

Biology 112

Study Notes Exam 4

Chapter 9: The Nervous System

Introduction

- **neurons: nerve cells;** structural & functional units of nervous system
 - o specialized to react to physical & chemical stimuli
 - o transmit *nerve impulses* (information in the form of electrochemical changes) to other neurons & cells outside nervous system
 - o 3 structural parts of neuron: cell body (soma), dendrites & axon
 - o **cell body:** rounded area of neuron containing nucleus & most organelles
 - o **dendrites:** extensions from cell body that *receive* electrochemical messages
 - o **axon:** long process from cell body that *transmits* nerve impulse
- **nerves:** bundles of axons
- **neuroglial cells:** *supporting cells* of nervous system
 - o provide physical support, insulation & nutrients for neurons
 - o during development, guide differentiation of neurons
- 2 major divisions of nervous system:
 - o **central nervous system (CNS):** brain & spinal cord
 - o **peripheral nervous system (PNS):** peripheral nerves that connect CNS with other body regions
- nervous system provides 3 general functions: *sensory, integrative & motor*

General Functions of the Nervous System

- **sensory input:** *sensory receptors* detect internal stimuli (temperature, oxygen levels, etc.) & external stimuli (light, sound, etc.), & send information as nerve impulses along peripheral nerves to central nervous system
- **integration:** nervous system processes information & makes decisions (conscious or subconscious) for appropriate responses
- **motor output:** motor neurons carry information about decision to *effectors* (muscle cells, glands) to generate response
 - o **somatic nervous system:** controls effectors that are voluntary (conscious), the skeletal muscles
 - o **autonomic nervous system:** controls effectors that are involuntary, including smooth muscle, cardiac muscle & glands

Neuroglial Cells:

- in CNS, includes microglial cells, oligodendrocytes, astrocytes & ependymal cells
- **microglial cells:** small ovoid cells with long "thorny" processes that contact neurons
 - o can transform into *phagocytic* cells & engulf/break down bacteria & cell debris
- **oligodendrocytes:** wrap processes around axons of thicker neurons of CNS for insulation - produce *myelin sheath* of CNS neurons
- **astrocytes:** star-shaped; most abundant & versatile neuroglial cells
 - o anchor neurons to capillaries & aid in exchange & permeability

- regulate concentrations of nutrients & ions within nervous tissue
- form scar tissue that fills spaces following injury to CNS
- **ependymal cells:** shape varies from squamous to columnar; many are *ciliated*
 - form epithelia-like membrane lining central cavities of brain (ventricles) & spinal cord (central canal)
 - cilia circulate CSF (CSF is secreted by capillaries of *choroid plexuses*)
- in PNS, Schwann cells
- **Schwann cells:** form myelin sheath of PNS neurons

Neurons

- extreme longevity; high metabolic rate
- most neurons are **amitotic** (some olfactory & hippocampal neurons can divide)
- 3 structural & functional parts of neuron: cell body (soma), dendrites & axon
- **cell body:** contains granular cytoplasm, cell membrane, many organelles (Golgi complex, lysosomes & large numbers of mitochondria) and a network of neurofibrils that extend into axon & dendrites
- **chromatophilic substance** (Nissl bodies): rough endoplasmic reticulum of neuron
- large nucleus with nucleolus near center of cell body
- short, branched **dendrites** & adjacent cell body membrane make up receptive surface of neuron; communication with axons of other neurons
- **axon** conducts impulses away from cell body; axon arises from elevation of cell body called **axon hillock**
- larger axons of peripheral neurons enclosed in **myelin sheath** composed of many Schwann cells
 - Schwann cells wrap tightly around axon; membrane of Schwann cells has insulating lipid called myelin
 - **neurilemma:** bulge of plasma membrane with nucleus & most of cytoplasm of Schwann cell just external to myelin sheath
 - **nodes of Ranvier:** gaps in myelin sheath between adjacent Schwann cells
 - **white matter:** myelinated fiber tracts in CNS
 - **gray matter:** mostly nerve cell bodies & unmyelinated fibers in CNS
 - myelinated fibers conduct impulses rapidly; unmyelinated fibers conduct impulses slowly
- following injury to myelinated axon in PNS, **Schwann cells** proliferate & release growth factors to stimulate axonal growth... then, they guide axon extensions across the gap (form **regeneration tube** to bridge gap) & remyelinate the axon
 - the greater distance between broken axon ends, the less the chance of regeneration
- when CNS neurons are damaged, they usually do not regenerate
 - neural stem cells in hippocampus & near ventricles in brain can divide & give rise to new neurons & neuroglial cells

Classification of Neurons:

Structural:

- **multipolar neurons:** 3 or more processes; most common type
- **bipolar neurons:** 2 processes, usually an axon & a dendrite with cell body in between

- **unipolar neurons** (pseudounipolar neurons): 1 process emerging from cell body forming proximal & distal branches

Functional:

- **sensory or afferent neurons:** transmit impulses from *sensory receptors* in skin or internal organs **toward CNS**
 - o almost all are unipolar neurons
 - o cell bodies are located in ganglia outside CNS (spinal cord)
- **motor or efferent neurons:** carry impulses away from CNS to effector organs (muscles & glands)
 - o multipolar neurons
 - o cell bodies generally located in CNS
- **interneurons (association neurons):** between sensory & motor neurons in neural pathways; integrate signals within CNS
 - o almost all are multipolar neurons
 - o > 99% of neurons in body

Neurophysiology:

- neurons highly irritable (respond to stimuli) - can be excited or inhibited; sufficient stimulation results in conduction of an electrical impulse (***action potential***) along the length of the axon
- **voltage (*potential*):** potential energy generated by separated charge

Membrane potentials:

- resting membrane is ***polarized*** - the inside of the neuron is negative with respect to the outside (fewer positively charged ions)
- sodium ion concentration is higher outside cell than inside; potassium ion concentration is higher inside cell than outside
- positive sodium ions outside neuron balanced with (-) chloride ions; positive potassium ions inside neuron balanced with negatively charged (anionic) proteins
- potassium ions diffuse more easily & rapidly than sodium ions - leaves inside of cell with excess negative charge
- the voltage in a resting neuron is between -40 mV & -90 mV
- an ATP-dependent sodium-potassium pump can move sodium back out of cell & potassium back into cell
- **graded potentials:** short distance signal; local changes in membrane potential that decrease in strength with distance (fade quickly)
- **action potentials:** long-distance signals that do not decrease in strength; in *neurons*, ***nerve impulses***
 - o *only axons can generate action potentials* (total change in voltage inside neuron of ~ 100mV (from -70mV to +30mV))
- ***temporal summation:*** postsynaptic neuron stimulated by the same terminal in rapid succession
- ***spatial summation:*** postsynaptic neuron stimulated by multiple terminals at the same time

- **depolarization:** inside of cell becomes *less negative* (e.g.: -70mV → -50mV)
- **hyperpolarization:** inside of cell becomes *more negative* (e.g.: -70mV → -90mV)

Action Potential:

- **resting state:** voltage-gated channels closed; diffusion of sodium & potassium ions through leakage channels
- **depolarizing phase:** increase in sodium permeability & reversal of membrane potential
 - o local influx of sodium leads to slight depolarizations
 - o fast sodium channel activation gates open quickly & sodium rushes into cell
 - o more sodium channels open - positive feedback cycle
 - o if threshold voltage (generally between -50mV & -55mV) is reached by sodium influx, all sodium channels open & action potential is generated
 - o voltage inside cell becomes positive (about +30mV)
- **repolarizing phase:** decrease in sodium permeability & increase in potassium permeability
 - o action potential is rapid; lasts ~ 1 sec.... buildup of positive charge in cell resists further sodium entry & slow sodium inactivation gates close
 - o as sodium entry declines, slow potassium gates open & potassium rushes out of the cell
 - o cell returns to negative resting potential

Synapse: junction that mediates transfer of information from neuron to neuron or effector (muscle, gland)

- axodendritic & axosomatic most common... also axoaxonic, dendrodendritic & dendrosomatic
- **presynaptic neuron:** conducts impulses toward synapse
- **postsynaptic neuron:** transmits signal away from the synapse
- **Electrical synapses:** less common; much like gap junctions
 - o Channel proteins connect neurons & allow ions to flow directly from one neuron to the next
- **Chemical synapses:** chemical **neurotransmitters** act to open or close ion channels
 - o Calcium gates open in the presynaptic axon terminal - calcium floods into axon terminal from extracellular space
 - o Neurotransmitter released from synaptic vesicles by exocytosis in response to calcium signal
 - o Neurotransmitter binds to postsynaptic receptors
 - o Ion channels open in postsynaptic membrane in response to neurotransmitter binding
 - o Neurotransmitter is removed from receptor by enzyme degradation, reuptake by astrocytes or the presynaptic terminal, or diffusion away from the synapse
 - o **excitatory synapses:** neurotransmitter binding causes depolarization of the postsynaptic membrane & **excitatory postsynaptic potentials** (EPSPs)
 - o **inhibitory synapses:** neurotransmitter binding causes hyperpolarization of the postsynaptic membrane & **inhibitory postsynaptic potentials** (IPSPs)

Neurotransmitters:

- **acetylcholine (ACh)** - released at neuromuscular junctions throughout nervous system (excitatory for skeletal muscle; inhibitory for cardiac muscle; also used in ANS & CNS)
 - o Alzheimer disease may be due to loss of neurons that use ACh as neurotransmitter
 - o ACh degraded by the enzyme *acetylcholinesterase*
- **biogenic amines:** catecholamines (*dopamine, epinephrine & norepinephrine*) & indolamines (*histamine & serotonin*)...
 - o biogenic amines are synthesized from *amino acids* (catecholamines from *tyrosine*; serotonin from *tryptophan*; histamine from *histidine*)
 - o catecholamines are inactivated by reuptake & recycled or degraded by enzymes (COMT or *monoamine oxidase (MAO)*)
- **amino acids:** *GABA, glycine, aspartate, & glutamate*... (in CNS)
 - o *aspartate & glutamate* are excitatory neurotransmitters in the CNS
 - o *GABA & glycine* are inhibitory neurotransmitters in the CNS (open Cl⁻ channels for hyperpolarization)
- **peptides:** substance P, endorphins & enkephalins...
 - o *substance P* mediates pain signals
 - o *endorphins & enkephalins* act as natural opiates, reducing perception of pain in stressful situations
- **Other neurotransmitters:**
 - o *ATP & Other Purines:* ATP is an excitatory neurotransmitter in the CNS & PNS; it's usually released with another neurotransmitter (norepinephrine, acetylcholine)
 - o **nitric oxide:** a gaseous neurotransmitter; short-lived & produced on demand from the amino acid arginine
 - nitric oxide is also a potent **vasodilator** (lowers blood pressure & increases blood flow)

Neural circuits: functional groups of neurons that integrate incoming information from other sources & forward processed information to other sources

- **circuits:** patterns of synaptic connections in neuronal pools
- reflexes occur over neural pathways called **reflex arcs**
- *series circuit:* one neuron stimulates the next in a sequence
- *diverging circuit:* one presynaptic neuron stimulates several postsynaptic neurons
- *converging circuit:* several presynaptic neuron stimulate one postsynaptic neuron

Nerves & Associated Ganglia:

Nerve: cordlike organ of PNS consisting of bundles of axons enclosed in layers of connective tissue

- **sensory (afferent) nerves:** carry impulses toward CNS
- **motor (efferent) nerves:** carry impulses away from CNS
- **mixed nerves:** contain both sensory & motor fibers (can be somatic &/or autonomic fibers)
- peripheral nerves classified as **spinal nerves** or **cranial nerves**

Reflex arc:

- **sensory receptor:** distal end of sensory neuron; responds to *stimulus*
 - **sensory neuron:** carries impulse from receptor to axon terminals in gray matter of spinal cord (or brain stem)
 - **integration center:** within CNS gray matter, signal travels across synapse or through interneuron, generating a response
 - **motor neuron:** response impulse is sent from sensory neuron or interneuron through motor neuron to effector
 - **effector:** muscle or gland that carries out response (reflex)
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- **stretch reflex:** causes contraction of skeletal muscle in response to muscle stretching
 - **tendon reflex:** causes muscle relaxation in response to increasing muscle tension (to prevent tendons from tearing)
 - **flexor (withdrawal) reflex:** causes muscle contraction to move body region away from painful stimulus
 - **crossed extensor reflex:** works with withdrawal reflex to maintain balance
 - contraction of extensors on opposite side of body to balance withdrawal

Central Nervous System: Brain and Spinal Cord

- **Introduction to the CNS**
 - the CNS receives sensory impulses and initiates motor control
 - **protective coverings**
 - **cranial bones** (brain) & **vertebral column** (spinal cord)
 - cranial & spinal **meninges**
 - **meninges:** 3 connective tissue membranes just external to spinal cord & brain
 - **dura mater:** outer layer; tough white fibrous connective tissue with blood vessels & nerves; extends into partitions between lobes in some regions
 - **arachnoid:** middle layer; thin weblike membrane
 - subarachnoid space contains large capillaries & CSF
 - **pia mater:** innermost layer; just superficial to spinal cord; contains nerves & blood vessels that nourish cells of CNS
 - **cerebrospinal fluid (CSF)** cushions & protects brain & spinal cord within meninges, central canal of spinal cord & ventricles (cavities) in brain
- **The Spinal Cord:** the center for many reflex actions (*spinal reflexes*) and a means of communication between the brain and the spinal nerves
 - 31 pairs of **spinal nerves** attach to spinal cord by paired roots
 - 2 enlargements (thickenings of spinal cord)
 - cervical enlargement: from C4-T1: sends nerves to upper limbs
 - lumbar enlargement: from T9-T12: sends nerves to lower limbs
 - grooves: **anterior median fissure** & **posterior median sulcus**
 - **inner gray matter** & **outer white matter**
 - **gray matter:** butterfly-shaped region surrounded by outer white matter
 - **anterior, lateral & posterior horns** contain primarily cell bodies of neurons
 - **gray commissure:** across center of gray matter; contains **central canal** – an opening with CSF continuous with ventricles of the brain (arises from 4th ventricle)

- **white matter:** nerve fibers allow communication between different parts of spinal cord & between spinal cord & brain
 - **anterior, posterior & lateral columns (funiculi)** containing axons carrying information to & from the brain
 - **ascending (sensory) tracts:** axons carrying nerve impulses up spinal cord toward brain
 - *lateral & anterior spinothalamic tracts* convey nerve impulses for sensing pain, temperature, deep pressure & touch
 - **descending (motor) tracts:** axons carrying nerve impulses down spinal cord from brain
 - *lateral & anterior corticospinal tracts* control skeletal muscle movements (called *pyramidal tracts* due to pyramid shape of neurons in medulla oblongata through which they pass)
 - *extrapyramidal tracts* control balance & posture

- **The Brain**
 - **cerebrum:** left & right *cerebral hemispheres* joined by **corpus callosum**
 - **brain stem:** inferior portion; continuous with spinal cord
 - *midbrain, pons & medulla oblongata*
 - **diencephalon:** superior to brain stem
 - *thalamus, hypothalamus, epithalamus & subthalamus*
 - **cerebellum:** posterior to brain stem
 - **Cerebrum:**
 - superior part of brain; ~ 83% of total brain mass
 - 3 regions: cerebral cortex (gray matter), white matter & basal nuclei
 - **gyri:** elevated ridges of brain tissue, separated by shallow grooves called **sulci**
 - **fissures:** deeper grooves separating larger regions of brain
 - **longitudinal fissure:** separates cerebral hemispheres
 - **transverse fissure:** separates cerebral hemispheres from cerebellum
 - deep *sulci* divide cerebral hemisphere into **5 lobes:** *frontal, parietal, temporal, occipital & insula*
 - **cerebral cortex:** outermost portion of cerebrum; contains most (~75%) of cell bodies in brain
 - **cerebral white matter:** most of cerebrum; myelinated axons connecting cell bodies in cortex with other neurons
 - **Motor Areas:**
 - **primary (somatic) motor cortex & premotor cortex** in frontal lobe
 - **upper motor neurons** are pyramidal cells that carry impulses downward through brainstem on corticospinal tracts; they synapse with **lower motor neurons** whose axons travel from spinal cord to skeletal muscles
 - *tracts cross over in brainstem. so motor areas of cerebrum control muscle activity on opposite side of body*
 - **Broca's area:** anterior to inferior region of premotor area
 - present in one hemisphere only (generally left)
 - special motor speech area – controls muscles of tongue, throat & lips during (& possibly in planning of) speech

- **Sensory Areas:**
 - **primary somatosensory cortex:** in parietal lobe processes spatial discrimination: receive input from sensory receptors in skin & proprioceptors in skeletal muscles & identify region being stimulated
 - **visual areas** in occipital lobe receive visual information from retinas
 - **auditory areas** in temporal lobe next determine pitch, rhythm, & loudness of sound
 - **olfactory (smell) cortex** in frontal lobe controls conscious awareness of odors
 - **gustatory (taste) cortex** in parietal lobe controls perception of taste stimuli
 - **vestibular (equilibrium) cortex** in insula controls conscious awareness of balance
- **Association Areas** connect with one another & other brain regions
 - most complex cortical regions; involved with intellect, cognition, recall & personality
 - necessary for production of abstract ideas, judgment, reasoning, planning, conscience, etc.
- **Lateralization:** each hemisphere may have unique abilities
 - **cerebral dominance:** one hemisphere dominant for language & verbal, analytical & computational skills (usually left)
 - non-dominant hemisphere usually controls patterns (musical, visual) & emotional & intuitive thinking
- **Ventricles of Brain:**
 - **lateral ventricles:** deep within cerebral hemispheres, separated anteriorly by the *septum pellucidum*
 - **third ventricle:** in diencephalon; communicates with lateral ventricles via the intraventricular foramen
 - **fourth ventricle:** in hindbrain; continuous with third ventricle via the *cerebral aqueduct* (in midbrain)
 - the ventricles & subarachnoid space are filled with *cerebrospinal fluid*
- **Diencephalon:** hypothalamus and thalamus; third ventricle
 - the **hypothalamus** maintains **homeostasis**; regulates hunger, sleep, thirst, body temperature, water balance, and blood pressure
 - it controls the pituitary gland and thereby serves as a link between the nervous and endocrine systems
 - the **thalamus** is the last portion of the brain for sensory input before the cerebrum; it is a **central relay station** for sensory impulses traveling up from the body or from the brain to cerebrum
 - the **pineal gland** secretes hormone **melatonin**
- **Limbic System** blends higher mental functions and primitive **emotions**
 - the **hippocampus** makes prefrontal area aware of past experiences stored in association areas
 - the **amygdala** causes experiences to have emotional overtones
 - inclusion of the frontal lobe in the limbic system allows reasoning to keep us from acting out strong feelings
- **Cerebellum:** 2 lobes separated from brain stem by fourth ventricle

- integrates impulses from higher centers to coordinate muscle actions, maintain equilibrium and muscle tone, and sustain normal posture
- assists in the learning of new motor skills, as in sports or playing the piano
- **Brain Stem:** the medulla oblongata, pons, and midbrain
 - **midbrain** contains reflex centers for visual & auditory responses
 - the **pons** is a bridge between the cerebellum and rest of CNS
 - the **medulla oblongata** lies between the spinal cord and the pons
 - it contains vital centers for regulating **heartbeat, breathing, and vasoconstriction** and reflex centers for vomiting, coughing, sneezing, hiccuping, and swallowing
 - it contains nerve tracts that ascend or descend between the spinal cord and the brain's higher centers

Peripheral Nervous System: lies outside the CNS

- **Cranial nerves** connect to the brain; humans have 12 pairs
- **Spinal nerves** lie on either side of the spinal cord; humans have 31 pairs
- Ganglia are collections of cell bodies in the PNS
- Cranial nerves mostly connect to the head, neck, and facial regions; the vagus nerve also branches to the pharynx, larynx, and some internal organs
- **Somatic System:** nerves that carry sensory information to the CNS and motor commands away from the CNS to skeletal muscles
- voluntary muscle control involves the brain; reflexes involve the brain or spinal cord
- **Autonomic System:** regulates cardiac and smooth muscle and glands
 - there are two divisions: the *sympathetic* and *parasympathetic* systems
 - **Sympathetic Division:** most preganglionic fibers of the sympathetic system arise from the middle (**thoracic-lumbar**) portion of the spinal cord and almost immediately terminate in ganglia that lie near the cord (paravertebral ganglia)
 - the preganglionic fiber is short; the postganglionic fiber is long
 - the sympathetic system is especially important during emergency situations (the “fight or flight” response)
 - to defend or flee, muscles need a supply of glucose and oxygen; the sympathetic system accelerates heartbeat, and dilates bronchi; to divert energy from less necessary digestive functions, the sympathetic system inhibits digestion
 - the neurotransmitter released by the postganglionic axon is mainly norepinephrine, similar to epinephrine (adrenaline) used as a heart stimulant
 - **Parasympathetic Division:** consists of a few **cranial nerves**, including the **vagus** nerve, and fibers that arise from the bottom **sacral** portion of the spinal cord
 - the preganglionic fibers are long and the postganglionic fibers are short
 - this system is a “housekeeper system”; it promotes internal responses resulting in a relaxed state
 - the parasympathetic system causes the eye pupil to constrict, promotes digestion, and retards heartbeat
 - the neurotransmitter released is acetylcholine

Chapter 10: Somatic & Special Senses

Sensory Receptors: specialized to respond to changes (stimuli) in environment

Classification by Stimulus Type:

- **chemoreceptors:** respond to chemicals in solution (molecules smelled, tasted; changes in blood pH, solutes)
- **pain receptors:** respond to pain from potentially damaging stimuli
- **thermoreceptors:** respond to temperature changes
- **mechanoreceptors:** respond to touch, pressure (including blood pressure), vibration, stretch & itch
- **photoreceptors:** respond to light energy

Sensation (perception): a feeling that occurs when the brain interprets sensory impulses

- sensations depend on which part of the brain receives sensory impulse
- **projection:** cerebral cortex processes impulse & projects sensation to apparent source
- **sensory adaptation:** ability to ignore unimportant stimuli & focus on a smaller subset of stimuli; in *peripheral adaptation*, sensory receptors become unresponsive (adapt); in *central adaptation*, CNS pathways to sensory receptors are inhibited

Somatic Senses: senses associated with receptors in skin, muscles, joints & viscera

- **touch & pressure receptors:**
 - o **free nerve endings:** common between epithelial cells; sensations of touch & pressure
 - o **Meissner's corpuscles:** oval masses of connective tissue within connective tissue sheaths; abundant in dermal papilla in hairless portions of skin (lips, palms, soles)
 - function as light touch receptors
 - o **Pacinian corpuscles:** large concentric masses of connective tissue in subcutaneous tissue, muscle tendons & joint ligaments
 - deep pressure receptors
- **temperature senses:** depend on free nerve endings in skin: *warm receptors* (sense 25°C – 45°C or 77°F – 113°F) & cold receptors (sense 10°C – 20°C or 50°F – 68°F)
 - o temperatures below 10°C or above 45°C stimulate pain receptors
- **sense of pain:** free nerve endings throughout skin & internal tissues (except brain)
 - o pain receptors protect body; response is usually removal of stimulation
 - o pain receptors poorly adapt – constant awareness of painful stimulus
 - o **visceral pain** may stem from stimulation of mechanoreceptors (overstretching) or chemoreceptors (decreased blood flow & oxygen as blood vessels compressed)
 - o pain receptors in internal organs contact neurons in spinal cord also contacted by pain receptors in skin
 - o **referred pain:** pain in internal organ felt in part of body other than part being stimulated (e.g.: pain in heart is felt in skin of left shoulder & arm)
 - o **acute pain fibers:** myelinated fibers; conduct impulses rapidly; sense sharp pain
 - o **chronic pain fibers:** unmyelinated fibers; conduct impulses slowly; sense dull, aching pain difficult to localize
 - o pain impulses conducted to brain through cranial nerves (from head) or spinal nerves (from rest of body)

- sent to thalamus where awareness may begin, then on to cerebral cortex to determine intensity, localization & emotional responses to pain
- areas of gray matter of *brainstem* stimulate nerve fibers in lateral funiculus (in white matter of spinal cord) to secrete inhibitory neurotransmitters (*enkephalins*, *serotonin*) that suppress acute & chronic pain sensations
- *pituitary gland* & *hypothalamus* may release *endorphins* to suppress pain

Special Senses: smell, taste, hearing, equilibrium & sight

Sense of Smell

- **olfactory receptors:** taste in food chemicals sensed by chemoreceptors in the nose
- *olfactory cells* for smell are located at the roof of the nasal cavity
- olfactory receptor cells are neurons that have *olfactory cilia* covered by a coat of mucus that dissolves airborne chemicals (odors)
- there are perhaps more than 1000 types of receptors; the specific odor detected depends on the combination of olfactory cells stimulated
- the olfactory cells stimulate neurons in the *olfactory bulbs*, which send the stimulus to the *olfactory cortex* of the brain

Sense of Taste

- *taste buds* within papillae on surface of tongue respond to 4 types of taste (*sweet*, *salty*, *sour* & *bitter*)
- each taste bud has 40-100 epithelial cells
- *gustatory (taste) cells:* *epithelial* receptor cells with membranes with *taste hairs* that sense stimuli; contacted by dendrites of sensory neurons; replaced every 7-10 days
- pure taste sensations are grouped into 4 types:
 - *sweet:* sensed at anterior tip of tongue
 - *salty:* sensed at anterior sides of tongue
 - *sour:* sensed at middle sides of tongue
 - *bitter:* sensed at posterior of tongue
- taste receptor activation: chemical dissolved in saliva contacts gustatory hairs, causing depolarization & release of neurotransmitter from the gustatory cells... the neurotransmitter binds sensory dendrites which respond with an action potential that delivers an impulse to the CNS
- **pathway to brain:** taste afferents from *facial*, *glossopharyngeal* & *vagus* cranial nerves travel to the *medulla*, the *thalamus*, & then on to the *gustatory cortex* in the parietal lobes
- taste is possibly about 80% smell... when olfactory receptors are blocked (nasal congestion), taste of food is partially to mostly blocked

Sense of Hearing & Equilibrium

- **mechanoreceptors** in the inner ear provide senses of equilibrium (balance) & hearing
- **external ear:** consists of *pinna* (auricle or visible portion of ear) & *external auditory canal*
 - *ceruminous glands:* modified sweat glands in upper wall of canal that secrete earwax, which protects against particle entry into middle & inner ear

- **middle ear:** begins at *tympanic membrane (eardrum)* & ends at 2 small openings (oval & round window) to inner ear
 - contains 3 **ossicles** (small bones) suspended by ligaments
 - *malleus (hammer)* – attaches to eardrum
 - *incus (anvil)*
 - *stapes (stirrup)* – attaches to oval window of vestibule (inner ear)
 - the anterior wall of the middle ear contains an opening to the **auditory (eustachian) tube** (leads to nasopharynx) that allows pressure equalization
 - **otitis media:** middle ear infection causing inflammation & blockage
 - **myringotomy:** incision in eardrum, followed by insertion of tube to equalize pressure (can be surgically removed later)
- **inner ear:**
 - **vestibule:** central region composed of 2 sacs – the *sacculle & utricle*
 - contains static equilibrium receptors called *maculae*
 - **semicircular canals:** 3 rounded tubes projecting from utricle through swellings called *ampullae*
 - ampullae contain dynamic equilibrium receptors called *crisae ampullaris*
 - **cochlea:** snail-shaped chamber extending from the sacculle
 - contains *cochlear duct* housing the **organ of Corti**, which contains receptors for hearing
- **Hearing:**
 - sound waves enter the auditory canal & cause the tympanic membrane to vibrate
 - the ossicles receive the vibration, amplify & transmit it to the *oval window*, causing pressure waves in the cochlear fluid
 - the pressure waves move from the vestibular to cochlear to tympanic canal within the cochlea, causing bulging of the *round window* & reverberation of fluid
 - the fluid movement moves the cilia of the **hair cells** within the *organ of Corti*, initiating nerve impulses which are transmitted along the **cochlear branch** of the **vestibulocochlear nerve** to the **auditory cortex** of the temporal lobe of the brain, which interprets the sound
- **Equilibrium:**
 - **dynamic equilibrium:** required when a person is in angular or rotational motion
 - fluid within the **semicircular canals** flows over the *ampullae*, causing displacement of the cilia of *hair cells*
 - the hair cells generate impulses that are transmitted along the **vestibular branch** of the **vestibulocochlear nerve** to the brain
 - continuous fluid movement in semicircular canals can cause *motion sickness*
 - **static equilibrium:** required when the body moves horizontally or vertically
 - **otoliths** (calcium carbonate granules) in the vestibule are displaced from the otolithic membrane, & the membrane sags
 - the sagging membrane bends the cilia of the *hair cells*, which generate impulses that are transmitted along the **vestibular branch** of the **vestibulocochlear nerve** to the brain

Sense of Vision

- **photoreceptors:** light-sensitive receptors in the eyes within the orbits of the skull
- **eyebrows & eyelashes:** divert sweat & debris from around eyes
- **eyelids:** thin skin covered folds of epithelium supported by connective tissue; contraction of the *orbicularis oculi* muscle closes eyelids & contraction of the *levator palpebrae superioris* opens eyelids
- **conjunctiva:** transparent mucus membrane that lines the eyelids & reflects back over the anterior surface of the eyeballs (except cornea)
- **lacrimal gland:** lies within the orbit above the eye; releases a moisturizing lacrimal secretion (tears) containing mucus, antibodies & the antimicrobial enzymes
- **extrinsic eye muscles:**
 - o lateral rectus: moves eye laterally (control by CN VI)
 - o medial rectus: moves eye medially (control by CN III)
 - o superior rectus: elevates eye (control by CN III)
 - o inferior rectus: depresses eye (control by CN III)
 - o inferior oblique: elevates eye & turns it laterally (control by CN III)
 - o superior oblique: depresses eye & turns it laterally (control by CN IV)
- **structure of the eye**
 - o **sclera:** white of eye
 - **cornea:** anterior 1/6 of sclera; transparent CT
 - o **choroid:** highly vascular dark brown membrane; blood vessels supply nutrients to all tunics
 - melanin from melanocytes absorb light & prevent scattering
 - **ciliary body:** contains smooth muscle bundles (ciliary muscles) that control lens shape
 - **lens:** biconvex, transparent structure attached to ciliary body
 - divides eye into *anterior cavity* in front of lens & *posterior cavity* behind lens
 - anterior cavity is filled with watery aqueous humor; posterior cavity is filled with gel-like vitreous humor
 - **glaucoma:** due to faulty drainage & thus buildup of aqueous humor in anterior chamber; pressure buildup can damage photoreceptors & lead to partial or total blindness
 - **iris:** lies between cornea & lens; has round central opening called **pupil**
 - **pupil** opens & closes to control light entry into eye; controlled by smooth muscle in iris
 - o **retina:** consists of 2 layers:
 - outer **pigmented layer:** contains *phagocytic* pigmented epithelial cells that absorb light & prevent scattering
 - inner **neural layer:** 3 main types of neurons
 - **photoreceptors: rods & cones**
 1. rods: respond to dim light; blurry shades of gray
 2. cones: respond to bright light; sharp, color vision
 - **bipolar cells:** link between photoreceptors & ganglion cells

- **ganglion cells:** receive input from bipolar cells & their axons leave eye as optic nerve
 - **blind spot (optic disc):** location on retina where the optic nerve exits eye
 - **fovea centralis:** only cones present; region of greatest visual acuity
- **rods:** contain **rhodopsin**, which consists of the pigment **retinal** (a vitamin A derivative) linked to a form of **opsin** (protein)
 - rods are sensitive to faint light (night) & motion, but do not detect color or fine detail
 - hence, at night objects are seen as blurry & in shades of gray
 - when light strikes rhodopsin, it breaks down & generates a nerve impulse
 - in dim light, the pupils dilate to allow more light to reach the retina; at the same time, rhodopsin forms to improve vision -> 2 delays to adjustment to dim light
- **cones:** contain one of 3 opsins with retinal, allowing absorption of 3 different colors of light (*red, green & blue*)
 - cones are sensitive to bright light & detect fine detail & color
 - color observed depends on combination of cones (RGB) stimulated
 - **color blindness:** usually, one type of cone is deficient (red or green cone deficiency is most common -> red-green color-blindness)
- **stereoscopic vision:** each eye forms image from different angle & sends independent stimulus to brain
 - optic nerve fibers cross at optic chiasma, & one hemisphere of brain receives information from both eyes about the same part of an object
 - the 2 hemispheres share information to arrive at complete 3D image
- lens: **the cornea, vitreous humor & lens all participate in refraction of light to focus it on the retina**
 - **accommodation:** bulging of lens by contraction of ciliary muscle to view close objects (no accommodation is required to view distant objects)
 - if accommodation is not enough to focus image, prescription lenses may be required
 - **cataract:** lens becomes opaque (perhaps due to oxidation of lens proteins) & unable to transmit light to retina (lens can be surgically replaced with plastic lens)

Effects of Aging:

- the need for eyeglasses & hearing aids increases with age
- incidence of cataracts, glaucoma & age-related macular degeneration increases with age
- overgrowth of the stapes (otosclerosis) & atrophy of the organ of Corti (presbycusis) can lead to the development of hearing loss later in life

Chapter 11: The Endocrine System

Endocrine System: a system of small glands scattered throughout the body that influences the metabolic activities of cells through hormones

- **Hormones:** chemical messengers released to the blood by the cells of endocrine glands that regulate the metabolic activities of other cells in the body
 - o Hormones signal target cells to perform specific chemical reactions

Endocrine Glands: pituitary, thyroid, parathyroid, adrenal, pineal and thymus glands.

- Organs with major functions outside the endocrine system containing endocrine tissue/cells: pancreas, gonads, hypothalamus (neuroendocrine organ)
- Tissues that produce hormones also found within: adipose cells, small intestine, stomach, kidneys, heart

Hormones:

Amino acid-based (peptide) hormones: contain from a couple to many amino acids... vary in size from simple amino acid derivatives to proteins (polypeptides)

- peptide hormones use **second messenger systems**
- proteins and peptides cannot freely penetrate plasma membrane
- these hormones bind to a membrane receptor that starts a chain of reactions that activates an intracellular second messenger molecule
- the second messenger then activates other cellular enzymes to carry out certain activities
- **cyclic AMP** (derived from ATP) & **calcium** are second messengers used by peptide hormones

Steroid hormones: synthesized from **cholesterol** (includes hormones from the gonads and adrenal cortex (outer region of the adrenal gland))

- steroid hormones use **direct gene activation**
- steroid hormones are lipid-based and can easily diffuse into target cells (no need for intracellular second messengers since the hormone can enter the cell)
- hormone enters the nucleus; binds to & activates intracellular receptor
- the hormone-receptor complex binds a DNA-associated receptor protein, which turns on transcription & translation of the associated gene
- the protein synthesized in many cases is an enzyme that effects the metabolic activities of the cell to transmit the effects of the hormone
- **thyroid hormone** also uses this mechanism

Control of hormone release:

Negative feedback: hormone secretion triggered by an external stimulus; as hormone levels rise, the hormones feed back to the metabolic pathway that produces them & inhibit their further release

Major Endocrine Glands:

Pituitary Gland (Hypophysis): connected to hypothalamus by stalk called infundibulum

- **Anterior Pituitary (Adenohypophysis):**

- **Growth Hormone (GH):** stimulates cell division in most cells (major targets are bone & skeletal muscle)
 - *Hypersecretion:* in children, can lead to ***gigantism***; after long bones have developed, can lead to ***acromegaly***
 - *Hyposecretion:* in children, can lead to ***pituitary dwarfism***
- **Prolactin (PRL):** stimulates milk production by mammary glands of breasts
- **Follicle-stimulating hormone (FSH):** stimulates gamete production in gonads (ovaries & testes)
- **Leutinizing hormone (LH):** promotes production of gonadal hormones (testosterone, estrogen & progesterone)
- **Thyroid-stimulating hormone (TSH):** stimulates normal development of & secretion of hormones from thyroid gland
- **Adrenocorticotrophic hormone (ACTH or corticotropin):** stimulates release of corticosteroid hormones from adrenal cortex
- **Posterior pituitary (Neurohypophysis):** receives & stores hormones from hypothalamus for later release
 - **Oxytocin:** produced by paraventricular nucleus of ***hypothalamus***; stimulates uterine contraction during childbirth & milk ejection during nursing
 - **Antidiuretic hormone (ADH):** produced by supraoptic nucleus of ***hypothalamus***; stimulates kidney tubules to retain water
 - deficiency of ADH secretion leads to ***diabetes insipidus*** (excessive urination & fluid loss)

Hypothalamus: secretes releasing & inhibiting hormones that regulate release of hormones from anterior pituitary

- **hypophyseal portal system:** network of blood vessels that delivers hormones to anterior pituitary from hypothalamus

Thyroid Gland:

- **Thyroid Hormone:** amino acid hormones containing 2 tyrosine molecules each bound to iodine molecules; regulates metabolic activities of all cell types, especially glucose oxidation (energy & heat production)
 - **Thyroxine (T₄):** major hormone released from thyroid follicles (contains 4 iodine molecules)
 - **Triiodothyronine (T₃):** (contains 3 iodine molecules); generally formed from T₄ by cleaving an iodine molecule
- ***simple goiter:*** enlargement of thyroid gland due to lack of dietary iodine (thyroid hormone precursors accumulate in gland)

- hypothyroidism in infants may be associated with **cretinism** (underdeveloped thyroid gland); symptoms are short, stocky stature & may lead to mental retardation
- **myxedema**: hypothyroidism in adults (lethargy, weight gain, hair loss, slow pulse, etc.)
- treatment for hypothyroidism is generally thyroxine therapy
- **Graves' disease**: hyperthyroidism due to enlarged & overactive thyroid gland; produces exophthalmic goiter (swelling & protrusion of eyes)
- treatment of hyperthyroidism involves thyroid gland surgery &/or radioactive iodine
- **Calcitonin**: produced by parafollicular cells (C cells) of thyroid gland
 - o lowers blood calcium levels by inhibiting osteoclasts & stimulating calcium uptake by bones

Parathyroid Glands: paired glands on posterior aspect of thyroid gland

- **Parathyroid hormone (Parathormone or PTH):** raises blood calcium levels by stimulating osteoclasts, enhancing absorption of calcium by kidneys, & increasing absorption of calcium by cells of intestine
 - o PTH activates the inactive form of vitamin D in the kidneys; vitamin D enhances absorption of calcium by intestine

Adrenal Glands (Suprarenal Glands): pyramid-shaped glands above kidneys

- **Adrenal Cortex:** releases corticosteroid hormones
 - o **Mineralocorticoids:** regulate salt concentrations in extracellular fluids
 - **Aldosterone:** primary mineralocorticoid: enhances *sodium* (& water) reabsorption from kidney tubules
 - sodium ion concentration in body fluids also regulated by renin-angiotensin system, ACTH & atrial natriuretic peptide (ANP)
 - o **Glucocorticoids:** influence metabolism of body cells & help resist stressors
 - During times of stress (injury/blood loss), glucocorticoids stimulate gluconeogenesis (glucose synthesis) & mobilize fats & proteins to be used for energy to save glucose for the brain
 - **Cortisol (hydrocortisone)** is major glucocorticoid (also cortisone & corticosterone)
 - Glucocorticoids also prevent water loss from cells into tissue fluids; used as **anti-inflammatory agents**
- **Gonadocorticoids:** secondary source of sex hormones; primarily *androgens* (testosterone), but also *estrogens*
 - o may contribute to onset of puberty
- **Addison's disease:** low level of adrenal cortex hormones resulting in bronzing of skin, low blood sugar (low energy & weak immunity) & low blood sodium (low blood pressure)

- **Cushing syndrome:** high level of adrenal cortex hormones resulting in high blood sugar (& possibly diabetes mellitus), high blood sodium (hypertension), swelling & obesity & possible masculinization in women
- **Adrenal medulla:** releases *catecholamines* (norepinephrine & epinephrine)
 - o Release is stimulated by *sympathetic nervous system* (“fight or flight” response)
 - o **Epinephrine:** stimulates heart rate & metabolism
 - o **Norepinephrine:** influences peripheral vasoconstriction & blood pressure

Pancreas: releases insulin & glucagon from *islets of Langerhans*

- **Insulin:** released by beta cells of islets; lowers blood glucose levels by stimulating glucose storage & uptake of glucose by cells for energy
 - o Insulin deficiency may lead to **diabetes mellitus**
 - *Insulin-dependent diabetes mellitus* (IDDM): autoimmune disease where immune cells attack & destroy beta cells
 - *Non-insulin-dependent diabetes mellitus* (NIDDM): insulin receptors do not properly respond to insulin
- **Glucagon:** raises blood glucose levels by stimulating glucose removal from glycogen storage deposits in liver cells & gluconeogenesis

Gonads: produce steroidal sex hormones

- **estrogens & progesterone:** produced by ovary cells; responsible for maturation of female reproductive organs & menstrual cycle
- **testosterone:** produced by cells of testes; responsible for maturation of male reproductive organs & sperm cell production

Pineal Gland: secretes *melatonin*

- **melatonin** appears to be involved in maintenance or sleep/wake (day/night) cycles

Thymus: secretes *thymopoietins & thymosins*; involved with normal development of T cells (lymphocytes)

Hormones not associated with glands:

- **atrial natriuretic peptide (ANP):** specialized cardiac muscle cells of the heart secrete ANP, which reduces blood volume, blood pressure, & blood sodium levels
- hormones that aid in digestion secreted by cells of the **GI tract**
- **platelet-derived growth factor (PDGF):** secreted by platelets & other cell types; helps in wound healing & cell growth
- **tumor angiogenesis factor:** released by tumor cells; stimulates growth of capillaries networks within tumor
- **prostaglandins:** local (paracrine) hormones that affect nearby cells
 - o many targets/effects... raise blood pressure, stimulate uterine contractions during birth, enhance blood clotting & inflammation

Chapter 12: Blood

Blood Characteristics:

- **pH** of blood is maintained between **7.35** and **7.45** by *carbonic acid-bicarbonate ion buffer system*
- blood accounts for ~ 8% body weight
- blood volume in adults is normally 5-6 L in males and 4-5 L in females

Blood Components:

- plasma & formed elements (erythrocytes, leukocytes & platelets)
- **plasma**: fluid component of blood; ~ 55% volume of whole blood
- **hematocrit**: % of total blood volume occupied by *erythrocytes* (normally between 42% and 47% ± 5%)

Erythrocytes: red blood cells (RBCs)

- small cells; biconcave discs (flattened disc shape with thin, depressed centers – look like mini doughnuts)
- **anucleate** – RBCs have no nucleus
- *function in gas transport*
- most of contents of RBC (other than water) is the protein **hemoglobin**
 - o **hemoglobin** is composed of 4 globin polypeptide chains each bound to a **heme** group
 - o **heme** is a ringlike compound with an **iron** atom at its center
 - o the iron atom in heme binds to **oxygen**
 - o hemoglobin can also bind **carbon dioxide**; carbon dioxide binds to globin chain **amino acids** rather than heme
 - o **oxyhemoglobin**: hemoglobin with bound oxygen (appears red in color)
 - o **deoxyhemoglobin**: hemoglobin without bound oxygen (appears dark purple in color)
- **red blood cell count**: # of red blood cells in a cubic millimeter (mm³)
 - o males: 4.6 – 6.2 million cells/ mm³
 - o females: 4.2 – 5.4 million cells/ mm³
- RBCs last ~ 100-120 days in circulation
 - o aged & damaged RBCs are broken down in small channels of the spleen, liver & marrow by macrophages
 - o **heme** is broken from hemoglobin; **iron** is salvaged & stored and the remainder of the group is *degraded* to **bilirubin** (yellow pigment), which is picked up by the liver, converted into bile & excreted
 - o **globin** chains are metabolized are broken down into *amino acids* for protein synthesis
- **Erythrocyte disorders**:
 - o **anemias**: conditions that involve blood with a very low oxygen-carrying capacity

- caused by an *insufficient number of RBCs* (hemorrhagic, hemolytic & aplastic anemias), *decreased hemoglobin content* (iron-deficiency & athlete's anemia) or *abnormal hemoglobin* (thalassemias & sickle cell anemia)
- **polycythemia**: abnormal excess of RBCs; increases blood viscosity & can impair circulation
 - can be treated by diluting blood with saline
 - artificial polycythemia can be induced by infusing RBCs (blood doping used by some athletes to increase available oxygen... considered unfair by many games committees)

Leukocytes: white blood cells (WBCs)

- only formed elements with *nucleus* & normal organelles
- involved in immune responses; protect the body from damage by bacteria, viruses, parasites, toxins & tumor cells
- *white blood cell count*: 5,000 – 10,000 cells/ mm³ (much fewer than RBCs)
- white blood cells can move out of capillaries & into tissues (RBCs are usually confined to blood)
- **Granulocytes**: WBCs with membrane-bound cytoplasmic *granules*
 - **Neutrophils**: most numerous WBCs (~ 60-70% of WBC volume)
 - ~ 2x size of RBCs
 - very fine, lightly staining granules containing enzymes or antibiotic-like proteins (defensins)
 - *nucleus* has from **3-6 lobes** (also known as **PMNs** (polymorphonuclear leukocytes))
 - **phagocytic cells** (*kill bacteria & fungi by oxidation*), chemically attracted to sites of inflammation
 - **Eosinophils**: ~ 1-4% of WBCs; about size of neutrophils
 - *nucleus* with **2 lobes** (like telephone receiver)
 - large, *red-staining granules* with enzymes
 - *digest* invading *parasitic flatworms & roundworms* with digestive enzymes
 - *phagocytic*; ingest immune complexes during allergic reactions
 - **Basophils**: ~ 0.5% of WBCs (rare); about size of neutrophils
 - large *purplish-black-staining granules* containing **histamine**
 - *histamine*: inflammatory chemical - vasodilator & chemoattractant – released by basophils
- **Agranulocytes**: WBCs *without* visible granules
 - **Monocytes**: largest WBCs (2-3x size of RBCs); 3-8% of WBCs
 - Large U or kidney-shaped nucleus
 - differentiate into *macrophages* in tissues
 - *macrophages* are phagocytic cells that destroy bacteria & help in immune response against viruses
 - **Lymphocytes**: small, medium & large sizes; 20-25% of WBCs

- large spherical nucleus occupies most of cell volume
 - most lymphocytes are in *lymphatic* organs
 - **T lymphocytes:** fight virus-infected cells & tumor cells
 - **B lymphocytes:** give rise to plasma cells that produce antibodies (immunoglobulins)
- **Leukocyte disorders:**
- **Leukemias:** cancer of myeloid or lymphoid cell lines
 - Leukemias can be acute (rapidly advancing) or chronic (slowly advancing)
 - Treated with radiation & chemotherapy & bone marrow transplant to replace cancerous cells
 - **Infectious mononucleosis:** highly contagious viral infection
 - caused by Epstein-Barr virus (EBV)
 - symptoms (fatigue, aches, fever) last a few weeks until virus is dealt with by immune system

Platelets: cytoplasmic fragments of *megakaryocytes* with granules containing blood-clotting enzymes

- sometimes referred to as *thrombocytes*
- *platelet count:* 150,000-300,000/mm³
- stick together to form a plug to prevent blood loss in torn vessels
- platelet formation regulated by hormone thrombopoietin
- thrombocytopenia: platelet deficiency (less than 50,000/mm³)

Hematopoiesis (*hemopoiesis*): blood cell formation; occurs in **red bone marrow** (in adults, in bones of girdles & proximal epiphyses of humerus & femur)

- starts with **stem cell** called **hemocytoblast** (hematopoietic stem cell that is used to form all formed elements of blood)
- **erythropoiesis** (erythrocyte production): **hemocytoblast** -> **myeloid stem cell** -> proerythroblast -> early erythroblast -> late erythroblast -> normoblast -> **reticulocyte** -> **erythrocyte**
 - ~ 2.5 million RBCs produced every second
 - controlled hormonally by **erythropoietin** (EPO) produced by the kidneys (responding to hypoxia (low oxygen levels))
 - cell **loses its nucleus** in transition from normoblast to reticulocyte
- **leukopoiesis:** WBC production
 - stimulated by *hormones* (**cytokines** such as *interleukins* & colony-stimulating factors (*CSFs*) from macrophages & lymphocytes

Blood Plasma: fluid component of blood

- mostly (~ 90%) water
- serum: plasma without clotting factors (fibrinogen & prothrombin)
- contains over 100 different dissolved solutes, including:
 - **proteins:** albumin, globulins, clotting proteins, etc.
 - **albumin** is majority of plasma protein; albumin is carrier molecule & contributes to plasma osmotic pressure

- *globulins* include transport proteins & *antibodies*
- *fibrinogen*: clotting protein; converted to *fibrin* to form clot
- *nutrients*: sugars, amino acids, fatty acids, cholesterol, vitamins, etc.
- *electrolytes*: cations (positive ions) such as sodium, potassium, calcium & magnesium; anions (negative ions) such as chloride, phosphate & bicarbonate
- *respiratory* gases: oxygen & carbon dioxide

Blood Functions:

- transport & *distribution* of oxygen & nutrients, carbon dioxide & metabolic waste, and hormones
- *regulation* of body temperature, normal pH and fluid volume in cells & tissues
- *protection* against blood loss (clotting) and infection (white blood cells)

Hemostasis: stoppage of bleeding from a torn blood vessel

- *vasoconstriction*: blood vessels constrict to reduce blood flow
 - caused by damage to smooth muscle, chemicals & reflexes
- *platelet plug formation*: in response to blood vessel injury, platelets swell & form spiked processes
- *coagulation (blood clotting)*: blood transformed from a liquid to a gel
 - *prothrombin activator* converts the plasma protein *prothrombin* to *thrombin*; requires calcium
 - *thrombin* catalyzes joining of *fibrinogen* molecules in plasma to form a *fibrin* mesh that seals vessel
 - *clotting factors* enhance clot formation (several require *vitamin K* for formation)
 - *anticoagulants* inhibit clotting
- *clotting disorders*:
 - *hemophilia A*: inherited deficiency of clotting factor VIII:C
 - hemarthroses: bleeding into joints
 - also bleeding into muscles, GI tract & urine
 - death may result from intracranial bleeding & neurological damage
- *thromboembolytic disorders*: a *thrombus* (clot) forms in an unbroken blood vessel; if it detaches from the vessel wall, the resulting *embolus* can travel through the blood & block blood vessels
 - free blood clots can be treated by anticoagulants aspirin, heparin & warfarin

Human Blood Groups: red blood cells have many (perhaps > 100) cell surface antigens – glycoproteins known as agglutinogens

- antigens determining ABO and Rh blood groups cause transfusion reactions
- **ABO blood groups**:
 - type A blood individuals have A surface antigen; type B blood individuals have B surface antigen; type AB blood individuals have both A & B surface antigens; type O blood individuals have neither A nor B surface antigens
 - individuals make antibodies (agglutinins) against the antigen(s) not present on their red blood cells (e.g.: type A blood individuals will make anti-B agglutinins); this does not require previous exposure to the antigen(s)

- **Rh blood groups:**
 - humans may also have one of several *Rh factors* present on the surface of their red blood cells
 - an individual without Rh factor will make antibodies against Rh factor, but only after exposure to the antigen

- ***Blood Typing & Transfusion reactions:*** agglutination & hemolysis
 - important to determine a person's blood type to match for transfusion (can use antibodies in blood plasma)
 - following infusion of mismatched blood, agglutination occurs as antibodies complex with the foreign blood group antigens
 - this blocks blood vessels & hinders blood flow; reduces oxygen availability to tissues, as the RBCs are lysed, hemoglobin escapes & may precipitate in kidney tubules leading to renal failure
 - treatment involves diluting agents & diuretics
 - *type O blood is the universal donor*
 - *type AB blood is the universal recipient*