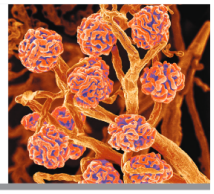
24
The Urinary System



24.1 Overview of the Urinary System

Overview of the Urinary System Structures

- **Urinary system** (organs of excretion) – composed of a pair of kidneys and urinary tract
  - _____ filter blood to remove metabolic waste products; modify resulting fluid for following purposes:
    - Fluid and electrolyte homeostasis
    - Acid-base and blood pressure homeostasis

- **Urinary tract** – composed of a pair of **ureters**, urinary **bladder**, and a single **urethra**
  - Urine exits kidneys through _____ found on posterior body wall
  - Each ureters empties into **urinary bladder** on floor of pelvic cavity where urine is stored
  - Urine exits from urinary bladder through _____ ; allows urine to exit body

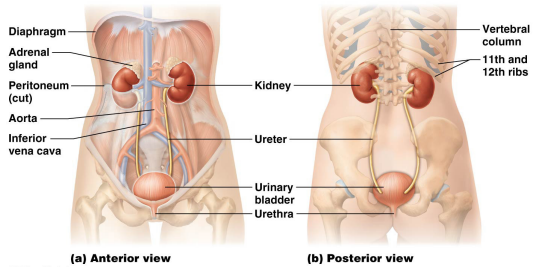
Overview of Kidney Function

- Kidneys are site where urinary system regulates homeostatic processes:
  - Filter blood to remove metabolic wastes
  - Regulate fluid and electrolyte balance
  -
  - Influence blood pressure
  - Releasing hormone **erythropoietin**
  -
  -

Overview of the Urinary System Structures

- Kidneys look like beans in both shape and color
- Both kidneys are found outside and posterior to peritoneal membrane (_____)
- Right kidney is found in a slightly inferior position due to liver

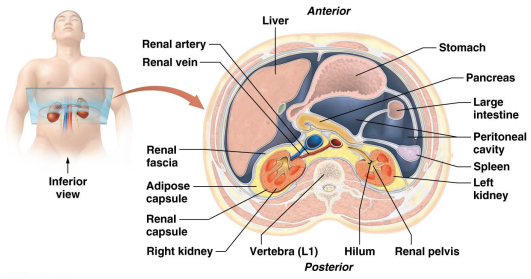
- Left kidney is positioned between T_{12}–L_3 using vertebral column as reference
- 11th and 12th ribs provide some protection for both kidneys
- _____ _____ – component of *endocrine system*; found on superior pole of each kidney



24.2 Anatomy of the Kidneys

External Anatomy of the Kidneys

- Three external layers of connective tissue from deep to superficial:
  1. _____ **capsule** – thin layer of dense irregular connective tissue; covers exterior of each kidney
  2. _____ **capsule** – protects from physical trauma
  3. _____ **fascia** – dense irregular connective tissue; anchors each kidney to peritoneum and musculature of posterior abdominal wall
- **Hilum** – opening on medial surface of kidney where renal artery, vein, nerves, and ureters enter and exit

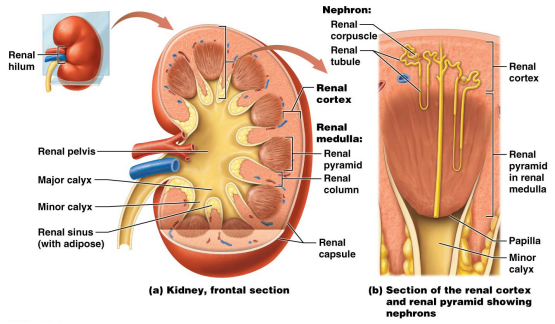


Internal Anatomy of the Kidneys

- Renal cortex and the renal medulla make up *urine-forming* portion of kidney
  - _____ 90–95% of all kidney's blood vessels are found in renal cortex
  - **Renal columns** – *extensions of renal cortex*; pass through renal medulla toward renal pelvis

- Over one million **nephrons** are found within cortex and medulla of each kidney
  - **Renal corpuscle** found in
  - **Renal tubule** found mostly in cortex with some tubules dipping into medulla
- Cone-shaped _____ are found within **renal medulla** separated by renal columns on either side

- Each renal pyramid tapers into a slender papilla
  - →
  - →
  - →
  - →
  - Smooth muscle tissue contraction within walls of the calyces and renal pelvis propel urine towards the ureter



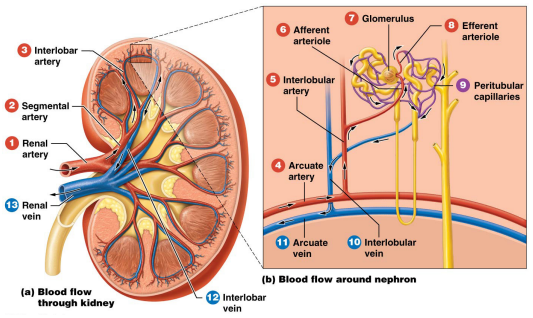
BLOOD SUPPLY OF THE KIDNEYS

- Left and right **renal arteries** are branches of **abdominal aorta**
  - **1-renal artery →**
  - **2-segmental artery →**
  - **3-interlobar artery →**
  - **4- →**
  - **5-interlobular (cortical radiate artery)**

- Kidney contains unusual capillary bed system where arterioles both feed and drain capillaries; normally function of a venule
  - **6-afferent arteriole →**
  - **7- →**
  - **8-efferent arteriole →**
  - **9- capillaries →**

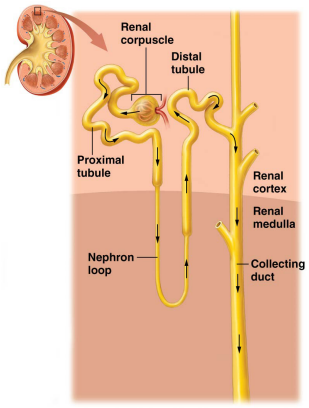
- Venous blood exits kidney *parallel to arterial pathway*
  - **10-interlobular veins →**
  - **11-arcuate veins →**
  - **12-interlobar vein →**
  - **13-**
  - **Renal vein** exits kidney from hilum to drain into inferior vena cava

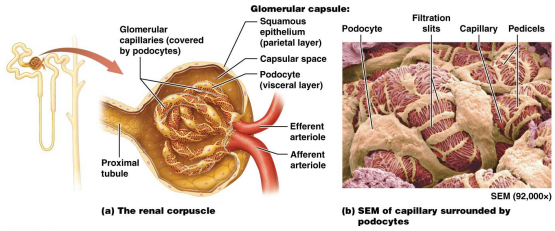
Blood Supply of the Kidneys



Nephron and the Collecting System

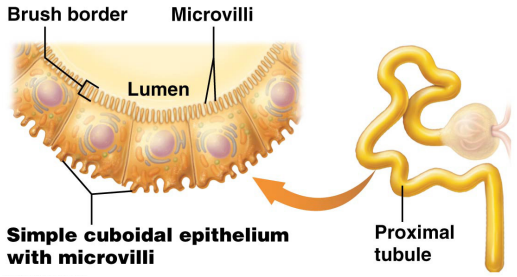
- **Nephron** – renal corpuscle and renal tubule
  - **Renal corpuscle** –filters blood
    - _____ – group of looping fenestrated capillaries
    - **Glomerular capsule** (**Bowman's capsule**) – consists of outer parietal and inner visceral layer
    - _____ **space** – hollow region between parietal and visceral layers



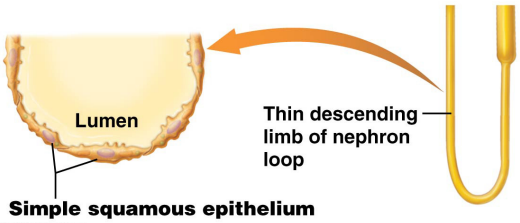


Filtrate from Bowman's capsule enters **renal tubule**:

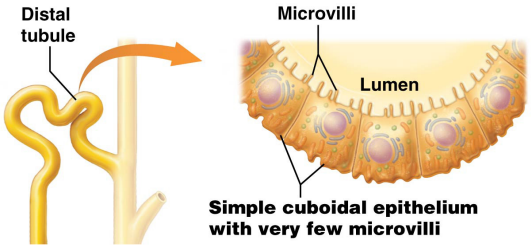
- **Proximal tubule** – reabsorption (some secretion)

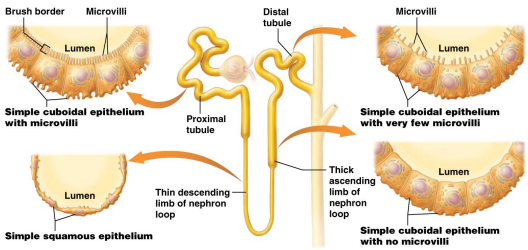


- **Nephron loop (loop of Henle)** – dips into medulla; consists of a descending and an ascending limb (reabsorption)

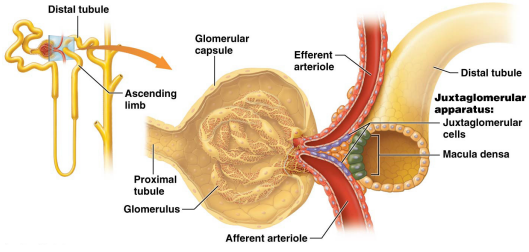


- **Distal tubule** –

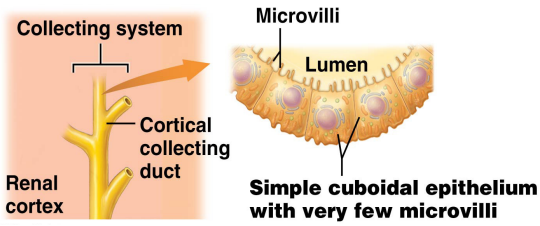




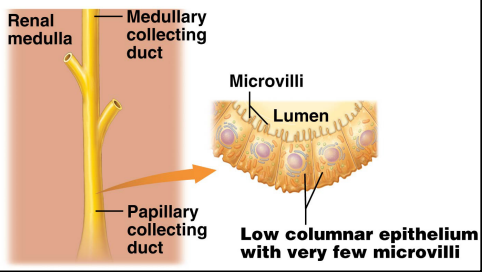
- **Juxtaglomerular apparatus (JGA)** – composed of both **macula densa** and **juxtaglomerular (JG) cells**;
  - **Macula densa** is a group of cells in contact with modified smooth muscle cells (**juxtaglomerular (JG) cells**)
  - JGA regulates *blood pressure* and *glomerular filtration rate*

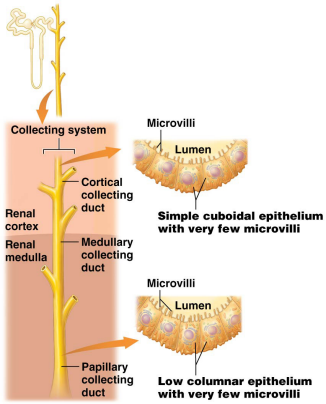


- **Collecting system** – both medullary collecting duct and papillary duct that *further modify* filtrate before it exits kidney
  - **cortical collecting duct → medullary collecting duct →**



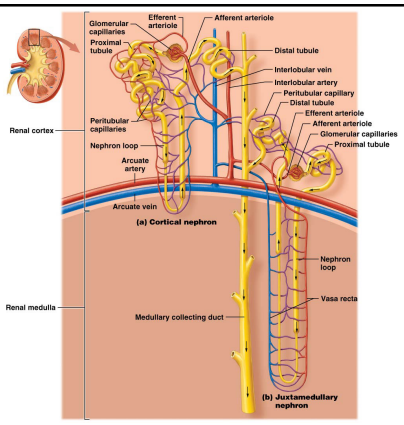
- Once filtrate enters papillary duct it is known as **urine**, not **filtrate**
- Urine exits papillary duct at papilla of renal pyramid into a _____





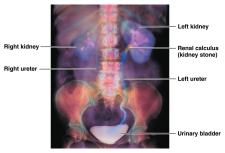
Types of Nephrons

- _____ **nephrons** make up about 80% of nephrons in kidneys
  - Renal corpuscles are found in outer renal cortex; have short nephron loops that barely enter renal medulla
- _____ **nephrons** – much less common than cortical nephrons
  - Renal corpuscles are found near boundary between renal cortex and medulla; have long nephron loops that travel deep within renal medulla



Nephrolithiasis

- Formation of **renal calculi** (**kidney stones**); crystalline structures composed most commonly of *calcium oxalate salts*
- Form when concentrations of ions (also sodium ions, hydrogen ions, and uric acid) are present in filtrate in higher than normal amounts; known as **supersaturation**



24.3 Overview of Renal Physiology

Glomerular Filtration

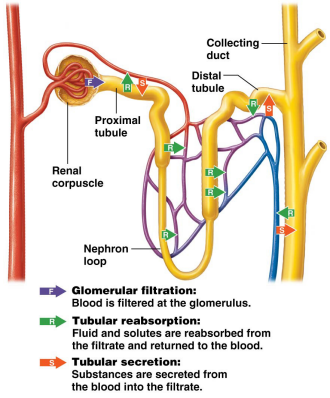
- Selectively based on size so cells and large proteins are not filtered and remain in the circulating blood
  - Smaller substances exit blood to enter capsular space as filtrate

Tubular Reabsorption

- Reclaiming or reabsorbing substances such as water, glucose, amino acids, and electrolytes from tubular fluid to return them into circulating blood

Tubular Secretion

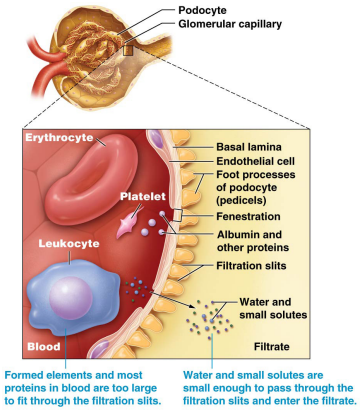
- Substances are added into filtrate from peritubular capillaries
  - Helps maintain electrolyte and acid-base homeostasis; removes toxins from blood that did not enter tubular fluid by filtration



24.4 Renal Physiology I: Glomerular Filtration

The Filtration Membrane and the Filtrate

- **Fenestrated glomerular capillary**
  - **Fenestrations**
  - Water and small dissolved solutes pass through filtration membrane easily
  - **Nitrogenous wastes** – group of small substances that are readily filtered; include:
    - _____ and **ammonium ions** (NH_4^+) from protein metabolism
    - Creatinine
    - _____ – product of nucleic acid metabolism



GLOMERULAR FILTRATION RATE

Amount of filtrate formed by both kidneys in one minute is known as **glomerular filtration rate** (**GFR**); 125 ml/min (_____)

- **Net filtration pressure** at glomerulus is determined by three driving forces:

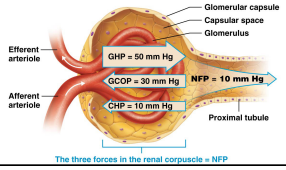
1. Glomerular hydrostatic pressure (_____) – blood pressure; higher than average capillary bed hydrostatic pressure

2. Glomerular colloid osmotic pressure (_____) – created mostly by albumin; pulls water back into glomerular capillaries

3. Capsular hydrostatic pressure (**CHP**) – generated as capsular space rapidly fills with new filtrate (10 mm Hg) as fluid can only move so quickly into renal tubule which opposes filtration

- **Net filtration pressure** (**NFP**) is combination of these three forces:

- NFP favors filtration as GHP is greater than sum of forces that oppose filtration (GCOP + CHP)



GLOMERULONEPHRITIS

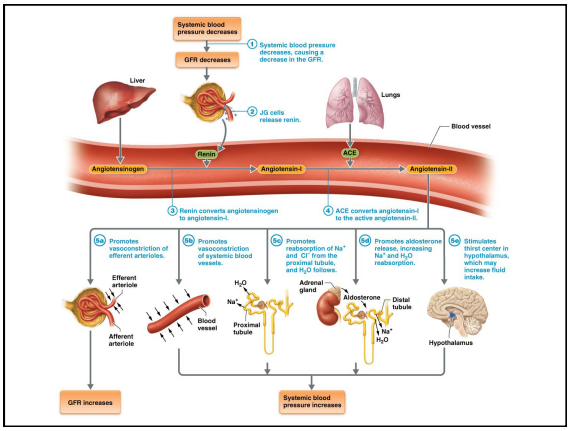
- Common condition that involves damage to and destruction of glomeruli; **inflammation** of glomerular capillaries and basement membrane results
- Inflammation increases *blood flow* and *capillary permeability*; increases GHP; causes filtration membrane to become excessively leaky; leads to *loss of blood cells* and *proteins* to urine

FACTORS THAT AFFECT THE GLOMERULAR FILTRATION RATE

Autoregulation – internal kidney mechanisms that work to maintain GFR

- _____ **mechanism** – constriction of smooth muscle in blood vessel walls in response to increases in blood pressure
- **Tubuloglomerular feedback** – uses **macula densa** of distal renal tubule to control pressure in glomerulus in response to NaCl concentration of filtrate

- Hormonal effects on GFR are part of a larger system that involves regulation of *systemic blood pressure* and includes angiotensin-II and natriuretic peptides
  - **Renin-angiotensin-aldosterone system** (**RAAS**) – complex system that maintains systemic blood pressure
  - **Atrial natriuretic peptide** (**ANP**) – hormone released by heart cells in **atria** in response to increasing fluid volume; lowers blood volume and blood pressure to reduce workload of the heart
    - ANP increases *GFR* by dilating *afferent arterioles* and constricting *efferent arterioles*; increases glomerular hydrostatic pressure



- Neural regulation of GFR primarily involves _____ _____ of autonomic nervous system

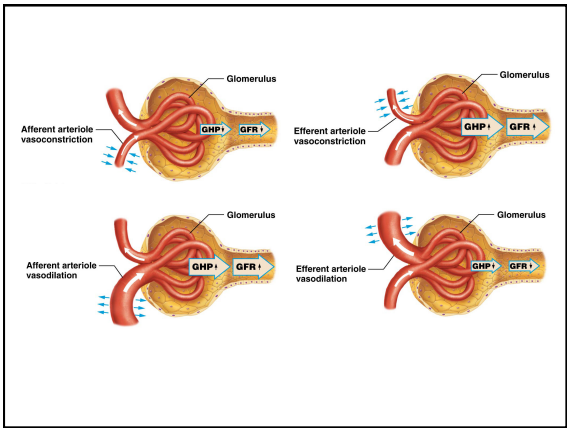


TABLE 24.1 SUMMARY OF CONTROL OF THE GLOMERULAR FILTRATION RATE

Stimulus	Responding Mechanism	Main Effect(s)	Effect on GFR
Autoregulation			
Increased stretching of the afferent arteriole (due to increased blood pressure)	Myogenic mechanism	• Vasoconstriction of the afferent arteriole	Decrease
Increased sodium ion delivery to the macula densa cells (due to increased GFR)	Tubuloglomerular feedback	• Vasoconstriction of the afferent arteriole • Vasodilation of the efferent arteriole	Decrease
Hormonal Mechanisms			
Sympathetic nervous system activated; decreased GFR; decreased systemic blood pressure	Renin-angiotensin-aldosterone system	• Vasoconstriction of the efferent arteriole • Systemic vasoconstriction • Reabsorption of sodium ions from the filtrate in the proximal tubule • Release of aldosterone • Reabsorption of water	Increase (decrease at high levels of activation)
Increased systemic blood pressure	Atrial natriuretic peptide	• Vasodilation of the afferent arteriole • Vasoconstriction of the efferent arteriole • Decreased reabsorption of sodium ions • Increased water loss	Increase
Neural Mechanisms			
Multiple	Sympathetic nervous system	• Constriction of all vessels, including the afferent and efferent arterioles • Stimulates RAAS	Decrease (increase at low levels of activation)

RENAL FAILURE

- If GFR decreases, kidneys may be unable to carry out their vital functions; called **renal failure**
  - Renal failure may be a short-term condition known as **acute renal failure** or **acute kidney injury**; *resolves* with treatment
  - Renal failure may become **chronic** after three or more months of decreased GFR; commonly seen with long-standing *diabetes mellitus* and *hypertension*

RENAL FAILURE

- _____ – condition that can develop when GFR is less than *50% of normal*; leads to buildup of *waste products*, *fluid*, *electrolytes*, as well as *acid-base imbalances*, all of which can lead to coma, seizures, and death if untreated
- _____ can be used to treat the signs and symptoms of uremia

The RAAS and Hypertension

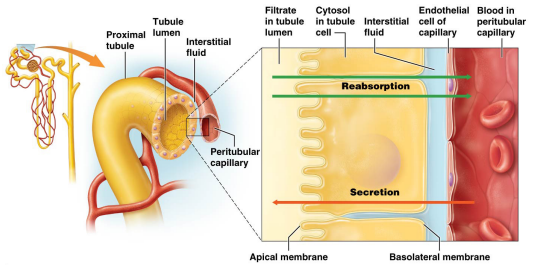
- Three classes of drugs have been developed that act on RAAS to reduce *blood pressure*:
  - **ACE inhibitors** – developed from snake venom; block ACE; therefore *inhibit conversion of angiotensin I to II*
  - **Angiotensin-receptor blockers** – block receptors on blood vessels and proximal tubule cells; *prevents* vasoconstriction and *reabsorption of water and sodium*
  - **Aldosterone antagonists** – block effects of aldosterone on distal tubule; decrease reabsorption of sodium and water; leads to *diuretic effect*
- Drugs may decrease GFR in patients with *pre-existing renal disease*; must be monitored

24.5 Renal Physiology II: Tubular Reabsorption and Secretion

Principles of Tubular Reabsorption and Secretion

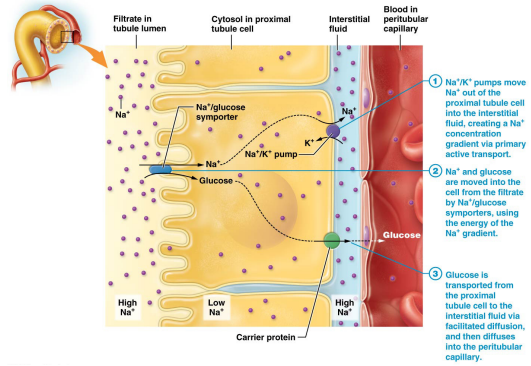
- In _____ _____ , substances pass from filtrate into interstitial fluid then into peritubular capillaries to re-enter blood
- In **tubular secretion**, substances move in *opposite direction*

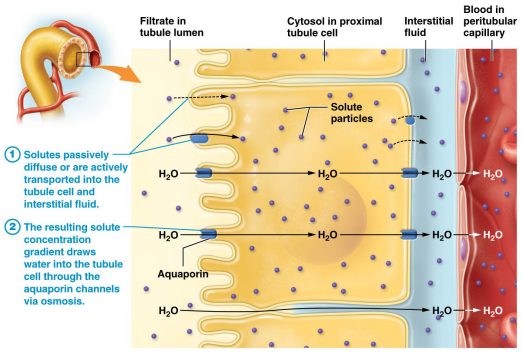
- _____ _____ – substances move from blood into interstitial fluid then into tubule with filtrate
  - Secretion is an **active process**



Reabsorption and Secretion in the Proximal Tubule

- Reabsorption is the main function of proximal tubule
  - Large quantity of ions, sodium, potassium, chloride, sulfate, and phosphate; vital to electrolyte homeostasis
  - Almost 100% of nutrients including glucose, amino acids, water-soluble vitamins, and lactic acid





GLYCOSURIA

- **Transport maximum** – especially important with substances such as **glucose**
- If too much glucose is present in filtrate, TM will be reached before all glucose is reabsorbed; excess will appear in urine (**glycosuria**)
- Commonly seen in **diabetes mellitus** – due to defects in production of or response to **insulin**; causes inability of cells to take up glucose; leads to high circulating blood glucose (**hyperglycemia**), high filtrate glucose content, and therefore glucose remaining in urine

_____ in proximal tubule

- Ammonium ions (NH_4^+), creatinine, and small amounts of urea are also secreted
- Drugs such as penicillin and morphine have significant renal secretion; must be taken often (typically 3–5 times per day), because amount lost through renal secretion must be replaced in order to maintain *relatively consistent blood levels*

REABSORPTION IN THE NEPHRON LOOP

- Once filtrate reaches nephron loop, 60–70% of water and electrolytes and most organic solutes have been reabsorbed (returned to blood)
- About 20% of water and 25% of sodium and chloride ions are reabsorbed from loop

REABSORPTION AND SECRETION-DISTAL TUBULE AND COLLECTING SYSTEM

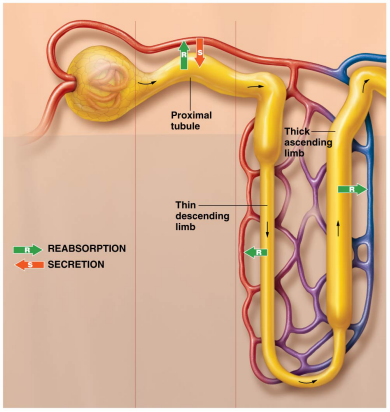
Facultative water reabsorption – water is reabsorbed based on body's needs

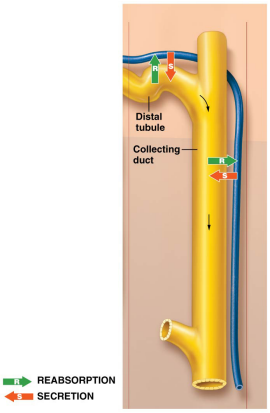
- _____ –from adrenal cortex; increases reabsorption of sodium ions from filtrate and secretion of potassium ions into filtrate
- _____ **hormone** (ADH) – from hypothalamus and secreted by posterior pituitary; causes water reabsorption; reduces urine output
- **Atrial natriuretic peptide** (ANP) – stimulates urinary excretion of sodium ions while it also inhibits release of both aldosterone and ADH

Medullary collecting system – last chance for regulation of fluid, electrolyte, and acid-base balance before filtrate becomes urine

- Impermeable to water in absence of _____
- Permeable to urea; allows urea to be reabsorbed passively into interstitial fluid

- Cells of proximal tubule secrete hydrogen ions to maintain blood pH



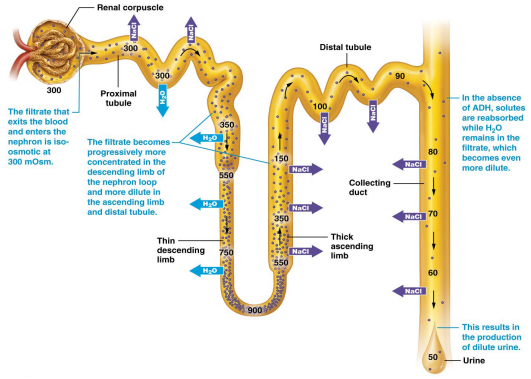


TUBULAR SEGMENTS	PROXIMAL TUBULE	NEPHRON LOOP		DISTAL TUBULE AND COLLECTING DUCT
		Thin descending limb	Thick ascending limb	
SUBSTANCES REABSORBED (R)	• 65% of H_2O in the filtrate • Nearly 100% of glucose, amino acids, and other organic solutes • About 90% of bicarbonate ions (HCO_3^-) • 65% or more of Na^+, K^+, Ca^{2+}, Cl^-, and Mg^{2+}	• 20% of H_2O in the filtrate	• 25% of Na^+ and Cl^-	• Most of remaining H_2O • Nearly all of the remaining Na^+, Cl^-, and Ca^{2+} • Bicarbonate ions (HCO_3^-)
SUBSTANCES SECRETED (S)	• Hydrogen ions (H^+) • Nitrogenous wastes such as uric acid • Some drugs			• K^+ and H^+ (regulated by hormones)

24.6 Renal Physiology III: Regulation of Urine Concentration and Volume

Production of Dilute Urine

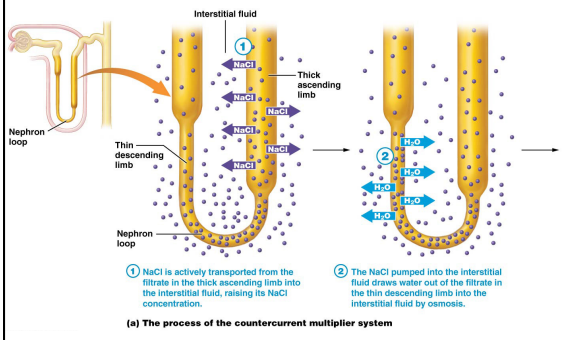
- Kidneys produce dilute urine when solute concentration of extracellular fluid is too low
  -
  - Distal tubule and collecting duct become impermeable to water

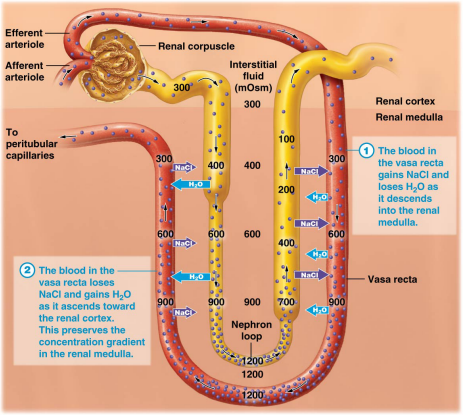


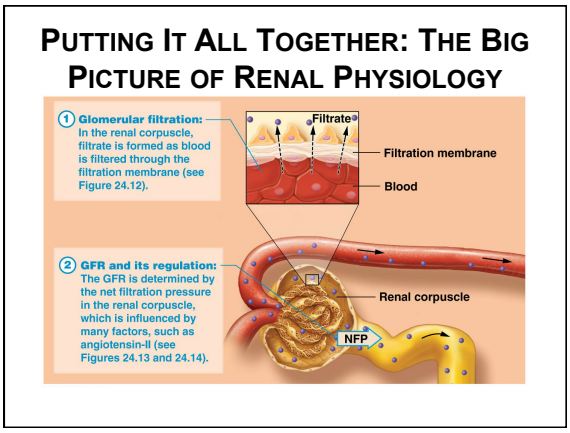
Countercurrent Mechanism and Production of Concentrated Urine

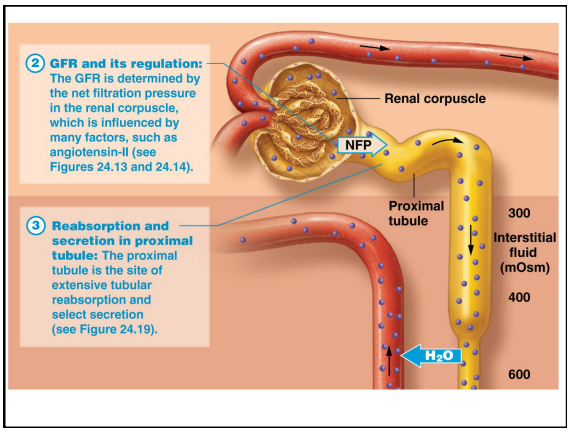
- Kidneys effectively conserve water by producing very concentrated urine (reaching nearly 1200 mOsm) using two mechanisms:
  -
  - **Countercurrent mechanism** creates and maintains osmotic gradient by exchanging materials in opposite directions between filtrate and interstitial fluids

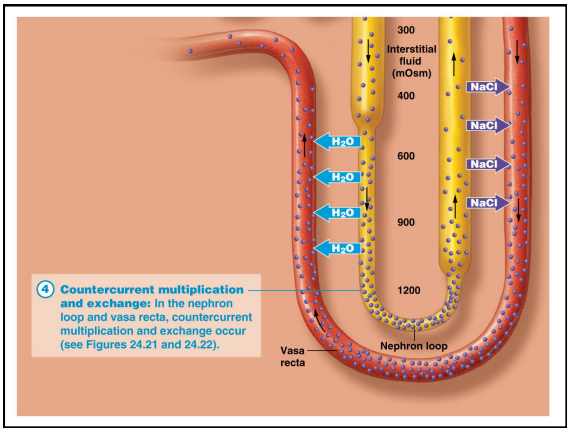
- **Countercurrent multiplier** proceeds in following steps
  - NaCl is actively transported _____ limb filtrate into interstitial fluid
  - Hypertonic fluid then pulls water out of filtrate in _____ limb

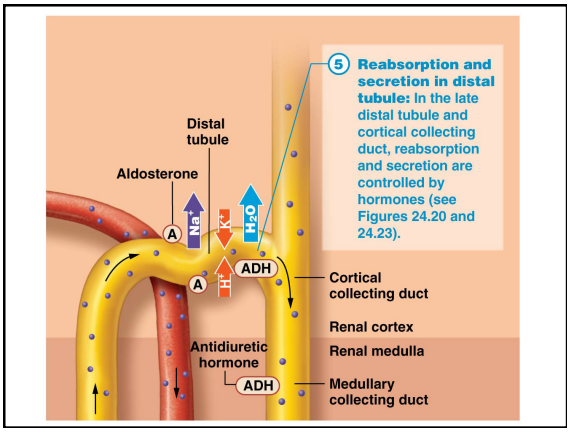


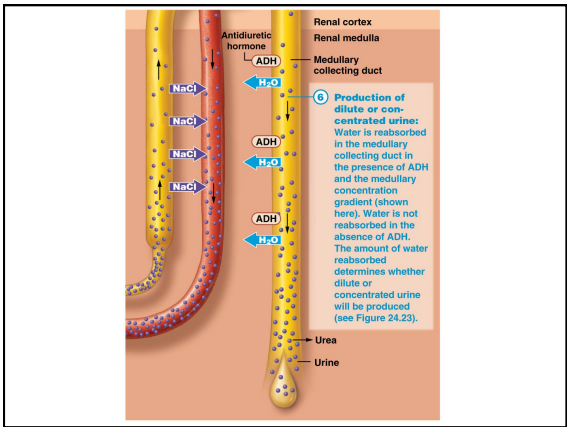


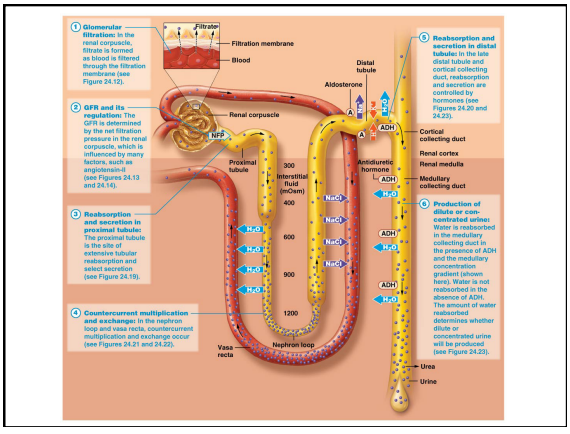

PUTTING IT ALL TOGETHER: THE BIG PICTURE OF RENAL PHYSIOLOGY
1 Glomerular filtration: In the renal corpuscle, filtrate is formed as blood is filtered through the filtration membrane (see Figure 24.12).
Filtrate
Filtration membrane
Blood
2 GFR and its regulation: The GFR is determined by the net filtration pressure in the renal corpuscle, which is influenced by many factors, such as angiotensin-II (see Figures 24.13 and 24.14).
Renal corpuscle
NFP


2 GFR and its regulation: The GFR is determined by the net filtration pressure in the renal corpuscle, which is influenced by many factors, such as angiotensin-II (see Figures 24.13 and 24.14).
Renal corpuscle
NFP
3 Reabsorption and secretion in proximal tubule: The proximal tubule is the site of extensive tubular reabsorption and select secretion (see Figure 24.19).
Proximal tubule
300
Interstitial fluid (mOsm)
400
600
H2O


300
Interstitial fluid (mOsm)
400
600
900
1200
NaCl
H2O
4 Countercurrent multiplication and exchange: In the nephron loop and vasa recta, countercurrent multiplication and exchange occur (see Figures 24.21 and 24.22).
Vasa recta
Nephron loop


5 Reabsorption and secretion in distal tubule: In the late distal tubule and cortical collecting duct, reabsorption and secretion are controlled by hormones (see Figures 24.20 and 24.23).
Distal tubule
Aldosterone
A
Na+
K+
H+
H2O
ADH
Cortical collecting duct
Renal cortex
Renal medulla
Antidiuretic hormone
ADH
Medullary collecting duct


Renal cortex
Renal medulla
Antidiuretic hormone
ADH
Medullary collecting duct
NaCl
H2O
6 Production of dilute or concentrated urine: Water is reabsorbed in the medullary collecting duct in the presence of ADH and the medullary concentration gradient (shown here). Water is not reabsorbed in the absence of ADH. The amount of water reabsorbed determines whether dilute or concentrated urine will be produced (see Figure 24.23).
Urea
Urine


1 Glomerular filtration: In the renal corpuscle, filtrate is formed as blood is filtered through the filtration membrane (see Figure 24.12).
Filtrate
Filtration membrane
Blood
2 GFR and its regulation: The GFR is determined by the net filtration pressure in the renal corpuscle, which is influenced by many factors, such as angiotensin-II (see Figures 24.13 and 24.14).
Renal corpuscle
NFP
3 Reabsorption and secretion in proximal tubule: The proximal tubule is the site of extensive tubular reabsorption and select secretion (see Figure 24.19).
Proximal tubule
300
Interstitial fluid (mOsm)
400
600
900
1200
4 Countercurrent multiplication and exchange: In the nephron loop and vasa recta, countercurrent multiplication and exchange occur (see Figures 24.21 and 24.22).
Vasa recta
Nephron loop
5 Reabsorption and secretion in distal tubule: In the late distal tubule and cortical collecting duct, reabsorption and secretion are controlled by hormones (see Figures 24.20 and 24.23).
Distal tubule
Aldosterone
Cortical collecting duct
Renal cortex
Renal medulla
Antidiuretic hormone
Medullary collecting duct
6 Production of dilute or concentrated urine: Water is reabsorbed in the medullary collecting duct in the presence of ADH and the medullary concentration gradient (shown here). Water is not reabsorbed in the absence of ADH. The amount of water reabsorbed determines whether dilute or concentrated urine will be produced (see Figure 24.23).
Urea
Urine

24.8 Urine and Renal Clearance

Urine Composition and Urinalysis

- **Urine** normally contains:
  - _____
  - _____
  - Potassium
  - Chloride
  - _____
  - Phosphates
  - Sulfates
  - Metabolic wastes such as urea, creatinine, ammonia, and uric acid
  - Small amounts of bicarbonate, calcium, and magnesium may also be present

Urine Composition and Urinalysis

- Urine **color**
  - _____ ; breakdown product of hemoglobin
  - Darker urine is more concentrated; has less water
  - Lighter urine is less concentrated; has more water
- Urine should be _____
- Mild odor; strong odor may be caused by diseases, infections, or by ingesting certain foods
- Normal pH (6.0); ranges from _____
- **Specific gravity** 1.001 (very dilute) to 1.035 (very concentrated)

Urine Composition and Urinalysis

- **Renal clearance**:
  - Measurement of rate at which kidneys remove a substance from blood
  - For a substance to provide an accurate measure of renal clearance and GFR, substance should be completely filtered and neither reabsorbed nor secreted
  - _____ –not totally accurate (5–50% in urine arrived via secretion, not filtration)
  - More accurate assessment of GFR can be obtained using _____; neither secreted or absorbed; must be injected

24.9 Urine Transport, Storage, and Elimination

Anatomy of the Urinary Tract

Urinary tract consists of two ureters, urinary bladder, and urethra

- U**reter** is 25–30 cm long and empties into bladder

1. _____ – most superficial layer; made of fibrous connective tissue

2. _____ – middle layer; made of smooth muscle cells that contract rhythmically (**peristalsis**) to propel urine toward urinary bladder

3. _____ – deepest layer; mucous membrane composed of transitional epithelium

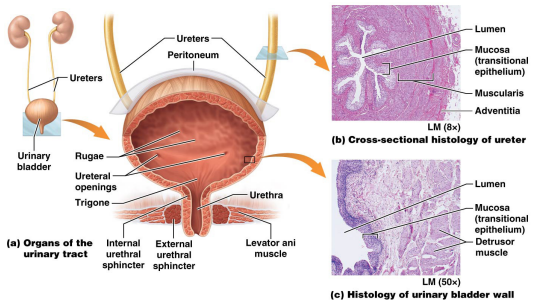
Urinary bladder – hollow, distensible organ found on pelvic cavity floor

- _____ – triangular region on bladder floor; openings of two ureters are found at each posterior corner
- Bladder wall:

  1. Adventitia – most superficial layer; made of areolar connective tissue

  2. Detrusor muscle – middle layer; squeeze bladder; (**internal urethral sphincter**) is found at opening of urethra

  3. _____ – innermost layer; made of transitional epithelium



- _____ –drains urine from urinary bladder to outside of body; walls are similar to ureters
  - A second **external urethral sphincter** is formed by **levator ani muscle** – *skeletal muscle* of pelvic floor; allows for voluntary control of urination

- Male and female urethra differ structurally and functionally
  - Female – about four cm in length; opens at **external urethral orifice** between vagina and clitoris
  - Male – about 20 cm, consists of following three regions:
    1. _____ urethra
    2. _____ urethra
    3. _____ (penile) urethra

ANATOMY OF THE URINARY TRACT

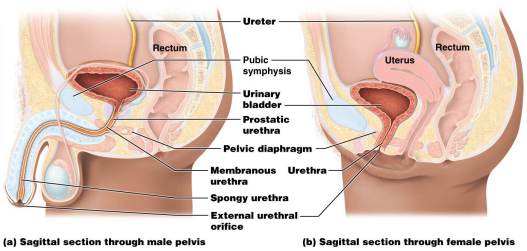


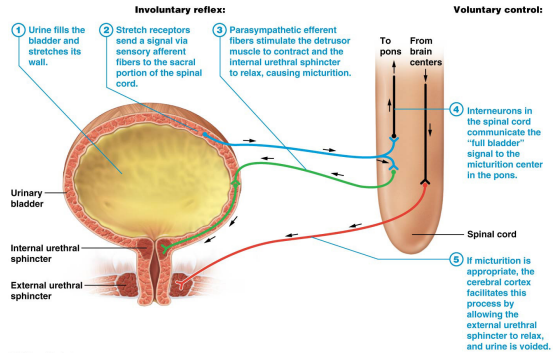
Figure 24.26 Comparison of urinary tract anatomy in the male and female.

MICTURITION

- **Micturition** – _____ ; discharge of urine from urinary bladder to outside of body
- **Micturition reflex** – reflex arc mediated by **parasympathetic nervous system** when urine fills bladder and stretches walls:
  - **Stretch receptors** send a signal to sacral region of the spinal cord via sensory afferent fibers
  - _____ efferent fibers stimulate detrusor muscle to contract and internal urethral sphincter to relax; allows for micturition

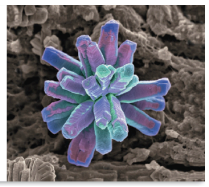
MICTURITION

- **Micturition center** – found in **pons** (central nervous system); given time and training makes micturition a voluntary process



25

Fluid, Electrolyte, and Acid-Base Homeostasis



25.1 OVERVIEW OF FLUID, ELECTROLYTE, AND ACID-BASE HOMEOSTASIS

INTRODUCTION TO BODY FLUIDS

Body fluids – blood plasma, interstitial fluid, cytosol, cerebrospinal fluid, lymph and exocrine secretions

- Mostly water

- **Fluid balance** –maintaining volume and concentration of body's intracellular and extracellular fluids

- Water that is gained must equal water that is lost
- Multiple factors impact fluid balance including:
  - Amount ingested
  -
  -
  - Medications
  - Digestive activities

ELECTROLYTES

- **Electrolytes** – substances that dissociate into ions, or charged particles
  - Electrolytes obtained from diet equals those lost
  - Controlled mostly _____
  - Ion concentration is dependent not only on number of ions in a body fluid, but also on amount of water in body fluid
  - Fluid balance is a critical factor that determines electrolyte balance

ACIDS, BASES, AND PH

- An **acid** is a chemical that dissociates in water to release a _____ (H^+)
  - H^+ ion plays a role in: digestion of food, inactivation of microbes and pathogens, and intracellular digestion in lysosomes
- A _____ , or **alkali**, is a chemical that accepts a hydrogen ion or releases a hydroxide ion (_____)
  - Bicarbonate and other bases are components of **buffer systems**

- **pH scale** – used to measure hydrogen ion concentration of a solution
  - An increase in hydrogen ion concentration results in a solution with a lower pH
  - Solutions with a lower hydrogen ion concentration has a higher pH

pH less than 7 are _____

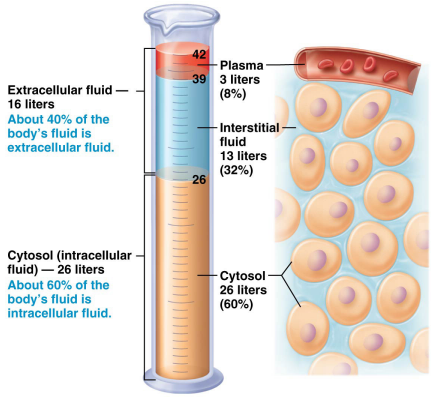
pH greater than 7 are _____

pH of 7 are _____

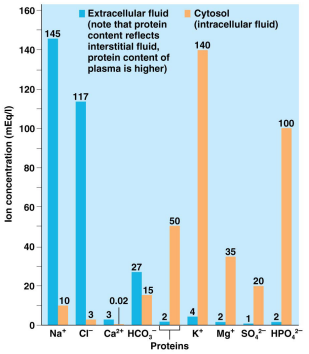
25.2 FLUID HOMEOSTASIS

FLUID COMPARTMENTS

- **Intracellular fluid** (**ICF**); accounts for about 60% of body's fluids
- **Extracellular fluid** (**ECF**) composed of a variety of body fluids
  - _____ – about 8% of total body water
  - _____ – about 32% of total body water



- Solute composition of ECF and ICF varies
  - _____ , chloride, calcium, and bicarbonate ions are higher in ECF
  - _____ , magnesium, sulfate, and monohydrogen phosphate ions higher in cytosol



WATER LOSSES AND GAINS

- **Factors that influence water loss** – majority of water lost daily is in urine via kidneys

  1. Obligatory water loss – (500 ml) urine produced daily irrespective of fluid intake

  - Required to prevent toxic buildup of molecules and electrolyte imbalances

2. Sensible water loss – usually about 100 ml in feces (noticeable amount of water lost)

3. Insensible water loss – usually 600 ml from skin in form of sweat and evaporation

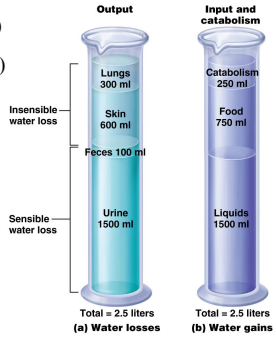
300 ml lost in expired humidified air (an unnoticed amount of daily water loss)

- Most people lose about _____ of water daily

Fluctuates with water intake, physical activity, and food intake

Water Gains:

1. Water ingested from foods (750 ml)
2. Metabolic water (250 ml)
3. Drinking liquid (1500 ml)



- Water intake driven by **thirst mechanism:**

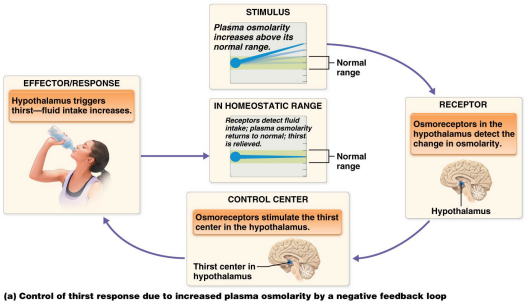
1. Osmoreceptors in hypothalamus
2. Decreased plasma volume that results in a blood pressure drop detected by baroreceptors →

Stimulates juxtaglomerular cells →

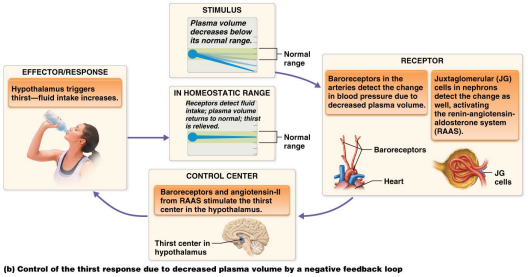
renin-angiotensin-aldosterone system →

angiotensin-II →

_____ _____ _____



(a) Control of thirst response due to increased plasma osmolarity by a negative feedback loop

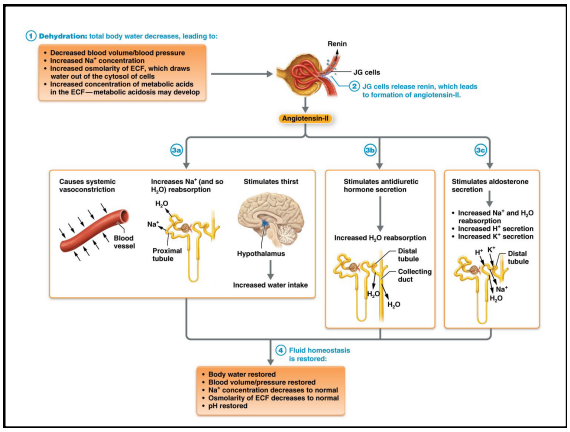


Hormonal Regulation of Fluid Balance

- **ADH** (**antidiuretic hormone**) plays most important role in balancing water intake with water loss, or fluid balance
  - Produced in hypothalamus and released from posterior pituitary;
  - _____ and _____ reabsorb water
  - Increased ADH leads to more water reabsorption that decreases urine volume
  - Decreased ADH leads to more water elimination that increases urine volume

Imbalances of Fluid Homeostasis

- _____ – decreased volume and increased concentration of ECF
  - Common causes include: profuse sweating, diarrhea and/or vomiting, some endocrine conditions, and diuretic overuse
  - Water loss decreases plasma volume and increases solute concentration; increases osmotic pressure

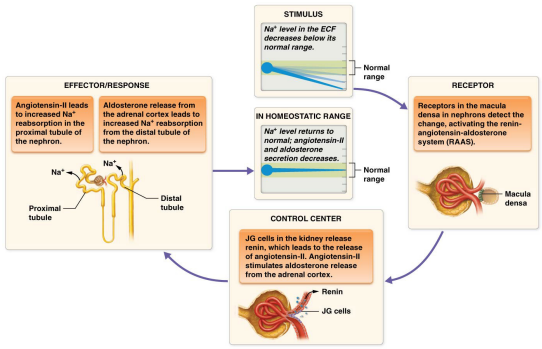


- **Overhydration** (**hypotonic hydration**) – when ECF volume increases; decreases its osmotic pressure
  - ADH secretion is abnormal or an extreme amount of water is consumed in a brief time period (_____ _____)
  - Electrolyte imbalances, especially sodium ion decreases (**hyponatremia**) result from diluted ECF

25.3 Electrolyte Homeostasis

SODIUM

- Sodium ions are most abundant in ECF
- **Regulation of sodium ion concentration:**
  - Angiotensin-II and aldosterone are two main hormones that increase Na^+ retention
  - ANP decreases Na^+ and water reabsorption



- **Hypernatremia** – elevated Na^+ concentration; greater than 145 mEq/l; commonly caused by *dehydration*
- **Hyponatremia** – decreased Na^+ concentration; less than 135 mEq/l; commonly caused by *overhydration*

POTASSIUM

- **Potassium ions** are most abundant in ICF
- **Regulation of potassium ion concentration:**
  - Insulin, aldosterone, and epinephrine are hormones that stimulate uptake of K^+ by cells
  - Excess K^+ is secreted into urine and excreted from body (_____)

POTASSIUM

- **Hyperkalemia** – high K^+ in plasma
  - Potentially fatal; resting membrane potential more positive (cells incapable of functioning)
- **Hypokalemia** – low K^+ in plasma
  - Commonly caused by **diuretics** that lead to excess K^+ loss in urine
  - Resting membrane potential more negative (less responsive to stimuli)

25.4 ACID-BASE HOMEOSTASIS

Hydrogen Ions and Buffering Systems

- *Normal* H^+ level in body fluids equals a pH range of about **7.35–7.45**
- pH is maintained by:
  - Respiratory and urinary system using two types of **buffer systems**

    1. Chemical buffer systems

    2. Physiological buffer systems

Acid-Base Imbalances

- **Acidosis** - body fluid pH of less than 7.35,
  - More H^+ are added
  - Acidosis causes neurons to become less excitable; leads to signs and symptoms of nervous system depression
- **Alkalosis** - body fluid pH greater than 7.45
  - more base ions are added
  - Increases excitability of neurons causing them to fire action potentials inappropriately