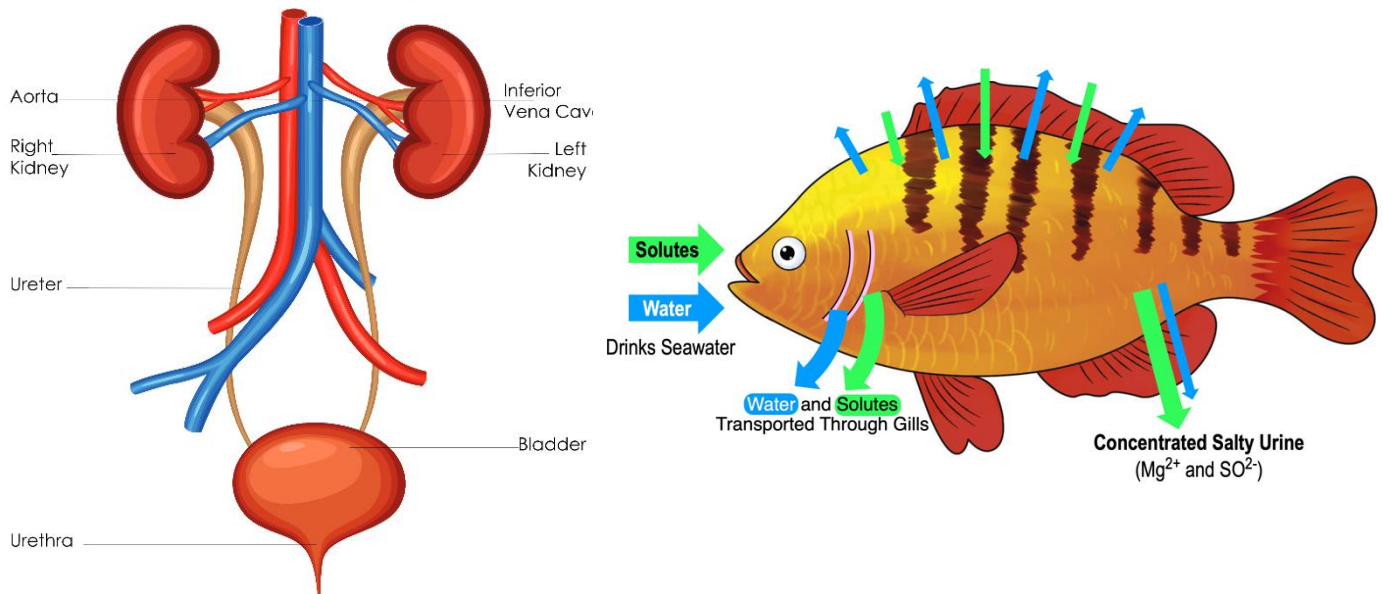


CONCEPT: OSMOREGULATION

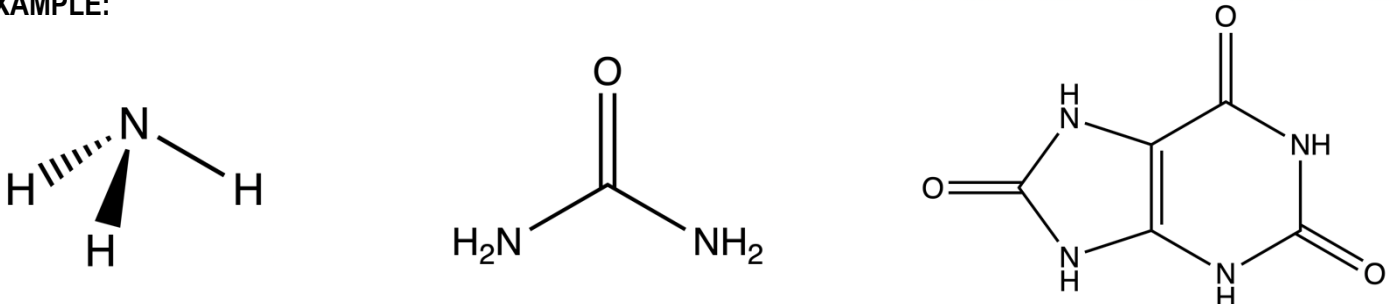
- **Osmoregulation** – regulation of solute balance and water loss to maintain homeostasis of water content
- **Excretion** – process of eliminating waste from the body, like nitrogenous waste
- **Kidney** – bean-shaped organs that filter blood plasma, and form urine
- **Ureter** – transport urine from 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

