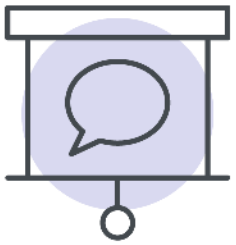
Western

Physiology 1021

MIDTERM EXAM

STUDY GUIDE



Lecture Notes

Homeostasis, Membrane Transport & the Excitable Cell

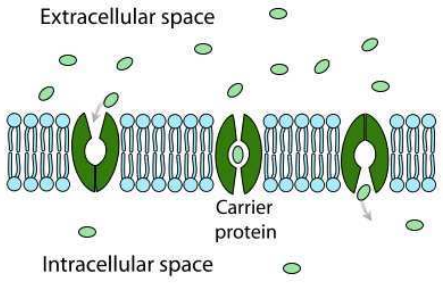
Homeostasis and Body Fluid Compartments

1. Physiology is the study of the normal functioning of a living organism and its component parts.
   - External environments: Respiratory, digestive, urinary, and reproductive.
2. Homeostasis is the ability of the body to maintain a relatively constant internal environment. Diseases and pathological conditions can develop when this isn't maintained.
3. Negative feedback control systems work as a thermostat. The initial stimulant triggers a response, which will then decrease the stimulant, causing the loop to stop.
4. A response, which cancels/counteracts the initial stimulants, triggers a stimulus which goes to the receptors in the integrating center (CNS). This in turn triggers an effector, which loops back to the response.
5. - Intracellular fluid is the fluid inside the cell (cytoplasm)
   - Extracellular fluid is the fluid outside the cell (plasma, interstitial)
   - Interstitial fluid acts as a transition between the external environment and fluid inside the cell
6. There is more chlorine and sodium ions outside the cell, and more potassium ions inside the cell.
7. With the most sodium and chlorine outside the cell compared to inside the cell, and the most potassium inside the cell than outside, it called a **SALTY BANANA.**
8. - **Nucleus:** contains most of the genetic material of the cell. Controls expression of genes and preserves DNA integrity
   - **Centrioles:** structures that direct the DNA movement during cell division
   - **Cytoskeleton:** maintains cell shape, internal organization, and intracellular transport, provides cell support and enable cell mobility
   - **Mitochondria:** produces ATP and is the main energy source of the cell
   - **Smooth ER:** synthesis of lipids and fatty acids
   - **Rough ER:** synthesis and transport of biomolecules
   - **Golgi Apparatus:** participates in protein modification and packaging. They enter through cis. end and leave through trans. End
   - **Lysosome:** digestive system of the cell, responsible for digestion of bacteria, proteins and old organelles
   - **Cell Membrane:** fatty acid chains are hydrophobic making it a good barrier to water and water soluble substances. Fat soluble substances can penetrate the membrane
9. The 3 main functions of the cell membrane are:
   a. Physical isolation
   b. Exchange with environment
   c. Communication
10. The phospholipid bilayer is made up of a polar phosphate head, and a non polar fatty acid chain which forms a hydrophobic core.
11. - **Glycoprotein:** CHO attached to a protein, cell communication and immune system
    - **Glycolipid:** CHO attached to a lipid, cell recognition
    - **Transmembrane:** protein that spans the membrane (receptors, channels)

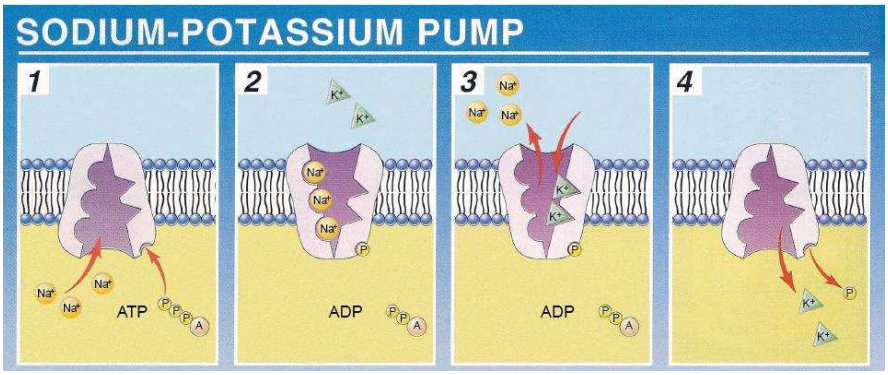
- **Peripheral Protein:** protein attached to one side of the membrane, can perform a wide variety of functions
- **Cholesterol:** makes membrane more impermeable to water, alters membrane flexibility at different temperatures.

The Interaction of the Cell with its Environment

1. The functions of membrane proteins
    a. Ions channels
    b. Enzymes
    c. Receptors
    d. Membrane carriers
2. Mechanisms of membrane transport
    a. Endo/exocytosis → phagocytosis of small molecules
    b. Diffusion through lipid bilayer → fat soluble molecules
    c. Diffusion through protein channels → water soluble molecules
    d. Facilitated diffusion → large molecules (glucose)
    e. Active transport → against concentration gradient
3. Simple diffusion does not require energy, movement of molecules of high concentration to n area of low concentration
4. Factors affecting rate of diffusion
    a. Concentration gradient: concentration gradient increases, diffusion increases
    b. Membrane thickness: the thicker it is, the slower it is
    c. Molecule size: the smaller it is, the faster it is
    d. Surface area: surface area increases, diffusion increases
    e. Lipid solubility: lipid solubility increases, the faster diffusion
    f. Composition of lipid bilayer
        i. Fat soluble molecules through lipid bilayer (must be non-polar)
        ii. Water-soluble molecules through protein channels: transmembrane protein makes a tunnel in the membrane
5. Factors affecting diffusion of water-soluble molecules
    a. Concentration gradient (larger = faster)
    b. Molecule size
    c. Charge of molecules
    d. # of protein channels
6. Facilitated diffusion: competitive inhibition prevents getting shot out of it looks like glucose "**lock and key**". It limits transport capacity and saturation affinity.



7. Active transport is a process that moves molecules against their concentration gradient. 1 molecule of ATP = 3 Na^+ out, 2 K^+ in. The sodium potassium pump helps to maintain the concentration gradients of Na and K across the membrane.



8.

	Diffusion	Facilitated Diffusion	Active Transport
Selective?			
Competitive Inhibition?			
Goes with the concentration gradient?			
ATP required?			

9. **Chemical-Mediated Cell-Cell Communication**
   - Autocrine signal acts on the cell that made it
   - Paracrine signal acts on neighbouring cells

   Contact Dependent Signals

   - Communication in close proximity (puzzle piece). Surface molecules on one cell membrane bind to a membrane protein of another cell

   Gap Junctions

   - Protein channels make bridges between cells. It is a direct transfer of chemical and electrical signals. They are made of proteins called CONNEXINS.

Osmosis, Tonicity and the Resting Membrane Potential

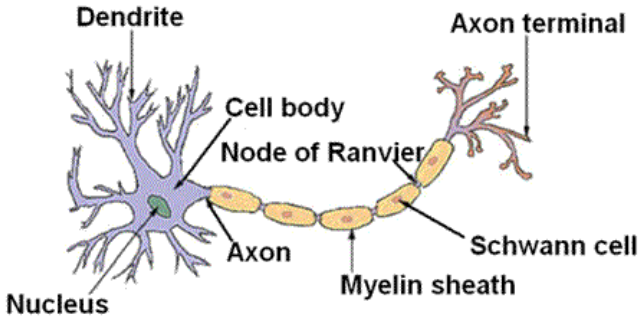
1. Osmosis- the net movement of water down its concentration gradient. Water moves to dilute the more concentrated solution. Osmosis across a membrane is affected by:
   a. Permeability of the membrane
   b. Concentration gradient of solutes
   c. Pressure gradient across the cell membrane

   Osmotic Pressure- pressure applied to exactly oppose the osmotic movement of water.

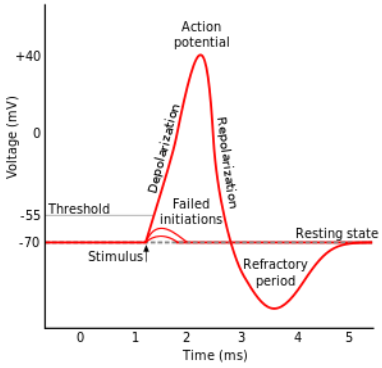
2. Osmolarity is the number of particles/L of solution. The osmolarity of body fluids in approximately 300 mosmoles/L of solution.
3. Tonicity- the ability of a solution to cause osmosis across biological cell membranes.
    a. Isotonic: same osmolarity as body fluids (stays same) (300)
    b. Hypotonic: Lower osmolarity as body fluid (cell swells) (200)
    c. Hypertonic: higher osmolarity as body fluids (cell shrinks) (500)
4. Molecules move down their chemical gradient is they move from high concentration to low concentration. Electrically charged molecules move down their electrical gradient, tend to move towards area of opposite charge.
5. Resting membrane potential- the electrical potential of a cell membrane, resulting from an unequal distribution of a few key ions across biological membranes. **-70**, all cells have a membrane potential.
6. When there are 2 compartments with equal molar solutions of NaCl and KCl, and the membrane is only permeable to K ions, K ions diffuse from A to B. Because B is now more positive than A, the Cl ions shift towards the membrane by do not cross.
7. Factors affecting the cell's membrane potential
    a. The concentration gradients of different ions across the membrane
    b. The permeability of the membrane to these ions
8. The sodium-potassium pump moves 3 Na ions out, and 2 K ions in. It is a form of active transport because it requires ATP, and does not generate RMP

The Action Potential

1. Excited cells generate and respond to electrical signals. Neurons use electrical signals (in the form of action potential) to communicate with one another. They are able to carry this signal rapidly and over long distance.
2. **Dendrites:** receive the incoming signals
   Axons: carry the outgoing information
   Soma/body: cellular processes take place here (protein synthesis)
   Synapse: region where axon terminals meet the target cell
   Myelin: formed by Schwan cells. Consist of multiple layers of cell membrane wrapped around segments of the axon
   NoR: gap between the 2 Schwann cells, unmyelinated area
   Axon hillock: trigger zone of the neuron

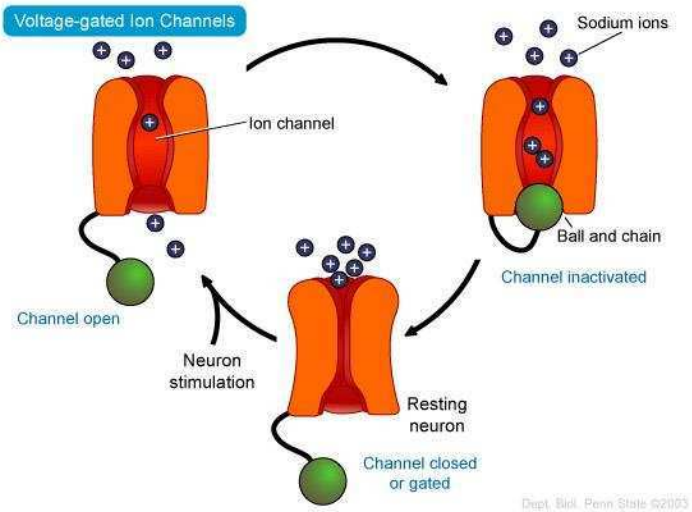


3. Depolarization: cell becomes more positive (-40)
   Repolarization: the depolarized membrane returns to RMP (-70)
   Threshold: the minimum depolarization that will initiate an action potential (-55)
   Hyperpolarization: a membrane potential that is more negative than RMP (-90)
4. Graded potential is like throwing a pebble into a pond (different amplitude). It occurs in the soma or dendrites. Depolarization or hyperpolarization caused by the opening of mechanically/chemically gated channels. Travel only a short distance due to a current leak and cytoplasmic resistance. Important for local communication

   Action potential: all or nothing. At the axon hillock, if the depolarizing stimulus reaches threshold (-55), an action potential will be triggered and propagated down the axon. Always goes from the axon hillock to the axon terminal. Always the same amplitude and duration.
5. 

   a) RMP (-70)
   b) Depolarizing stimulus
   c) Threshold: Na^+ VG channels open quick, K^+ VG channels open slow (-55)
   d) Na^+ into cell, depolarization
   e) Na^+ VG channels close, K^+ fully open (+30)
   f) K^+ leaves the cell, repolarization
   g) More K^+ leaves, hyperpolarization
   h) VG K^+ channels close
   i) Return to RMP (-70)
6. The axon hillock acts as the deciding point, if the depolarized stimulus reaches threshold (-55), an action potential will be triggered and propagated down the axon.
7. Voltage-gated channels exist for sodium and potassium in plasma membranes. The walls of the channels contain oxygen atoms to which the dehydrated sodium and potassium can bind. The configuration of the oxygen atoms lining the channels determines their specificity for either sodium or potassium.
8. **Voltage-Dependent Sodium Channel**

	Activation Gate	Inactivation Gate (Green)
Will open at approximately:	-55mV (Threshold)	-70mV (RMP)
At RMP (Bottom)	Closed	Open
During depolarization (Left)	Open	Open
During repolarization (Right)	Open	Closed



The absolute refractory period is the delay between when the voltage-dependent sodium channels finish and when it returns to resting potential. The inactivation gate (green) is responsible for ARP.

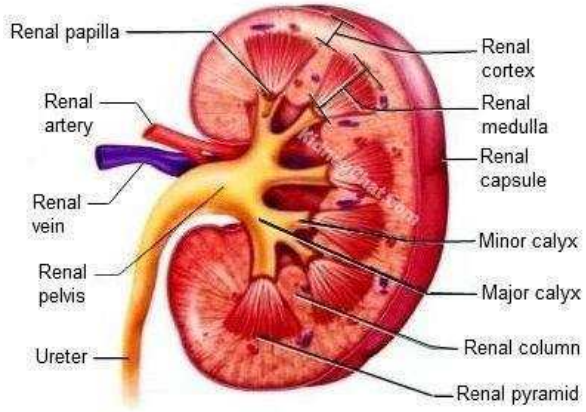
9. **Voltage-Dependent Potassium Channel**
   This begins to open during depolarization. This is much slower than the sodium channel and its peak permeability occurs at approximately +30mV. The loss of K^+ through the potassium channel is responsible for the hyperpolarization phase of the action potential.

Propagation of the Action Potential and the Chemical Synapse

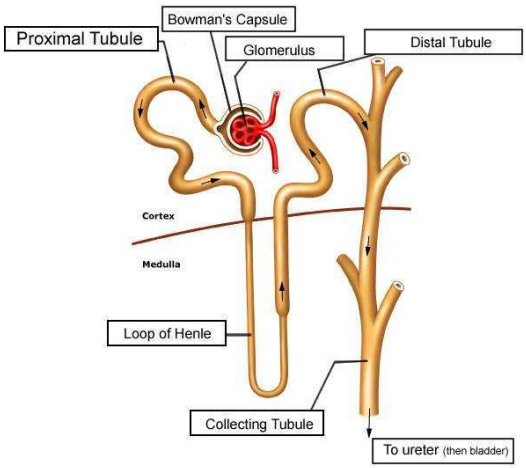
1. Propagation of an action potential down an axon terminal (Wave)
   a. Graded potential reaches axon hillock
   b. Na^+ VG channels open
   c. Positive charges flow into adjacent parts due to current flow
   d. Current flow causes new section to depolarize
   e. Unidirectional due to the refractory period, K^+ leaves
2. The all-or-nothing principle of action potentials is because the Na^+ VG channels open at threshold, causing an action potential.
3. Na^+ VG inactivation gate determines unidirectional nature of the action potential. It prevents Na^+ from entering during the absolute refractory period.
4. Main factors that affect the speed of action potential conduction down an axon
   a. Diameter of the axon: larger axon diameter means faster conduction *water through a hose is faster than a straw*
   b. The resistance of the axon membrane to ion leakage: increased ion leakage means slower action potential.
5. Saltatory conduction of action potentials is faster when myelinated (tab key, vs. space bar). AP peak → spreading → RMP → repolarizing → AP peak
6. The advantages of saltatory conduction is, less current leak, less resistance, and a smaller axon diameter.
7. Multiple sclerosis is due to autoimmune response of failure of myelin producing cells. Myelin sheath is stripped away.v

Renal Physiology

Renal Anatomy

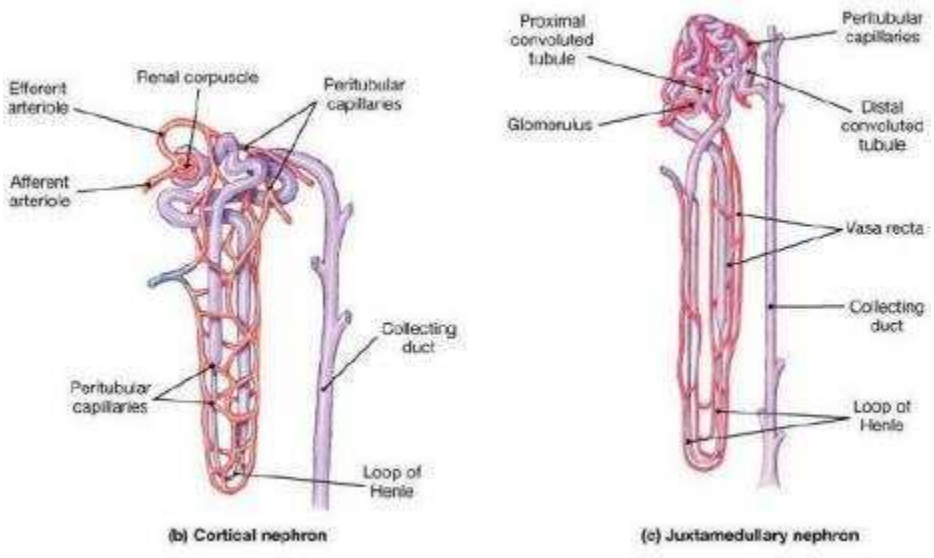
1. Functions of the kidney
    a. Regulation of extracellular fluid volume (ECF) & blood pressure
    b. Regulation of osmolarity
    c. Maintenance of ion balance
    d. Maintenance of body pH
    e. Excretion of wastes
    f. Production of hormones
    g. Gluconeogenesis
2. 

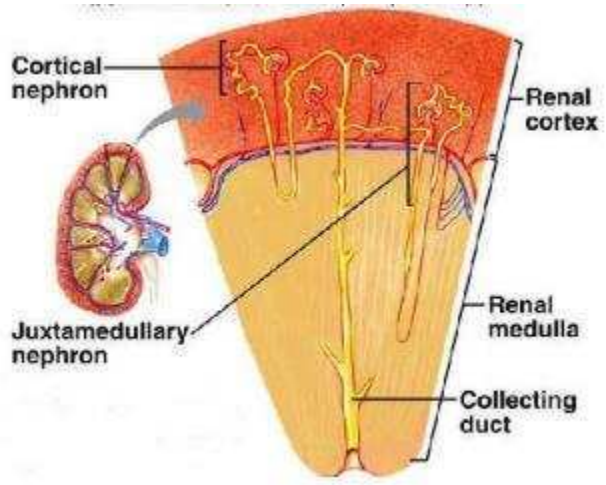
    a. The major calyces are large funnel shaped structures that collect the processed fluid from the minor calyces, which fit over pyramid shaped segments of the filtering units. These calyces are located in the medulla and are organized radially around the renal pelvis.
    b. The cortex is the tissue that lies on top of the medulla.
    c. The nephrons are the filtering units of the kidney and are found throughout the medulla and cortex, intertwined with blood vessels.
3. The nephron:



a. Functional unit of the kidney
b. Approximately one million nephrons per kidney
c. Composed of
    i. Renal Corpuscle
        1. Where filtration of blood occurs
    ii. Tubule
        2. Where the filtered fluid is processed

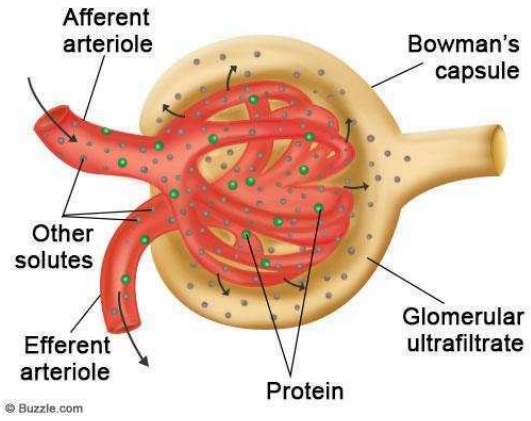
4.



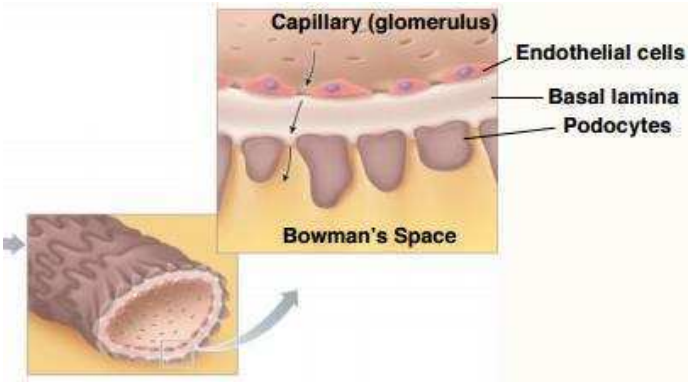


a. Categorization of nephrons based on positons within the kidney and some anatomical differences
   i. Cortical nephrons
   ii. Juxtamedullary nephrons
b. Ratios of these varies between species
c. Both have the same ability to filter blood
d. Juxtamedullary nephrons involved in producing more concentrated urine due to anatomical differences in and around the loop of Henle

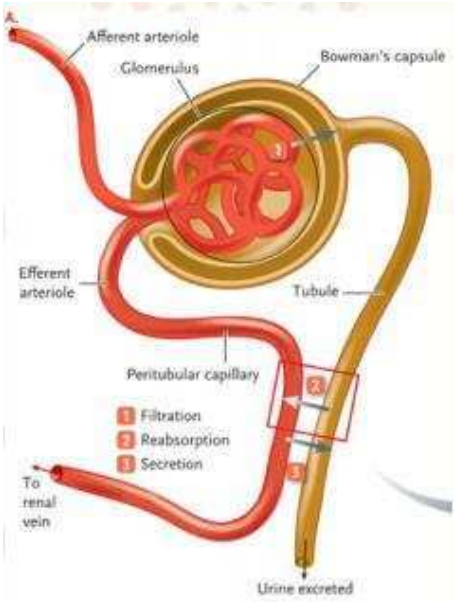
5. Renal Corpuscle
   a. Site of blood filtration to produce the filtrate
   b. All corpuscles of nephrons (both cortical and juxtamedullary) found in the kidney cortex layer
   c. Components
      i. Bowman's capsule: where fluid enters into
      ii. Glomerulus: specialized leaky capillaries
      iii. Juxtaglomerular apparatus (JGA): junction of a segment of the tubule and arterioles around Bowman's capsule



6. Renal corpuscle: Filtration structure
    a. Promote filtration & inhibits some items from filtering out of the blood
        i. Glomerulus: many pores (fenestrations) in between capillary cells
        ii. Podocytes wrap around the leaky glomerulus and prevent filtration
            1. The cells of Bowman's capsule that directly tough the glomerulus are specialized, called podocyte
            2. Fusion of glomerulus to podocytes by sticky extracellular matrix called the basal lamina, the basal lamina prevents filtration of larger items.
    b. Barriers to filtration
        i. Size of pores of glomerulus
        ii. Basal lamina
        iii. Size of slits in between podocytes



7. Blood flow to the kidneys
    a. Renal Corpuscle
        i. Blood enters the Renal corpuscle in an arteriole
        ii. Enters capillaries in the Glomerulus
        iii. Passes into a second stretch of arteriole after filtration in Glomerulus
        iv. Enters second capillary bed that surrounds Tubule
    b. Kidney blood flow
        i. Heart → artery → arteriole (afferent) → capillary (glomerulus) → arteriole (efferent) → capillary (peritubular capillaries) → venule → vein → heart
    c. 20% of cardiac output goes to the kidneys to allow for proper filtration
8. 3 process of a nephron
    a. Filtration
        i. From the blood in the glomerulus into Bowman's space
    b. Reabsorption
        i. Form the filtrate in the tubule to the surrounding capillaries (water, glucose AA)
    c. Secretion
        i. From the surrounding capillaries to the tubule filtrate



Glomerular Filtration and Circulation

1. Glomerular filtration
    a. Healthy kidneys produce a large volume of filtrate per day
    b. Ability to produce large volumes of filtrate are due to a number of pressure in the renal corpuscle
    c. Sum of these forces produces is called net filtration pressure
        i. If NFP is approximately 10 mm Hg, then proper filtration can occur
2. Pressures that affect the glomerular filtration
    a. Hydrostatic Pressure of Glomerular Capillaries (P_{GC})
        i. Pressure caused by blood flowing into glomerulus
        ii. Promotes filtration
        iii. Value of 55 mm Hg
    b. Colloid Osmotic Pressure of Glomerular Capillaries (π_{GC})
        i. Pressure caused by the presence of proteins in the glomerulus
        ii. Inhibits filtration
        iii. Value of 30 mm Hg
    c. Hydrostatic Pressure of Bowman's Capsule (P_{BC})
        i. Pressure caused by filtrate remaining in Bowman's capsule
        ii. Inhibits filtration
        iii. Value of 15 mm Hg
    d. Colloid Osmotic Pressure of Bowman's Capsule (π_{BC})
        i. Pressure caused by the presence of proteins in Bowman's capsule
        ii. Promotes filtration
        iii. Value of 0 mm Hg

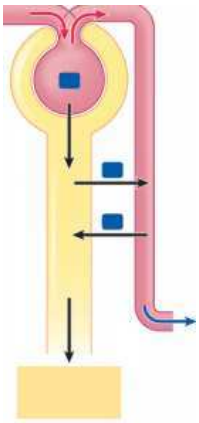
$$(P_{GC} + \pi_{BC}) - (P_{BC} + \pi_{GC})$$

3. Glomerular Filtration Rate (GFR)
    a. The amount of fluid filtered in a day by the kidneys
    b. Normal value of 180 L/day
    c. Affected by:
        i. Net filtration pressure
            1. Mostly affected by the renal blood flow and blood pressure (P_{GC})
        ii. Filtration coefficient
            1. Influenced by surface area of glomerular capillaries available for filtration
            2. Permeability of barriers between capillaries and Bowman's capsule
4. Autoregulation of GFR
    a. Myogenic response
        i. Afferent arterioles stretch
        ii. Stretch sensitive ion channels open
        iii. Smooth muscle cells depolarize
        iv. Voltage-gated calcium channels in smooth muscle open
        v. Smooth muscle of the afferent arteriole contracts (constricts afferent arteriole)

vi. Blood flow decreases in the glomerulus

b. Tubuloglomerular Feedback
   i. Content of the filtrate can affect the GFR locally
   ii. If Na^+ and Cl^- levels are higher than "normal" due to an increase
      1. Macula dense cells detect and release a chemical messenger
      2. Chemical messenger causes the afferent arteriole to constrict
      3. Blood flow decreases in the glomerulus

5. Measuring GFR
   a. Select a substance that is excreted and not reabsorbed (creatinine)
   b. Excretion = Filtration – reabsorption + secretion
   c. Rate of excretion from the body is equivalent to the GFR
   d. [Creatinine (Urine) x Urine/day] / [Creatinine (Plasma)] = GFR

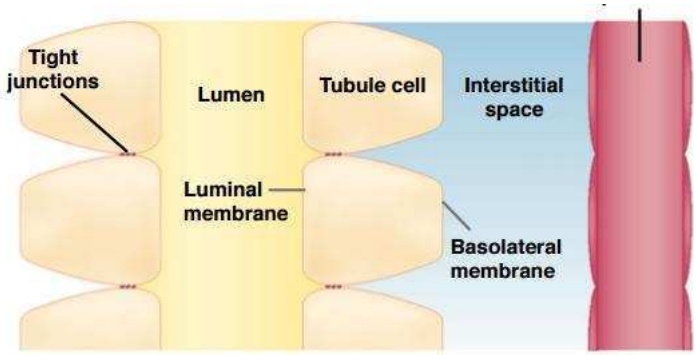


6. Renal Handling
   a. filtered load calculates how much of a substance filters into Bowman's space in a day
   b. Determined by the concentration of that substance in the blood and the individuals GFR

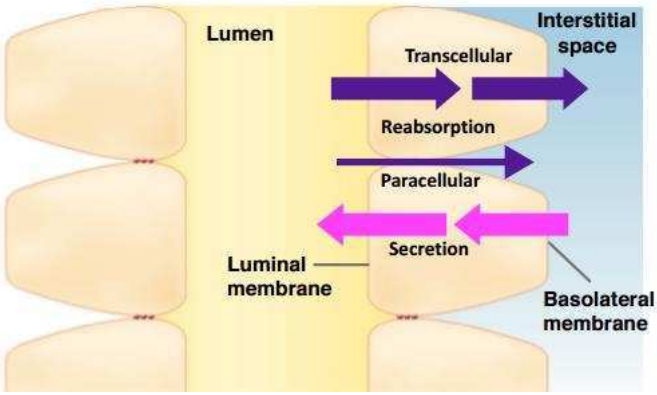
      Filtered load X = [X] plasma x GFR

   c. Renal handling is then determining how much of that substance gets into the urine and hypothesizing how that substance was handled

Transport Mechanisms

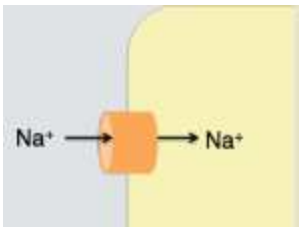


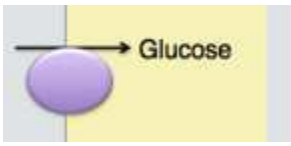
1. Cells of the tubule
   a. The tubule of the nephron is made of a single layer of epithelial cells.
   They are linked together via tight junctions.
   The membrane facing the inside of the tubule, or the lumen, is called the luminal membrane.
   The membrane that faces the outside is called the basolateral membrane.

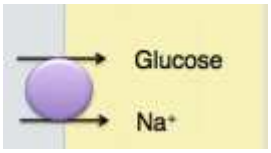


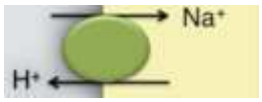
2. Mechanisms of tubule transport
   a. Reabsorption
      i. Paracellular: one step process, substance moves in between tubule cells to the surrounding capillaries (peritubular or vasa recti)
      ii. Transcellular: two-step process, substances move through the luminal (aka apical) membrane and then through the basolateral membrane and then to the capillary.

3. Basic Transport Mechanisms
    a. Channels: implies a simple diffusion mechanism, such as a basic ion channel. Channels are small protein lined pores that permit specific molecules through them. This movement is passive (no ATP required) and is driven by a concentration or electrochemical gradient.
    b. Transporters
        i. Uniporters: permits movement of a single molecule through the membrane. These are protein carriers that bind to molecules
        ii. Symporters (co-transport): permits the movement of 2 molecules in the same direction across a membrane. At least 1 molecule must move down its concentration gradient to move both molecules. For symporters that do not use energy to move molecules, the use of one molecules energy derived concentration gradient is called secondary active transport.
        iii. Antiporters (exchangers): permits the movement of 2 molecules in opposite directions across a membrane. One molecule must move down its concentration gradient in order for the other molecule to also move.
    c. Primary active transporters: requires ATP to move molecules against their concentration gradients.





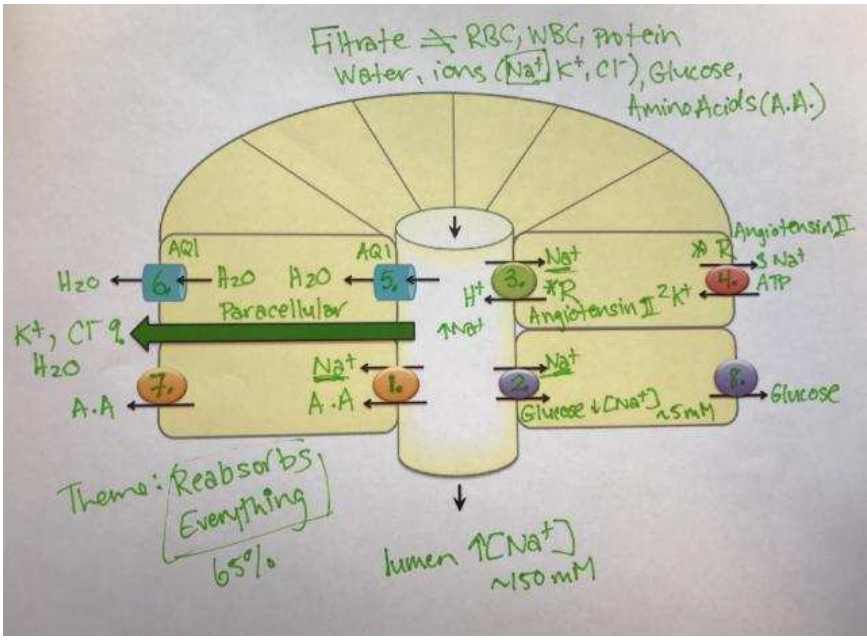




4. 3 types of regulation of channels and transporters
    a. Regulation at the level of gene expression
    b. Regulation at the level of cellular location
    c. Regulation at the level of activity

Transport Mechanisms in the Nephron

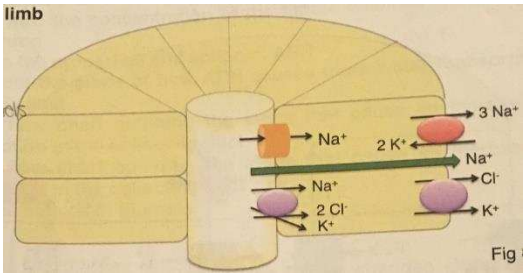
1. Proximal tubule channels/transporters
    a. Na^+/amino acid symporter (luminal)
    b. Na^+/glucose symporter (luminal)
    c. Na^+/H^+ exchanger (luminal)
    d. Na^+/K^+ ATPase (basolateral)
    e. Water channel [AQI] (luminal)
    f. Water channel [AQI] (basolateral)
    g. Amino acid uniporter (basolateral)
    h. Glucose uniporter (basolateral)
    i. Paracellular [H_2O, K^+, Cl^-] (NA)



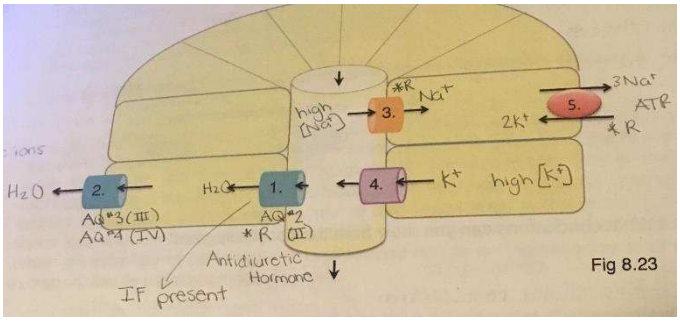
2. Diabetes Mellitus
    a. Symptoms: glucose in the urine (glucosoria), increased urine volume

b. The nephron is incapable of reabsorbing all the glucose that is normally was able to
    i. Saturation of the sodium/glucose symporter
c. Increased level of glucose filtering into Bowman's space compared to healthy individuals

3. Descending limb of loop of Henle
    a. Reabsorbs only water
    b. Epithelial cells are closely packed with each other, so no Paracellular transport
    c. No hormonal control
    d. No paracellular reabsorption
4. Ascending limb of the loop of Henle
    a. Overall theme: reabsorbs ions
    b. No hormones affecting the channels
    c. Impermeable to water
    d. No water reabsorption
    e. Paracellular reabsorption

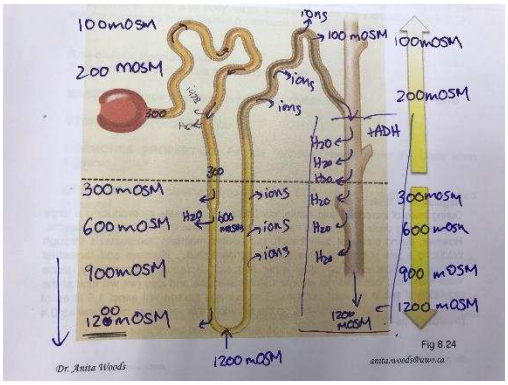


5. Distal convoluted tubule
    a. Does not reabsorb water, reabsorbs ions
    b. There is no paracellular reabsorption
    c. Reabsorbs the same ions as the ascending limb of the loop of Henle ** but also reabsorbs calcium
    d. Calcium reabsorption is hormonally regulated (parathyroid hormone)
6. Collecting duct
    a. Water channel [AQII] (luminal), regulated by antidiuretic hormone
    b. Water channel [AQII & IV] (basolateral), not regulated and is the only channel not regulated by a hormone
    c. Na^+ Channel (luminal), regulated by aldosterone
    d. K^+ Channel (luminal), secreted and regulated by aldosterone
    e. Na^+/ K^+ ATPase (basolateral), regulated by aldosterone

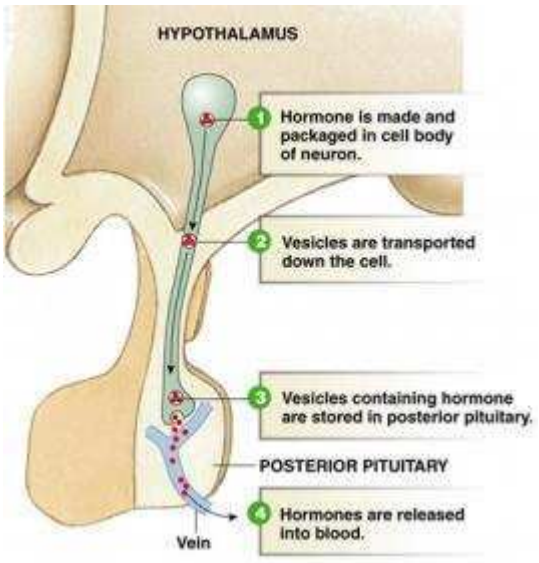


Water Handling

1. Concentration of the filtrate changes along the length of the nephron
    a. Equal ions: water is reabsorbed; filtrate is 300mOSM
    b. Only reabsorbs water, filtrate OSM increases and water moves to make equilibrium
    c. Reabsorbs ions
        i. Ratio of ions: water changes
        ii. Concentration decreases so the ions leave
    d. If ADH is in the blood, then water is reabsorbed



2. Regulation of water balance
    a. Increased fluid intake generally means increased urine output (and vise versa)
    b. Water balance controlled independently of salt balance in humans
    c. Urine volume can be as low as 0.4 L/day, and as high as 25 l/day (avg. is 1.5 L/day)
    d. Most fluid intake comes from beverages and food
    e. Most fluid is lost through urine excretion
3. Water levels and blood pressure
    a. Kidneys can control blood pressure through adjusting the blood volume
    b. If the total body water decreases, the extracellular fluid volume is decreased and this causes a decrease in blood pressure.



4. Anti – Diuretic Hormone (ADH)
    a. AKA: vasopressin
    b. Made by the neuroendocrine cells un the hypothalamus
    c. Stored in the posterior pituitary
    d. Peptide hormone
    e. Released when triggered by the stimulus
    f. Stimulus: high plasma osmolarity, low ECF volume
    g. Sensors
        i. Osmoreceptors (in hypothalamus & beside hypothalamus)
            1. When osmoreceptors decrease in volume (shrivel) then ADH is released.
            2. Osmoreceptors decrease in volume when surrounding fluid is hyperosmotic
        ii. Baroreceptors: located in the aortic arch and the carotid sinus
            1. If ECF volume decreases, less action potentials sent to hypothalamus via these receptors → ADH released
    h. ADH increases the number of aquaporin II channels on the luminal membrane of the collecting duct (relocation of existing channels)
        i. There are conditions that can occur that cause the plasma osmolarity to increase in the body. Osmoreceptors detect these changes and trigger a chain reaction. ADH is released when plasma osmolarity is higher than normal.
5. Steps that cause an increase in water reabsorption in the collecting duct, starting with an increase in plasma osmolarity
    a. Increase in plasma osmolarity
    b. Osmoreceptors shrivel
    c. ADH is released
    d. ADH binds to receptors (collecting duct)
    e. More AQII channels in luminal membrane
    f. More water is absorbed
6. Steps that cause an increase in waster reabsorption in the collecting duct, starting with a decrease in total body water

a. Decrease in total body water
b.

Sensory Physiology

Nervous System Overview

1. Divisions of the nervous system
    a. CNS- spinal cord, brain (encased in bone)
    b. PNS
        i. Somatic system- spinal nerves, dorsal root ganglia (voluntary)
        ii. Autonomic system (visceral)- blood pressure, sweating, crying (involuntary)
            1) Parasympathetic “rest and digest”
            2) Sympathetic “fight or flight”
2. The spinal cord has 31 segments, each with a pair of spinal nerves, that consist of a dorsal root (sensory) and ventral root (motor). Each segment of the spinal cord receives sensory input from a particular region of the body and supplies motor input to a similar region called a dermatome. The spinal cord has 5 regions:
    a. Cervical- 8
    b. Thoracic- 12
    c. Lumbar- 5
    d. Sacral- 5
    e. Coccygeal- 1
3. Spinal nerves carry 2 types of signals
    a. Afferent: carry information to a place, bringing sensory information to CNS
    b. Efferent: carry information from a place, taking motor information to CNS, to a motor target.

    Cranial nerves have 12 pairs that come directly off the brain. They take care of function in the head.
4. Three meninges (covering) cover the brain:
    a. Dura Mater “hard mother”- against the skull, thick like leather
    b. Arachnoid “spider”
    c. Pia Mater “gentle mother”- directly attached to the brain or spinal cord.

    Cerebrospinal fluid (CSF) is the clear fluid that exists between the arachnoid and pia mater.
5. The ventricle system- CSF is produced by choroid plexus, mostly found in the ventricle system in the brain. Spaces that contain CSF are called ventricles. This system moves CSF within the brain and transport in out to the subarachnoid space.
6. Lobes of the brain
    a. Frontal (front)
    b. Parietal (top, behind frontal)
    c. Occipital (back)
    d. Temporal (Side)

Touch (Somatosensation)

1. Skin types
    a. Hairy- arms and legs
    b. Glabrous (hairless)- palm

Layers of the skin

a. Epidermis- outer layer
b. Dermis- inner layer (receptors)

2. Mechanoreceptors- most sensory receptors of the somatosensory system are mechanoreceptors – that are sensitive to physical distortion of the skin, such as bending or stretching.
    a. Merkel's Disks (receptor)- disk-shaped receptor near the border of the epidermis
    b. Meissner's corpuscles- a stack of flattened cells in the dermis, just bellow the epidermis.
    c. Ruffini's endings (cylinder)- many branched fibres within cylindrical capsule.
    d. Pacinian corpuscles- largest – a layered, onion-like capsule that surrounds a nerve fibre deep in the dermis.

	Small (surface touch)	Large (deep touch)
Rapid	Meissner's Corpuscles	Pacinian Corpuscles
Slow	Merkel's Disks	Ruffini's Endings

3. Thermoreceptors
    a. Respond to specific temperature and to change in temperature
    b. There are separate receptors for warm and cold
    c. They are particularly interested in change
4. Nociceptors
    a. Receive the sensation of pain
    b. If you touch a hot stove the first thing to react would be these
5. The somatosensory cortex (S1) is located on the postcentral gyrus, where primary motor cortex is located. All tactile information will eventually reach the somatosensory cortex. It is arranged in columns where all neurons have the same receptive field.
6. The body is represented in the somatosensory cortex because it has somatotopy (how the body wall is represented on the brain). Particular body regions are also overrepresented in the brain.
7. Plasticity in the Somatosensory System
    a. Changes in cortical maps caused by increasing or decreasing stimulation
    b. Plasticity from amputation
    c. Plasticity following training
8. Hyperalgesia- an increased sensitivity to painful stimuli, resulting in a decreased pain threshold

    Analgesia- the inability to sense pain

    the brain cannot feel itself, nor does it have pain receptors

Vision- Eye and Retina

1. **Pupil:** the "hole" in the centre of the eye
   Iris: colour if the eye, regulated size of pupil
   Cornea: protective layer
   Sclera: white of the eye
   Extraocular Eye Muscles: rotate the eye up, down, left and right to allow it to be aimed
   Optic Nerve: carries signal from retina to the brain

Lens: focuses light onto the retina; changes shape to change where it is focused. It also filters out UV light so it doesn't damage the cell.
Ciliary Muscles: contract to change the shape of the lens
Aqueous Humor: between cornea & lens, 98% water, maintains pressure and constant refractory index, continually replenished
Vitreous Humor: between lens & retina, gelatinous, not continuously replenished
Retina: photo transduction membrane
Fovea: depression on back of retina, lens focuses all the light here

2. Retina targets
    a. Lateral Geniculate Nucleus (LGN): main target, initial image processing, visual sections of the thalamus, relays info to primary visual cortex
    b. Superior Colliculus (SC)- Tectum- Midbrain: moves head & eyes towards stimulus
    c. Pretectum- Edinger-Westphal nucleus: in front of SC, controls pupillary constriction
    d. Hypothalamus- superchiasmatic nucleus (SCN): synchronization of diurnal rhythms with the day-night cycle
3. Visual acuity: the capacity of the visual system to resolve fine special detail. Three factors:
    a. The stimulus
    b. The eye
    c. The central visual pathways

    Legal blindness is when a persons best-corrected vision is 20/200 or worse
4. The retina contains 5 basic cell types:
    a. Photoreceptors- light sensitive, stimulated by light to send signal to bipolar cells
    b. Bipolar cells- carry signal to ganglion cells, interact
    c. Ganglion cells- axons bundled together to form optic nerve (output neurons), carries signal across the top of the retina to the optic disk
    d. Horizontal cells- run between bipolar cells
    e. Amacrine cells

    The layers of the retina
    a. Nuclear layers- where the cell bodies are
    b. Plexiform layers- when the synapse and axons are
        a. Ganglion cell layer
        b. Inner plexiform layer
        c. Inner nuclear layer
        d. Outer plexiform layer
        e. Outer nuclear layer
        f. Photoreceptor outer segments
5. Photoreceptors have an outer segment (photosensitive part) and an inner segment (contains cell body). There are 2 different types:
    a. Rods:
        i. Light sensitive
        ii. Used during dim lighting conditions – scotopic vision
        iii. 120 million rods in each retina
    b. Cones:
        i. Colour sensitive

ii. Used during daylight conditions – photopic vision
iii. Fovea contains only cones
iv. 5 million cones in each retina

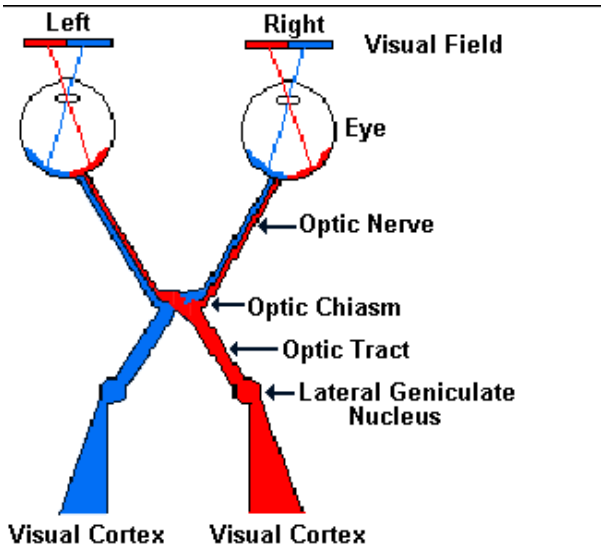
Distribution of rods and cones

a. Nasal retina is physically larger than temporal retina and contains the blind spot (no photoreceptors)
b. Rods and cones are not evenly distributed across the retina
c. In the periphery, rods outnumber cones (20:1)
d. Cones are concentrated in the fovea
e. Rods are concentrated in the peripheral vision
f. No photoreceptors can be found in the optic disk

6. Phototransduction turns light into electricity and occurs in the photoreceptors outer segment.
7. Colour impairments occur because the retina does not absorb the same wavelengths of light as the rest of the population.
    a. Red-green colour blind: referred to as dichromats: lack red or green pigment

Vision- Pathways and Brain

1. The visual field is what you can see. There is a right and a left hemifield. Binocular vision is the region seen by both eyes, and monocular vision is the region seen only by one eye.
2. The optic chiasm is important because ganglion cell axons originating from the nasal retina cross to the contralateral side.



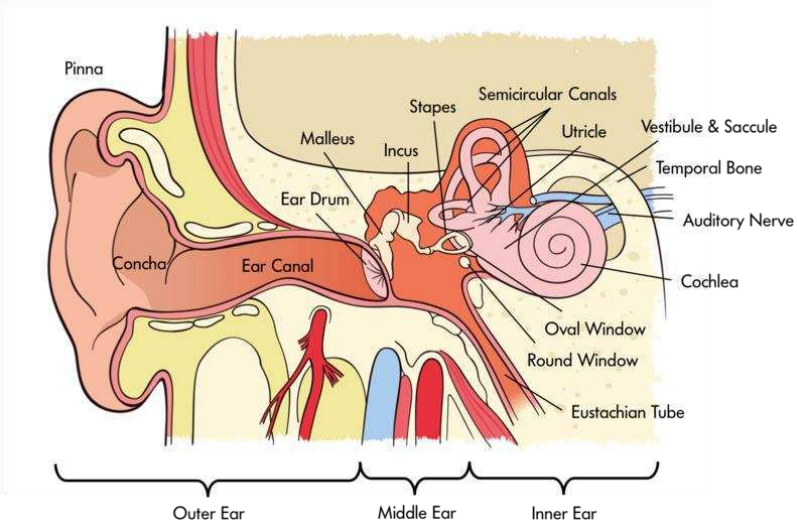
3. When you cut the left nerve, you lose monocular vision on that side (closing an eye)
   When you cut the optic chiasm, you can only see the overlapping vision (tunnel vision)
   When you cut the left tract, you lose that hemifield (cut right side, lose left hemifield)
4. Hubel and Wiesel experiment
    - Spots of light stimulate ganglion cells
    - Sports of light do little to stimulate neurons in V1
    - Sliding a slit of light across the visual field caused neurons to discharge

- They would that V1 neurons respond best to bar-like stimuli with specific orientations

5. Orientation Selectivity
   - Cortical neurons fire in response to specific features of the stimulus, such as orientation or direction of motion
   - These neurons are called feature detectors
   - Moving farther from the retina, neurons will only respond to more complex stimuli
6. Parallel Processing Steams in Visual Cortex
   a. Dorsal stream
      - Where or how pathway
      - Motion
      - Visual control movement
   b. Ventral Stream
      - What pathway
      - Pattern and object recognition

Audition

1. Variables in sound
   a. Frequency (pitch)
   b. Intensity (loudness)
2. Humans can hear between 20-20,000 Hz (measures pitch)
3. Structure of the Auditory system
   a. Outer ear- air filled space
      i. Auricle (Pinna) -movable in some animals
      ii. Auditory Canal (eternal Auditory Meatus)
   b. Middle ear- air filled space
      i. Tympanic membrane (ear drum)
      ii. Ossicles (3 small bones)
   c. Inner ear- fluid filled space
      i. Oval window
      ii. Cochlea



4. Ossicles are necessary because
    a. Sound vibrations are ineffective for moving fluid
    b. They amplify the force exerted against the oval window
    c. They convert air pressure changed into mechanical pressure.
5. The cochlear has 3 chambers:
    a. Scala Vestibuli- filed with perilymph

    Reissner's membrane separates
    b. Scala Media- filled with endolymph

    Basilar membrane separates
    c. Scala Tympani- filled with perilymph

Sound moved through the cochlea from: Oval window → Scala Vestibuli → Helicotrema → Scale Tympani → Round Window

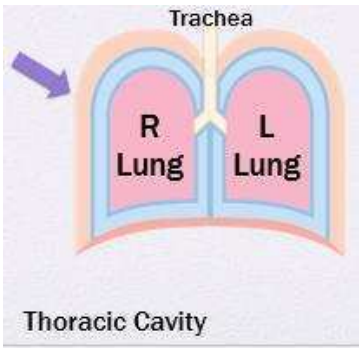
The Organ of Corti lies on the basilar membrane and contains hair cells. The tips of the hair cells contact the tectorial membrane by the movement against it changes the activity of the hair cells. Hair cells depolarize when the stereocilia bend

6. Types of hair cells
    a. inner hair cells: auditory receptor cells in the inner ear that are primarily responsible for auditory transduction and perception of pitch
    b. outer hair cells: auditory receptor cells in the inner ear that amplify the response of the inner hair cells. (More outer than inner).
7. Auditory pathway: Cochlear nucleus → Superior olive → inferior colliculus (hear while your eating) → medial geniculate → Auditory cortex
8. Low frequencies are represented anteriorly and high frequencies are represented posteriorly
9. Deafness is due to death or destruction of hair cells, and hair cells do not regenerate.

