)
			* Pleural cavity: space
				+ Contains pleural fluid
				+ Slight vacuum is important for breathing
			* Visceral pleura: inner pleura
		- Divisions of the lungs:
			* Lobes:
				+ Left lung: 2 lobes
				+ Right lung: 3 lobes
			* Bronchopulmonary segments (parts of lobes):
				+ About 10 per lung
		- Bronchial tree:
			* Connects trachea to alveoli
			* Right and left primary (main) bronchi (outside lung)
			* Second lobar bronchi (1 per lobe)
			* Tertiary (segmental) bronchi (1 per bronchopulmonary segment)
			* Bronchioles (<1mm wide)
				+ Terminal bronchioles: end of conducting zone
				+ Respiratory bronchioles: start of respiratory zone (attached to alveoli)
			* Pathologies:
				+ Asthma: allergic inflammation

Smooth muscle of bronchioles contracts

Increased mucus secretion

* + - Respiratory zone:
			* Pulmonary alveoli: where gas exchange occurs by diffusion
			* Covered with pulmonary capillaries
			* Very short diffusion distance
			* Very large surface area
			* No mucus! (would slow down diffusion)
			* Pathologies:
				+ Emphysema: walls between alveoli break down -> decreased surface area
			* Alveolar macrophages: trap dust
			* Cells of alveolar wall:
				+ Type I cells: main component of alveolar lining

Simple squamous epithelium

Thinnest for diffusion

* + - * + Type II cells:

Simple cuboidal epithelial cells

Secrete surfactant: molecule that decreases surface tension of water (allows alveoli to expand)

Respiratory Distress Syndrome:

Common in premature infants

Insufficient surfactant produced

Difficult to expand alveoli

* Ventilation
	+ Breathing
	+ Inspiration:
		- Active process
		- Diaphragm and external intercostals contract -> increase thoracic volume -> decrease pressure in lungs -> air enters
	+ Expiration:
		- Passive process: muscles relax
		- Tissues recoil (elastic CT)
	+ Pathologies:
		- Pneumothorax: presence of air in the pleural cavity
			* Causes lung collapse
* **Cardiovascular System**
* Function
	+ Transport and deliver (via the blood):
		- Nutrients and metabolic waste
		- O2 and CO2
		- Hormones
		- Heat, etc.
* Circulatory routes
	+ Pulmonary circuit:
		- Delivers blood to and from the lungs
			* For external respiration
	+ Systemic circuit:
		- Delivers blood to and from the rest of the body
			* For internal respiration
* General circulatory principles
	+ Capillary beds: where exchange takes place
	+ Artery: delivers blood from the hear to the capillary beds
		- Most arteries have oxygenated blood but not all
	+ Vein: delivers blood from capillary beds
		- Back to the heart (most veins)
		- Or to another capillary bed
			* Portal veins
		- Most veins have deoxygenated blood but not all
		- Hepatic portal system
* The heart
	+ A muscular pump that circulates the blood
	+ Four-chambered
	+ Surrounded by pericardial cavity
	+ Coverings of heart (superficial to deep):
		- Enclosed in pericardium
		- Fibrous pericardium (outer): not serosa
		- Parietal layer of serous pericardium
		- Pericardial cavity: contains serous fluid
		- Visceral layer of serous pericardium (epicardium)
	+ Pathologies:
		- Cardiac tamponade: compression of the heart due to excess fluid in pericardial cavity
	+ Wall of heart (outer to inner):
		- Epicardium (visceral layer of serous pericardium)
		- Myocardium: cardiac muscle
		- Endocardium:
			* Epithelium: simple squamous (endothelium)
			* Lines inner heart (including valves)
	+ Chambers and vessels:
		- Overview of heart, chambers, valves, and vessels (diagram)
		- Atria: receive blood from veins
			* Right atrium: receives deoxygenated blood from:
				+ Inferior and superior vena cava
				+ Coronary sinus: returns blood from heart tissue
			* Left atrium: receives oxygenated blood from:
				+ Pulmonary veins
		- Ventricles: eject blood from heart
			* Right ventricle: pumps deoxygenated blood to:
				+ Pulmonary trunk -> pulmonary arteries
			* Left ventricle: pumps oxygenated blood to:
				+ Aorta

Coronary arteries (supplying blood to heart tissues) are branches of aorta

* \* A to V: arteries before veins, atria before ventricles
	+ Heart valves: prevent backflow of blood
		- Atrioventricular valves (AV valves): between atrium and ventricle
			* Tricuspid valve (R AV): between R atrium and ventricle
			* Bicuspid valve (L AV, mitral): between L atrium and ventricle
			* Chordae tendinae:
				+ Hold valved in place
				+ Anchored to papillary muscles
				+ Prevents eversion (prolapse)
			* Try before you buy
		- Semilunar valves (SL valves): between great arteries and ventricles
			* Aortic SL valve: between left ventricle and aorta
			* Pulmonary SL valve: between right ventricle and pulmonary trunk
		- Heart sounds in each heart beat:
			* First sound (“lub”): closing of both AV valves when ventricles begin contracting
			* Second sound (“dup”): closing of both SL valves when ventricles being relaxing
	+ Conducting system:
		- Heart muscle has intrinsic rhythm
		- Conducting system: specialized cardiac muscle cells
			* Initiates electrical signal (“firing”)
			* Signals heart chambers to contract in proper sequence
			* Signal spreads from one cardiac muscle cell to another through gap junctions
		- Sequence of conduction:
			* 1. Sinoatrial node (SA node): pacemaker
				+ NOTE: All cardiac muscle cells can spontaneously fire, but SA node cells have fastest rate
			* 2. Atrioventricular node (AV node)
			* 3. Bundle of His (AV node)
			* 4. Bundle of branches
			* 5. Purkinje fibers
		- Disorders of conducting system:
			* Heart block: damage to AV node or Bundle of His (only path from atria to ventricles)
				+ Signal doesn’t reach ventricles: ventricles still beat but at slower pace
				+ Artificial pacemaker restores normal function
* Blood
	+ A type of connective tissue
	+ Components of blood:
		- Plasma: fluid with dissolved nutrients, etc.
		- Erythrocytes (red blood cells): carry oxygen
		- Leukocytes (white blood cells): immune cells
		- Platelets: cell fragments for clot formation
* Blood vessels
	+ Function of blood vessels:
		- Capillary: allows diffusion between blood and other tissues
		- Artery: carries blood away from heart
		- Vein: carries blood away from capillaries
			* Eventually back to heart
	+ General structure of blood vessel wall:
		- Tunica intima:
			* Has endothelium: simple squamous
		- Tunica media:
			* Smooth muscle, collagen, elastin – all circularly arranged
		- Tunica externa:
			* Collagen, elastin – all longitudinally arranged
		- Arteries:
			* Structure (compared to veins and capillaries)
				+ Subject to highest pressure
				+ Thicker walls

Mainly due to thicker tunica media

* + - * + More elastic
			* Types of arteries:
				+ Elastic arteries: conducting arteries

Largest arteries: 1 cm – 1 inch wide

Thick wall, highest elastin content

Very elastic: smoothes out pressure fluctuations

* + - * + Muscular arteries:

Most of the named arteries

0.3 mm – 1 cm

Thickest tunica media relative to vessel diameter

Regulate blood pressure and distribution

* + - * + Arterioles:

Smallest arteries: 0.1 – 0.3 mm

Regulate blood pressure and distribution

* + - Capillaries:
			* Structure: facilitates diffusion
				+ Wall only has tunica intima (mostly endothelium)

Very thin wall

* + - * + Tiny: capillary diameter < 0.01 mm wide

All blood in capillary is close to wall

* + - * + Many branches: large surface area
			* Capillary beds:
				+ Precapillary sphincters open when tissue is active:

Lets blood into capillaries

* + - * + Precapillary sphincters close when tissue inactive:

Shuts off exchange

Blood still travels across through metarteriole and thoroughfare channel

* + - * Types of capillaries:
				+ Continuous capillaries:

Many tight junctions between endothelial cells

In brain:

Completely sealed by tight junctions

All molecules must go across membrane of endothelial cell

Least leaky of all

Blood-brain barrier

In most organs (muscles, lungs, skin, etc.):

Not completely sealed by tight junctions

Small molecules can pass through intercellular clefts (where tight junctions are absent)

* + - * + Fenestrated capillaries:

Have fenestrations: holes through endothelial cells (in other aspects, similar to continuous capillaries)

Allows more rapid exchange of small molecules

Kidney, endocrine glands, intestines, synovial membrane (places where filtration most important)

* + - * + Discontinuous capillaries:

Have fenestrations

Intercellular clefts are large (very few tight junctions)

Allows exchange of proteins and cells, lots of fluid

Liver, lymphoid organs (spleen, bone marrow)

* + - Veins:
			* Structure:
				+ Very low pressure system
				+ Thinner wall than arteries:

Less smooth muscle and elastin (collapsible)

* + - * + Larger lumen than arteries:

Blood reservoir

65% of total body blood

* + - * + Have valves to prevent backflow of blood
			* Types of veins:
				+ Venules (small veins):

Receive blood from capillaries

* + - * + Veins (other than venules):

Receive blood from venules

Portal veins: deliver blood from capillary bed to capillary bed

Ex: hepatic portal vein

* + - * Mechanisms of enhancing venous return:
				+ Return of blood to heart is slow because of low pressure -> need way to enhance blood return to heart

Ex: skeletal muscular pump

Pressure changes (and valves) dive blood back to heart

* **Lymphatic and Immune Systems**
* Lymphatic system
	+ Function:
		- A system of vessels and nodes that returns excess tissue fluid to the blood
		- Needed because plasma tends to leak out of blood capillaries
		- NOTE: Most cells get oxygen and nutrients directly from interstitial fluid (tissue fluid)
		- Filters pathogens to be targeted by immune system
	+ Pathway of flow:
		- Throughout most of body, tissue fluid (interstitial fluid) enters lymphatic capillaries
			* The fluid is now called lymph
		- Moves through lymph vessels and lymph nodes
			* Blood plasma -> tissue fluid -> lymph
		- Returned to the blood at veins at the base of the neck
	+ Structures:
		- Very low pressure system:
			* Uses valves to maintain flow direction
		- Lymphatic capillaries:
			* Wall: endothelium (simple squamous epithelium)
			* Minivalves:
				+ Formed by loose edges of cells
		- Large lymph vessels:
			* Has valves (similar to those of veins)
		- Lymph nodes:
			* Contains reticular CT (with reticular fibers)
			* Lymph flows through
			* Pathogens are filtered out by immune cells
	+ Pathology:
		- Lymphedema: accumulation of interstitial fluid due to poor lymphatic drainage
			* Ex: elephantiasis (extreme)
				+ Caused by parasitic worm
* Immune system
	+ Function:
		- A system of cells, tissues, and organs that is dispersed widely throughout the body to defend against pathogens
	+ Cells:
		- Leukocytes: white “blood” cells
			* Examples:
				+ Macrophages:

Engulf foreign material/debris

NOT specific to one type of antigen

Presents antigen on cell surface

* + - * + Lymphocytes:

Recognizes and attacks one specific type of antigen

Must be activated first

Ex: by macrophage

* + Tissues and organs:
		- Lymphoid tissue: reticular CT with lots of lymphocytes
			* Common in places where pathogens may enter
			* Ex: MALT (mucosa associated lymphoid tissue)
		- Lymphoid organs: mostly lymphoid tissue
			* Primary lymphoid organs:
				+ Where lymphocytes are made
				+ Thymus and red bone marrow
			* Secondary lymphoid organs:
				+ Contain mature lymphocytes
				+ Lymph nodes
				+ Spleen
				+ Tonsils
				+ Appendix
				+ Peyer’s patches
* **Nervous System**
* Function
	+ Receive sensory input: monitor changes inside and outside the body
	+ Integration (most complex): processes and interprets sensory input
	+ Motor output: causes a response by activating effector organs (muscle or gland)
	+ Properties:
		- All cells are naturally charged
		- Nervous tissue: uses electrical charge for rapid communication
* Organization
	+ Central nervous system (CNS):
		- Brain
		- Spinal cord
	+ Peripheral nervous system (PNS): nerves and ganglia
		- Regional divisions:
			* Spinal nerves: nerves that transmit signals to and from spinal cord
			* Crania nerves: nerves that transmit signals to and from brain
		- Functional divisions: they are all connected!
			* Afferent (sensory): carries impulses to CNS
				+ Somatic sensory: monitors external environment, skin, body wall, limbs
				+ Visceral sensory: monitors visceral organs
			* Efferent (motor): carries impulses to effector organs
				+ Somatic motor (usually voluntary):

To skeletal muscle

* + - * + Visceral motor (involuntary): autonomic nervous system

To cardiac and smooth muscle, glands

Sympathetic: “fight or flight”

Parasympathetic: “rest and digest”

* Histology of nervous system
	+ Neurons: nerve cells – but NOT always found in nerves
		- Properties:
			* Function: rapid transmission and integration of signals
			* Specialized for conducting electrical impulses
			* Cannot divide after birth: BUT new neurons can be generated from stem cells
		- Anatomy of a typical (multipolar) neuron:
			* Cell body (soma):
				+ Contains nucleus
			* Dendrites:
				+ Receive signals from other cells
				+ Send signals to cell body
			* Axon:
				+ Receives signals from axon hillock of cell body
				+ Axon terminals: transmit signal to other neurons
				+ Myelin sheath:

Made of glial cells

Insulates axons from each other

Speeds up signal

* + - * + Nodes of Ranvier: gaps in myelin
			* Synapse: site of neuron-neuron communication
				+ Most are chemical, using neurotransmitter that diffuses across synaptic cleft
				+ Some are electrical, using gap junctions
		- Pathology:
			* Multiple sclerosis: an autoimmune disease of the CNS
				+ Results in damage to both myelin and axons
		- Types of neurons
			* Functional classification:
				+ Sensory (afferent) neurons:

Carry signals to CNS

Make up the sensory division of PNS

NOTE: axon terminal is (typically) in CNS

* + - * + Motor (efferent) neurons:

Carry signal from CNS to effector

Make up the motor division of PNS

NOTE: cell body is (typically) in CNS

* + - * + Interneurons: between sensory and motor neurons

Found entirely within CNS

* + - * Structural classification:
				+ Multipolar (many things to cut):

Many processes

Most neurons (typical)

* + - * + Bipolar (two things to cut):

One axon, one fused dendrite

Found in some sensory organs

* + - * + Unipolar/pseudounipolar (one thing to cut):

Typical sensory neurons

Receptive endings, no dendrites

Axon with peripheral and central processes

* + Neuroglia/glia: support cells
		- Properties:
			* Don’t send nervous signals
			* Outnumber neurons
			* Continue dividing through out life
				+ Most brain cancers are gliomas: tumors of glial cells
		- Types:
			* Found in CNS only:
				+ Oligodendrocytes: forms myelin sheath
				+ Astrocytes: most abundant, controls environment around neurons
				+ Microglia: immune cells
				+ Ependymal cells: lines fluid-filled cavities, propels fluid
			* Found in PNS only:
				+ Schwann cells: forms myelin sheath
				+ Satellite cells: controls environment around neuron cell bodies
	+ Histology of gross anatomy:
		- Nerve: group of axons traveling together in the PNS
			* Nerve anatomy (deep to superficial):
				+ Endoneurium: surrounds axon
				+ Perineurium: surrounds each subgroup of axons
				+ Epineurium: wraps around outside of nerve
				+ Fascicle: subgroup of axons
			* Nerves vs. neurons:
				+ Each nerve contains the axons of many neurons
				+ Axons are also called nerve fibers
				+ Axons carry signals toward the axon terminals
				+ Most nerves carry signals in both directions because contain neurons oriented in both directions

Only exceptions are some cranial nerves

* + - Ganglion: collection of neuron cell bodies in PNS
		- Grey and white matter: general types of nervous tissue in CNS
			* White matter: myelinated axons
			* Gray matter: everything else = unmyelinated axons, dendrites, cell bodies
		- Tract: collection of axons traveling together inside the CNS
			* White matter
		- Nucleus: collection of neuron cell bodies inside the CNS
			* Gray matter
* Brain
	+ Complexity:
		- 100 billion neurons
		- Many synapses per neuron
	+ Development:
		- Neural tube: fluid filled
		- Primary brain vesicles:
			* Prosencephalon: forebrain
			* Mesencephalon: midbrain
			* Rhombencephalon: hindbrain
		- Secondary brain vesicles:
			* Forebrain:
				+ Telencephalon
				+ Diencephalon
			* Midbrain:
				+ Mesencephalon
			* Hindbrain:
				+ Metencephalon
				+ Myelencephalon
		- Adult brain structures (rostral to caudal):
			* Telencephalon: cerebrum
			* Diencephalon: diencephalon
			* \*Mesencephalon: midbrain
			* \*Metencephalon (they “met”):
				+ Pons
				+ Cerebellum
			* \*Myelencephalon: medulla oblongata
			* \* = brain stem
		- Ventricles: fluid-filled cavities
			* Lateral ventricles in cerebrum
			* Third ventricle in diencephalon
			* Cerebral aqueduct in midbrain
			* Fourth ventricle between pons, cerebellum, medulla oblonglata
	+ Cerebrospinal fluid:
		- CSF: fluid that fills ventricles
			* Cushions brain
			* Transports nutrients, wastes, other chemicals
		- Choroid plexus:
			* Found in all 4 ventricles
			* Produces the CSF
			* Contains:
				+ Capillaries: produce CSF by filtration
				+ Ependymal cells: modify CSF
		- Circulation of CSF: propelled by cilia of ependymal cells
			* Produced in later ventricles
			* 3rd ventricle (also makes CSF)
			* Cerebral aqueduct
			* 4th ventricle (also makes CSF)
				+ Central canal of spinal cord (some CSF)
			* Apertures
			* Subarachnoid space
			* Arachnoid villi
			* Dural sinuses (combines with blood from veins)
			* Internal jugular veins
			* Back to heart
	+ Meninges: 3 layers of CT surrounding the CNS
		- Protect the CNS
		- Contains a portion of the CSF
		- Dura mater: outer layer (“tough mother”)
			* Periosteal layer (outer): periosteum
			* Meningeal layer (inner)
			* Dural sinus: space between these layers that carries blood
				+ Functions as a vein
		- Arachnoid mater: middle layer (“spidery mother”)
			* Subarachnoid space: contains CSF and large blood vessels
		- Pia mater: inner layer (“gentle mother”)
			* Carries small blood vessels to nervous tissue
	+ Pathologies:
		- Spina bifida:
			* Neural tube fails to close completely
			* Can result in partial paralysis and risk of infection
		- Hydrocephalus
			* Buildup of excess CSF in the brain