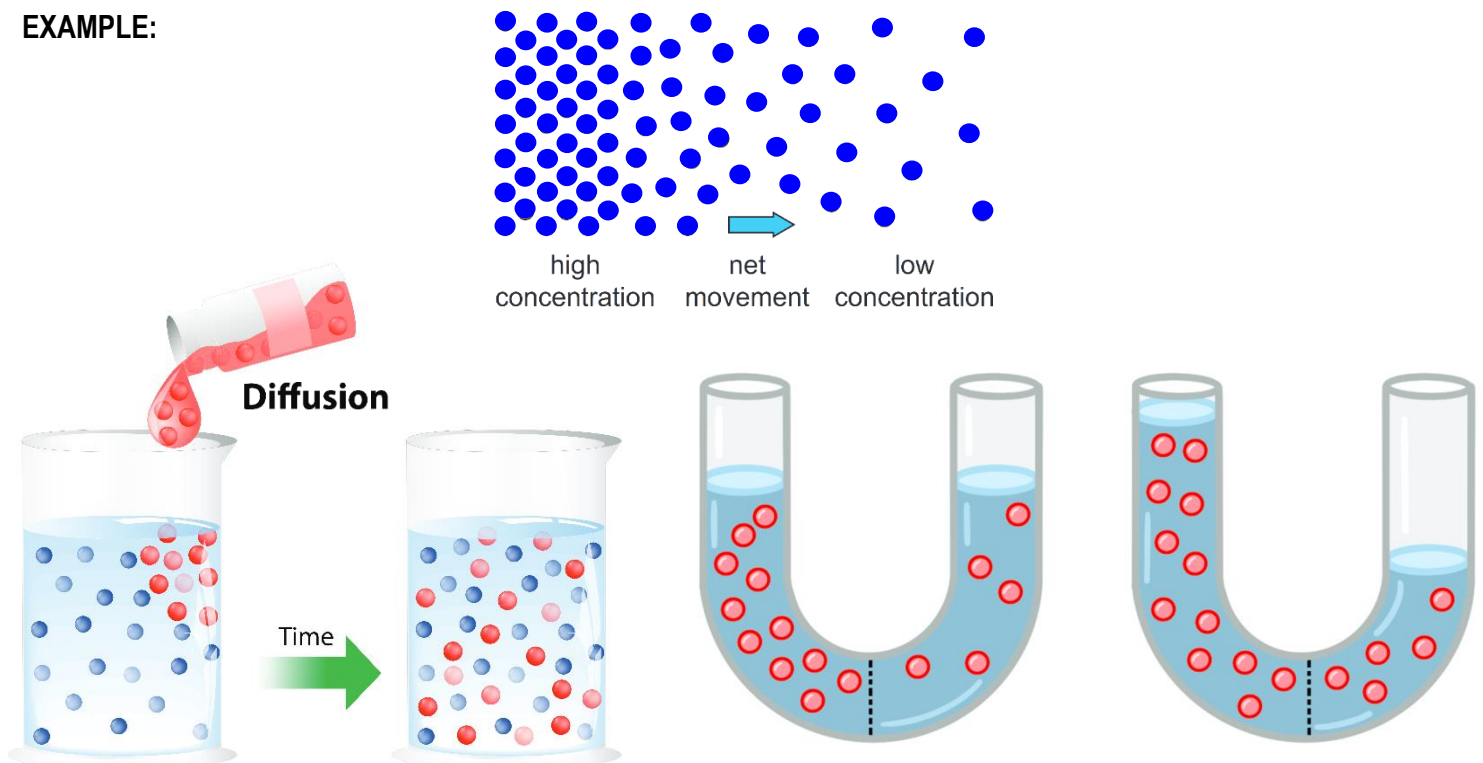
EXAMPLE:



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

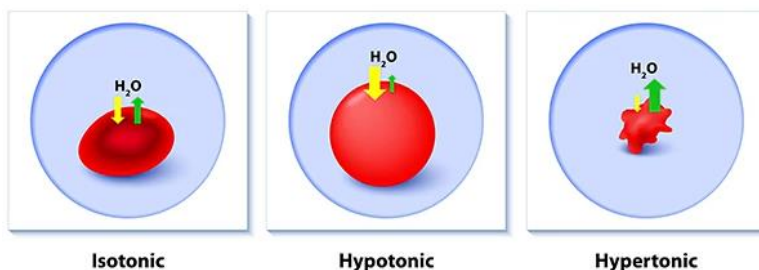
EXAMPLE:



- **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:

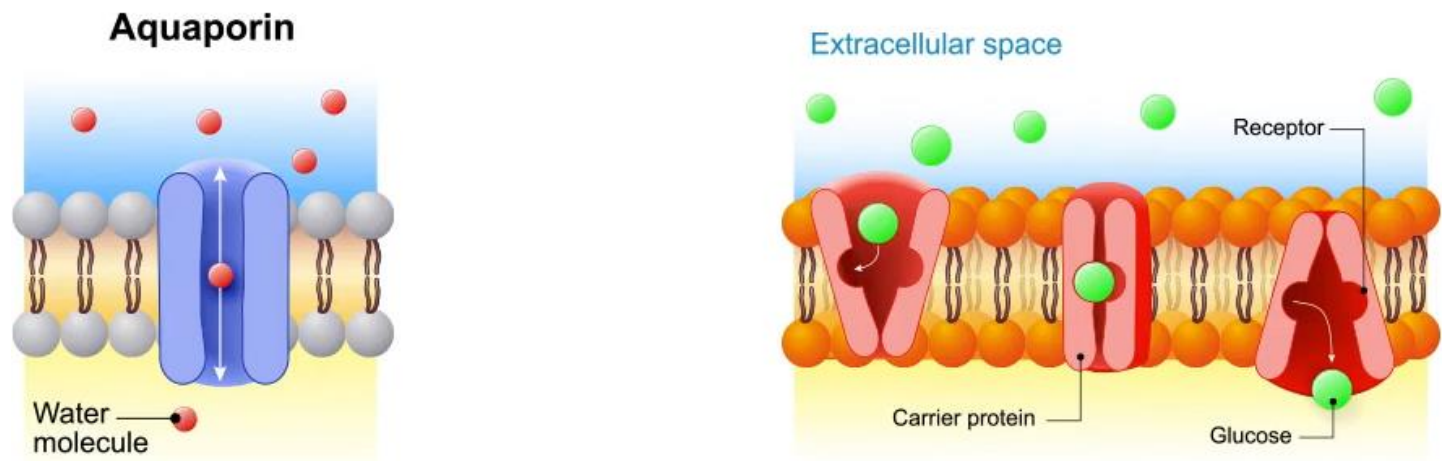
Tonicity and Osmosis



CONCEPT: OSMOREGULATION

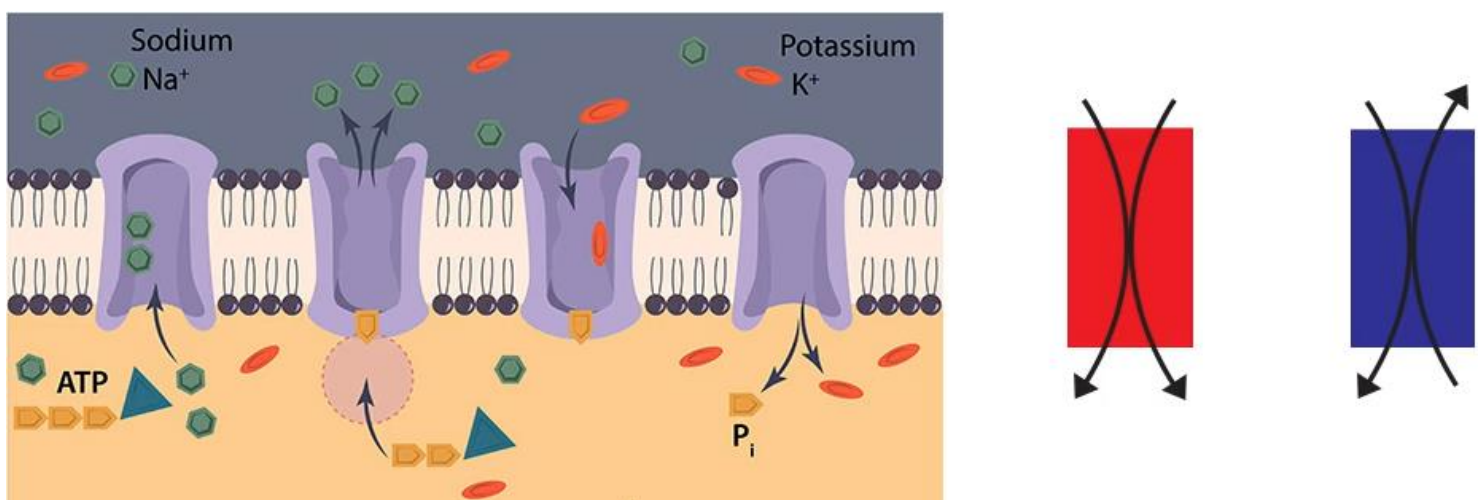
- **Passive transport** – movement of molecules or atoms across the membrane via electrochemical gradients
- **Facilitated diffusion** – movement of molecules across the membrane via channels and carrier proteins
- **Channels** – transmembrane protein pore that allows specific molecules or ions to pass 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 ($\text{Na}^+/\text{K}^+ \text{-ATPase}$)** – 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 its 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

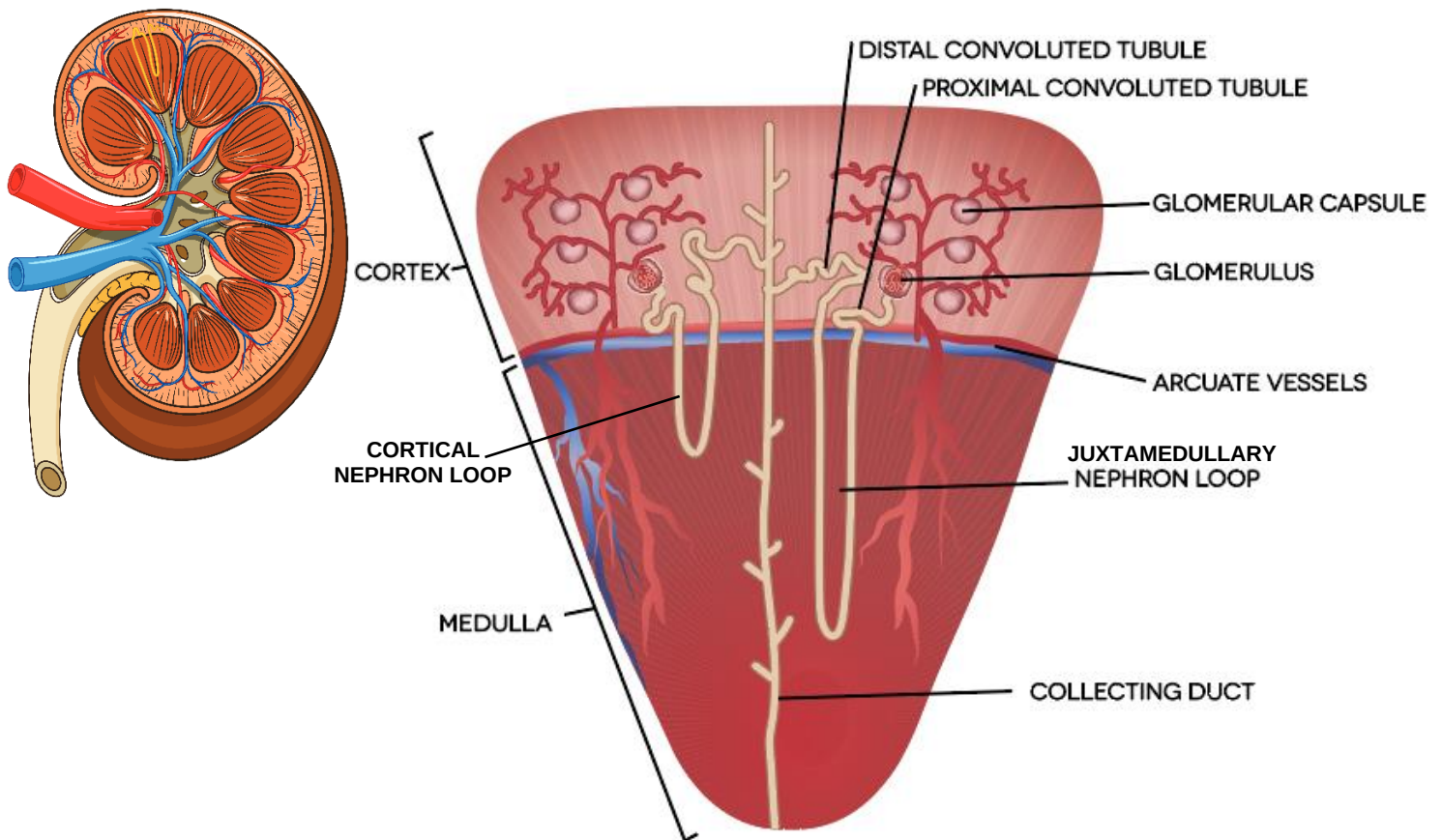
EXAMPLE:



CONCEPT: OSMOREGULATION

- 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

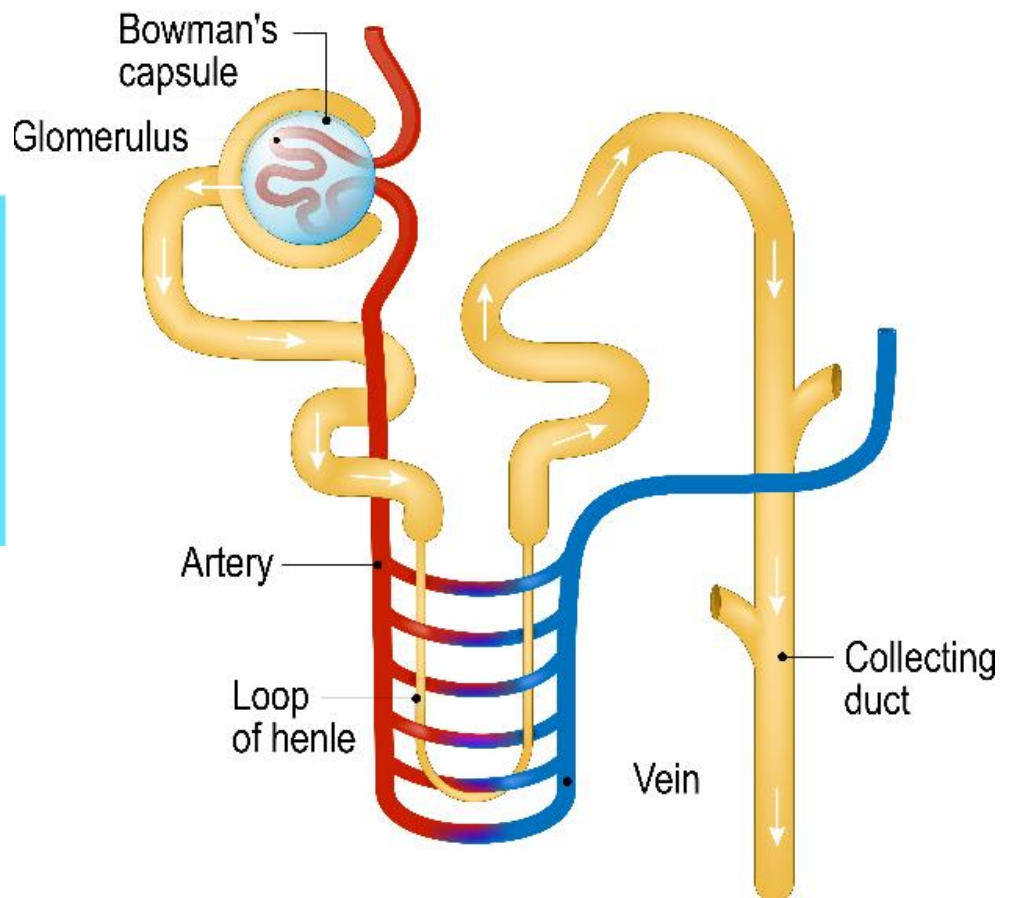
EXAMPLE:



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

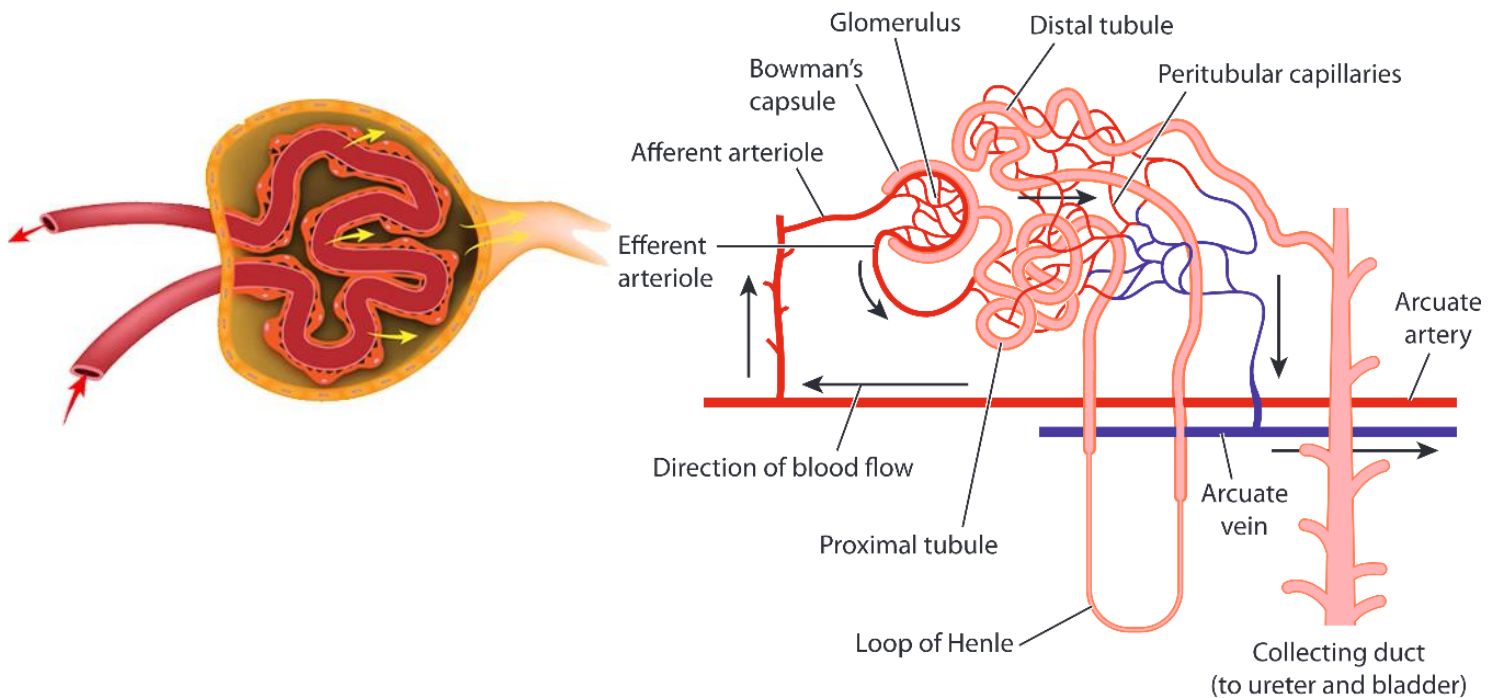
EXAMPLE:



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

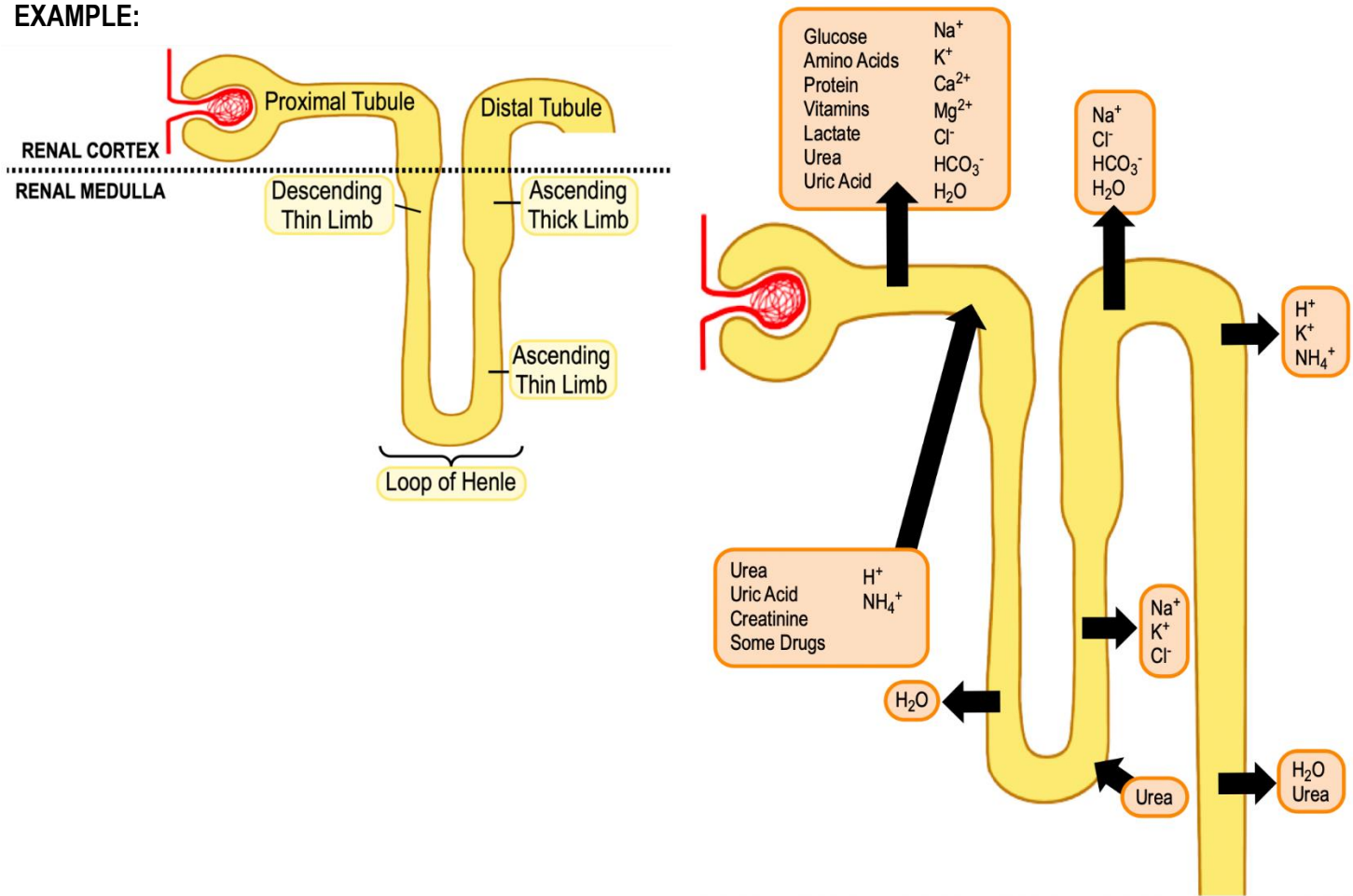
EXAMPLE:



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

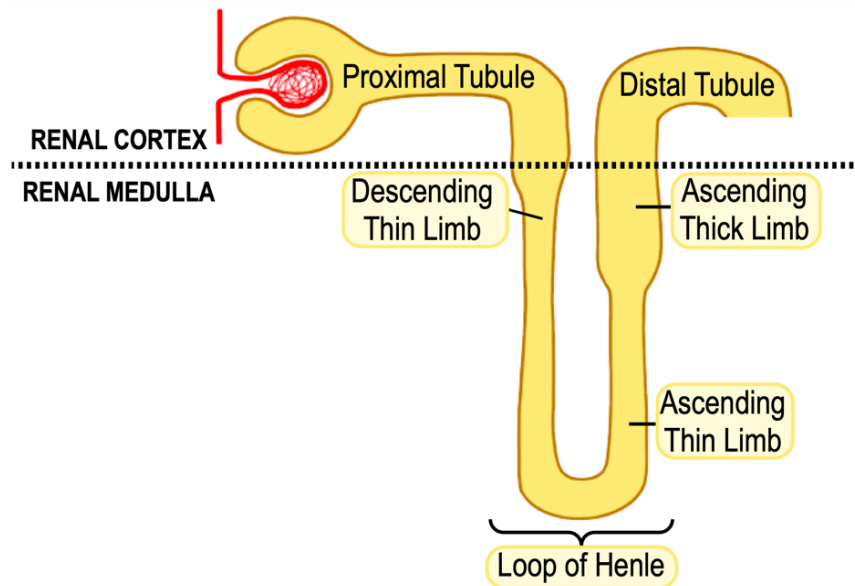
EXAMPLE:



CONCEPT: OSMOREGULATION

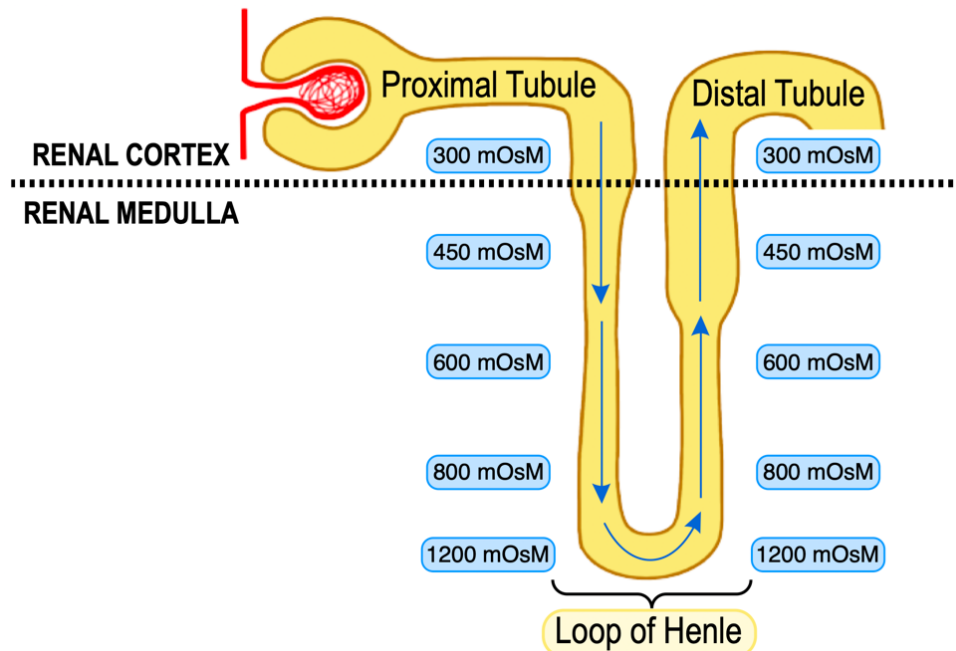
- **Loop of Henle** – transports filtrate from the proximal tubule, into then out of the medulla, and connects to the distal tubule
 - **Descending limb** – thin and permeable to water, lots of water reabsorption occurs here
 - Volume of filtrate decreases, but solute concentration of filtrate increases
 - **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

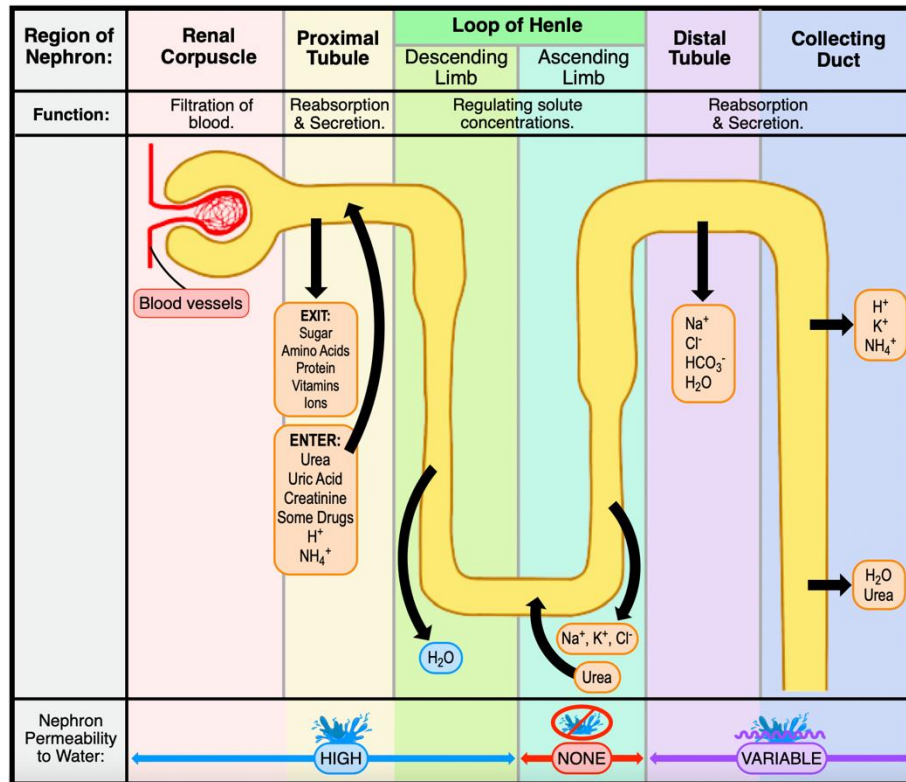
EXAMPLE:



CONCEPT: OSMOREGULATION

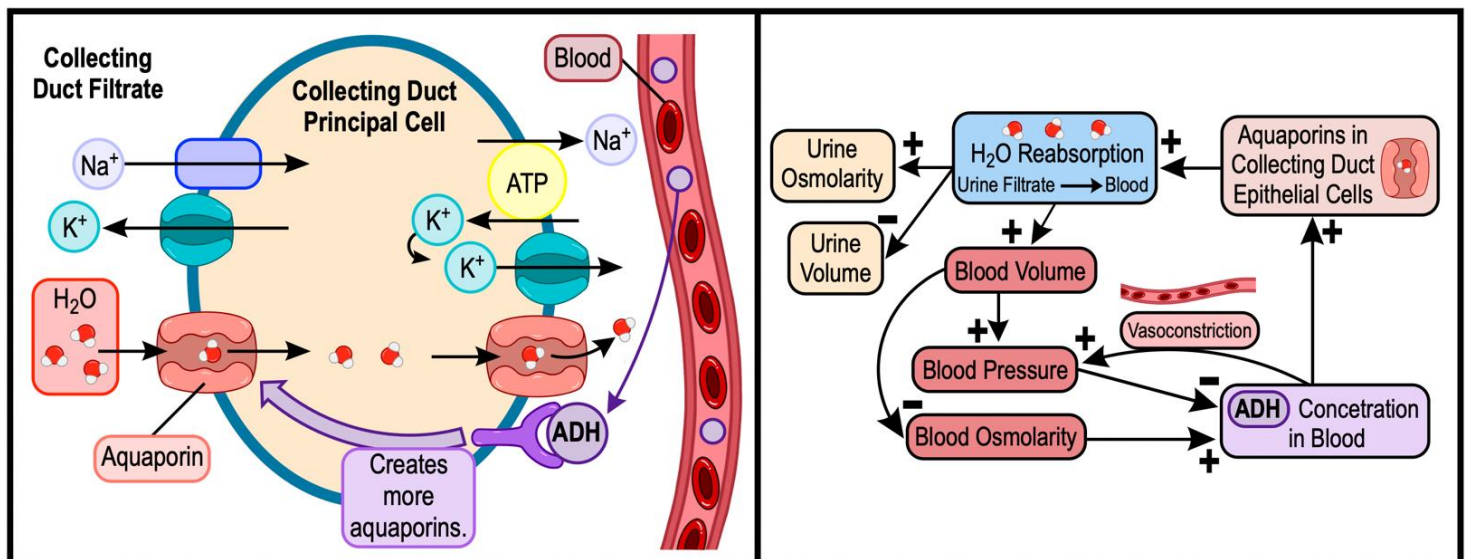
- **Distal tubule** – connects loop of Henle to collecting duct, and actively reabsorbs solutes
- **Collecting duct** – final tubule element that can reabsorb water and urea
 - Region in the inner medulla is permeable to urea, which helps create the strong osmotic gradient

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: OSMOREGULATION

- **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 angiotensinogen → angiotensin I
 - Angiotensin I 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:

