CONCEPT: OSMOREGULATION

● ***Osmoregulation*** – regulation of solute balance and water loss to maintain homeostasis of water content

● ***Excretion*** – process of eliminating waste from the body, like nitrogenous waste

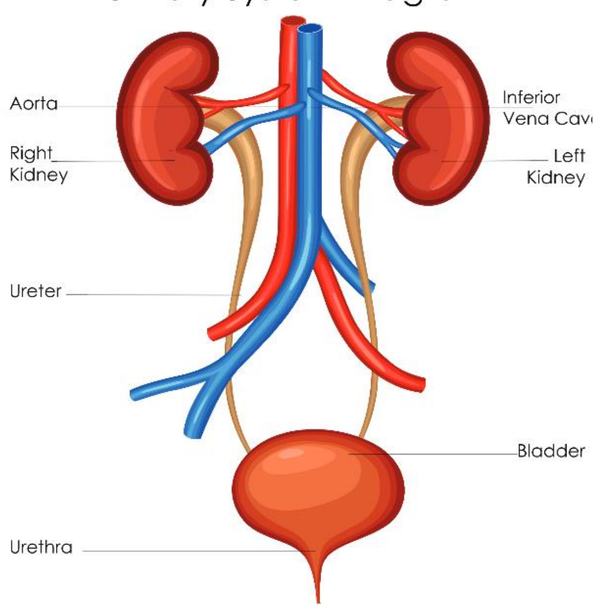
● ***Kidney*** – bean-shaped organs that filter blood plasma, and form urine

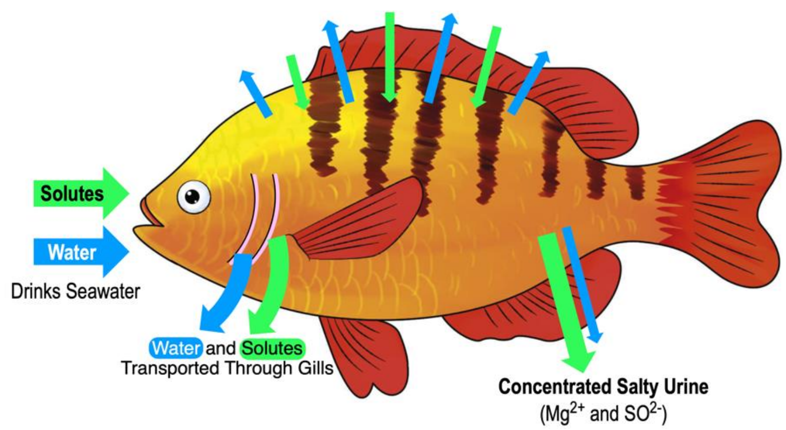
● ***Ureter*** – transport urine from the kidney to the bladder

● ***Bladder*** – organ that stores urine for elimination through the urethra

● ***Urethra*** – opening through which urine leaves

EXAMPLE: Urinary System Diagram

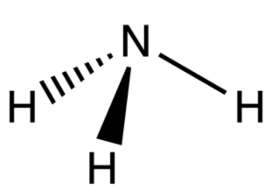


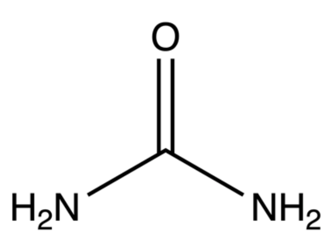


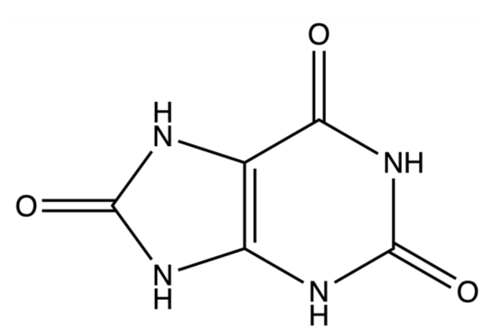
● ***Nitrogenous waste*** – nitrogen-containing metabolic wastes

- □ ***Ammonia*** – toxic substance that must be heavily diluted, forms from the breakdown of proteins and nucleic acids
- □ ***Urea*** – requires energy to produce, but is far less toxic than ammonia, excreted with minimal water loss
- □ ***Uric acid*** – mostly insoluble, so excreted with almost no water loss, but energy intensive to produce
- □ Type of waste tied to evolutionary history, habitat, and osmotic stress
- □ Fitness trade-off between energetic cost of excreting waste and conserving water

EXAMPLE:



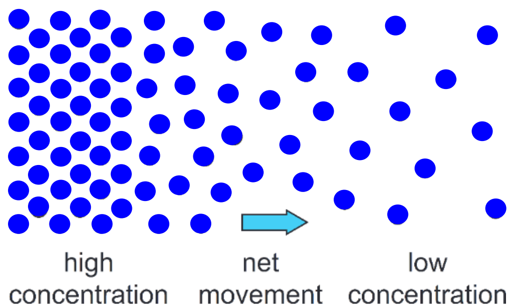


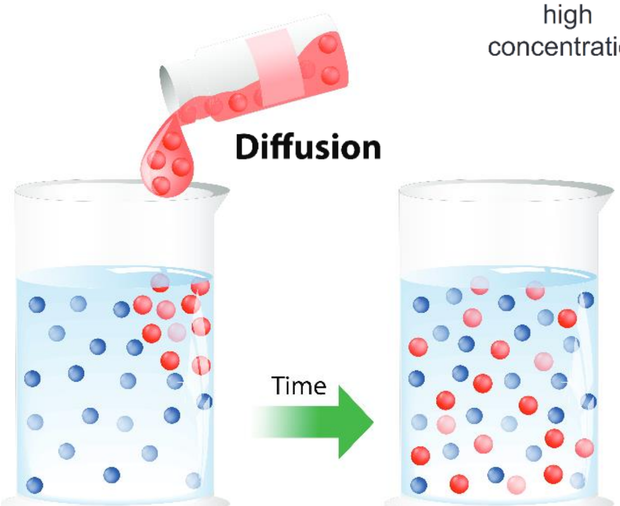


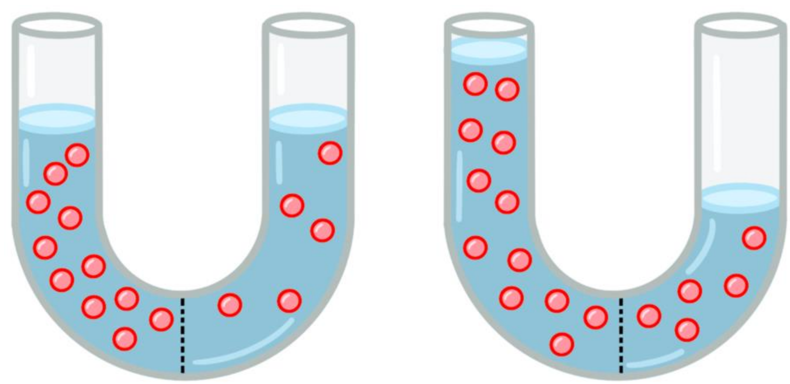
CONCEPT: OSMOREGULATION

- ***Solutes*** – substance dissolved in a solution
  - □ ***Electrolyte*** – compound that dissociates ions in water, like NaCl → Na^+ and Cl^-
- ***Concentration gradient*** – difference in concentration of a solute over an area
- ***Diffusion*** – net movement of molecules or atoms from an area of high concentration to an area of low concentration
- ***Osmosis*** – movement of water across membrane from low solute concentration to high solute concentration
- ***Selective permeability*** – solutes can/can't cross the membrane due to the presence/absence of transport proteins

EXAMPLE:

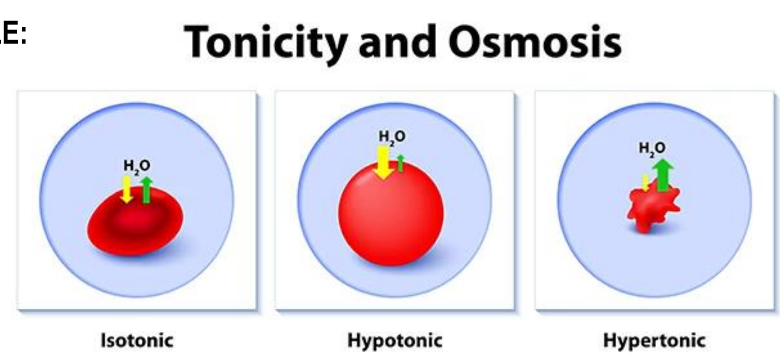






- ***Osmolarity*** – concentration of a solute measured as of moles of dissolved solute per liter
  - □ ***Hyperosmotic*** – higher osmolarity than another solution
  - □ ***Isosmotic*** – two solutions of the same osmolarity
  - □ ***Hypoosmotic*** – lower osmolarity than another solution
- ***Osmoconformers*** – marine organisms that are isosmotic with their environment
- ***Osmoregulators*** – organisms that actively regulate the osmolarity of their internal environment
- ***Anhydrobiosis*** – adaptation that allows organisms like tardigrades to survive without water

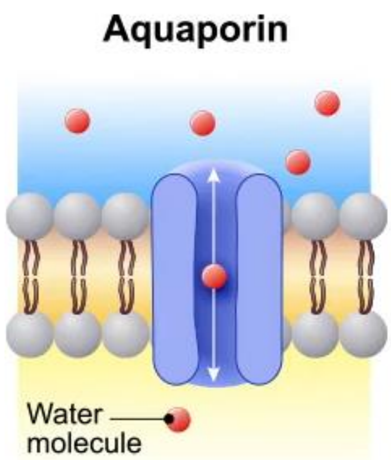
EXAMPLE:

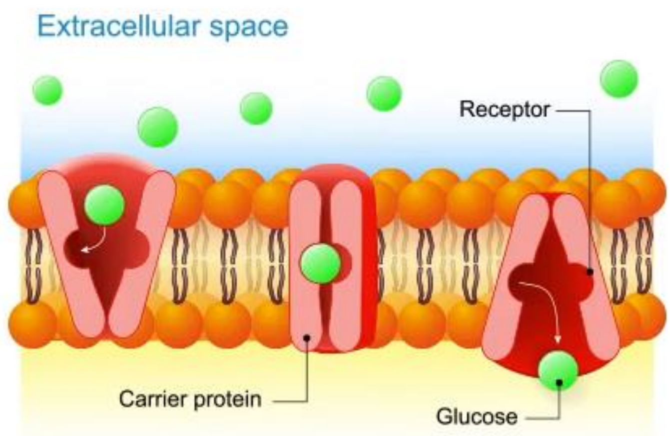


CONCEPT: OSMOREGULATION

- ***Passive transport*** – movement of molecules or atoms across the membrane via electrochemical gradients
- ***Facilitated diffusion*** – movement of molecules across the membrane via channels and carrier proteins
- ***Channels*** – transmembrane protein pore that allows specific molecules or ions to pass through
  - □ ***Aquaporins*** – water channels
- ***Carrier proteins*** – bind a molecule and change shape to carry it through the membrane

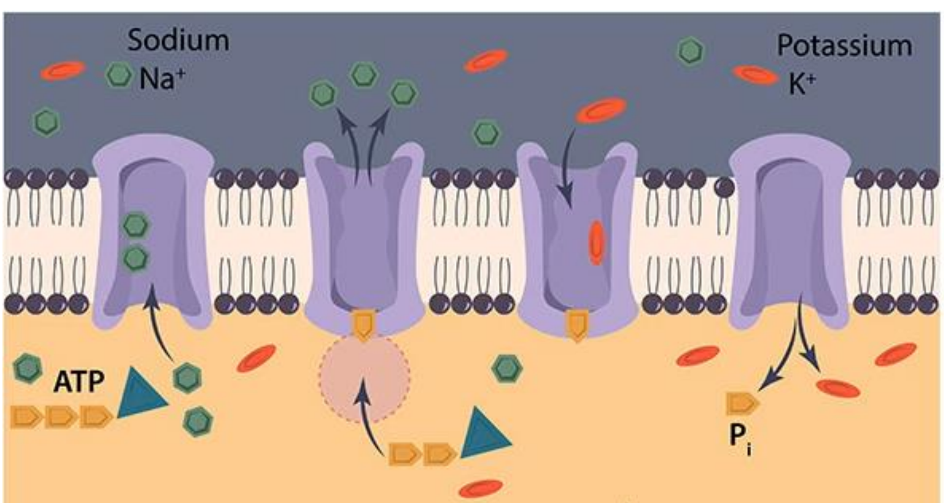
EXAMPLE:

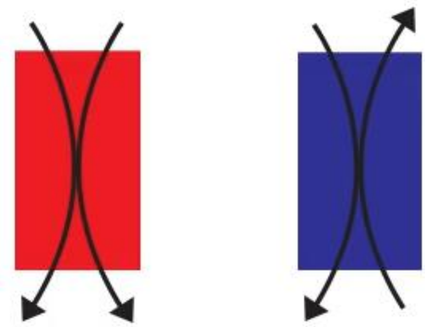




- ***Active transport*** – consumes ATP to move molecules or ions across the membrane
- ***Primary active transport*** – directly hydrolyzes ATP to power protein pumps
  - □ ***Sodium-potassium pump*** (***Na^+/K^+-ATPase***) – pumps $3Na^+$ and $2K^+$ in opposite directions across a membrane
- ***Secondary active transport*** – harnesses potential energy created by pumps to move substances across the membrane
  - □ ***Cotransporter*** - move one substance along it's gradient to carry another substance against its gradient
    - - ***Symporter*** – moves both substances across the membrane in the same direction
    - - ***Antiporter*** – moves both substances across the membrane in opposite directions

EXAMPLE:

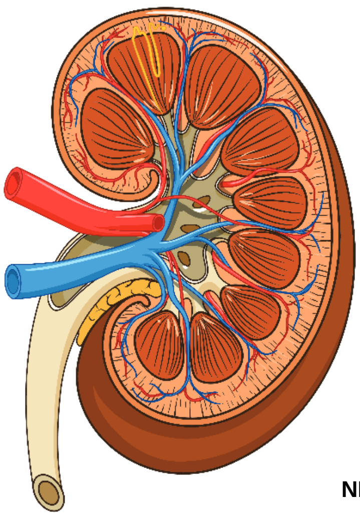


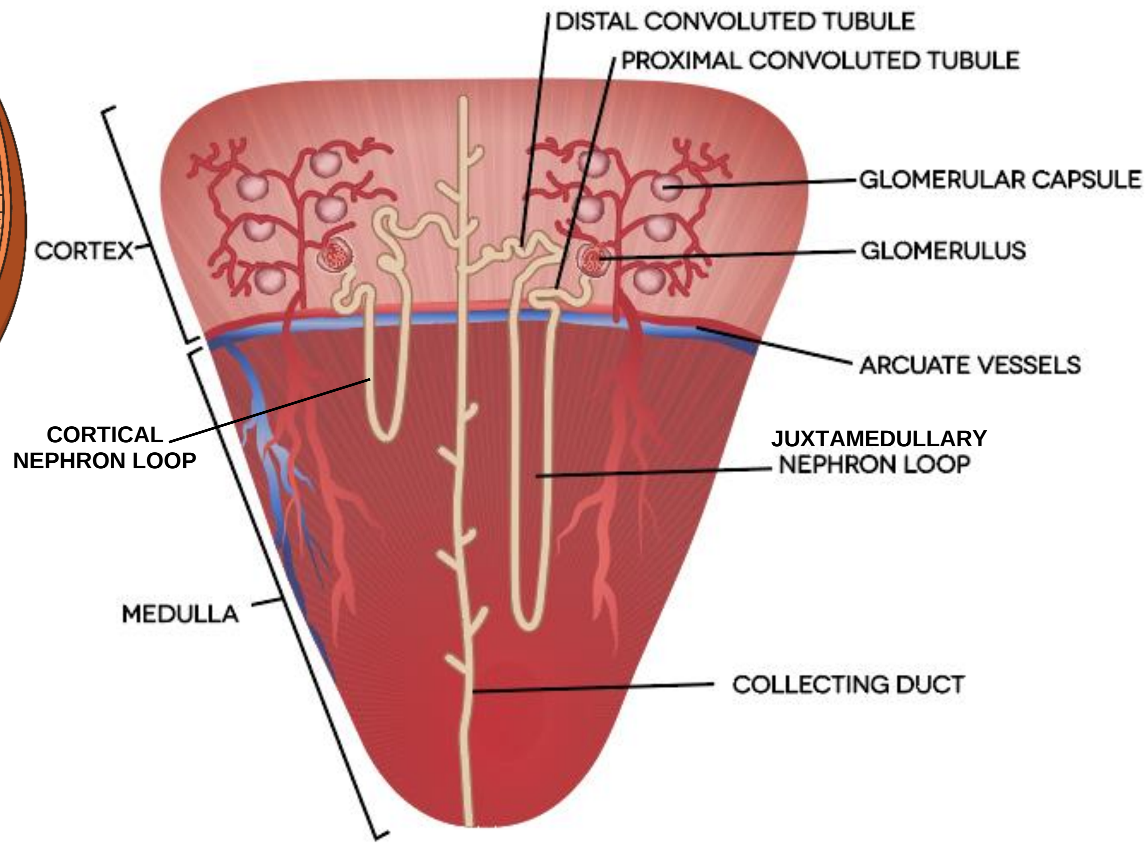


<u>CONCEPT:</u> <u>OSMOREGULATION</u>

- Kidney is mostly made of nephrons, small specialized structures that carry out the filtration and formation of urine
  - □ ***Cortex*** – outer layer of the kidney
  - □ ***Medulla*** – inner, “saltiest” layer of the kidney
- ***Nephron*** – functional unit of the kidney made of tubule structures that transport filtrate surrounded by blood vessels
  - □ Nephron uses active transport of solutes to create a “salty” environment to reabsorb lots of water
  - □ ***Cortical nephron*** – most common type of nephron that doesn’t extend as deeply into the medulla
  - □ ***Juxtamedullary nephron*** – responsible for generating and maintaining strong osmotic gradient for reabsorption

EXAMPLE:





CONCEPT: OSMOREGULATION

● Filtration: water and small solutes cross the epithelial membrane forming filtrate

□ ***Filtrate*** – solution of water and solutes like salts, sugars, amino acids, and nitrogenous wastes

□ Filtrate formation is not very selective

● ***Reabsorption***: valuable solutes like glucose and vitamins are actively reabsorbed from the filtrate to the blood

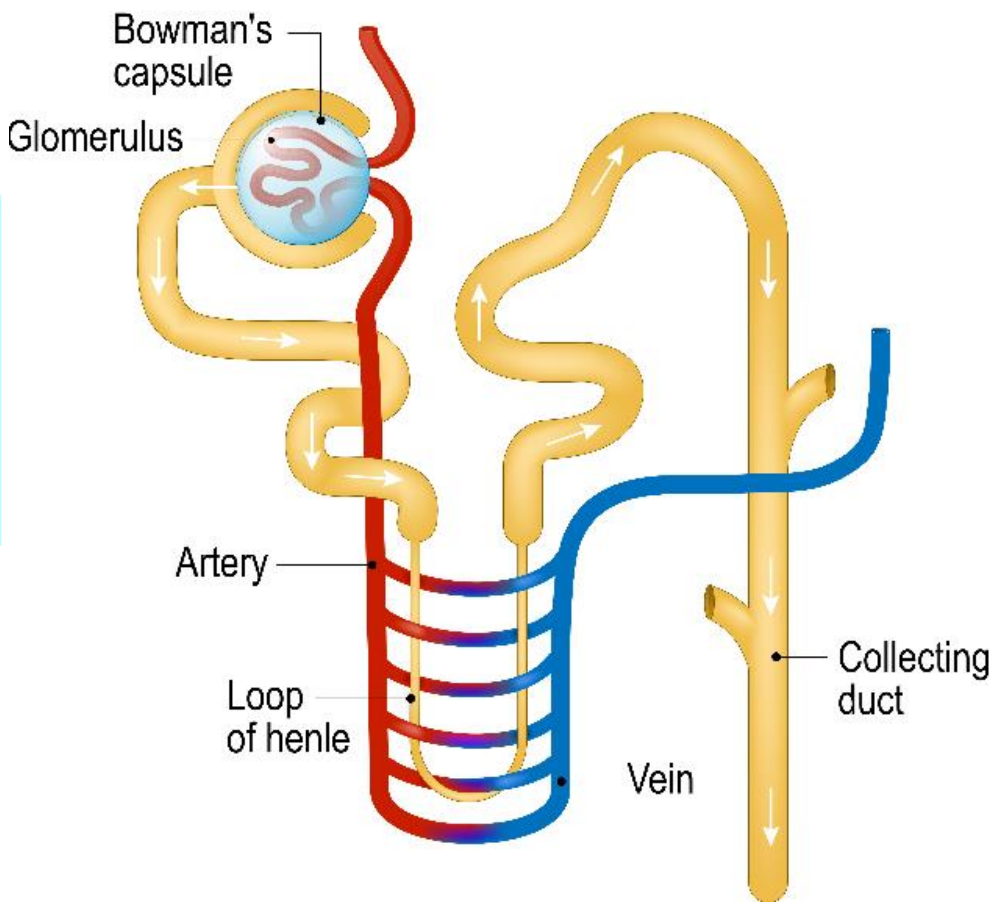
□ Water moves passively by osmosis, but follows solutes that are actively maintained

□ Reabsorption is highly selective and tightly regulated

● Secretion: wastes and solutes are actively added to the filtrate from the blood

● Excretion = Filtration + Secretion – Reabsorption

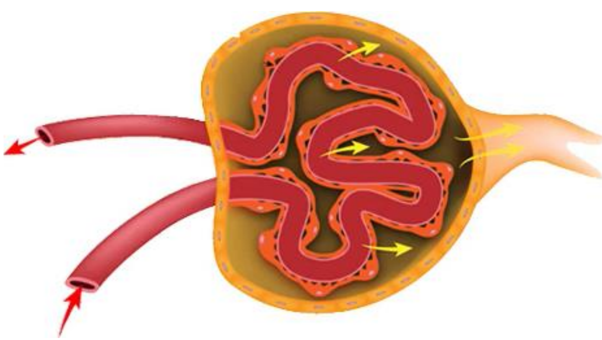
EXAMPLE:

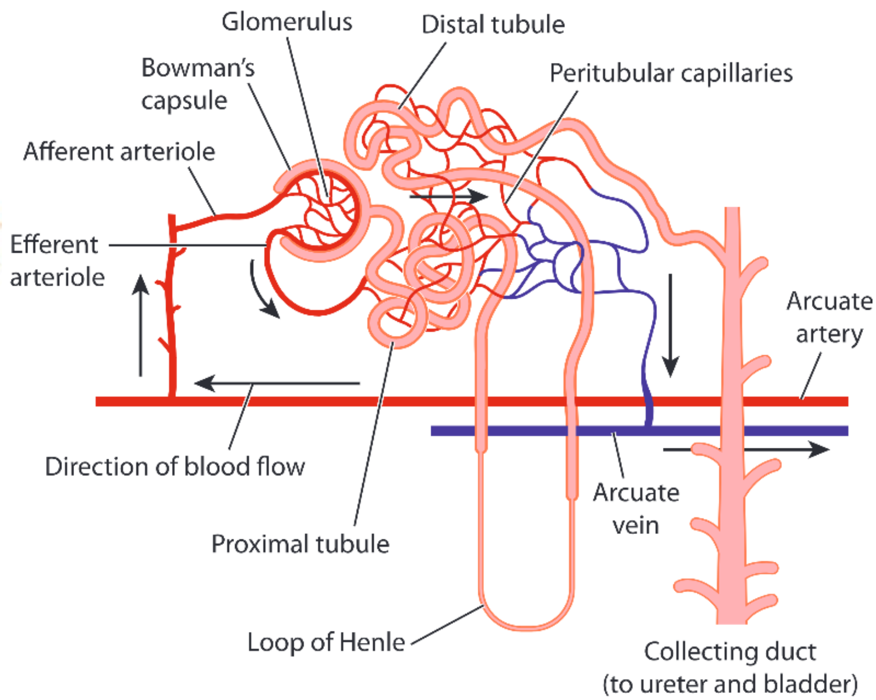


CONCEPT: OSMOREGULATION

- ***Peritubular capillaries*** – small blood vessels that surround nephrons, specifically the proximal and distal tubules
  - □ ***Vasa recta*** – peritubular capillaries that surround the loop of Henle
- ***Renal corpuscle*** – blood-collecting component of the nephron that consists of the glomerulus and Bowman's capsule
  - □ ***Glomerulus*** – ball of capillaries that provides the blood to be filtered
  - □ ***Bowman's capsule*** – collects the filtrate as it flows out of the blood
  - □ Filtration occurs as fluid moves from the glomerulus into Bowman's capsule, renal corpuscle acts like a sieve
    - Filtration is based on size, big molecules or cells in filtrate indicate damage to renal corpuscle
    - Blood pressure drives fluid into Bowman's capsule
  - □ ~99% of the filtrate is reabsorbed, allowing for selective reabsorption with minimal water loss