Respiratory Physiology

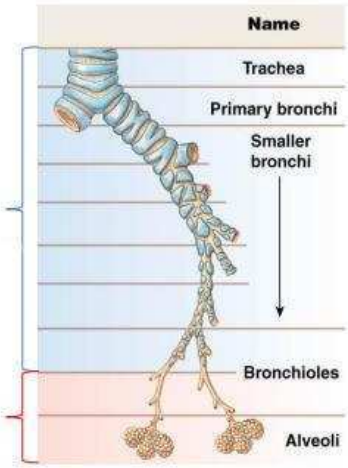
Respiratory System Organization and Function

1. Functions of the respiratory system
    a. Provides oxygen to the blood
    b. Removes carbon dioxide to the blood
    c. Regulates blood pH
    d. Speech
    e. Microbial defense
    f. Influences arterial concentration of chemical messengers
    g. Traps and dissolves small blood clots
2. Lung anatomy: the thoracic cavity
    a. Lungs are suspended in the thoracic cavity and are surrounded by the chest wall
    b. Thoracic cavity is separated from the abdominal cavity and the diaphragm
    c. The space between the lung and the chest wall is called the intrapleural space
    d. The right lungs have 3 lobes and the left lung has 2 lobes
    e. Visceral pleura is the inner membrane and it cover slung tissue
    f. Intrapleural space is in the middle and filled with pleural fluid
    g. Parietal pleura is the outer membrane and is fused to the ribcage

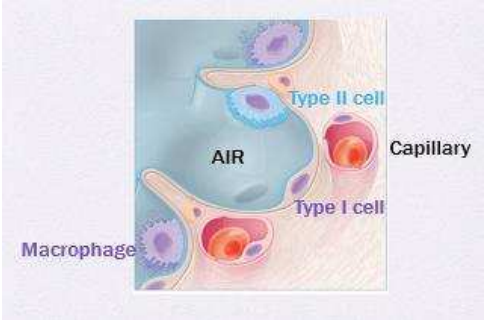


3. Functional region
    a. Conducting zone
        i. Air travels through and is conditioned to be safe for gas exchange
            1. Includes humidification, temperature change, mucocilliary elevator (microbial defense)
    b. Respiratory zone
        i. Gas exchange
        ii. Microbial defense (macrophages)

    ** Bronchioles exist in both zones**



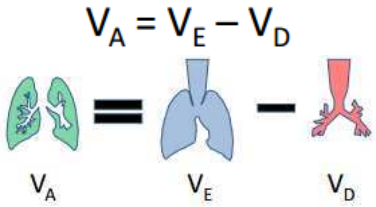
4. Alveoli
    a. Type 2 cells make surfactant
    b. Type 1 cells are a flat cell and they transport gases and forms Blood Gas Barrier
        i. Maximizing surface area maximizes gas exchange
    c. Macrophage moves from alveolus to alveolus taking up debris



5. Air in the lung
    a. Respiratory rate = number of breaths per minute
    b. Tidal volume = volume of air inhaled per breath
    c. Pulmonary ventilation = amount of air travelling through lungs per minute

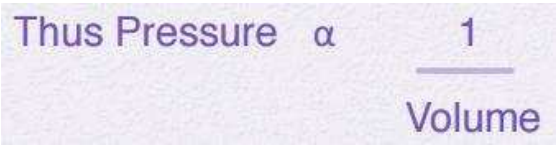
Pulmonary Ventilation = Respiratory Rate x Tidal Volume

6. Calculating aveolar ventilation (V_A)
    a. Pulmonary ventilation (V_E) is the total air moving trough the lung per minute
    b. "Non-alveolar air" per minute is the conducting zone X RR



Mechanics of Pulmonary Ventilation

1. Boyle's law states the pressure is inversely proportional to volume.
    a. Moving air into the lungs requires a gradient. When there is no air flowing in or out of the lungs the pressure inside the lungs (intrapulmonary) equals atmospheric pressure (760mmHg).
    b. The movement of air requires an air pressure gradient, so in order to get air into the lungs, you need high pressure on the outside and low pressure inside the lungs.
    c. If V goes up, P goes down
    d. If V goes down, P goes up



2. Process involved in inspiration
    a. At rest
        i. External intercostal muscles, found between the ribs, contract
        ii. Diaphragm, dome-shaped skeletal muscle, contract
        iii. Bigger pleural cavity
        iv. Always an active process
        v. Since we have expanded the volume hat air occupies without changing the mass of the air, the pressure goes down
        vi. High pressure outside the lungs pushes air into low pressure environment inside the lungs
3. Process involved in exhalation
    a. At rest
        i. Diaphragm and external intercostals relax
        ii. Smaller pleural cavity
        iii. Since we have reduced the volume that the air occupies without changing the mass of the air, the pressure goes up
        iv. High pressure inside the lungs pushes air into low pressure environment outside the lungs
        v. The lung never deflates completely because the intrapleural space has a unique subatmospheric pressure. Its advantages are:
            1. The lung does not collapse even at the end of expiration

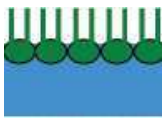
2. It allows for easy expansion of the lung, i.e. there is no resistance against inflation

b. During exercise
   i. Relax diaphragm and external intercostals
   ii. The internal intercostals, obliques, and rectus abdominus also contract

4. Transpulmonary pressure
   a. The difference between intrapulmonary P and intrapleural P
   b. This is generated because elastic recoil forces at both the lungs and the chest wall
   c. At the end of exhalation, the tendency of the lung to pull inwardly away from the chest wall is balanced by the tendency of the chest wall to recoil in the opposite direction
5. Pneumothorax
   a. The loss of the negative pressure in the intrapleural space due to a hole in either the chest walls or the lung
   b. Leading to a lung collapse (no negative pressure resisting lung elastin makes transpulmonary pressure equal to 0)
6. Elastin
   a. Most important contributor to elasticity
   b. Can stretch to 140% of resting length
   c. Fibres start in submucosal airways and become more and more distinct as they get closer to alveoli
   d. More elastin = lower compliance
   e. More collagen = lower compliance
7. Lung compliance
   a. It is the change in lung volume as a result of a change in lung pressure

$$\text{Compliance} = \frac{\text{change in lung volume}}{\text{change in lung pressure}}$$

   b. Can be considered as the “stretchability” of the lung
   c. Factors that influence compliance
      i. The elastic components of the lung itself
         1. Fibres of elastin and collagen are present in alveolar walls and throughout the lung
         2. 1/3 contribution
      ii. Surface tension inside the alveoli
         1. The film of liquid the lines the inside of the alveoli has its own surface tension.
         2. It is very powerful recoiling force and prevents the lungs from expanding and promotes lung collapse causing a decrease in compliance
         3. 2/3 contribution
8. Pulmonary surfactant

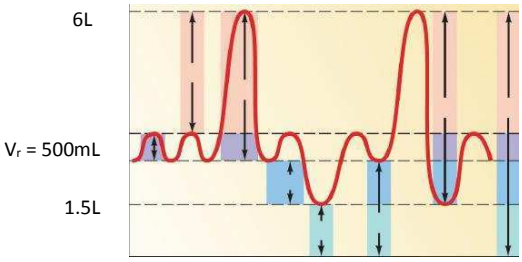


   a. Made of phospholipids spread over the top of the water in our alveoli
   b. It reduces surface tension (Soap in dill)
      i. Prevents alveolar collapse
   c. Mirobial defence system in type II cells
   d. Deficiency
      i. Poor lung compliance

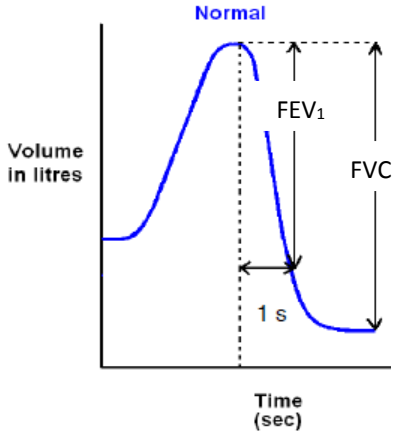
   ii. Alveolar collapse
   iii. Hypoxemia (low blood oxygen)
9. Neonatal Respiratory Distress Syndrome (nRDS)
   a. Occurs in premature infants
   b. Lack mature surfactant system
      i. Poor lung function, alveolar collapse, hypoxemia
   c. Treatment = administer surfactant

Lung Volume Measurements and Indications of Pathology

1. Spirometer
   a. Tests lung function
   b. Tidal volume (purple)
      i. Volume of inhalation & exhalation during normal breathing
   c. Inspiratory reserve volume (Pink)
      i. Amount of air you can still inhale after normal inhalation



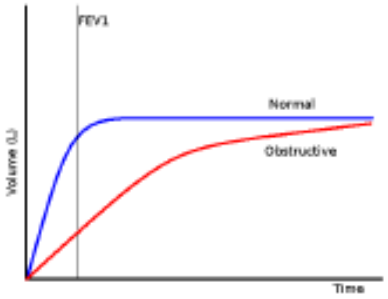
   d. Expiratory reserve volume (Blue)
      i. Amount of are you can still exhale after normal exhalation
   e. Residual volume (Green)
      i. Cant be measured by spirometer
      ii. Amount of air left in lung after exhaling as much as possible
      i. Volume that we are incapable of exhaling
   f. Total lung capacity
      i. Add all the above 4 numbers together
         1. Total volume of air in your lungs
      ii. 6L for average men
   g. Vital capacity
      i. Amount of air you can move in or out of lungs
      ii. Add all but residual volume
      iii. Movable air
   h. Forced vital capacity (FVC)
      i. Add a time component
      ii. As fast as you can breathe in and out
      iii. Volumes are mostly the same
   i. Forces expiratory volume (in 1s) (FEV-1)
      i. Normal FEV_1/FVC = 80%



2. Obstructive
   a. Characteristics
      i. Reduction in the speed at which air can move out of the lungs
      ii. >80%
   b. Asthma
      i. Spasms in airways can be triggered by exercise, air pollution, and allergies
      ii. Airway spasms in smooth muscle

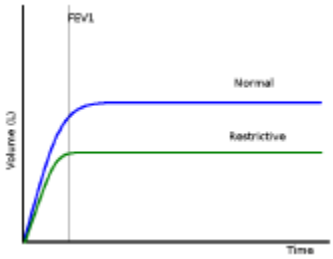
iii. Airway hyper responsiveness = airway narrowing

c. Chronic Bronchitis
   i. Excessive mucus and inflammation in the airways
   ii. Inflammation, enlarged mucus glands
   iii. Excessive mucus in airways
   iv. Smoking is the #1 cause



d. Emphysema
   i. Walls between alveoli break down creating large air sacs (decreased surface area)
   ii. Smoking is a major cause
   iii. Destruction of alveolar walls
   iv. Loss of elastin
   v. Reduces elastic recoil
   vi. Taking air in is easy but exhaling not so much (plastic bag Vs. balloon)

3. Restrictive
   a. Characteristics
      i. Reduction in amount of air that can be held in lungs
      ii. <80%

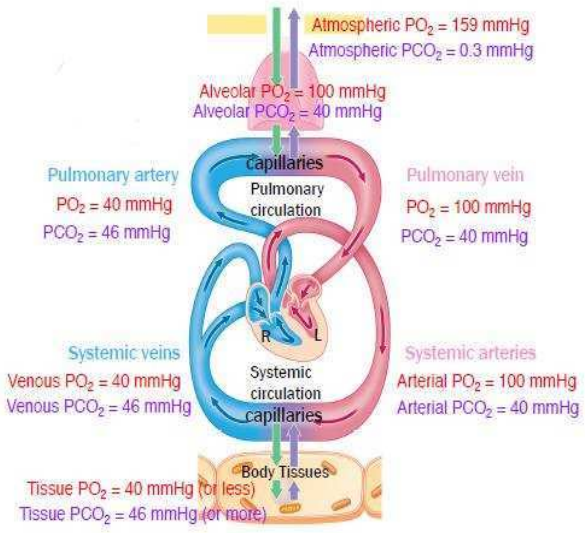


   b. Pulmonary Fibrosis
      i. Fibrosis scar tissue forms in the alveoli and other lung tissue, causing the lungs to become stiff (less compliant)
      ii. Increases collagen (inelastin) in alveolar walls compared to elastin
      iii. Caused by chronic inhalation of asbestos, coal dust, pollution, sometimes unknown (idiopathic)

Partial Pressure of Gases and Effects on Gas Exchange

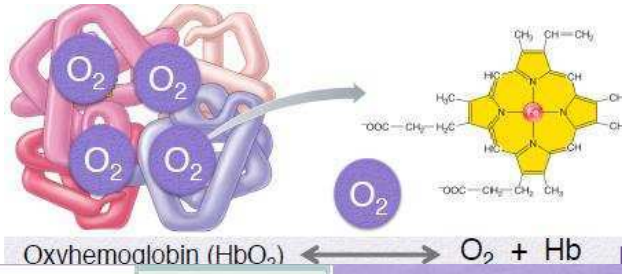
1. Partial Pressures
   a. PCO2 of air at sea level = 760 mmHg x 0.03/100 = 0.3 mmHg
   b. PO_2 of air at sea level = 760 mmHg x 20.93/100 = 159 mmHg
2. 5 factors maximizing simple diffusion across BGB
   a. Thin membrane (BGB)
   b. High SA (400+ million alveoli)
   c. High pressure gradient
   d. Low blood velocity
      i. More time for gas to pass through BGB
   e. Lipid solubility
3. The processes in gas exchange
   a. Pulmonary gas exchange
      i. Exchange of gasses between alveoli and pulmonary capillaries

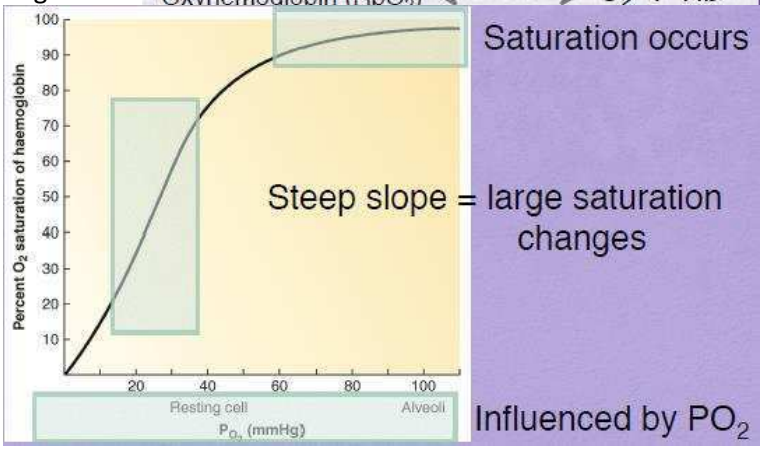
Holding breath = #'s drop



   ii. Blood gains O_2 and loses CO_2
- b. Tissue gas exchange
   i. Exchange between systematic capillaries & cells of tissues
   ii. Blood loses O_2 and gains CO_2

4. Changing ventilation
   a. Holding breath without changing metabolic activity
      i. Decrease in PO_2 and increase in PCO_2 levels (increase in pH)
   b. Hyperventilating without changing metabolic activity
      i. Increase in PO_2 and decrease in PCO_2 levels (decrease in pH)
   c. Increase metabolic activity without changing ventilation
      i. Decrease in PO_2 and increase in PCO_2 levels (increase in pH)
5. Blood composition
   a. Red blood cells
      i. 45%
      ii. Oxygen carrying cells (erythrocytes)
   b. White blood cells and platelets
      i. <1%
      ii. Leukocytes
   c. Plasma
      i. 55%
      ii. Proteins, ions and water
6. Oxygen transport
   a. Dissolved in plasma (1.5%)
   b. Bound to hemoglobin: inside erythrocytes (98.5%)
      i. Attached to hemoglobin as oxyhemoglobin (HbO_2)
7. Functions of hemoglobin
   a. Pick up lots of oxygen at the lungs by binding to the heme group
   b. Be able to drop off that oxygen at the cells of the body's tissues through the process of dissociation
   c. Pick up the waste products from the cells (CO_2)
   d. Bring the CO_2 back to the lungs for removal
8. Oxyhemoglobin dissociation curve
   a. When it goes past the tissue, it drops off 1 O_2 but keeps 3 through back to the lungs

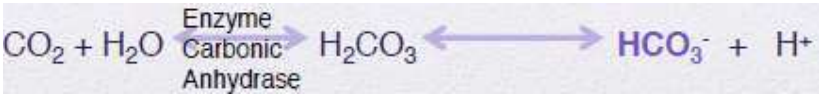




Carbon Dioxide Transport and Control of Respiration

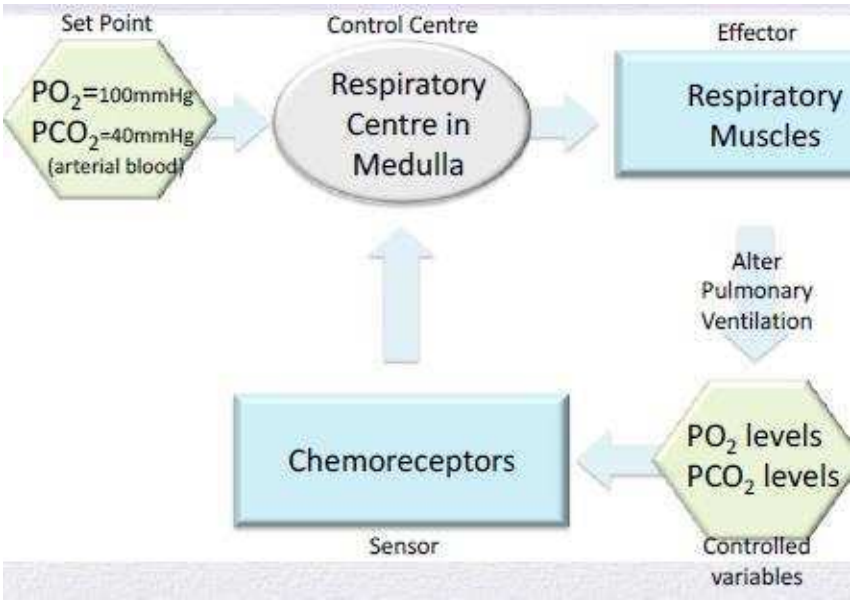
1. Offloading… makes oxygen more readily dissociable from hemoglobin
   a. Offload more when you exercise… makes a new curve (Starts later and stays underneath)
      i. Increase temperature and PCO_2
      ii. Decrease pH (acidic) and PO_2

2. Carbon dioxide transport
    a. Dissolved in plasma (10%)
    b. Carbamino form: attached to blood proteins (20%)
        e.g. “globin” subunits of hemoglobin (not heme)
    c. Bicarbonate ion (70%)
        i. $CO_2 + H_2O$ combine to form carbonic acid that dissociates into H^+ and HCO_3^- ion

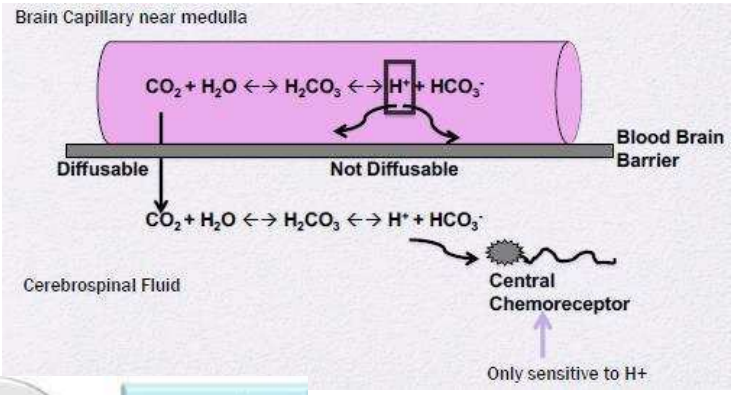


** Carbonic anhydrase is found in RBCs**

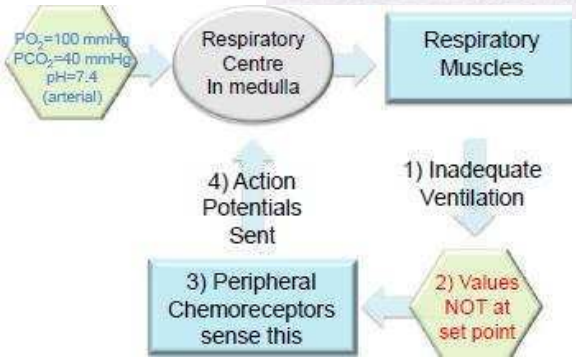
3. Negative feedback loop as it replies to the regulation of ventilation
    a.



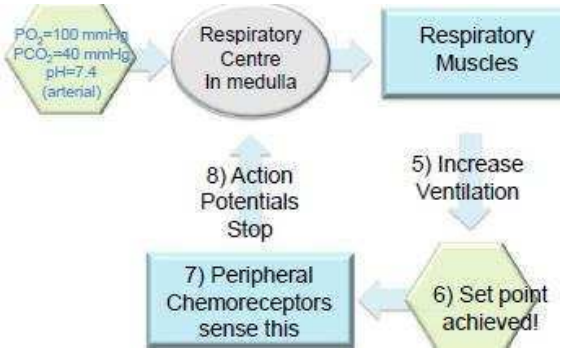
4. Chemoreceptors



Central chemoreceptors located in the medulla

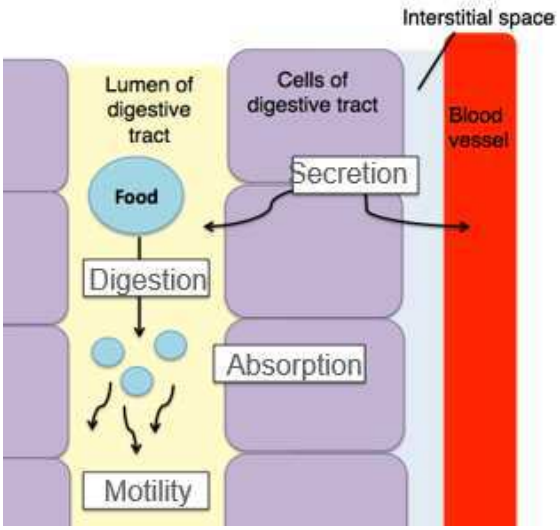


Peripheral chemoreceptors in aortic arch and carotid body: Sensitive to decreased PO_2, decreased pH, increased PCO_2

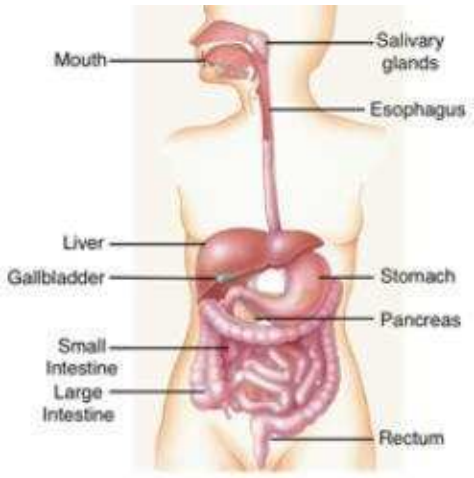


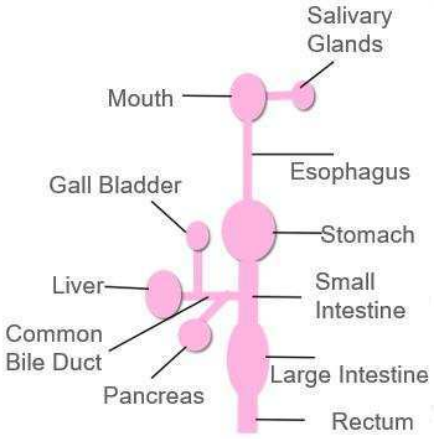
Gastrointestinal Physiology

Digestive System Anatomy and Function

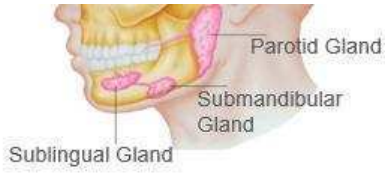


1. Four processes of the digestive system
    a. Secretion
        i. What gets added to the cavity to allow for proper function
        ii. Exocrine into lumen of the digestive tract, endocrine into blood stream
    b. Digestion
        i. What gets done to the food to make it more fit for absorption
        ii. Chemical (enzymes) and mechanical
    c. Motility
        i. Propels food through each segment of the tract
        ii. Can participate in mechanical digestion
    d. Absorption
        i. Movement of macronutrients into cells of the digestive tract and then into the blood (most occurs in the small intestine)
2. Anatomy of the gastrointestinal tract





3. Upper gastrointestinal tract
    a. Begins the digestion of food
    b. No macronutrient absorption here
    c. Mechanical and chemical digestion
    d. Saliva
        i. Complex solution containing the enzyme salivary amylase (in babies also some lingual lipase – helps babies digest fat)
        ii. Also composed of water, mucus and ions (helpful for making enzymes work)
        iii. 3 major glands secrete saliva and each gland secretes a different composition of fluid



1. Parotid gland
   - Secretes a watery liquid that contains salivary amylase
   - High in water, high in amylase
2. Submandibular gland
   - Secretes a thicker liquid that contains mucus and amylase
   - Mix of water & mucus, moderate levels of amylase
3. Sublingual gland
   - Secretes more mucus and less amylase (High in mucus but not amylase)

4. Three stages of swallowing
   a. Voluntary stage
      i. You have control
      ii. Tongue moves food towards back of mouth
   b. Pharyngeal stage
      i. Involuntary
   c. Esophageal phase
      i. Moving down esophagus
5. Mastication
   a. The mechanical manipulation (digestion) of food into a bolus
   b. Chemical digestion also occurs in the mouth
      i. Enzyme salivary amylase: digests carbohydrates
      ii. Enzyme lingual lipase: digests fat ** but doesn't begin until it reaches the stomach**
6. Peristalsis
   a. Co-ordinate contraction of the muscles in the esophagus
   b. Involuntary control
   c. Propels bolus toward the stomach (gravity not necessary)
   d. Secondary peristalsis initiated bolus is lodged items in the esophagus

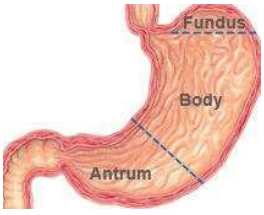
Summary- Mouth

Secretion: Saliva of varying composition

Digestion: chemical (amylase and lipase)

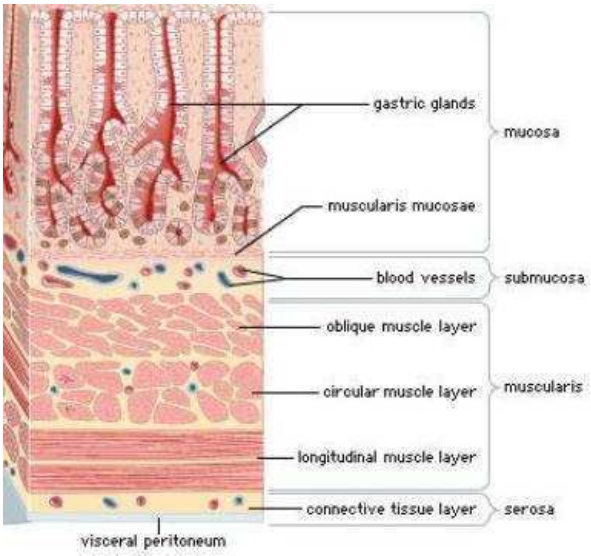
Motility: mastication in mouth, peristalsis in esophagus

Absorption: none



7. Anatomy of the stomach
   a. Acts as a reservoir for bolus before it enters the intestine
   b. Muscular contractions for mechanical breakdown
   c. Bolus is liquefied to enhance digestion
      i. Secretion of 2-3L of gastric juices
      ii. Gastric juices contributed by a number of cell types

8. Layers of the stomach
    a. Mucosa
        i. Single layer of cells
        ii. Large folds called rugae
            1. Unfold to allow stomach to accommodate food
        iii. Invaginations called Pits
            1. Contain endocrine and exocrine cells
    b. Submucosa
        i. Contains nervous plexus
            1. Submucosal Plexus
            2. Detects contents of stomach and controls stomach response
        ii. Connective tissue to adhere mucosa to smooth muscle
    c. Smooth muscle (muscularis externa)
        i. Controls shape of the stomach
        ii. Two layers perpendicular to each other
            1. Circular
            2. Longitudinal
        iii. Contains nervous plexus
            1. Myenteric Plexus
            2. Controls muscles of the stomach
    d. Serosa
        i. External layer of dense connective tissue



9. Exocrine cells of the stomach
    a. Mucus neck cells
        i. Secretes mucus
    b. Chief cells
        i. Secretes pepsinogen and gastric lipase
    c. Parietal cells (aka oxyntic cells)
        i. Secretes intrinsic factor, H^+ and Cl^- (HCL)
    d. Endocrine Cells
        i. G Cells
            1. Secrete gastrin
                - Stimulates secretion of gastric acid
                - Promotes muscle contraction
10. Digestion in the stomach
    a. Mechanical digestion
        i. Propulsion – gentle mixing waves, pyloric sphincter closed
        ii. Grinding – vigorous mixing from body to the pylorus
        iii. Retropulsion – slight opening of pyloric sphincter → very small amount of chyme exists to the duodenum
    b. Chemical digestion
        i. Hydrochloric acid (HCL) – converts pepsinogen to pepsin

ii. Pepsin – protein digestion
iii. Gastric lipase – lipid digestion
iv. Lingual lipase *activated by HCL – lipid digestion
v. Salivary amylase *inactivated by HCL – carbohydrate digestion stops

11. Functions of acid in the stomach
    a. Activation of lingual lipase – lipid digestion can occur
    b. Activation of pepsin (from pepsinogen) – protein digestion can occur
    c. Inactivation of salivary amylase – carbohydrate digestion stops
    d. Kills microbes
    e. Denatures (unwraps folded structure) proteins
    f. Stimulates secretion of hormones

Summary – Stomach

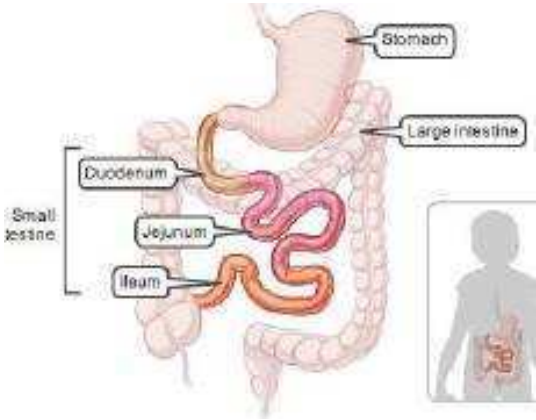
Secretion: HCL, pepsin, gastric lipase, intrinsic factor, mucus/bicarbonate, gastrin (endo)

Digestion: Gastric lipase, pepsin, HCL, lingual lipase

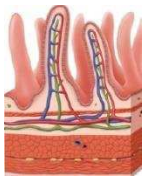
Motility: Mechanical digestion, gastrin

Absorption: none

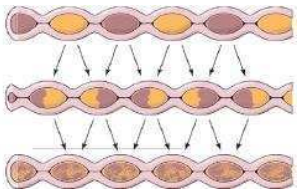
12. Regions of the small intestine
    a. Duodenum
        i. Location of enzymes mixing with chyme, most digestion occurs here
        ii. Can increase or decrease motility to optimize chemical digestion
    b. Jejunum
        i. Many villi to increase surface area for optimal absorption
        ii. Most absorption occurs here
    c. Ileum
        i. Less villi but can still absorb nutrients if necessary



13. Layers of the small intestine
    a. Mucosa
    b. Submucosa
    c. Smooth muscle (Muscularis)
    d. Serosa



14. Motility of the small intestine
    a. Segmentation
        i. Special localized contractions for mixing chyme with digestive juices
        ii. Increases the interactions of particles of food in chyme with absorptive cells of the mucosa layer
    b. Peristalsis
        i. Propels chyme from the pyloric sphincter towards to the large intestine



15. Cells types of the small intestine
    a. Absorptive cells
        i. Epithelial cells with microvilli
    b. Exocrine
        i. Goblet cells
            1. Secretes mucus
            2. Protects intestinal walls
        ii. Intestinal gland cells
            1. Secretes alkaline watery mucus that neutralizes stomach acid
        iii. Paneth cells
            1. Secretes lysozyme
                - Kills bacteria
    c. Endocrine
        i. S cells
            1. Secretes secretin
            2. Stimulates bicarbonate release
            3. Triggered by low pH
        ii. CCK cells
            1. Secretes cholecystokinin (CCK)
            2. Stimulates digestion of fat and protein
        iii. K cells
            1. Secretes glucose dependent insulinotropic peptide (GIP)
            2. Stimulates insulin secretion
            3. Triggered by carbohydrate presence
16. Microvilli
    a. Also called brush border (fuzzy appearance)
    b. Increases surface area for absorption of nutrients
    c. Cells on the microvilli have enzymes called brush border enzymes
    d. Final digestion of some nutrients to allow for absorption
17. Brush border enzymes
    a. Lactase
        i. Lactose → glucose + galactose
    b. Sucrase
        i. Sucrose → glucose + fructose
    c. Maltase
        i. Maltose → glucose + glucose
    d. Aminopeptidase (protein digestion enzyme)
        i. Cuts amino acids off the N-terminus of a protein
    e. Dipeptidase (protein digestion enzyme)
        i. Chops a dipeptide into two amino acids

Summary – Small Intestine

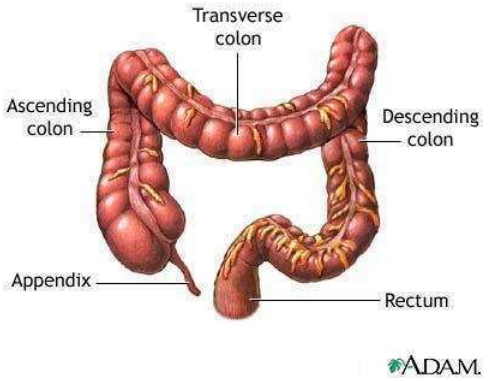
Secretion: Mucus, lysozyme, bicarbonate, zymogens, digestive enzymes, bile

Digestion: brush border enzymes, activated zymogens, pancreatic lipase & amylase

Motility: Peristalsis and segmentation

Absorption: amino acids, di- and tri- peptides, fatty acids, monoglycerides, simple carbohydrates, water

18. The large intestine
    a. Mostly water is absorbed
    b. Highly populated by bacteria
    c. About 5ft long
19. Motility in the large intestine
    a. Gastroileal reflex
        i. Presence of food in the stomach stimulates the opening of the ileocecal valve (neural reflex)
    b. Haustral churning
        i. Mixing of large intestine contents from one haustrau to the next
        ii. Allows for optimal absorption of mostly water from the lumen contents
    c. Peristalsis & mass peristalsis
        i. Unidirectional movement of lumen contents out of the large intestine



Summary – Large Intestine

Secretion: Bicarbonate, mucus

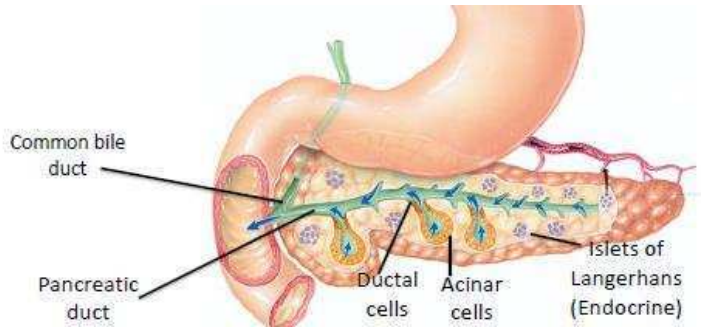
Digestion: haustral churning

Motility: haustral churning, peristalsis

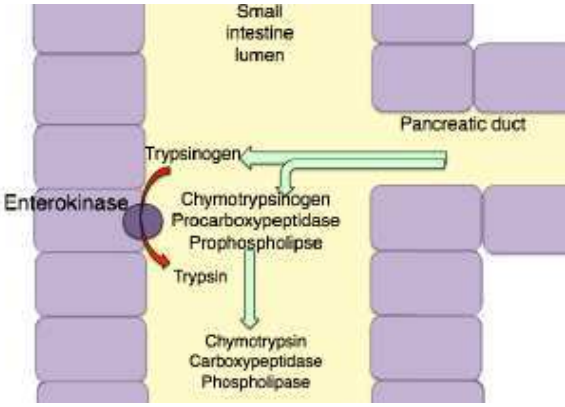
Absorption: water, vitamins, ions

Accessory Organs of the Digestive System

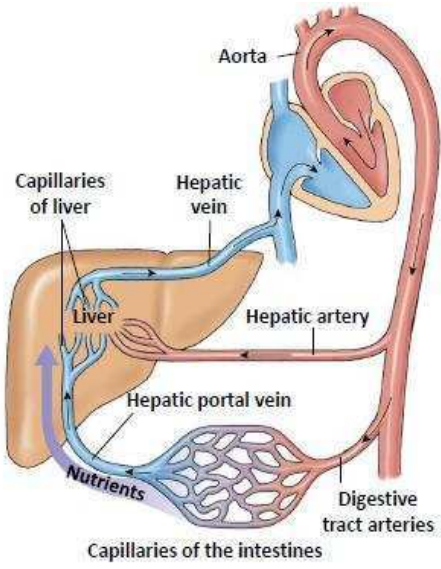
1. Pancreas
    a. Has both exocrine and endocrine functions
    b. The exocrine cells secrete into ducts that converge to form the pancreatic duct which joins t the common bile duct
    c. The exocrine secretions come from two different cell types found in the epithelial cell clusters and along the ducts



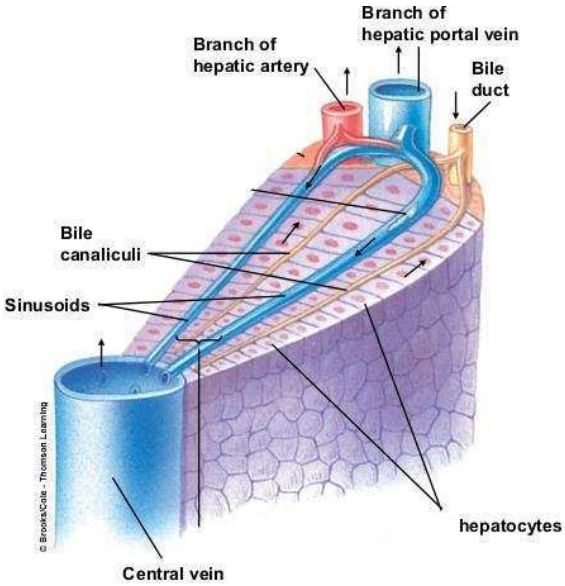
2. Exocrine secretions of the pancreas
    a. From ductal cells
        i. Bicarbonate
            1. Neutralizes the acid from the stomach
    b. From acinar cells
        i. Pancreatic amylase
            1. Digestion of carbohydrates
        ii. Pancreatic lipase
            1. Digestion of lipids
        iii. Trypsinogen → trypsin
            1. Tyrpsinogen doesn't do anything, trypsin digestions proteins
        iv. Chymotrypsinogen → Chymotypsin
            1. Digestion of proteins
        v. Procarboxypeptidase → carboxypeptidase
            1. Dogestion of proteins
        vi. Procolipase → colipase
            1. Aids in lipid digetion but NOT an enzyme



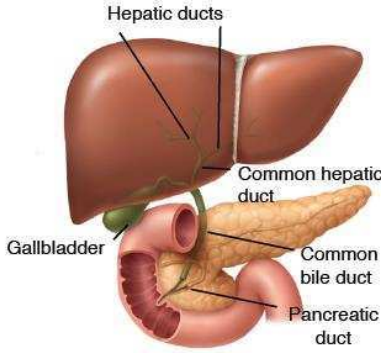
3. Exocrine secretions of the pancrease
    a. Insulin
        i. From beta cells
        ii. Moves gluocse into cells of the body (skeletal muscle & adipose cells)
    b. Glucagon
        i. From alpha cells
        ii. Releases glucose from cell stores back into the blood
    c. Somatostantin
        i. From delta cells
        ii. Decreases digestive activity by decreasing acid secretion in the stomach
4. Liver
    a. Made up of mostly hepatocytes (liver cell type)
    b. Many functions, but related to nutrient digestion is the secretion of bile which is important for lipid digestion
    c. Blood flow to liver has a special arrangement
        i. Oxygen rich blood artery
        ii. Nutrient rich blood portal system
        iii. Hepatic portal vein
            1. From digestive tract to liver
            2. Full of nutrients
        iv. Hepatic artery
            1. From heart to liver
            2. Full of oxygen



5. Inner structures of the liver
    a. Hepatocytes secrete bile into vessels called bile canaliculus
    b. These small vessels gather together and join to form a hepatic duct, which eventually forms the common hepatic duct
    c. Blood from the hepatic artery and blood from the hepatic portal vein merge together into vessels called sinusoids
    d. Sinusoids join to form central vein, and then the hepatic portal vein



6. Fucntions of the liver
    a. Synthesis of bile (contains bile salts)
        i. Functions to aid in lipid digestion
    b. Excretion of bilirubin
        i. Waste product derived from hemoglobin
    c. Metabolism of carbohydrates, lipids and proteins
        i. Nutrients from storage, or converting nutrients into each other
    d. Processing of drugs and hormones
7. Components of bile
    a. Bile salts
    b. Cholesterol
    c. Bile pigments (bilirubin)
    d. Water and ions
8. Gallbladder
    a. Storage of bile until the time it is needed
    b. As it stays in the gallbladder, bile concentrates
    c. Concentrated bile can better aid in the digestions of fats
    d. Bile is stimulated for release by actions of hormones like CCK, which causes contraction of the gallbladder



Regulation of Gastric Motility and Secretions

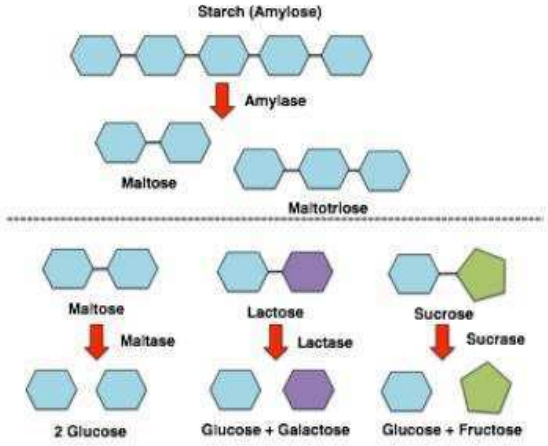
1. Cephalic phase
    a. Stimulus – sight, smell and taste of food
    b. Neural control – through medulla oblongata, activation of the submucosal plexus neurons (secretions) and myenteric plexus neurons (motility)
        i. Increased secretions from:
            1. Salivary glands (saliva)
            2. Stomach (HCL)
            3. Intestine (mucus)
        ii. Increased motility of:
            1. Stomach
            2. Small intestine

2. Gastric phase
    a. Stimulus – presence of bolus in the stomach causing stretching
    b. Neural control – sensory information to the submucosal plexus (secretions and to the myenteric plexus (motility)
    c. Hormonal control – gastrin (G cells)
    d. Both cause
        i. Increased secretions from
            1. Stomach (HCL)
            2. Intestine (mucus)
        ii. Increased motility of
            1. Stomach & increased gastric emptying
3. Intestinal phase
    a. Stimulus – presence of chyme in the intestine
    b. Neural control – sensory information to the submucosal plexus (secretions) and myenteric plexus (motility)
    c. Hormonal control – secretion (S cells), CCK (CCK cells), GIP (K cells)
        i. Increased secretions from
            1. Intestine (mucus)
            2. Pancreas
                - Bicarbonate from ductal cells *secretion
                - Digestive enzymes from acinar cells *CCK
                - Insulin from beta cells *GIP** endocrine pancreas
        ii. Increased motility of
            1. Intestine (segmentation & peristalsis)
            2. Gallbladder concentration
                - Bile released *CCK
    e. Intestinal phase also inhibits the gastric phase (bossy older sister)
        i. Decreased secretions from
            1. Stomach (HCL)
        ii. Decreased motility of
            1. Stomach & decreased gastric emptying

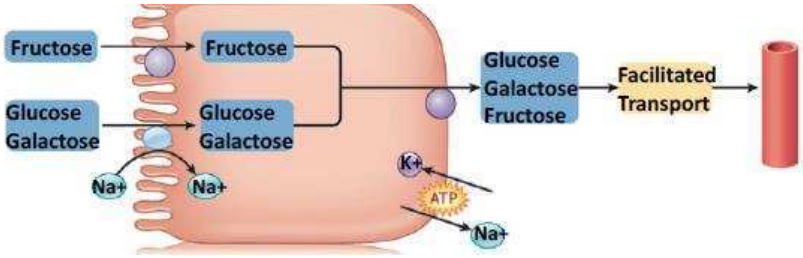
Nutrient Absorption

1. Carbohydrate sources
    a. Simple
        i. Monosaccharides (glucose, galactose and fructose)
        ii. Disaccharides (lactose, sucrose and maltose)
    b. Complex
        i. Starch (plant storage of glucose)
        ii. Glycogen (animal storage of glucose)
2. Carbohydrate digestion (chemical)
    a. Mouth – salivary amylase, starch → maltose

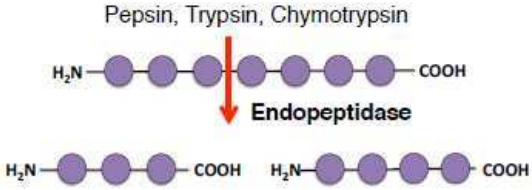
   b. Small intestine
      i. Pancreas – pancreatic amylase, starch → maltose
      ii. Lactase: lactose → glucose + galactose
      iii. Sucrase: sucrose → glucose + fructose
      iv. Maltase: maltose → glucose + glucose



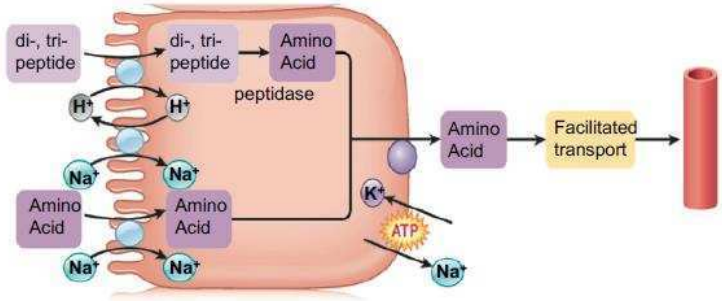
3. Carbohyrate absorption



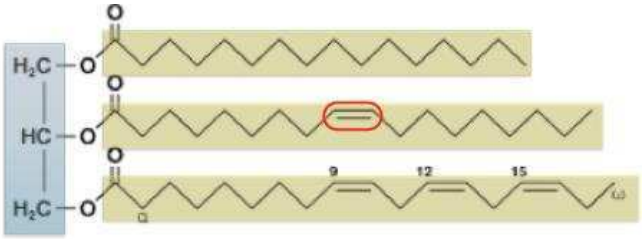
4. Protein sources
   a. Animal sources and plant sources
   b. Amino acids – have 20 different kinds
      i. Single amino acids can be organized as essential and non-essential
   c. Dipeptides – 2 amino acids bonded together
   d. Tripeptides – 3 amino acids bonded together
   e. Polypeptides – many amino acids bonded together
5. Protein digestion (chemical)
   a. Stomach
      i. Pepsin: polypeptides → smaller peptides
   b. Small intestine
      i. Pancrease: Trypsin, chymotrypsin, carboxypeptidase, aminopeptidase, dipeptidase



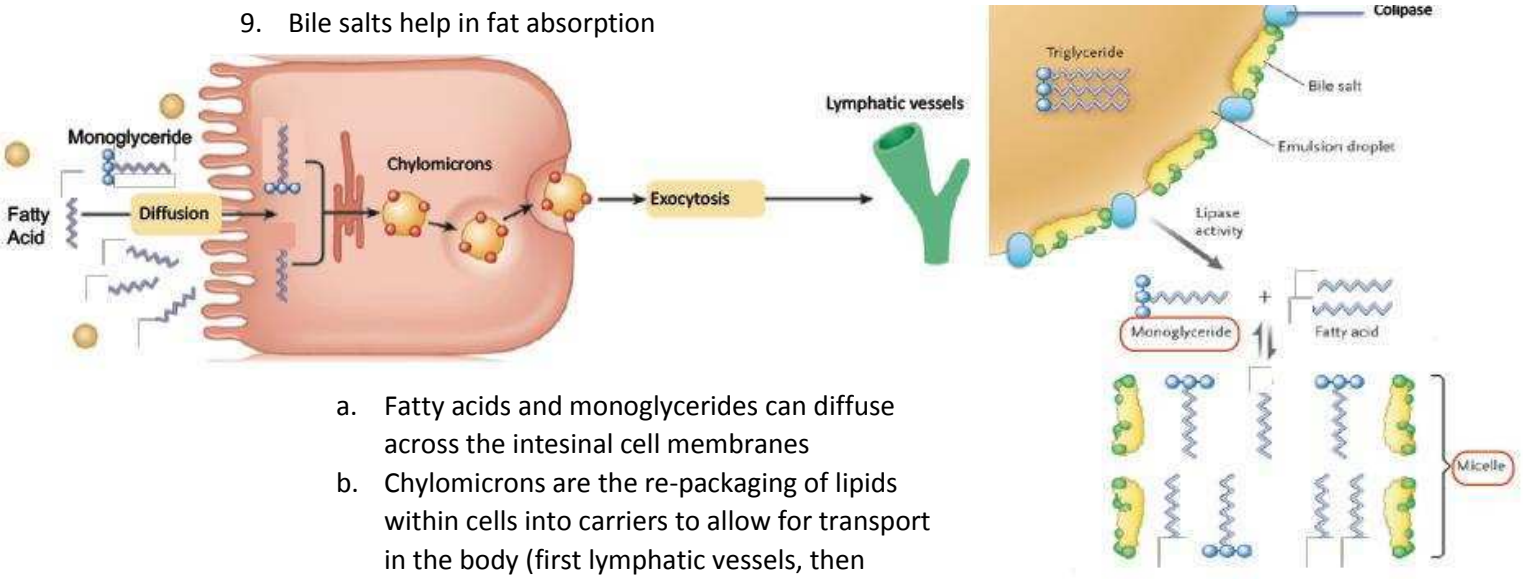
6. Protein absorption



7. Lipid (fat) sources
   a. Triglycerol – glycerol and 3 fatty acids
   b. Fatty acids are variable in length (4-24 carbons), 18 carbons most common
   c. Can be saturated or unsaturated



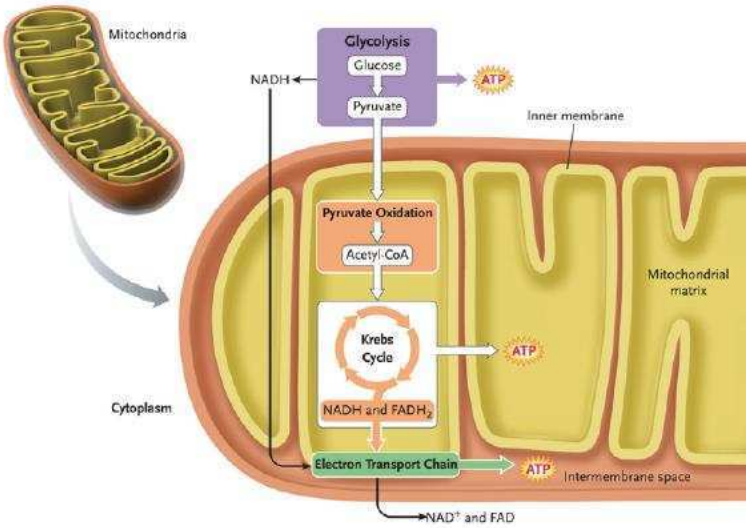
8. Lipid digestion (chemcial)
    a. Stomach – lingual lipase, gastric lipase
    b. Small intestine – pancreas: pancreatic lipase (+ colipase), liver: (+ bile)
9. Bile salts help in fat absorption



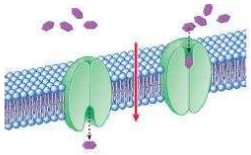
    a. Fatty acids and monoglycerides can diffuse across the intesinal cell membranes
    b. Chylomicrons are the re-packaging of lipids within cells into carriers to allow for transport in the body (first lymphatic vessels, then eventaully blood)
10. Vitamins
    a. Fat sloluble
        i. A, D, E, K
        ii. Found in lipid droplets in the GI tract
        iii. Formation of micelles by bile and colipase helps absoprtion
    b. Water soluble
        i. C, B (except B12)
        ii. Require trnasporters for absoprtion
        iii. B12 requires intrinsic factor (from parietal cells in the stomach)

Metabolism and Adaptations to Metabolism

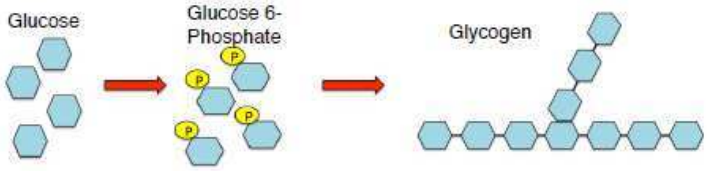
1. Sets of reactions that make-up cellular respiration
    a. Glycolysis – glucose converted to Pyruvate (10 steps)
    b. Pyruvate metabolism – Pyruvate to Acetyl-CoA
    c. Krebs cycle – Acetyl-CoA metabolized to form ATP and energy carriers (NADH & $FADH_2$)
    d. Electron transport chain – energy carriers (NADH & $FADH_2$) converted into more ATP



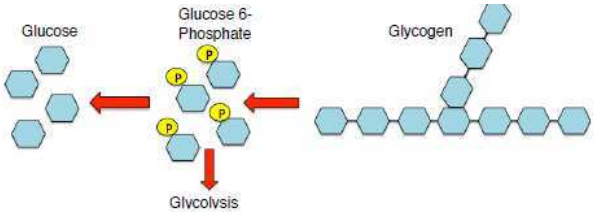
2. Fates of glucose
    a. ATP production – glucose it oxidized into ATP (glycolysis)
    b. Amino acid synthesis – converted to some amino acids if needed (protein anabolism)
    c. Glycogen synthesis – storage of glucose (glycogenesis)
    d. Triglyceride synthesis – when glucose is in excess (lipogenesis)
3. Glucose uptake
    a. Cells of the body take glucose from the blood in order to use for the production of ATP
        i. Glucose uniporters (present in the membranes of most cells of the body)
            1. Move glucose from a region of high concentration (blood) to a region of low concentration (cell)



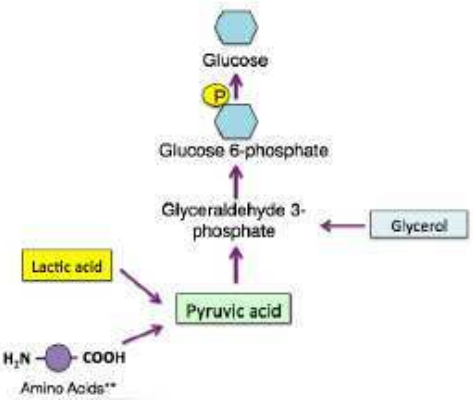
4. Glycogenesis – storage of glucose
    a. Some cells have a large capacity to store glucose as glycogen
        i. Skeletal muscle
        ii. Liver
    b. Some cellls canot, like the brain, store glucose as glycogen**



5. Glycogenolysis – breakdown of glycogen
    a. Glycogen is converted glucose 6-phosphate to be used for the production of ATP (step 1 of glycolysis)
    b. Liver is unique because it can continue to form glucose wich can then be released into the circulation

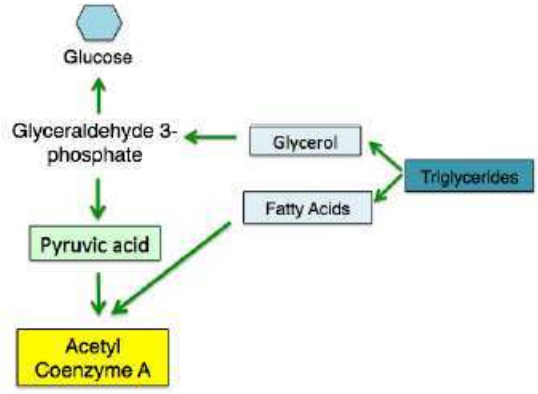


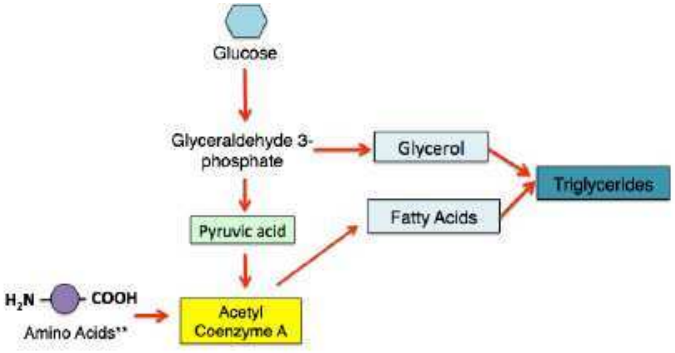
6. Glucogenesis – formation of new glucose
    a. Liver can create new glucose molecules from non-carb sources
    b. From amino acids*, lactic acid and glycerol (part of triglycerides)



7. Lipid fates
    a. Stored in adipose tissue as fat deposits (triglycerides*)
    b. Oxidized to produce ATP
    c. Formation of structural molecules – phospholipds, myelin sheaths
    d. **Triglyceride storage**
        i. *98% of our energy needed for daily use is stored as triglycerides
        ii. Distribution is mostly sub-cutaneous

8. Lipolysis- Breakdown of triglycerides into glycerol and fatty acids

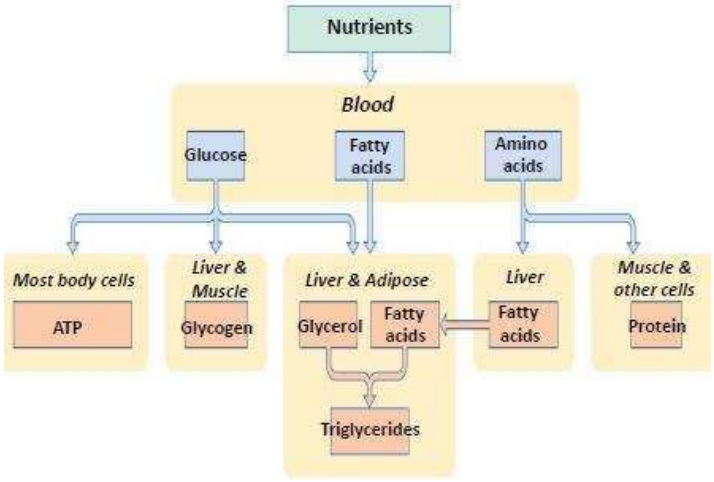




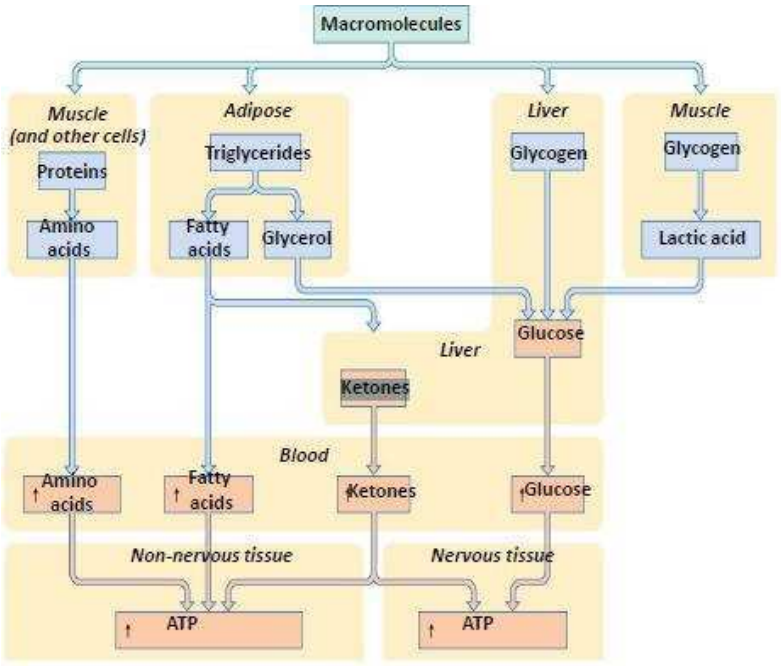
9. Lipogenesis- Formation of tryglycerides from non-lipid sources (how fat you get)
   Liver and adipose cells can make triglycerides from glucose and *amino acids

10. Ketogenesis
    a. Ketone bodies are formed by joining two Acetyl Coenzyme A molecules together
    b. Liver cells (hepatocytes) can make ketone bodies (ketogenesis) which diffuse into the blood
    c. Some cells (heart and kideny cortex) prefer ketone bodies to produce ATP
11. Proteins
    a. Protein anabolism: formation of proteins from amino acids
        i. Cells use amino acids to form new proteins
        ii. Most components of our bodies is made up of proteins
            1. Enzymes, hormones, structural components, transporters
    b. Protein catabolism: breakdwon of proteins into amino acids
        i. Amino acids from proteins can be converted into other amino acids
        ii. Liver cells can convert amino acids to fatty acids, ketone bodies or glucose

12. Absorptive (fed) state



13. Post-absorptive (fasted) state



Endocrine Physiology

Introduction to Endocrinology

1. For homeostasis to occur, the body needs to communicate to each other and the endocrine system uses hormones for cellular signaling to distant sites throughout the body.
2. a. Pituitary: oxytocin, antidiuretic hormone, various other hormones
   b. Hypothalamus: various hormones
   c. Pancreas: insulin, glucagon
   d. Adrenals: cortisol, aldosterone
   e. Thyroid: T_3, T_4
   f. A neurotransmitter differs from a hormone because a hormone travels through the bloodstream and NT travel to synapse. Hormones have a slow response time and NT have an extremely rapid response time.
3.

	Peptide/Protein	Steroid	Amine	
Example Hormone	Hypothalamic & pituitary	Testosterone, estrogen, cortisol	Thyroid	Epinephrine (adrenaline)
"Building Block"	Amino Acids	Cholesterol	Tyrosine	
Solubility	Hydrophilic	Lipophilic	Lipophilic	Hydrophilic
Transportation in blood	Dissolve well in plasma	Not soluble in water, needs protein carriers	Protein carrier	Plasma membrane
Location of receptor	Plasma membrane	Intracellular	Intracellular	Plasma membrane
Time before onset of each action	Fast	Slow	Slow	Fast

4. Anterior pituitary gland: endocrine cells (hormones shipped to), trophic hormones enter. Posterior pituitary gland: neurons, typical brain, oxytocin (uterine concentration, milk excretion) and antidiuretic hormones (water reabsorption in kidneys, act on plasma membrane bound receptors.
5. Vasopressin (ADH) acts on specific regions of the kidney tubules to conserve water by allowing reabsorption of water back into the blood. This affects blood pressure, since low blood volume = low blood pressure. Found on plasma membrane because its hydrophilic and alcohol inhibits ADH which explains peeing all the time.

The Anterior Pituitary and Thyroid Gland

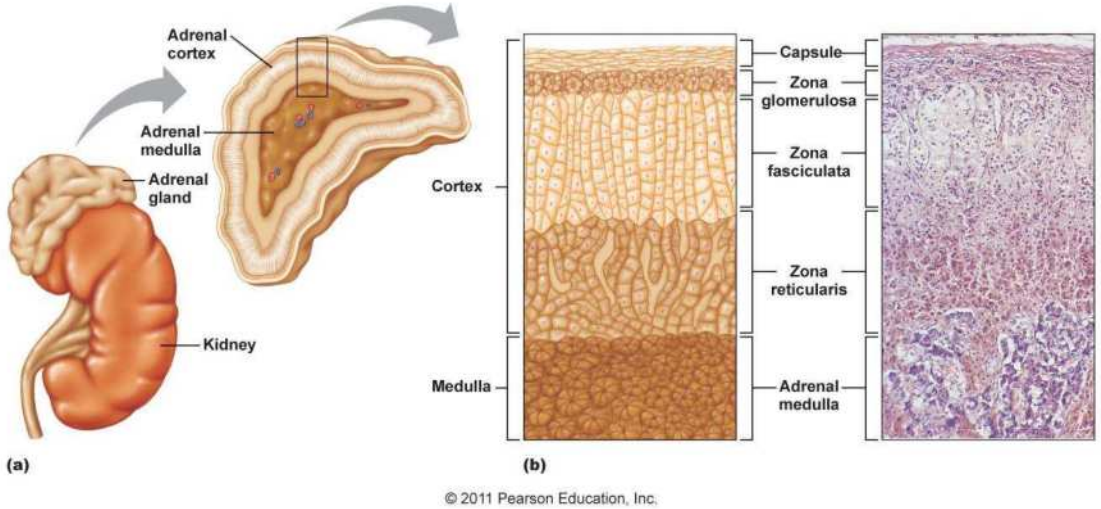
1. The APG releases numerous hormones in response to stimulation from the hypothalamus.
2.

Hypothalamus releases:	Anterior Pituitary Releases:	Acts on:
Gonadotropin (GnRH)	Luteinizing/ Follicle (LH/FSH)	Gonads
Thyrotropin (TRH)	Thyroid (TSH)	Thyroid Gland
Corticotrophin (CRH)	Adrenocorticotropic (ACTH)	Adrenal Gland (cortisol)
Growth hormone (GHRH)	Growth hormone (GH)	Various (bone, skeletal)
Dopamine: inhibitory (break)	Prolactin (Milk production)	Mammary gland (no hormone)

3. The thyroid gland is a butterfly shaped organ located in the lower neck region, just below the larynx. It produces hormones that act on most of the cells in your body to influence your metabolic rate.
4. Hormones are made in the follicles. Here thyroxin, also known as tetraiodothyronine (T_4), and triiodothyronine use the amino acid tyrosine as the basic building black to which iodine is added.
5. Synthesis of Thyroid Hormones
    a. Need iodine and tyrosine, iodide must be transported from the blood by active transport
    b. Protein thyroglobulin, with its tyrosine, must enter colloid by exocytosis
    c. Iodide must be added to tyrosine in thyroglobulin at apical surface
    d. Coupling must occur where 1MIT + 1DIT = T_3 and 1DIT + 1DIT = T_4
    e. Thyroglobulin with T_3 and T_4 must be taken out of the colloid into follicular cells by endocytosis.
    f. T_3 and T_4 are released by protein degradation and diffuse to blood

Thyroid Gland and Adrenal Gland

1. TRH produces TSH which produces T_3 and T_4 with iodine included.
2. Too much thyroid hormone causes hyperthyroidism. Symptoms include, elevated MR, high heart rate, sensitive to heat, weight loss, fidgety, goiter.
   Too little thyroid hormone causes hypothyroidism. Symptoms include, slow heart rate, sensitive to cold, weight gain, fatigue, depression (metabolism slows down, not burning enough energy)
3. Structure of an adrenal gland GFR- Good for retirement- Glomenulous: aldosterone (salt), Fasciculata: cortisol (sugar), reticularis: androgens (sex). Medulla is the core → epinephrine.



4. Steroid hormones
    a. Mineralocorticoid- affects mineral production (aldosterone)
    b. Glucocorticoid- affects blood glucose levels (glucose)
    c. Androgens- male sex hormones (DHEA)

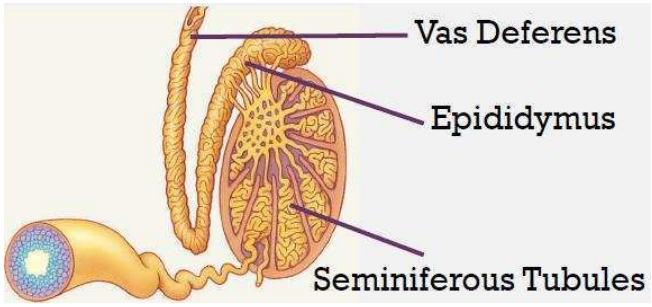
Adrenal Gland

1. CHR produces ACTH which creates cortisol in the zona fasciculata. This can also work back wards when too much is produced
2. Cortisol is catabolic so it breaks down larger molecules.
   Cortisol→Muscle→ Protein catabolism→proteins→amino acids *effects on bone*
   Cortisol→Liver→gluconeogenesis (makes new glucose)
   Cortisol→adipose→lipolysis→triglycerides→glycerol fatty acids
   Cortisol→immune system→immune suppression
3. Cushing's disease is due to the hypersecretion of cortisol. Symptoms include, hyperglycemia (high blood pressure), muscle atrophy & weakness, thinning skin & tearing, stunted growth & osteoporosis, redistribution of fat tissue, increased infections.
4. Aldosterone affects the transportation of ions by the kidneys. While this can be released by ATCH, it is often secreted when stimulated by angiotensin II. It is also stimulated by increases in blood potassium. Potassium is secreted into the kidney tubules, in part by increasing the number of sodium potassium ATPase pumps. Sodium enters the blood from the kidney tubule, and potassium leaves the blood into the kidney tubule.
5. Increased epinephrine could activate the fight or flight response, in turn, increasing heart rate because it influences blood glucose.
6. Beta cells release insulin, hyperglycemia is their stimulus, signals cells to take up glucose.
   Alfa cells release glucagon, hypoglycemia is their stimulus, releases stored glucose.

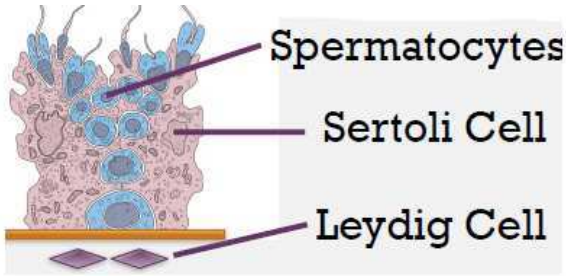
Reproductive Physiology

Male Reproductive System

1. Evidence that the reproductive system does not function primarily to maintain homeostasis
    a. Women get hysterectomies
    b. Animals get neutered
    c. Boys use to get testes removed to keep high voice for opera singers
2. The testis
    a. Vas deferens
        i. Delivers mature sperm to the urethra
    b. Epididymus
        i. Stores sperm and matures it
        ii. Can store over a month supply
    c. Seminiferous tubules
        i. Makes sperm (spermatogenesis)



3. Componets of a seminiferous tubules
    a. Sertoli cell
        i. Prouce testosterone
    b. Leydig cell
        i. Support and regulate spermatogenesis
    c. Spermatagonia/spermatocytes
        i. Sperm cells



4. Spermatogenesis

1 Spermatigonia –MITOSIS--> Spermatogonia
--> Primary spermatocyte (46 chromosomes)

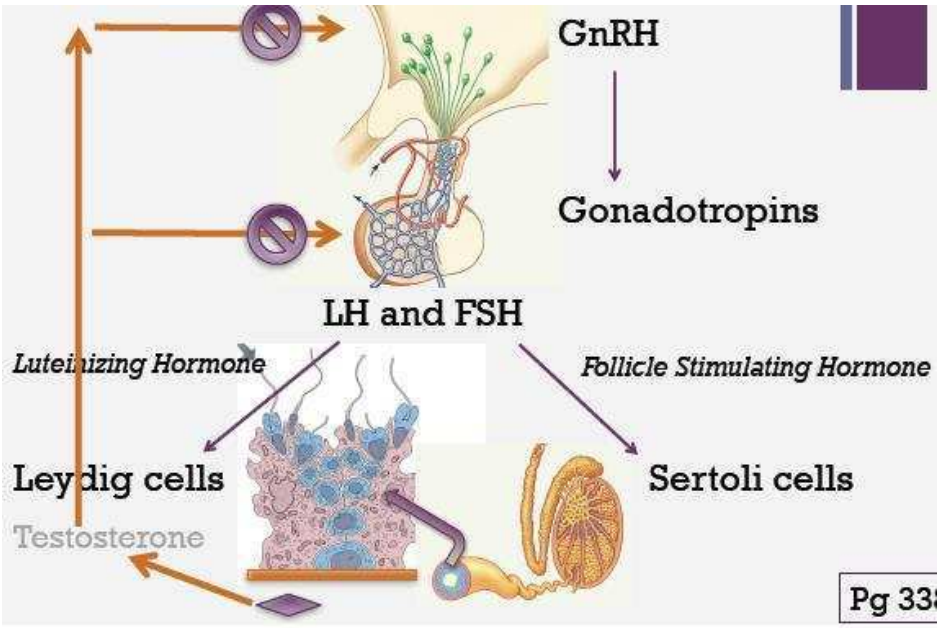
1 Primary spermatocyte –MEIOSIS I--> Secondary spermatocyte (23 chromosomes)
--> Secondary spermatocyte (23 chromosomes)

2 Secondary spermatocyte –MEIOSIS II--> Spermatid
--> Spermatid
--> Spermatid
--> Spermatid

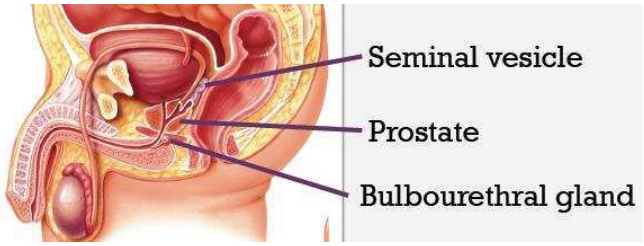
4 spermatid (23 chromosomes) --> Spermatozoa
--> Spermatozoa
--> Spermatozoa
--> Spermatozoa

5. Testosterone
    a. Steroid hormone
    b. Lipophilic because it is made from cholesterol
    c. Bound to blood proteins → travel through cell membrane

6. Regulating reproductive function

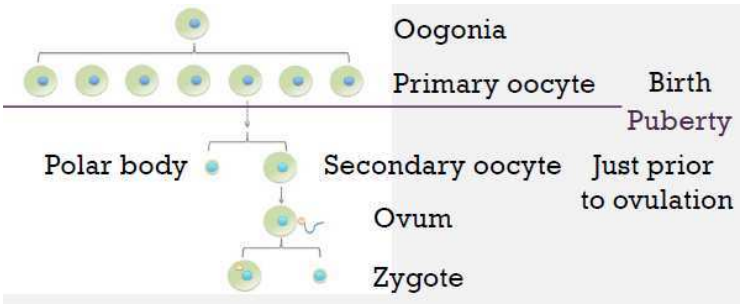


7. Functions of testosterone in the male
    a. Negative feedback
    b. Spermatogenesis
    c. Secondary sex characteristics
        i. Facial hair & growth
        ii. Deepening voice
        iii. Other hair growth
        iv. Increases size of reproductive organs
    d. Anabolic reactions (e.g. muscle mass increases)
8. Reproductive system
    a. Seminal vesicle: 60% of volume of semen (2)
        i. Fructose, clotting proteins (alkaline)
    b. Prostate gland: 30% of volume of semen
        i. Citric acid, enzymes (slightly acidic)
    c. Bulbourethral gland: minor contribution (2)
        i. Mainly mucus (alkaline)
    d. Testes
        i. External gonads because they work better when they are a few degrees cooler than body temperature



9. Prostate cancer
    a. Urethra passes through your prostate, so when inflamed you can't urinate (urethra blocked off)
    b. Prostate in front of rectum so a prostate exam consists of a finger going up the rectum to feel if inflamed
    c. Chemo/radiation or can remove part/all off the prostate

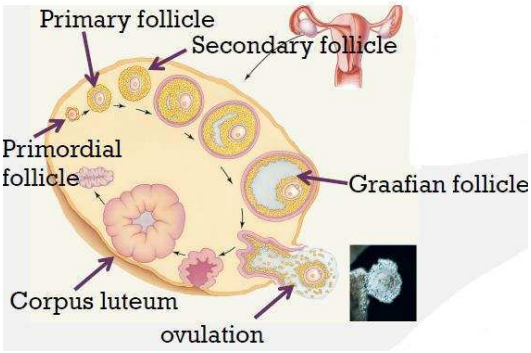
Female Reproductive System

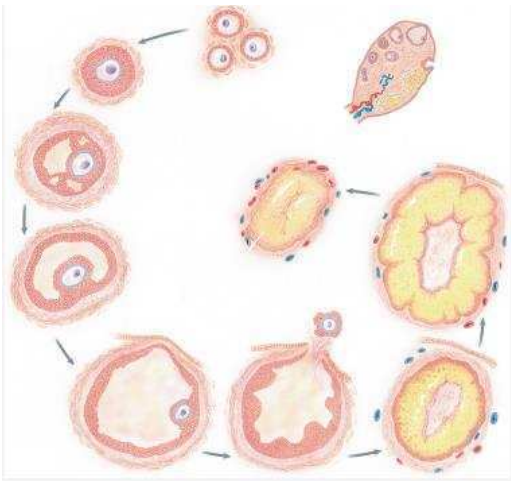


1. Oogenesis
   a. All the oogonia produced exist prior to birth
   b. Meiosis I happens between primary and secondary oocyte
   c. Meiosis II only occurs if the egg is fertilized
2. Comparing oogenesis and spermatogenesis

a. Men → Only some go into primary	Women → all go into primary
b. Men → always have 2nd meiosis	Women → 2nd meiosis only if fertilized
c. Men → produce 2 secondary (maximize)	Women → only produce 1 (no litter)
d. Men → starts @ puberty	Women → finish mitosis before birth
e. Men→ leydig & sertoli as support cells	Women → changes over a month

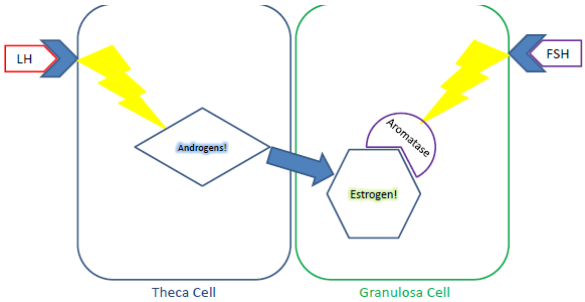
3. Follicular development
   a. A follicle includes an oocyte and support cells
   b. Primary follicle
      i. 1° oocyte
      ii. Granulosa cells (cubed shape)
      iii. Zona pellucida (where sperm binds to egg)
   c. Secondary follicle
      i. 1° oocyte
      ii. Granulosa layers
      iii. Theca cell appear
   d. Graafian follicle
      i. Antrum develops
      ii. Considerable size
      iii. 1° oocyte until just before ovulation (dominant Graafian follicle)
      iv. Early Graafian follicle
         1. Granulosa + theca + antrum

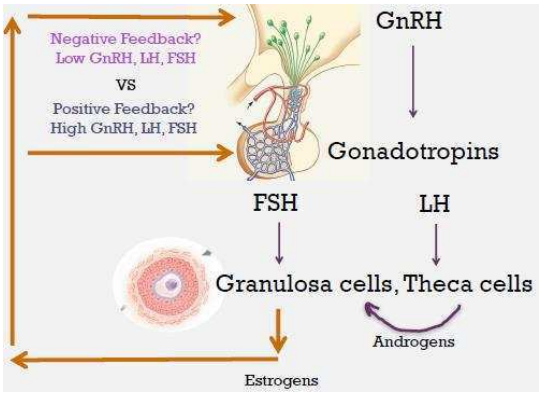




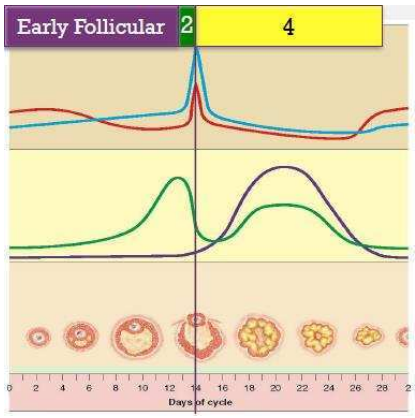
4. Cell types and functions
   a. Oocyte: “egg”
   b. Theca cells: produce androgens (LH) --> testosterone gets converted into estrogen by aromatase
   c. Granulosa cells: produce estrogens (FSH) --> have lots of aromatase

5. Regulating reproductive function
    a. Short period of time that is positive feedback
        i. Estrogen increase

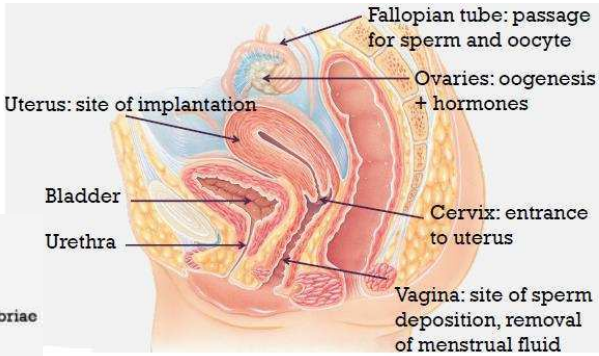


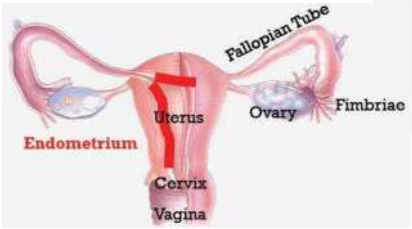


6. Hormonal regulation, LH FSH Estrogen Progesterone
    a. Phase 1: Early (to mid) follicular
        i. LH/FSH stay low
        ii. Estrogen rises (negative feedback)
            1. Follicle gets more ganulosa cells/layers = more estrogen
    b. Phase 2: Late follicular
        i. High estrogen & LH/FSH
        ii. Positive feedback
        iii. Ovulation doesn't happen without this
    c. Phase 3: Ovulation
        i. LH surge triggers ovulation
            1. Triggers 2^{o} oocyte to develop
        ii. High sustained estrogen levels switch to positive feedback
    d. Phase 4: Luteal phase
        i. Corpus luteum shows up
            1. Left over granulosa and theca cells
            2. Steroid hormone secreting structure
        ii. Progesterone is important to keep baby and prolongs cycle by 14 days
        iii. Negative feedback



7. Female anatomy
    a. Fimbriae – catcher mitt
        i. Catches egg and moves it down the tube
        ii. Cilia sweeps oocyte to uterus
    b. Endometrium
        i. Where you bleed from
        ii. Responds to hormones

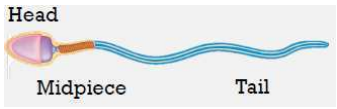




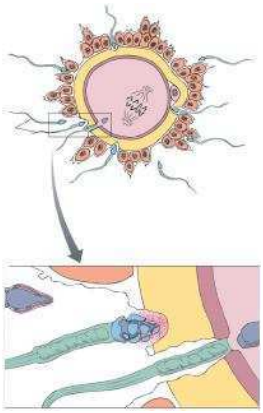
8. Endometrium thickens due to rise in hormones in the uterine events
9. Effects of female sex hormones on the body
    a. Follicular development (E)
    b. Uterine changes (E & P)
    c. Feedback (negative/positive)
    d. Cardiovascular health
    e. Bone density
    f. Breast changes
10. Oral contraceptive pills
    a. Stable levels of estrogen
        i. Follicle doesn't develop properly
        ii. No dominant follicle
        iii. No positive feedback = no ovulation
11. Menopause
    a. Menses ends, end of reproductive age
    b. Ovaries less responsive; hormone synthesis decreases
    c. Hot flashes, mood changes, sleep lees
    d. Average age of 52

Pregnancy

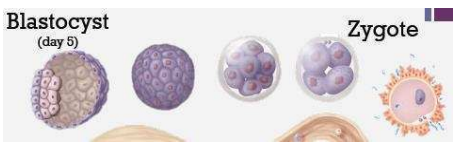
1. Sperm cell
    a. Head: contains nucleus (23 chromosomes) and acrosome (contains digestive enzymes)
    b. Midpiece: contains mitochondria
    c. Tail: flagellum (used for motility)



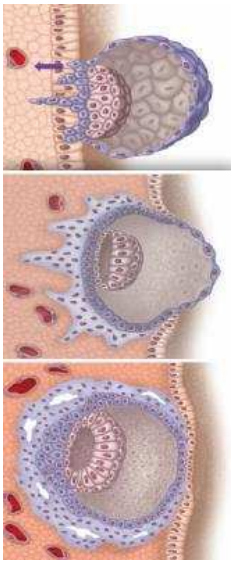
2. Fertilization
    a. Occurs in the fallopian tube
    b. Oocyte only lives for 24 hours, and is dead before it reaches any farther
    c. Timing of development is crucial
    d. Sperm lives for about 5 days
3. Steps for successful fertilization
    a. Reaches zona pellucida
    b. Acrosome reaction
    c. Fuse with plasma membrane
    d. Prevent other sperm from binding
    e. Sperm head enters ovum
    f. Meiosis (stage 2)
    g. Two nuclei fuse
    h. Zygote is created
    i. Rapid cell division begins



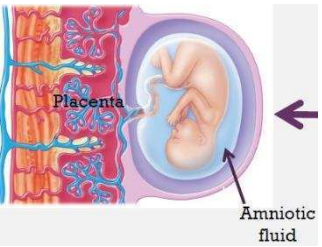
4. Stages of development after fertilization prior to implantation
    a. The blastocyst implants around 7 days after fertilization



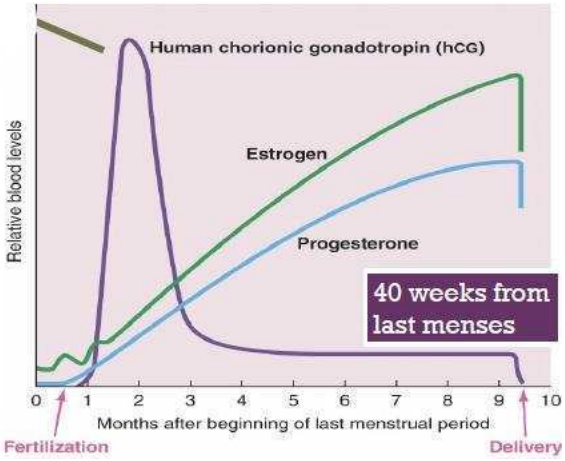
5. Implantation of blastocyst
    a. Trophoblast cells become the placenta
        i. The placenta must develop for a pregnancy to be carried to term
    b. Inner cell mass becomes the baby



6. Placental development
    a. The placenta is the baby's life line
    b. Functions
        i. Providing nutrients for growth and development
        ii. Gas exchanges between mother and developing baby
        iii. Removal of fetal waste products
        iv. Endocrine tissue



7. Hormonal changes during pregnancy
    a. Blastocyst makes hormones
        i. Keeps baby alive



ANS System & Movement and Motor Control

Autonomic Nervous System

1. There are 2 divisions of the ANS
    a. Sympathetic NS: fight or flight (increases energy usage)
    b. Parasympathetic NS: rest & digest (decreases energy usage)
2. In the sympathetic nervous system, the preganglionic and postganglionic fibres are the same length. In the parasympathetic nervous system, the preganglionic fibre is longer than the postganglionic fibre. In these systems, preganglionic neurons are myelinated, and postganglionic neurons are unmyelinated.
3. Anatomical and Neurochemical Organization
    a. Preganglionic connects to postganglionic neuron for all effectors, except the adrenal gland.
    b. Preganglionic to chromaffin cell in adrenal gland (adrenal medulla)
    c. Preganglionic to postganglionic neuron releases Acetylcholine
    d. Postganglionic neuron to effector organ releases Norepinephrine (Noradrenaline), except adrenal gland (A/NA)
    e. Norepinephrine acts at β (heart and coronary blood vessels) or α receptors (blood vessels)
4. Postganglionic sympathetic neurons to blood vessels in skeletal muscles can also release acetylcholine.
5.

	Sympathetic NS	Peripheral NS
Visceral Organs	Antagonist	Antagonist
Salivary Glands	Mucus	Watery
Blood Vessels	Vasoconstriction/ vasodilation	NR
Sweat Glands	Localized	NR
Adrenal Medulla	Adrenaline/ Noradrenaline	NR
Bladder	Retention	Release
Genitalia	Ejaculation (male)	Erection (male/female)

Saliva production- ANS complimentary function

Sexual function and bladder control – co-operative ANS functions

Take Home Messages

- Autonomic Nervous System: throughout neuroaxis-head is the hypothalamus.
    - Parasympathetic Nervous System (PNS)
        - Rest and Digest
        - High specificity
        - Both pre- and post- ganglionic neurons release acetylcholine
    - Sympathetic Nervous System (SNS)
        - Fight or flight

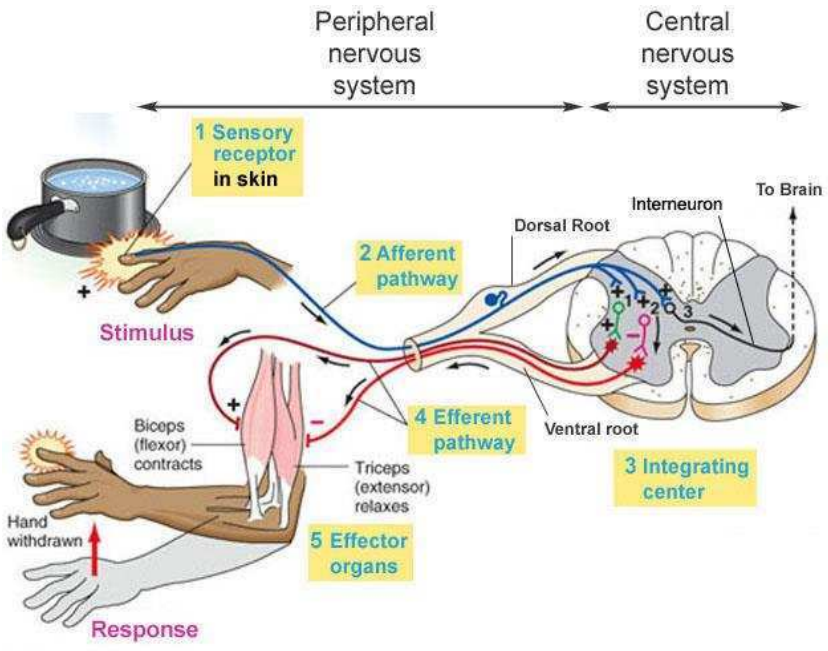
- Generalized activation
- Preganglionic neurons release acetylcholine while postganglionic neurons release norepinephrine (sometimes acetylcholine)

Movement and Motor Control

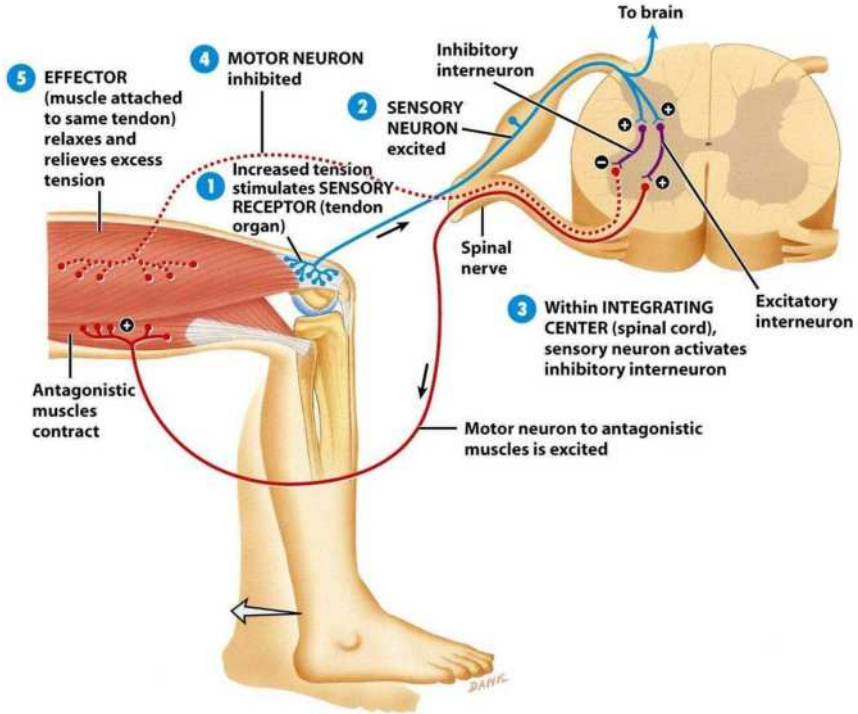
1. The basic unit needed to perform any movement is a motor unit. A motor unit is a group of skeletal muscles fibres and the somatic motor neuron that controls them.
   To perform a movement, we need to know:
   a. Which muscle group it will move: this is learned by trial and error
   b. Length
      - Receptor- muscle spindles
      - 1a afferent neurons
   c. Tension
      - Receptor- Golgi tendon organ (GTO)
      - 1b afferent neuron
2. An alpha motor neuron is a neuron that innervates skeletal muscle. Cell bodies found in the Ventral Horn throughout spinal cord that innervate skeletal muscle. They receive monosynaptic/polysynaptic inputs from peripheral and central nervous systems.
3. Muscle spindles send information about the muscle stretch to the CNS. That are buried (in parallel) among the extrafusal fibres of the muscle.
   Extrafusal fibres are normal contractile fibre.
   1a afferent neurons send length information from muscle spindle to brain and run up and down.
4. Golgi tendon organ consists of the sensory nerve endings interwoven (in series) among collagen fibres.
   1b afferent sends tension information form the Golgi tendon organ to the brain, only goes up.
5. During stretch
   a. Muscle spindles stretch which activate 1a (sensory) fibres to CNS
   b. Tension builds in the tendons which activates GTO's – activates 1b afferent (sensory) fibres to CNS.

   During contraction
   a. Muscle spindles become flaccid – no activation of 1a afferent fibres
   b. Tension increases in the muscle activating GTO's – activation of 1b afferent fibres
6. A reflex is an involuntary response to a stimulus which requires the integrity of the nervous system.
   A reflex arch is the pathway followed by the nerve impulse producing the reflex. It includes
   - Sensory receptor
   - Afferent/Sensory neurons
   - Synapse at an integrating centre
   - Motor neuron
   - Effector
7. Withdrawal Reflex:
   - Monosynaptic reflex: pathway in a reflex action that contains only 1 synapse
   - Polysynaptic reflex: contains more than 1 synapse

- Reciprocal innervation: inhibition of the neuron stimulating the muscle opposite to the one being triggered to contract. Prevents muscles fighting each other to move a limb.



8. The stretch reflex: both mono & polysynaptic
    a. Collateral from 1a excitatory inhibitory interneuron
    b. Inhibitory interneuron inhibits alpha motor neuron to antagonist muscle
    c. Antagonist muscle relaxes (reciprocal innervation)



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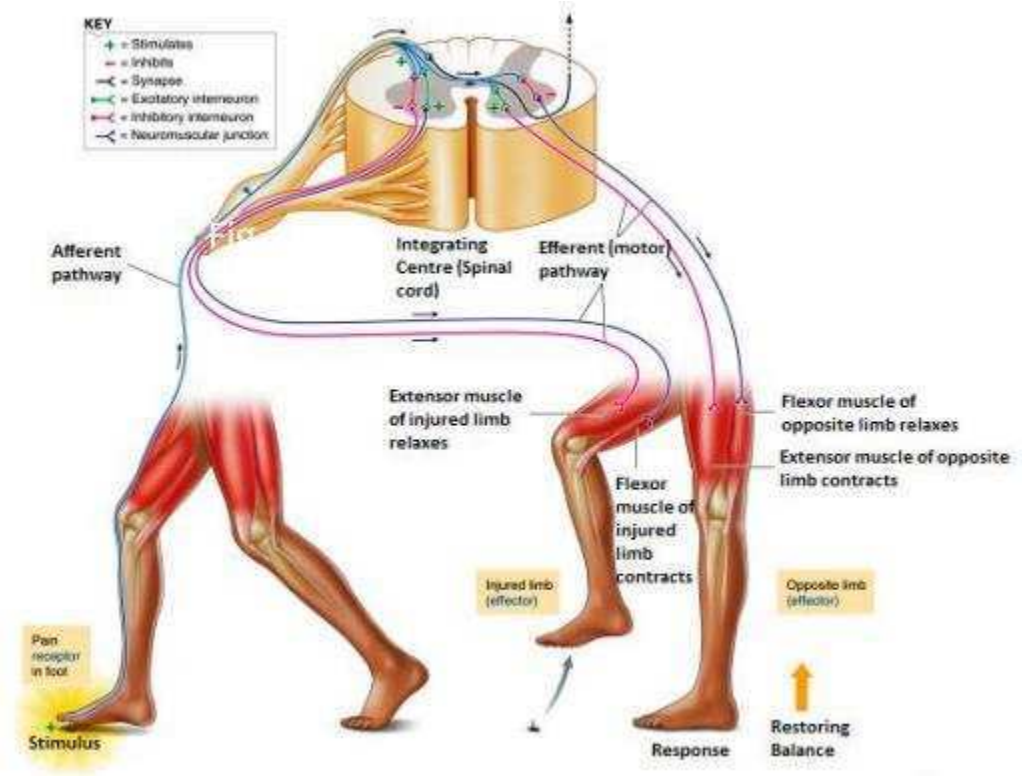
9. Cross Extensor Reflex helps your body maintain its balance when its position has been disrupted. This is an example of a withdrawal reflex.



10. Muscle Spindle Reflex: the addition of a load stretches the muscle and the spindles causing a reflex contraction. The load is added to the muscle, the muscle and the muscle spindle stretch as are passively extends and finally, the reflex contraction initiated by muscle spindles restores arm position.
11. Golgi Tendon Reflex: protects the muscle from heavy loads by causing the muscle to relax through reflex inhibition. First the muscle contraction stretches GTO, and the GTO reflex causes relaxation with excessive load.
    a. Neuron from Golgi tendon organ fires
    b. Motor neuron is inhibited
    c. Muscle relaxes
    d. Load is dropped
12. The motor cortex is the part of the cerebral cortex in the brain where the nerve impulses originate that initiate voluntary muscular activity. It is found in the frontal precentral gyrus. The exaggeration of the body on the cortex is referred to as the motor homunculus. The genitalia are the only body part that is in the somatosensory and not motor cortex.
13. The corticospinal pathway (pyramidal tract) is the primary pathway that leaves the area of the motor cortex to innervate motor neurons in the spinal cord. This is a bilateral pathway and the primary function is to control alpha motor neurons.
14. The difference between lateral and ventral corticospinal tracts
    a. Lateral
        - Crossed tract

- Fine & gross motor control (move finger & hands @ the same time)
- Contralateral alpha motor neurons relative to motor cortex

b. Ventral
- Uncrossed tract
- Gross motor control
- Bilateral alpha motor neurons (both sides of the spine)

15. The Babinski reflex is an extensor plantar reflex that naturally occurs in all infants. When the Babinski reflex is positive in a child older than 2, it is often a sign of a brain or nervous system (corticospinal tract) disorder.
16. Feedback circuits beginning in the motor cortex and returning through the cerebellum, basal ganglia and substantia nigra allow a comparison between the intentions of the cortex with the performance by the part of the body.
17. The major functions of the cerebellum are
    - Controls motor movement coordination
    - Timing of movement
    - Programs of movement
    - Balance (equilibrium)
    - Muscle tone

    Cerebellar Disease (loss of programed movement)
    - Hypotonia – decreased muscle time (can't stand)
    - Dysarthria – slurred speech
    - Ataxia – can't move properly
    - Dysmetria – unable to target (can't touch nose with eyes closed)
    - Intention tremor – shaking when moving only
18. The major functions of the basal ganglia (located deep within cerebral hemispheres) are
    - Controls cognition
    - Movement coordination
    - Voluntary movement

    Basal Ganglia disease
    - Athetosis – abnormal muscle contractions
    - Hemiballism – flinging limbs around
    - Increased muscle tone
    - Dyskinesia – impairment of voluntary movement
    - Resting tremor
19. Parkinson's disease
    - Unblinking mask-like face
    - Resting tremor
    - Rigidity
    - Slowness and poverty of movement

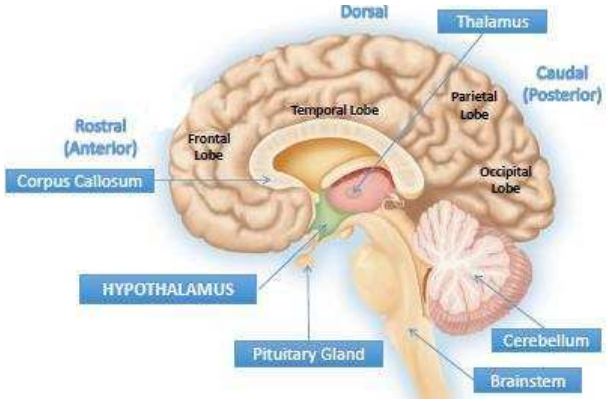
    The primary cause of Parkinson's disease is thought to be loss of dopamine, resulting in abnormal nerve firing patterns and irregular movement. There is no dopamine because neurons in the substantia nigra area of the brain die or become impaired.

Take Home Messages

- Reflex Arc
  - Receptor is the afferent neuron
  - Synaptic contact in spinal cord (CNS)
  - Motor neuron effector
- Monosynaptic Reflex
  - ie. Stretch reflex
- Polysynaptic Reflex
  - ie. Golgi tendon reflex (inverse stretch reflex)
- Stretch reflex
  - Helps in compensation for additional loads
- Golgi tendon reflex
  - Protective mechanism
- Crossed Extensor reflex
  - Helps your body maintain its balance while moving
- Motor cortex
  - Frontal lobe (precentral gyrus)
  - The organization in the motor cortex is due to the cerebral representation of body areas having dense and small motor units
- Motor homunculus
  - Somatotopically organized
- Corticospinal Tract
  - Direct pathways to alpha motor neurons
  - Lateral → crossed → used mainly for fin and gross motor movements
  - Ventral → uncrossed → used for gross motor movements
- Babinski sign (reflex)
  - Used to assess corticospinal tract damage
- Basal Ganglia and Substantia Nigra
  - The basal ganglia are primarily involved in action selection, that is, the decision and planning of which several possible behaviours to execute at a given time
  - The basal ganglia and substantia nigra exert an inhibitory influence on a number of motor systems, and that a release of this inhibition permits a motor system to become active.

Hypothalamus and Homeostasis

Hypothalamus and Limbic System

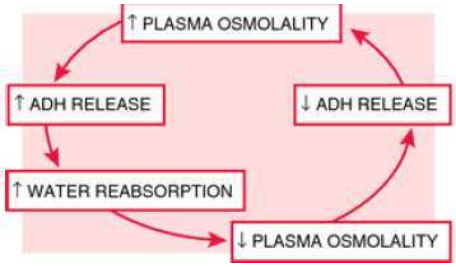


1. Hypothalamic functions
    a. Control of the ANS
    b. Neuroendocrine control
        i. Posterior pituitary gland, catecholamine release from adrenal medulla, etc.
    c. Reproduction
        i. Behaviour and pituitary function
    d. Water balance and exchange
    e. Sodium balance and exchange
    f. Body energy balance and exchange
        i. Nutrient intake and metabolism
    g. Drive and emotions
        i. E.g. feeding, attack
    h. Circadian rhythms
    i. Body temperature regulations
2. Hypothalamic nuclei functions ****
    a. **Supraoptic nucleus:** water balance
    b. **Suprachiasmatic nucleus:** biological clock
    c. **Arcuate nucleus:** satiety/feeding centre
    d. **Paraventricular nucleus:** water balance/stress/feeding
    e. **Lateral hypothalamus:** feeding
    f. **Preoptic/anterior hypothalamic region:** blood pressure (PNS)/body temperature
    g. **Posterior hypothalamus:** blood pressure (SNS)/body temperature
    h. **Basomedial hypothalamus:** anterior and posterior pituitary releasing factor
3. Functions of posterior/anterior hypothalamus in ANS control

a.	Blood pressure:	increase	decrease
b.	Heart rate:	increase	decrease
c.	Gastrointestinal motility:	decrease	increase
d.	Pupil size:	increase	decrease
e.	Sweat glands:	increase	no affect

Pituitary Gland Control

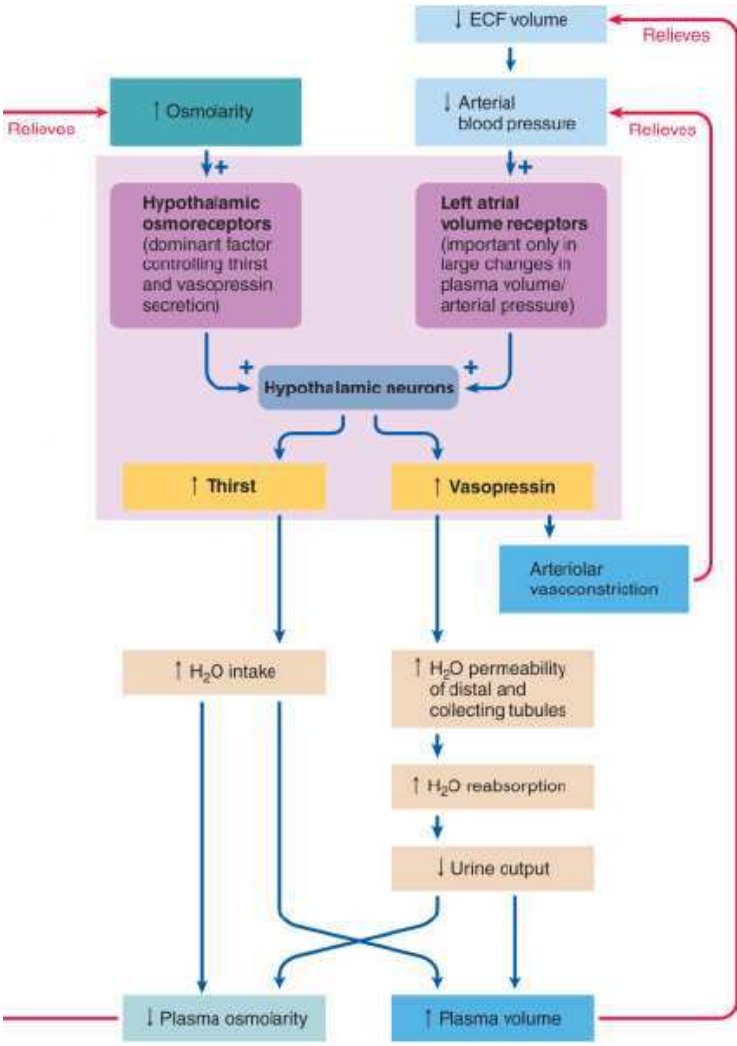
1. Hormones produced in hypothalamus and released directly into the circulation
    a. Oxytocin
        i. Breastfeeding, bonding & uterine contraction
        ii. Operates through positive feedback of control
    b. Vasopressin
        i. Known as antidiuretic hormone (ADH)
        ii. Operates through negative feedback control →



2. Neural-humoral reflex
    a. Oxytocin has positive feedback control to increase uterine contractions
        i. You want to keep producing milk so your baby won't starve
    b. Functions in lactating mom & not in non-lactating mom
        i. Called plastic brain because you can turn it on and off when you need to
    c. Males produce oxytocin for social bonding
        i. Transmitter in the brain for those pathways
3. **The posterior pituitary is made of the axons of neurons originating in the hypothalamus**

Hypothalamic Body Water Regulation

1. Summary of body fluid regulation
    a. Lateral hypothalamus contributed to the initiation of drinking behaviour
    b. Water reabsorption by the kidneys is influenced by the release of the Posterior Pituitary Gland Hormone vasopressin
    c. ADH neurons change their discharge to burst pattern to more efficiently release hormone
2. Main stimuli for thirst
    a. Increased osmolarity
    b. Decreased ECF volume
    c. Decreased blood pressure



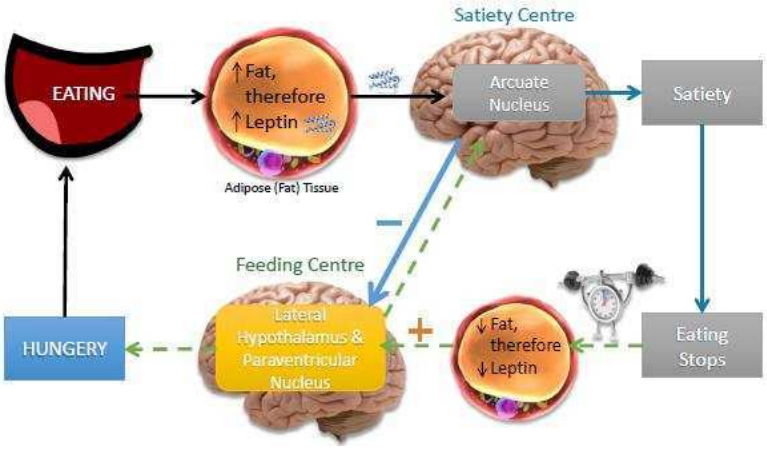
Take Home Messages

- Hypothalamus
    - Controls homeostasis
    - Made up if many different nuclei which control different bodily functions
- The hypothalamus is connected to the Posterior gland
- The Pituitary gland consists of the Posterior and Anterior Pituitary regions
- Posterior Pituitary:
    - Is part of the hypothalamus (brain)
    - Supraoptic nucleus and Paraventricular nucleus sends axons to the Posterior Pituitary
    - Controls the release of oxytocin and ADH
- Oxytocin release
    - Neural endocrine reflex and acts in a positive feedback manner
- Antidiuretic Hormone (ADH) release:
    - Stimulated by increases in plasma osmolarity and decreases in blood volume and pressure – neural endocrine reflex – negative feedback manner

- Oxytocin and ADH neurons change their discharge patterns to more efficient release hormones

Food Intake and Energy Homeostasis

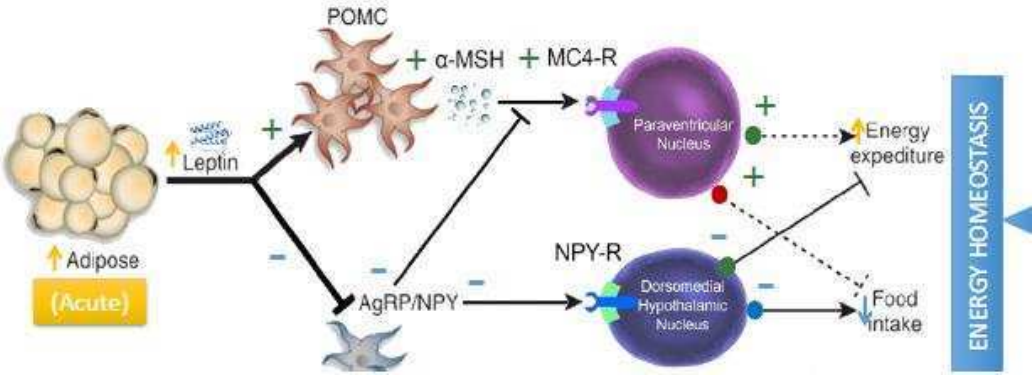
1. The participation of the lateral hypothalamus and the ventromedial nucleus of the hypothalamus in regulating energy intake and expenditure are clear from the effects of lesions and stimulation of the hypothalamus on food intake and body weight gain.
2. Prevalence of obesity
    a. Being obese is defined as having abnormal or excessive fat accumulation that presents a risk to an individual's health
    b. 25-29% of people in Ontario are overweight in 2008
3. Body Max Index
    a. A crude population measurement of obesity
    b. Compares height and weight
    c. BMI of 30+ is considered obese
4. Body Energy Balance
    a. Energy balance = energy intake – energy expenditure
    b. Increase energy expenditure & decrease energy intake
        i. Weight loss
    c. Decrease energy expenditure & increase energy intake
        i. Weight gain
5. Why do we over eat?
    a. Environmental lifestyle social factor (social patterns)
        i. Taste & smell
        ii. Cost/reward optimization
        iii. Availability
        iv. Clock
        v. Cues & social habits
    b. Individual predisposition/ "wiring"
        i. Genetics
        ii. Epigenetics
        iii. Imprinted
        iv. Early life events
6. Physiological signal for food intake
    a. Leptin
        i. Released by adipose tissues, signals you to stop eating
        ii. Obesity from leptin resistance, leptin is broken
        iii. Directly proportional to adipose tissue



7. White Adipose & Leptin Regulation
    a. Weight gain = increase in leptin causing elevated blood pressure

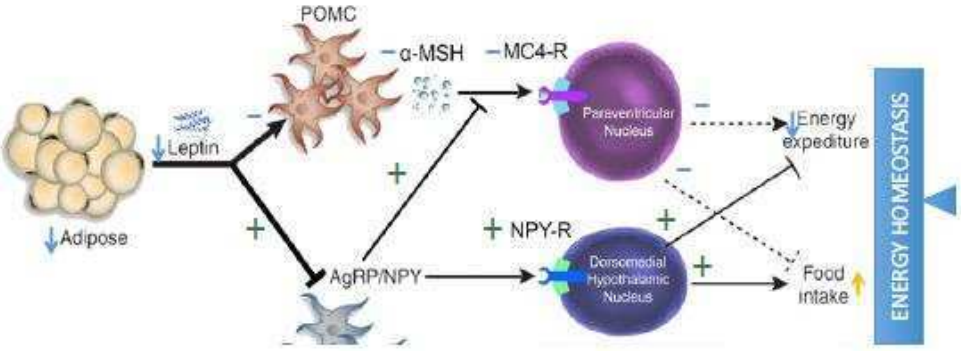
b. Expenditure = weight loss = decrease in leptin

8. Acute increase in leptin
    a. Leptin provides a key feedback signal from peripheral adipose to two types of neurons in the arcuate nucleus.
        i. POMC neurons are activated by leptin and inhibit food intake and increase energy expenditure
        ii. AgRP/NPY neurons are activated by decrease in leptin and increase food intake and decrease energy expenditure



    b. Lateral hypothalamic nucleus: leptin inhibits the neurotransmitter Orexin resulting in decreasing appetite

9. Decreased leptin
    a. Once activated, increased NPY-R (neuropeptide Y receptor) increases food intake by activating lateral hypothalamus, leading to an increase in orexin which increases appetite



10. Effect of a chronic increase in leptin in the circulation
    a. Orexin neurons activated due to the lack of inhibition from paraventricular nucleus resulting in increased food intake
    b. **Leptin resistance only occurs in the food intake pathway**
        i. Only associated with neurons involving in feeding and NOT in SNS control
            1. Obesity induced hypertension

11. **Function of MC4-R**

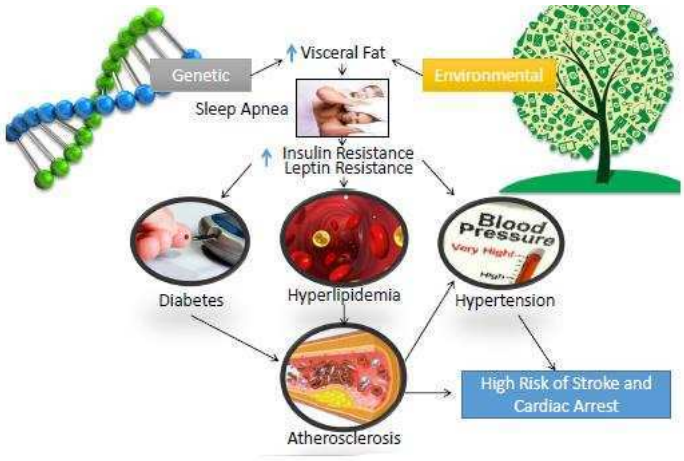
    a. Activates paraventricular nucleus to increase energy expenditure & decrease food intake

   b. Malfunctioning MC4-R
      i. Leads to obesity due to decreasing energy expenditure
      ii. Fatty acids accumulate causing obesity/overweight
      iii. An increase in leptin leads to an increase in food intake because of a leptin receptor malfunction

12. Functions:
   a. **Orexin**: neurotransmitter that stimulates food intake found in the lateral hypothalamus
   b. **NYP**: neurotransmitter that stimulates food intake found in the arcuate nucleus
   c. **POMC**: neurons that produce neurotransmitter α-MSH that inhibits food intake & activates energy expenditure – produced in the arcuate nucleus
   d. **Paraventricular Nucleus**: activates neuronal system for energy expenditure
   e. **Arcuate Nucleus**: satiety centre – responds to leptin
   f. **Lateral hypothalamus**: feeding centre – activates neuronal systems for food intake

Metabolic Syndrome

1. If you have 3 or more of the following conditions, you are considered to have metabolic syndrome:
   a. High fasting blood glucose levels
   b. High blood pressure
   c. High level of triglycerides, a type of fat in your blood
   d. Low levels of HDL
   e. Abdominal obesity or too much fat around your waist



2. Two most recognized under-eating disorders:
   a. **Anorexia Nervosa:** a psychiatric disorder characterized by an unrealistic fear of weight gain, self-starvation, and conspicuous distortion of body image. The individual is obsessed with becoming increasingly thinner and limits food intake to the point where health is compromised
   b. **Bulimia Nervosa:** a psychiatric disorder streaming from an excessing concern with weight control and self-image. Bulimics consume large amounts of food (binge) and then try to rid themselves of the food and calories (purge) by fasting, excessing exercise, vomiting, or using laxatives

Take Home Messages

- Why do we eat?
  - Lifestyle/environment and genetic predisposition
- Food intake is controlled by the Arcuate (Arc) and Lateral Hypothalamic (LH) nucleus
  - Together they form part of the negative feedback system
- Leptin is the body's satiety signal

  - Released by adipose (fat) tissue in proportion to the amount of fat in the body
  - Acts at the Arc Nucleus
- MC4-R is important for decreasing food intake
  - A malfunction leads to obesity (due to decreased energy expenditure)
- Orexin is the feeding hormone in the LH nucleus while NYP is the feeding hormone in the Arc nucleus
- Metabolic syndrome results in hyperlipidemia, diabetes, and hypertension
- Eating disorders are thought to be a combination of genetic, neurochemical, psycho-developmental, and socio-cultural factors

Circadian Rhythms

1. The natural pattern of physiological and behavioural processes that are times to a near 24-hour period. This activity is controlled by the biological clock which is located in the suprachiasmatic nucleus of the hypothalamus
   a. Highly influenced by natural dark-light cycles, but will persist under constant environmental conditions
   b. LED light can trick this system by supressing melatonin levels. Viewing any LED screens after dark can result in a decreased ability to fall asleep
2. Examples of circadian rhythms controlled by the hypothalamic suprachiasmatic nucleus
   a. Sleep
   b. Food & water intake
   c. Urine production
   d. Blood pressure → leads to heart attacks in the morning
   e. Platelet aggregation → leads to heart attacks in the morning
   f. White blood cell production
   g. Body temperature changes
   h. Hormone release: cortisol, luteinizing hormone & melatonin
   i. Menstrual cycle (longer cycle)

Thermoregulation

1. Basic principle
   a. Heat input + heat production/conservation = heat loss
2. Ways heat can be produced
   a. Metabolic activity
   b. Non-shivering thermogenesis
      i. Release of t_3/t_4 for basal metabolic activity
      ii. Thyroid hormones and noradrenaline to increase basal metabolic activity
   c. Muscle activity
   d. Shivering
      i. Number 1 way to produce heat in the body
   e. Vasoconstriction (conservation)
      i. Frost bite, cuts off blood supply to extremities to save for major organs
3. Ways heat can be lost
   a. Convection

i. Fan moves the hot air molecules away to replace with cold air

b. Radiation

c. Evaporation

i. We seat to cool down our body

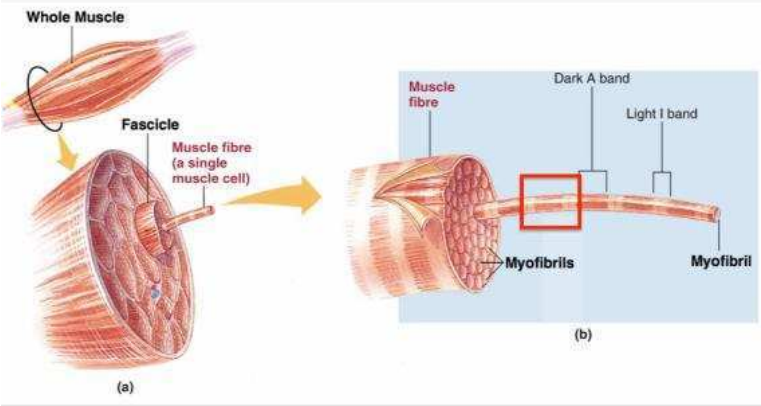
4. Thermoreceptors
   a. Sensory receptors that respond to specific changes in temperature
      i. Central (brain)
         1. In the posterior and anterior hypothalamus
      ii. Peripheral (outside the brain)
         1. Skin, organs, tongue, cornea, send sensory information to the hypothalamus
5. Responding to cold
   a. Hypothalamus will increase TRH → production of T_3/T_4 to increase basal metabolic rate
   b. Hypothalamus will activate SNS → vasoconstriction, shivering
   c. Behavioural: will be motivated to seek shelter, change thermostat, put on sweater, etc.

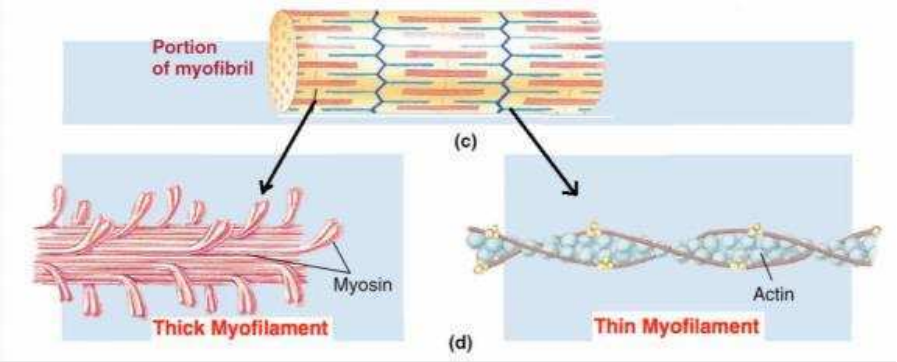
After Lecture Application

1. What behavioural changes will happen after:
   a. Lesion (tissue damage) of the arcuate nucleus of the hypothalamus
      i. Arcuate nucleus → satiety centre
      ii. Damage → unable to feel full
      iii. Behaviour: feeding/overeating
   b. Stimulation of the lateral hypothalamus
      i. Lateral hypothalamus → feeding (orexin)
      ii. Stimulation → increase activity of those neurons
      iii. Behaviour: feeding/overeating

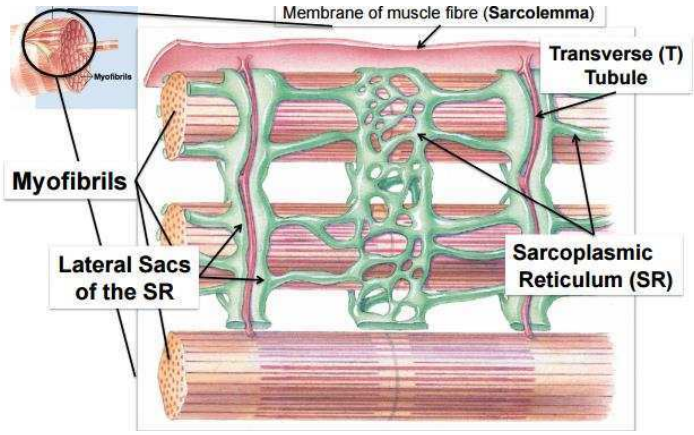
Muscle Physiology

1.





Skeletal muscle is striated caused by the arrangement of proteins in the thin and think myofilaments. The number of muscle cells in a whole muscle depends on the size of the whole muscle.



The dark A bands contain thick myofilaments. The light I bands contain thin myofilaments.

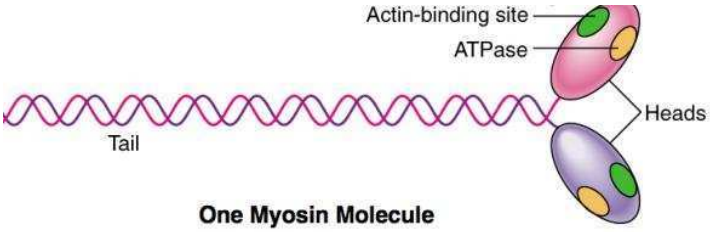
2. Thin myofilaments are made up of 3 proteins:
    a) **G-Actin**- Globular protein linked together to form a two-stranded chain. Each G-actin molecule contains a myosin binding site.

b) **Tropomyosin**- a rod shaped protein composed of 2 protein chains wrapped together in a super coil. In the relaxed muscle tropomyosin is situated so that it partially covers the myosin binding sites found on actin.

c) **Troponin**- in relaxed muscle troponin is attached to tropomyosin and G-actin so that is holds the tropomyosin over the myosin binding sites… until Ca^{++} arrives.

3. Thick myofilaments are made of many individual myosin molecules. Each myosin molecule is made of 2 long polypeptide chains. Each chain forms part of the tail and one head of the myosin molecule.

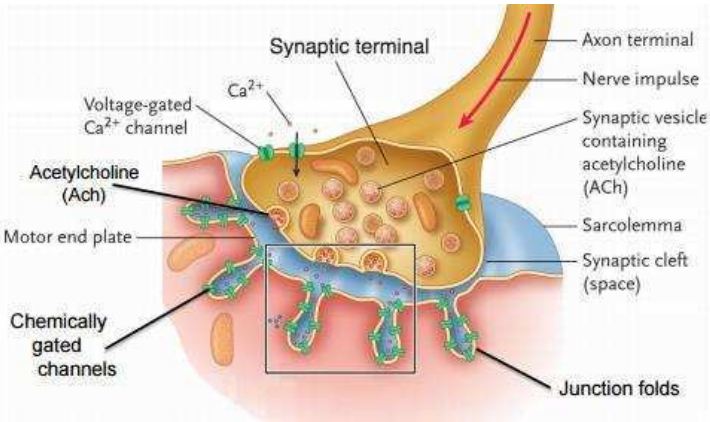
   Each head contains:
   - A binding site for actin
   - A binding site of ATP



   When the heads turn inward, it causes a power stroke.

4. Sliding Filament Theory
   - When myosin head binds to actin a cross-bridge is formed
   - Myosin then changed shape and a power stroke occurs
   - Actin slides past myosin…
   - Thin & thick myofilament lengths do not change, but the sarcomere length does change

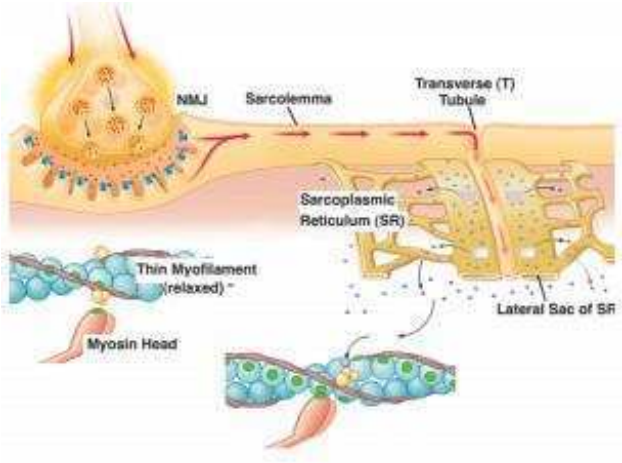
5. Structure of a Neuromuscular Junction (NMJ) is the point of contact between the motor nerve and the muscle cell/fibre.



   Neuromuscular Transmission

   1. AP on motor nerve depolarizes axon/synaptic terminal
   2. Voltage gated Ca^{++} channels open and it flows into the axon/ synaptic terminal.
   3. CA^{++} triggers vesicles to fuse to terminal and release Ach
   4. Ach diffuses across synaptic cleft to muscle end plate

5. Ach binds to receptors on chemically gated channels and channels open
6. Na^+ flows into muscle cell at end plate
7. Muscle membrane depolarizes (++) producing end plate potential
8. EPP triggers VG Na^+ channels to open → triggering AP
9. Ach is broken down by acetylcholinesterase (Ach-ase) into choline and acetate which are then recycled back into axon terminal (this is how we stop a contraction).
   ** 1 AP on the motor nerve will ALWAYS produce 1 action potential on the muscle cell membrane (sarcolemma)**

6. 

Excitation Contracting Coupling is where an AP on the sarcolemma of the muscle cell leads to the release of Ca^{++} from the sarcoplasmic reticulum (SR), cross bridge activity and muscle contraction.

   a) AP is generated at end plate of the muscle cell
   b) AP propagates over sarcolemma and down T-tubules
   c) AP triggers release of Ca^{++} from lateral sacs of SR
   d) Ca^{++} binds to troponin pulling tropomyosin off myosin binding sites
   e) Myosin attaches to actin (crossbridge) and powerstroke occurs
   f) Actin slides over myosin = muscle contraction
   g) Ca^{++} is actively pumped back into SR by Ca^{++} ATPase
   h) Tropomyosin covers myosin binding sites
   i) Muscle relaxes (no crossbridges)

7. Actin-Myosin-ATP Cycle: when the ATP is hydrolyzed (breaks down), the ADP and P remain bond to the myosin head and the energy released is transferred myosin, producing a high-energy form of myosin. The hydrolysis also positions the myosin head so its ready to attach to actin. However, the myosin can't attach to actin because the myosin-binding site is covered by tropomyosin. The energized myosin is waiting for the action potential to initiate excitation-contracting-coupling (the release of Ca^{++} from the SR) to remove the tropomyosin.
8. Rigor Mortis: stiffening of muscles after death. This begins 3-4 hours after death, reaches a maximum at 12hrs and slowly disappears over the next 24-48hrs.
   This is caused by:
   - No oxygen → no ATP
   - No ATP: Ca^{++} can't be pumped back into SR
     ➔ Cross bridges form

- No ATP → Actin and myosin can't dissociate → muscle is permanently fused… until muscled begin decomposing

9. A small motor unit: one motor neuron and a small # of muscle cells.
   A large motor unit: one motor neuron and a large # of muscle cells.
10. An increased in the force of a muscle contraction can be achieved by:
    a) Summation of twitch contractions – a muscle twitch is the muscle contraction in response to one AP on the motor neuron.
    b) Recruitment of motor unites (MU) – as more MU are recruited, more muscle cells contract → the overall contractile force increases.

    As stimulation (AP) frequency is increased, each muscle twitch has less time to relax before the next one occurs. Twitches start to "stack up" on one another causing greater tension (a more forceful contraction).

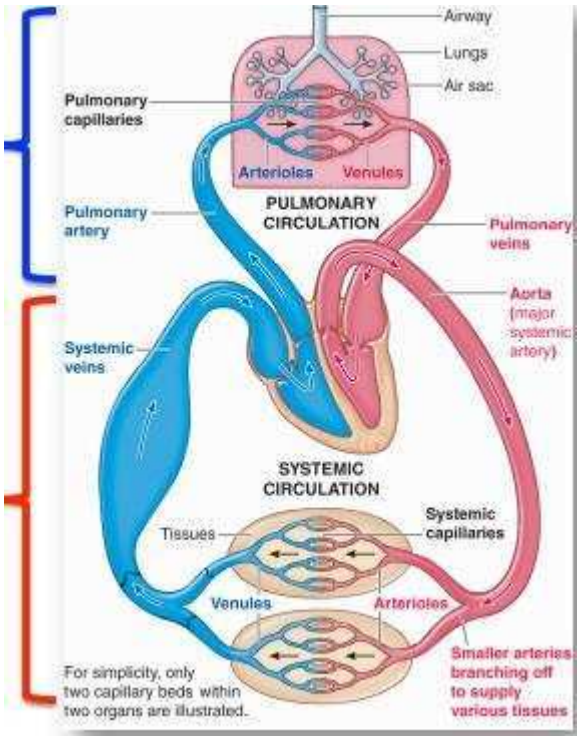
Cardiovascular Physiology

General Function, Organization, and Anatomy of Circulation

1. The principle functions of the cardio system:
    a. It transports oxygen and nutrients
    b. Removes carbon dioxide and waste
    c. Regulates body temperature and pH
    d. Transports and distributes hormones throughout the body
2. The components of the transport system include:
    a. Central pump (heart)
    b. Closed system of tubes (blood vessels)
    c. Fluid (blood)
3. There are 2 divisions of the CV system

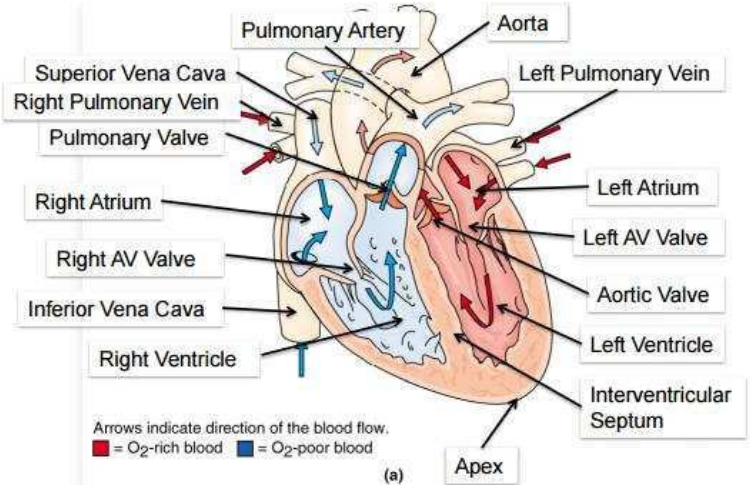
Pulmonary Circulation

Systemic circulation



4. Total Blood volume (TBV) = 5 liters
    15% = Heart and Pulmonary circ.
    10% = Systemic arteries/arterioles (distribution vessels)
    5% = Systemic capillaries (exchange vessels)
    70% = Systemic veins/venules (capacitance vessels)

5.



IVC/SVC → RA → RAV valve → RV → Pulmonary Semilunar valve → PA → Lungs

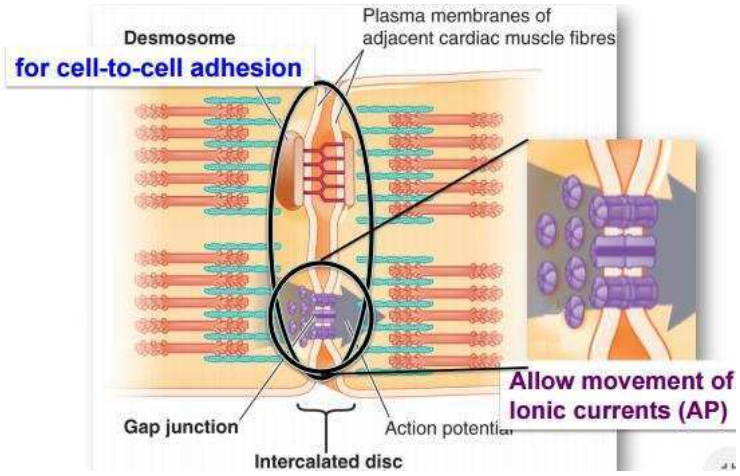
Lungs → LA → LAV valve → LV → aortic valve → Aorta

Cardiac Function

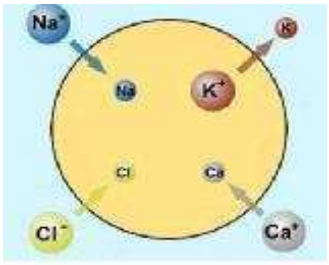
1. There are 2 types of myocardial cells
    a. Contractile cells (do the contracting)
    b. Specialized Nodal and Conducting cells (signaling contractile cells to contract)
2. Similarities between skeletal and cardiac muscle
    - Striated
    - Contain similar contractile proteins (actin & myosin)
    - Ca^{++} release from SR triggers contraction

    Differences (Contractile Cells)

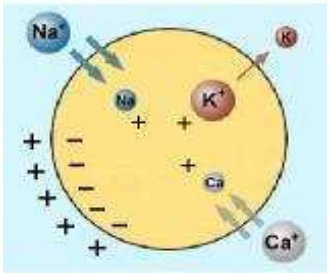
    - Short & branched
    - 1/3 of volume is occupied by mitochondria (to produce ATP)
    - Extracts 80% of the oxygen from the blood
    - Joined by intercalated discs that contain gap junctions and desmosomes
        - Gap junctions allow movement of ionic currents (APs) between cells



3. Nodal and Conducting Cells
   - Contain few contractile proteins
   - Self excitable: spontaneously generate Aps
   - Rapidly conducting AP through the heart
     a) Nodal Cells:
        - Sinoatrial (SA) node
        - Atrioventricular (AV) node
     b) Conducting Cells:
        - Bundle of His → bundle of fast conducting cells that travel from the AV node to the apex of the heart
        - Purkinje Fibres → very fast conducting cells that cause contractile cells to contract
4. The SA node:
   - Heart beats at roughly 72bpm
   - Impulses (APs) originate at SA node
     - It is the site of fastest spontaneous generation of the AP
     - SA node is the "Pacemaker" of the heart

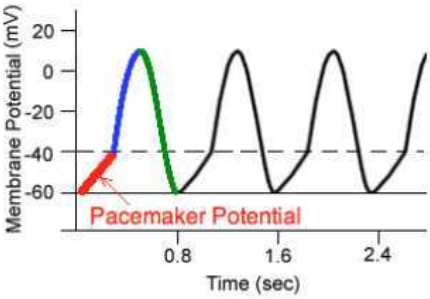


SA Node Self-Excitability = Spontaneous generation of the AP caused by
1. SA node cells have a greater Na^+ and Ca^{++} permeability
2. K^+ permeability of SA node cells declines during diastole (Less K^+ leaves these cells during relaxation of the heart)

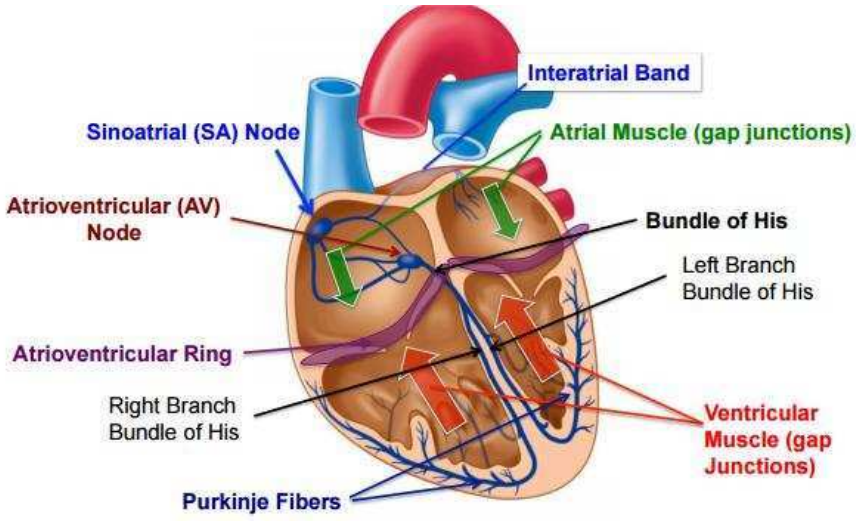


** Both of these characteristics cause the SA nodal cells to spontaneously depolarize to threshold**

5. SA Nodal Action Potential
   a) Pacemaker Potential → a slow depolarization caused by:
      - Increase permeability of cells to Na^+ and Ca^{++}
      - Decrease K^+ permeability
   b) Depolarizing phase → @ threshold (-40mV), Ca^{++} VG channels open
      ➔ Ca^{++} flows into SA nodal cell
      ➔ Membrane potential reaches +15mV
   c) Repolarization → Ca^{++} VG channels begin to close and
      - K^+ VG channels begin to open
      - K^+ leaves the cell
      - Membrane potential returns to -60mV
      - K^+ channels begin to close and cycle repeats

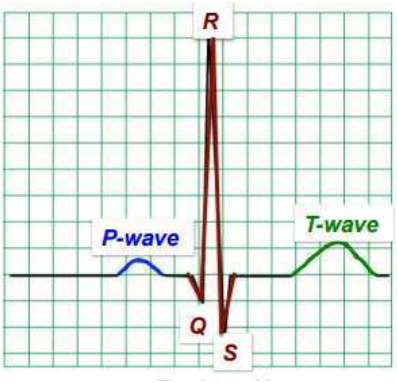


6. Conducting System of the Heart



AP propagation in both the atria & ventricles start in the corner of the chamber opposite to where the blood is going to move. If this wasn't the case, blood would be pushed into a corner of the chamber.

7. Electrocardiogram (ECG):
   - Body fluids are good conductors of electricity. Cardiac impulses pass through the heart → pass to surrounding tissue and to the surface of the body.
   - Electrodes can pick up these impulses. ECG is the sum of all the electrical events in the heart – both depolarizing and repolarizing.



P- Wave: Depolarization of atrial muscle

QRS complex: Depolarization of ventricular muscle

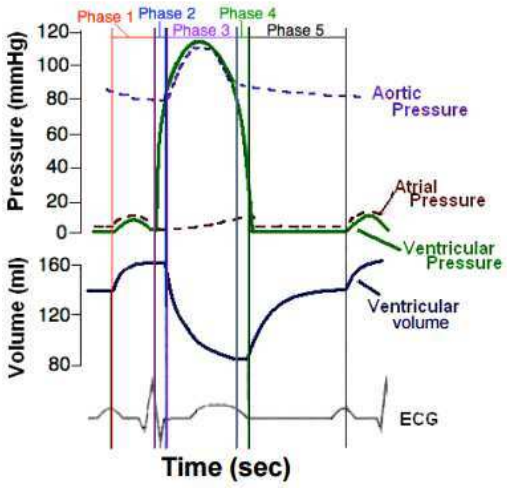
T- Wave: Repolarization of ventricular muscle

** Missing the repolarization of the atrial muscle because it's hard to see (falls in the QRS complex) **

   - The ECG can tell us
     - The extent and type of disturbances of rhythm or conduction
     - The approximate extent and location of myocardial damage
     - Effects of drugs
     - Heart rate

8. The cardiac cycle shows all the mechanical and electrical events during a single contraction on the left side of the heart. It includes:
   - Pressure changes in aorta, left atrium and left ventricle
   - Volume changes in left ventricle
   - Valves opening and closing
   - ECG

   It consists of a period of systole (contraction) and diastole (relaxation). Each cycle is initiated by the SA-node.



Phase 1: Atrial systole

- P wave represents the depolarization of the atria → atria contact
- Atria pressure in greater than ventricle pressure (AV valves are already open)
- Ventricles fill with last 30% of blood → end diastolic volume (EDV)

Phase 2: Early ventricle systole (isovolumetric ventricular contraction)

- QRS complex → ventricles begin contracting → builds pressure in ventricles
- Ventricular pressure > atrial pressure → AV valve closes
- No change in volume (aortic valve is closed)

Phase 3: Ventricular systole (rapid ejection period)

- Ventricles continue to contract
- Ventricular pressure > aortic pressure → aortic valve opens → blood leaves ventricle
- Ventricular volume decreases. However, not all blood leaves ventricles. → end systolic volume (ESV) remains
- T- wave begins

Phase 4: Early ventricle diastole (Isovolumetric ventricular relaxation)

- Ventricles relax causing pressure to drop
- Ventricular pressure < aortic pressure → aortic valve closes
- Ventricular pressure > atrial pressure → no change in volume (AV valve still closed)

Phase 5: Late ventricular diastole (ventricular filling)

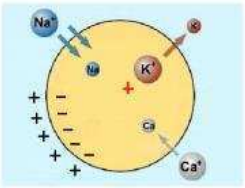
- Ventricles still relaxing
- Ventricular pressure < atrial pressure → AV valve opens
- Blood enters ventricles (70% of ventricular filling)

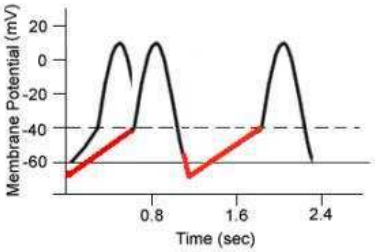
70% of ventricular filling occurs when ventricles relax (phase 5 – late ventricular diastole) – NOT when atria contract!

Last 30% of filling occurs when atria contract (phase 1) – which is just before ventricular systole

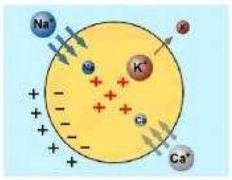
Mechanical Performance of the Heart

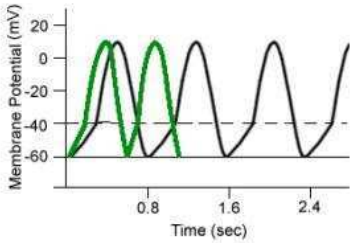
1. Cardiac output (C.O.) = the amount of blood pumped by each ventricle in one minute (l/min)
   CO = heart rate (bpm) x stroke volume (ml)
   Stroke volume (SV) = the amount of blood pumped by each ventricle during one contraction
2. Heart rate is controlled by the ANS by changing the slow op the pacemaker potential
   a. PNS – Decreases HR
   b. SNS- Increases HR





The PNS innervates the SA and AV nodes through vagus nerve.
PNS releases the neurotransmitter acetylcholine (Ach).
Ach binds to receptors on cells of the SA node
➔ Increases K^+ permeability
➔ Decrease in Ca^{++} permeability
With more K^+ leaving and less Ca^{++} entering SA node cells, the cell hyperpolarizes and the slope of the pacemaker potential decreases.





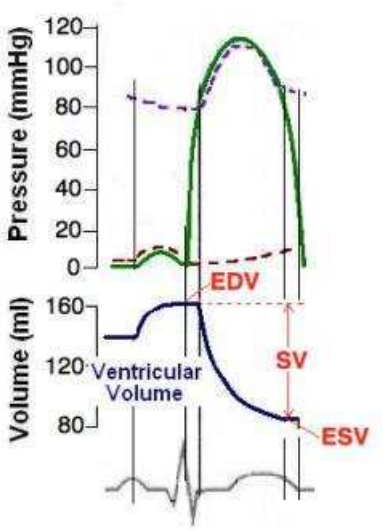
The SNS innervates SA and AV nodes and ventricular muscle.
SNS releases norepinephrine (and hormone epinephrine from adrenal gland)
Norepinephrine binds to receptors
➔ Increase in Na^+ and Ca^{++} permeability in all parts of the heart
With more Na^+ and C^{++} entering the cell, the cell gets more positive and the slope of the pacemaker potential increases.

Heart rates < 100bpm → activates PNS (at rest, there is always PNS activity "vagal tone")

Hearts rates = 100bpm → no PNS, no SNS (hearts own intrinsic rate; set by SA node)

Heart rates > 100bpm → activates SNS

3. Factors that control stroke volume:
   - Input from ANS
     - PNS (vagus nerve, decrease HR)
       - PNS releases NT Ach → closes Ca^{++} channels → less Ca^{++} in cardiac contractile cells → decreases force of contraction → decreases SV (decrease CO)
     - SNS (increase HR)
       - NT norepinephrine (epinephrine from adrenal glands) → opens Ca^{++} channels → more Ca^{++} flows into cardiac contractile cells → increases force of contraction → increases SV (increase CO)

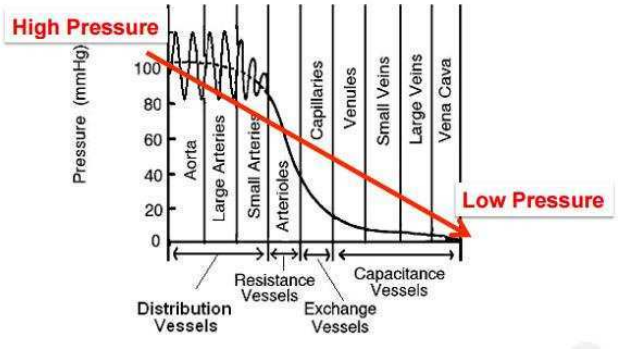


- Preload (EDV)… SV = EDV - ESV
  - EDV = volume of blood in ventricles at end of ventricular diastole (just before they contract)
  - ESV = volume of blood in ventricles at end of ventricular systole (just after contracting)
  - Altering either EDV or ESV will change stroke volume
    - ➔ During exercise/stress: SNS is activated: heart contracts more forcefully and will eject more blood → causes decrease in ESV → increase EDV → increase SV
  - Preload: the "load" on the cardiac muscle before contraction
    - ➔ This load comes from the blood filling the ventricles and stretches the ventricular muscle
    - ➔ The greater the EDV the greater the preload on the heart → causes a greater SV when the heart contracts
  - In increase in EDV = an increase in preload → increase the stretch of myocardial cells → increases the force of contraction of these cells when the heart contracts → increases the amount of blood ejected → increases SV → increase CO

4. The Frank-Starling Law of the Heart: "an increase in EDV will cause an increase in SV" (the more you put on him, the more he gives back)
5. You increase EDV by increasing venous return to the heart.
   - During dynamic exercise
     - Muscle pump
       - Pumps blood back to the heart → increasing venous return → increasing EDV → increasing SV → increasing CO
     - Respiratory pump
       - Decreases pressure in chest cavity → pulls blood back to heart and increases venous return → increases EDV → increases SV → increases CO
     - SNS
       - Increases HR and SV by small constrictions (squeezes) of veins → increase venous return → increase EDV → increase SV → increase CO

Vascular Function

1. The pressure change (or pressure gradient) in the circulatory system drives blood through vessels



- Blood flows from high pressure (P1) to low pressure (P2) down a pressure gradient
- Blood flow is decreased by resistance encountered by the blood

Blood Flow = pressure gradient / Resistance

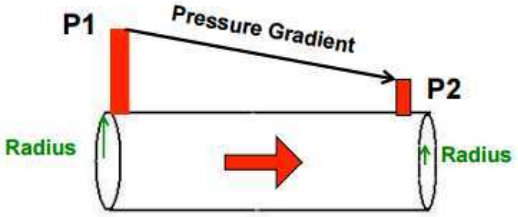
Blood Flow = P1 – P2 / Resistance

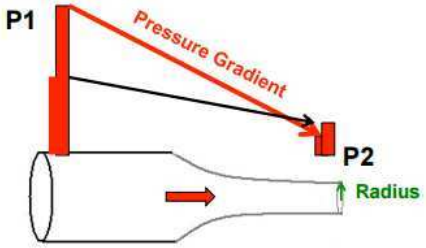
Resistance = Lη / r⁴ L = Length of the vessel r = radius of the vessel n = viscosity of the fluid

Resistance = 1 / r⁴

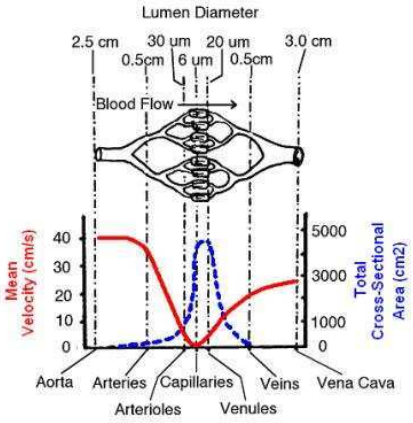
Blood Flow = (P1 – P2) x r⁴

* A small change in radius will have a large effect on blood flow*



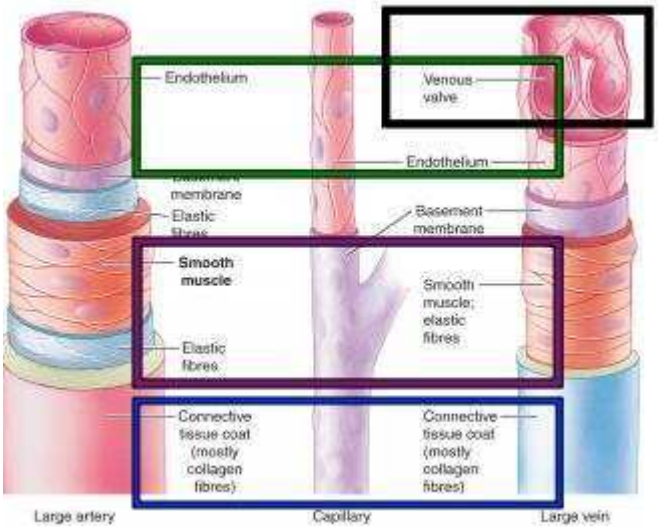


2. The special structural properties contribute to the characteristics seem throughout the circulation. Components in each vessel include: elastic tissue, smooth muscle, fibrous connective tissue.



Blood viscosity is the speed at which the blood is moving through a particular blood vessel. Mean blood viscosity is higher in the aorta compared to the vena cava yet blood flow is the same because the vena cava has a larger diameter. Blood has to flow faster through the smaller diameter to have the same blood flow.

3. Arteries and veins contain three layers in their walls:

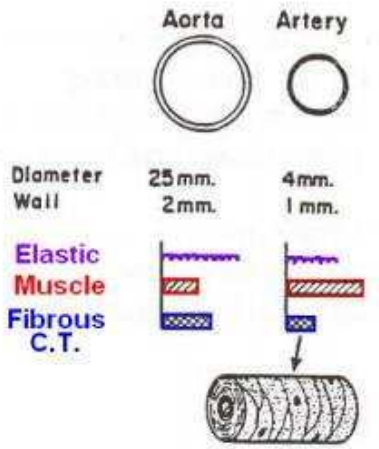


- Outer layer (tunica externa)
  - Fibrous connective tissue
- Middle layer (tunica media)
  - Smooth muscle and elastic tissue
- Inner layer (tunica interna)
  - Endothelial cells

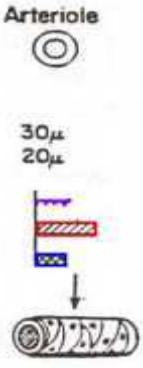
Veins also contain valves and capillaries have one layer

4. For each blood vessel consider: blood characteristics, structure, and function.

   a. Aorta and Large Arteries
      i. Blood characteristics
         1. Very high blood pressure
         2. Pulsates from 80 – 120 mmHg
         3. High blood viscosity
      ii. Structure
         1. Large diameter
         2. Lots of elastic tissue
         3. Relatively thin walls → easily distended → low resistance to blood flow → small drop in blood pressure
      iii. Purpose
         1. "shock absorbers"
         2. Distribute the blood

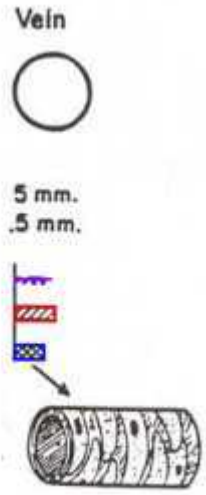


   b. Arterioles
      i. Blood characteristics
         1. Large drop in blood pressure
         2. Lower blood viscosity
      ii. Structure
         1. Small diameter
         2. Very thick walls → Large smooth muscle content innervated by ANS → causes vasoconstriction or vasodilation → control blood flow
      iii. Purpose
         1. Resistance vessels
         2. Control blood flow to organs

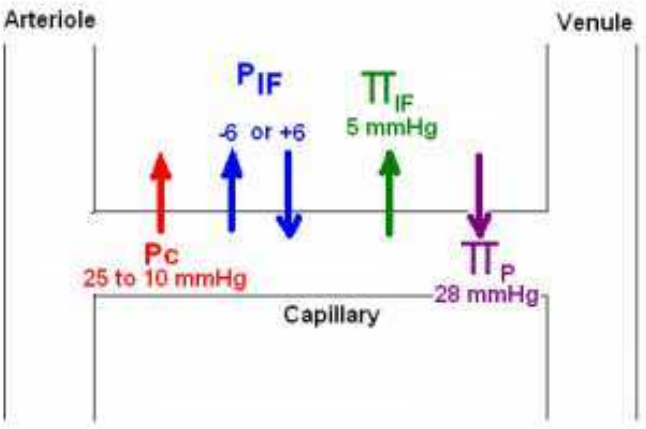


c. Capillaries
   i. Blood characteristics
      1. Low blood pressure
      2. Small drop in blood pressure
      3. Very low blood velocity
   ii. Structure
      1. Only 1 endothelial cell thick (no elastic or muscle)
      2. Extremely large total cross-sectional area
      3. Very large surface area for diffusion (gas, nutrients, waste)
   iii. Purpose
      1. Exchange vessels

d. Veins
   i. Blood characteristics
      1. Very low blood pressure
      2. Low – medium blood viscosity
   ii. Structure
      1. Very thin walls, large diameter
      2. Valves
      3. Some elastic tissue
      4. Some smooth muscle innervated by ANS → vasoconstriction or dilation
   iii. Purpose
      1. Capacitance vessels: 70% of TBV



5. Types of exchange in Capillaries
   a. Diffusion
      i. Substances moving down their concentration gradient
      ii. Oxygen and carbon dioxide
   b. Filtration and Reabsorption→ movement of fluid across capillary depends upon a balance of 4 forces called starling forces
6. 4 Starling forces
   a. Capillary hydrostatic pressure of the plasma (Pc)
      i. Pressure from the blood in the capillaries
      ii. Varies from 25mmHg (arteriole end) to 10mmHg (venous end)
      iii. Causes filtration (plasma → interstitium)
   b. Interstitial fluid hydrostatic pressure (P_{IF})
      i. Pressure on the fluid in the interstitial space
      ii. Varies from organ to organ
      iii. Can cause filtration (when pressure is negative) or reabsorption (when pressure is positive)



c. Interstitial osmotic pressure (π_{IF})
   i. Pressure caused by osmosis due to proteins in the interstitial fluid
   ii. Pressure = +5 mmHg
   iii. Causes filtration
d. Plasma osmotic pressure (π_P)
   i. Pressure caused by osmosis due to proteins in the plasma
   ii. Pressure = +28 mmHg
   iii. Causes reabsorption

Net Fluid Movement (NFM):

$$NFM = K_f [(P_C - P_{IF}) - (\pi_P - \pi_{IF})]$$

K_f = filtration coefficient and represents the permeability (leakiness) of the capillary (assume = 1). +'ve = filtration, -'ve = reabsorption.

NFM = +8 mmHg

Cardiovascular Regulatory Mechanisms

1. The purpose of all CV regulatory mechanisms is to
   a. Increase blood flow to active tissue and decrease it to inactive tissue
   b. Increase or decrease heat loss from the body
   c. Maintain blood flow to vital organs (heart and brain) even during stressful situations
   d. Maintain blood pressure (mean arterial pressure)

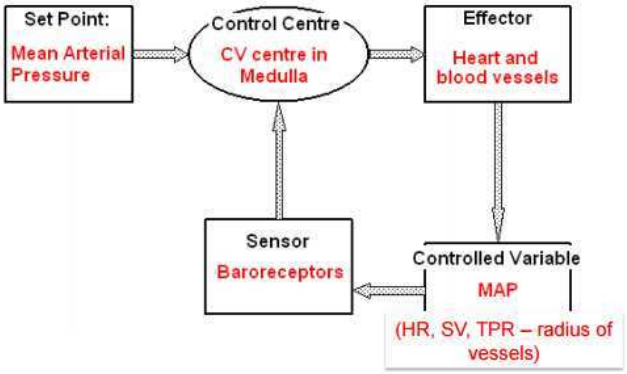
   To achieve these, multiple regulatory mechanisms to control circulation can be grouped into
   a. Local mechanisms (intrinsic)
      i. Most tissues have the capacity to control their own blood flow by this.
      ii. Allow the individual vascular beds to maintain a relatively constant blood flow when moderate changes occur in blood pressure.
      iii. Myogenic Theory
         1. Occurs as a result of local changes in blood flow to a capillary bed due to a change in local pressure causing either:
            a. Contraction of smooth muscle in arterioles (vasoconstriction)
            b. Relaxation of smooth muscle in arterioles (vasodilation)
         2. This is normally found in the brain, heart and kidneys for protection
         3. Sudden increase in blood pressure → stretches walls of arterioles → smooth muscle in walls contracts → vasoconstriction → decreases blood flow and pressure after constriction
      iv. Metabolic Theory
         1. Active (exercising) tissue releases metabolic by-products called vasodilator metabolites (VDMs) → VDMs cause a very local vasodilation of the blood vessels → leading to an increase in blood flow in that tissue
         2. Vasodilator metabolites (VDMs) released by active tissue:
            a. Increase in CO_2
            b. Increase in $[H^+]$ (increase in acidity = decrease in pH)
            c. Increase in adenosine (from ATP breakdown)

d. Increase in temperature
e. Decrease in O_2

These all cause the arterioles to vasodilate → increasing blood flow during exercise. If the opposite happens, constriction occurs.

b. Humoral mechanisms (extrinsic) – regulation by substances present in the blood causing vasoconstriction or vasodilation.
    i. Vasoconstrictors (decrease blood flow)
        1. Epinephrine (adrenaline, released by SNS) attaches to alpha receptors in blood vessels throughout the body → overall weak vasoconstriction
        2. Angiotensin II
            a. The most potent vasoconstrictor in the body
            b. Production is stimulated by a drop in blood pressure and drop in Na^+ levels
        3. Vasopressin (antidiuretic hormone, ADH)
            a. Formed in hypothalamus
            b. Promotes reabsorption of water in kidneys
            c. High concentrations will produce vasoconstriction
    ii. Vasodilators (increase blood flow) … AC/BD
        1. Epinephrine (released by SNS) attaches to beta receptors in blood vessels of skeletal and cardiac muscle and the liver → vasodilation
        2. Kinins: a group of blood proteins involved in inflammation, blood pressure and blood coagulation
        3. Histamine is a compound involved in inflammatory response and released by damaged cells
        4. Atrial natriuretic factor (ANF) a powerful vasodilator released by atrial muscle cells
c. Neural mechanisms (extrinsic)
    i. The ANS and control of blood flow; the ANS can rapidly induce changes in blood flow by causing vasodilation or vasoconstriction by directly innervating blood vessels.
        1. SNS (increase HR and SV)
            a. NT norepinephrine released onto blood vessels causes a general vasoconstriction
            b. NT Ach causes the release of epinephrine from adrenal glands (AC/BD)
        2. PNS (decrease HR and SV)
            a. Small indirect effect on blood vessels causing a weak vasodilation throughout the body
            b. Indirect because SNS is shut off (no more vasoconstriction)

ii. The Baroreceptor Reflex



1. A negative feedback system that works to maintain mean arterial pressure (MAP) for proper perfusion of tissue throughout the body.
2. They are stretch sensitive sensors and they monitor "blood pressure"
3. It does this by regulating cardiac output (CO) and total peripheral resistance (TPR).

2. Mean arterial pressure (MAP) is the average pressure throughout the entire cardiac cycle.
    a. MAP = CO x TPR… where CO = HR x SV… where TPR = all the resistance encountered by the blood in the entire systemic circulation
    b. Decrease radius → increase resistance → increase MAP
    c. Increase radius → decrease resistance → decrease MAP
3. Baroreceptor reflex would control a sudden increase in blood pressure and indicate the areas of the brain which are involved
    a. An increase in blood pressure (MAP) → stretches wall of aorta and carotid sinuses → activated baroreceptors → APs sent to CV centre in the medulla of brain stem → CV centre compares signals to set point → shuts of SNS and activates PNS → decrease in CO (decrease in HR and SV) and causes vasodilation (decrease in TPR) → decreases MAP
4. Hyperventilation causes you to pass out → increase CO_2 removal from blood → decreasing [CO_2] in the blood → (metabolic theory) vasoconstriction of blood vessels → decrease blood flow (in the brain) → pass out