EXAMPLE:





CONCEPT: OSMOREGULATION

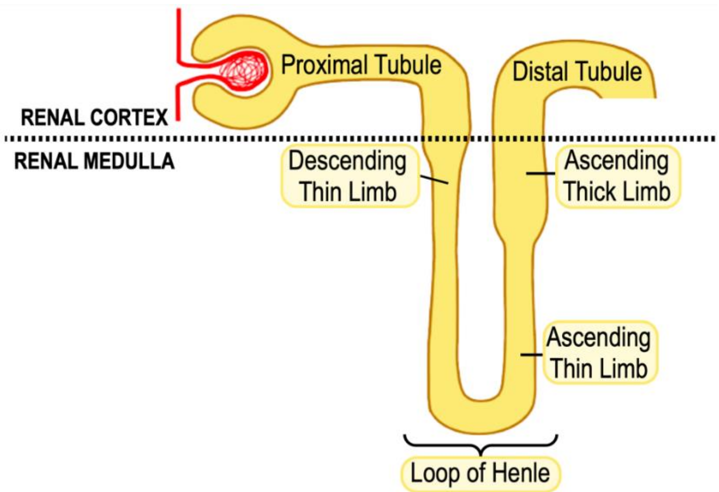
● ***Proximal tubule*** – convoluted structure that transports filtrate from Bowman's capsule to the loop of Henle

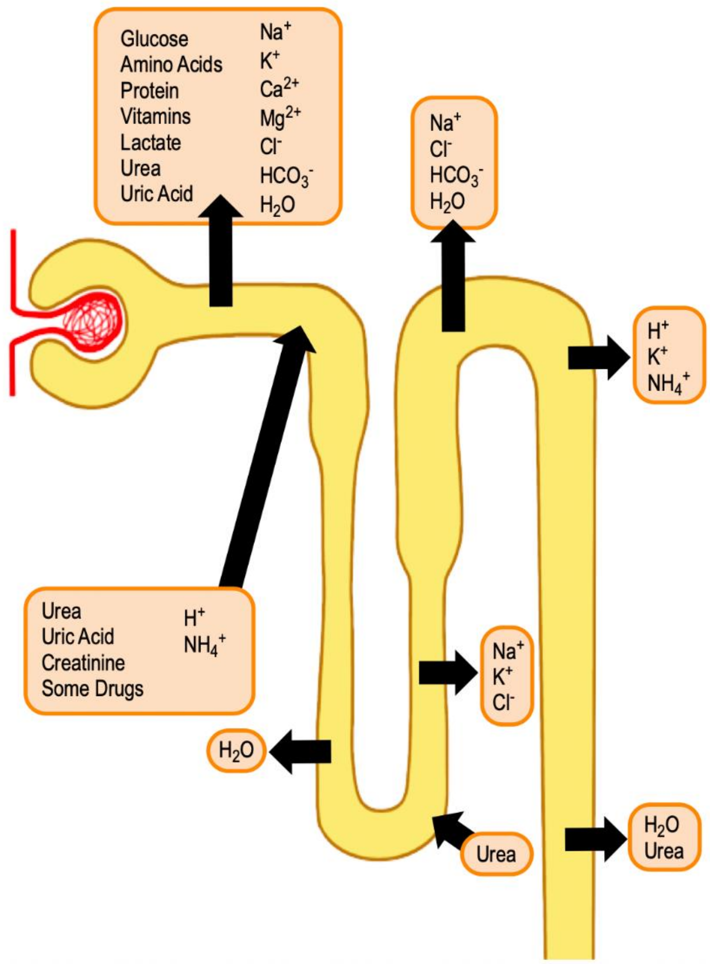
□ Microvilli in the lumen greatly expand the surface area of the proximal tubule

□ Glucose, amino acids, salts, and other solutes are reabsorbed via active transport, water follows passively

□ Osmolarity of filtrate does not change from reabsorption in proximal tubule

EXAMPLE:

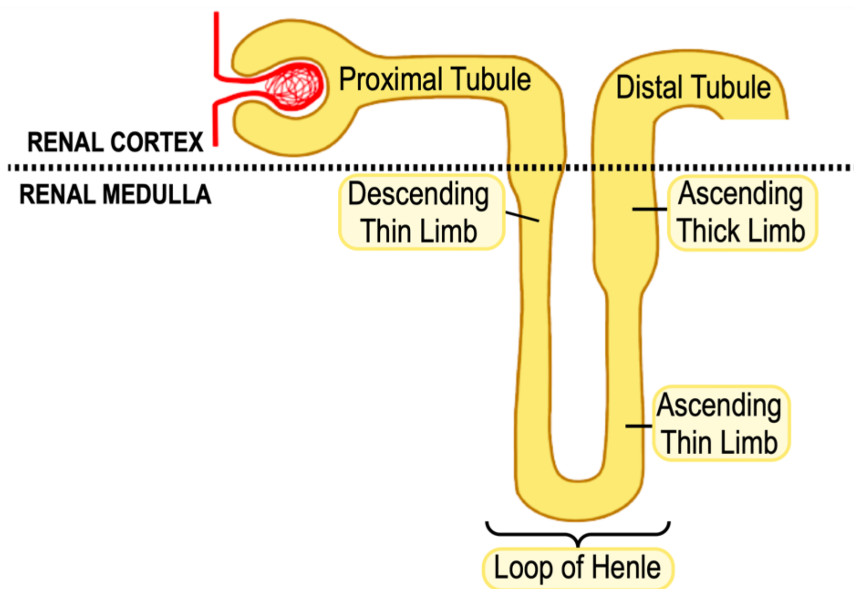




CONCEPT: <u>OSMOREGULATION</u>

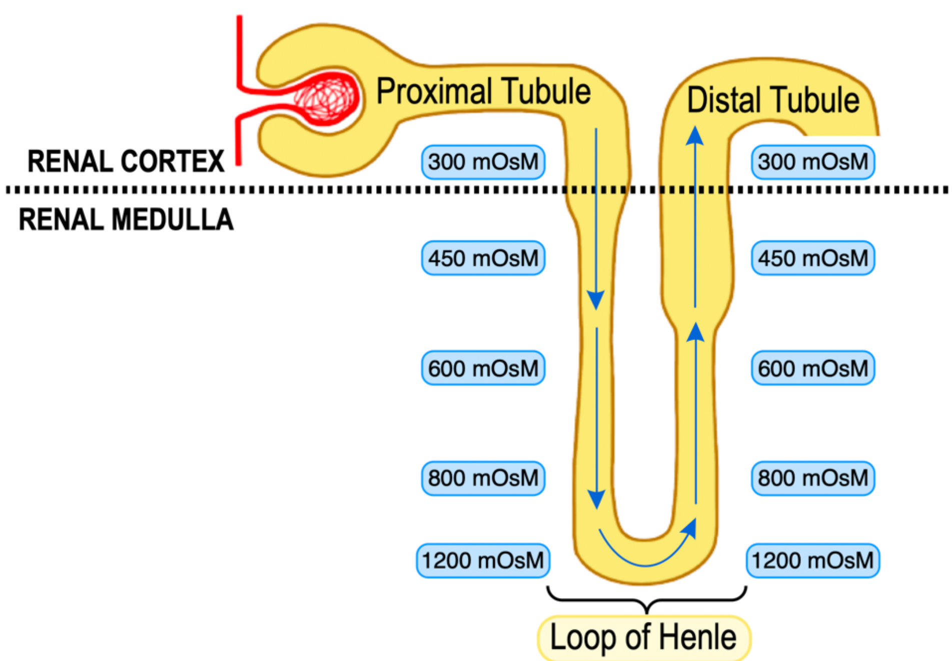
- ***Loop of Henle*** – transports filtrate from the proximal tubule, into then out of the medulla, and connects to the distal tubule
  - □ ***Descending limb*** – thin and permeable to water, lots of water reabsorption occurs here
    - - Volume of filtrate decreases, but solute concentration of filtrate increases
  - □ ***Ascending limb*** – has thin section for passive transport, and thick section for active transport
    - - Impermeable to water, only solutes are reabsorbed
    - - Volume stays the same, but solutes are reabsorbed, diluting the filtrate

EXAMPLE:



  - □ ***Countercurrent multiplier system*** – expends energy to create concentration gradient
    - - Water flows out of descending limb due to osmotic gradient created by ascending limb
    - - High solute concentrations at the beginning of ascending limb drive solute transport
    - - Active transport is used in last portion of ascending limb to maintain gradient

EXAMPLE:



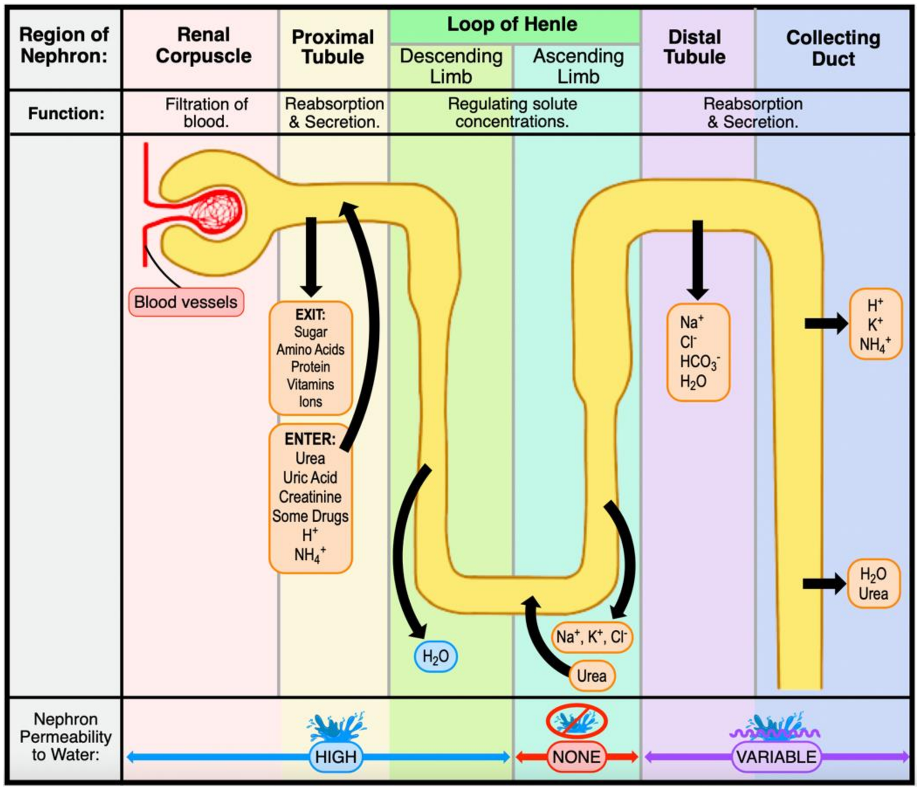
CONCEPT: OSMOREGULATION

● ***Distal tubule*** – connects loop of Henle to collecting duct, and actively reabsorbs solutes

● ***Collecting duct*** – final tubule element that can reabsorb water and urea

□ Region in the inner medulla is permeable to urea, which helps create the strong osmotic gradient

EXAMPLE:



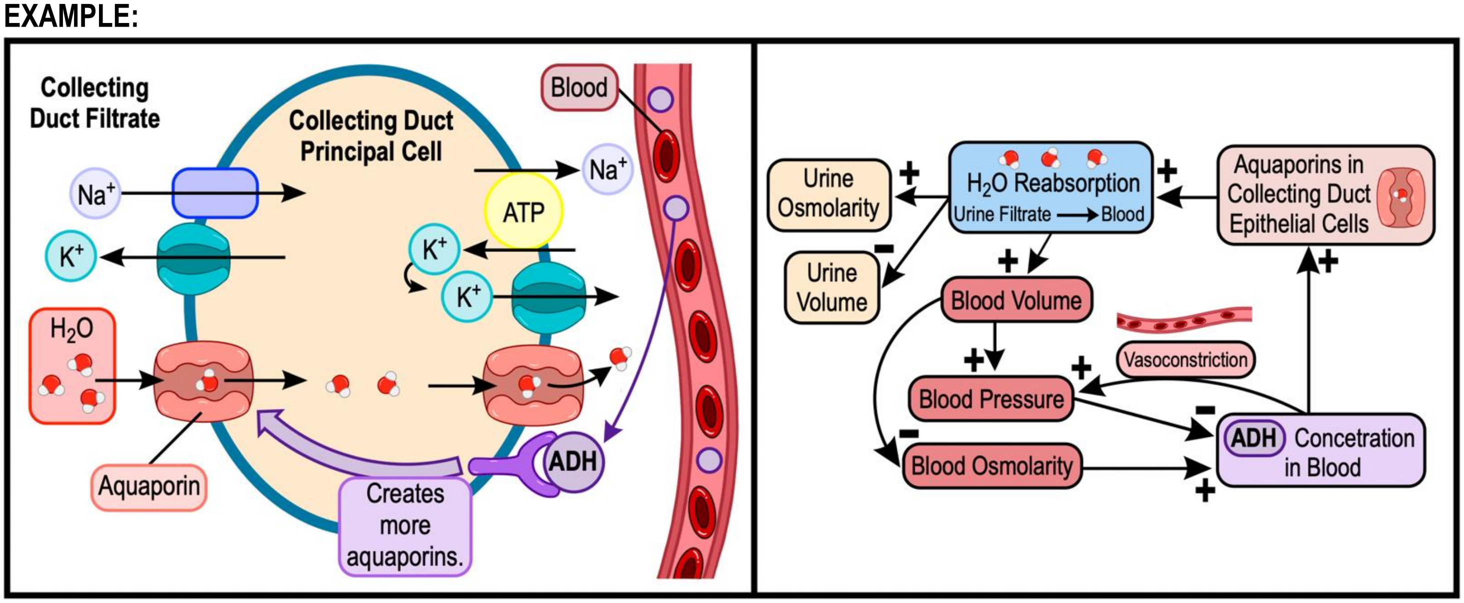
● ***Antidiuretic hormone*** (***ADH*** or ***vasopressin***) – hormone secreted by pituitary gland in response to high blood osmolarity

□ Walls of distal tubule and collecting duct become more permeable to water

- Permeability increased by adding aquaporins to apical membrane

□ Increases water reabsorption, leading to increased blood volume, and decreased blood osmolarity

EXAMPLE:



CONCEPT: <u>OSMOREGULATION</u>

- ***Renin-Angiotensin-Aldosterone-System*** – controls blood volume homeostasis, increases water and salt reabsorption
  - □ Renin is released by juxtaglomerular apparatus in response to drops in blood pressure or volume
  - □ Renin leads to the cleavage of angiotensin angiotensin II
  - □ Angiotensin II raises blood pressure by vasoconstriction, and stimulates adrenal cortex to release aldosterone
- Aldosterone stimulates distal tubule and collecting duct to reabsorb more salt
  - □ Water follows reabsorption of salt, leading to increased blood volume and pressure
    - Isosmotic increase in blood volume because water and salt absorbed together
  - □ Pituitary hormone ACTH also stimulates release of aldosterone

EXAMPLE: