



Renal and Urinary Anatomy and Physiology

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Purpose & Objectives

The focus of this renal and urinary anatomy and physiology course is to provide basic information about the structures and functions of the renal and urinary system. The anatomical structures of the renal and urinary systems work together to filter, secrete, excrete, and re-absorb key elements in the blood.

Understanding the fundamental structures and functions of the renal and urinary systems assist you to provide care for all patients you encounter and intervene effectively for those with alterations in renal and urinary status.

After successful completion of this course, you will be able to:

1. Identify the functions of various anatomical structures within the renal and urinary systems.
2. Describe the functions of the renal and urinary systems.
3. Discuss the physiology of how the renal and urinary systems work.

Introduction

The urinary system is comprised of the kidneys, ureters, urinary bladder, and urethra. The kidneys maintain fluid and electrolyte balance, dispose of waste and extracellular fluid, and help to protect the body against hypertension. The kidneys also have endocrine functions; they produce erythropoietin, a regulator of red blood cell mass, and they influence vitamin D activation that affects calcium absorption. The primary function of the ureters, bladder, and urethra is to provide a conduit and storage area for urine that is produced by the kidneys. This course will provide basic information to assist the healthcare professional to provide effective care to all patients.

Glossary

Definitions from *Tabers*® dictionary (Venes, 2017) and *Mosby's* dictionary (Mosby Co., 2016)

Adrenal glands - Triangle-shaped glands located on top of the kidneys.

Aerobic - Taking place in the presence of oxygen.

Afferent - Transporting toward a center; opposite of efferent.

Anaerobic - Taking place in the absence of oxygen.

Anterior - Before or in front of; in anatomical nomenclature, refers to the ventral or abdominal side of the body.

Arteriole - A minute artery, especially one that, at its distal end, leads into a capillary.

Ascend - To move from the lower part of the body toward the head; to move in a cephalic direction.

Autoregulation - Control of an event such as blood flow through a tissue by alteration of the tissue.

Bowman's capsule - Part of the renal corpuscle. It consists of a visceral layer of podocytes closely applied to the glomerulus and an outer parietal layer. The podocyte layer is part of the filter for the formation of renal filtrate in the space between the two layers.

Calices (Plural of calyx) - A cuplike extension of the renal pelvis that encloses the papilla of a renal pyramid; urine from the papillary duct is emptied into it.

Descend - To move from the top of the body toward the feet; to move in a caudal direction.

Detrusor muscle - The external longitudinal layer of the muscular coat of the bladder.

Diffusion - The tendency of the molecules of a substance (gas, liquid, or solid) to move from a region of high concentration to one of lower concentration.

Distal - Farthest from the center, from a medial line, or from the trunk; opposed to proximal.

Duct - A narrow enclosed channel containing a fluid.

Efferent - Carrying away from a central organ or section; opposite of afferent.

Endocrine - Pertaining to a gland that secretes directly into the bloodstream.

Erythropoietin - A cytokine made by the kidneys that stimulates the proliferation of red blood cells.

Extracellular fluid - Fluid outside the cell.

Glomerular filtration rate - The rate of urine formation as plasma passes through the glomeruli of the kidneys.

Glomerulus - One of the capillary networks that are part of the renal corpuscles in the nephrons of the kidney. Each is surrounded by a Bowman's capsule, the site of renal (glomerular) filtration, which is the first step in the formation of urine.

Hilum - A depression or recess at the exit or entrance of a duct into a gland or of nerves and vessels into an organ.

Hypothalamus - Brain structure that monitors internal environment and attempts to maintain balance of these systems. Controls the pituitary gland.

Intracellular fluid - Fluid within a cell.

Kidney - One of a pair of purple-brown organs situated at the back (retroperitoneal area) of the abdominal cavity; each is lateral to the spinal column. The kidneys form urine from blood plasma. They are the major regulators of the water, electrolyte, and acid-base content of the blood and, indirectly, all body fluids.

Loops of Henle - The U-shaped portion of a renal tubule lying between the proximal and distal convoluted portions. It consists of a thin descending limb and a thicker ascending limb.

Lymphatic - Pertaining to lymph and to the system of endothelial vessels that carry it.

Mucosa - A mucous membrane or moist tissue layer that lines the hollow organs and cavities of the body that open to the environment.

Nephron - The structural and functional unit of the kidney, consisting of a renal (malpighian) corpuscle (a glomerulus enclosed within Bowman's capsule), the proximal convoluted tubule, the loop of Henle, and the distal convoluted tubule. These connect by arched collecting tubules with straight collecting tubules. Urine is formed by filtration in renal corpuscles and selective reabsorption and secretion by the cells of the renal tubule. There are approx. one million nephrons in each kidney.

Osmosis - The passage of solvent through a semipermeable membrane that separates solutions of different concentrations. The solvent, usually water, passes through the membrane from the region of lower concentration of solute to that of a higher concentration of solute, thus tending to equalize the concentrations of the two solutions.

Papilla - A small, nipple-like protuberance or elevation.

Parasympathetic - Of or pertaining to the craniosacral division of the autonomic nervous system.

Parenchyma - The essential parts of an organ that are concerned with its function in contradistinction to its framework.

Peristalsis - A progressive wavelike movement that occurs involuntarily in hollow tubes of the body, esp. the alimentary canal. It is characteristic of tubes possessing longitudinal and circular layers of smooth muscle fibers.

Peritoneum - The serous membrane lining the abdominal cavity and reflected over the viscera.

Posterior - In human anatomy, pert. to or located at or toward the back; dorsal. In human anatomy, "caudal," "dorsal," and "posterior" mean the same thing.

Proximal - Nearest the point of attachment, center of the body, or point of reference; the opposite of distal.

Reabsorption - The process of absorbing again. It occurs in the kidney when some of the materials filtered out of the blood by the glomerulus are reabsorbed as the filtrate passes through the nephron.

Renal - Pertaining to the kidney.

Renal corpuscle - A glomerulus and Bowman's capsule of the nephron of a kidney, the site of glomerular filtration.

Renal cortex - The outer layer of an organ (kidney) as distinguished from the inner medulla.

Renal medulla/pyramid - The inner mass of the kidney consisting of 5 to 11 conical renal pyramids separated by renal columns. The renal pyramids contain the loops of Henle and the collecting ducts. The renal columns contain interlobar arteries and veins.

Renal pelvis - Any basin-shaped structure or cavity; pertaining to kidneys.

Renal pyramid/medulla - The inner mass of the kidney consisting of 5 to 11 conical renal pyramids separated by renal columns. The renal pyramids contain the loops of Henle and the collecting ducts. The renal columns contain interlobar arteries and veins.

Retroperitoneal space - Behind the peritoneum and outside the peritoneal cavity (e.g. the kidneys).

Rugae (Plural of ruga) - A fold or crease, esp. one of the folds of mucous membrane on the internal surface of the stomach.

Sympathetic - Pertaining to the sympathetic nervous system.

Symphysis pubis - The junction of the pubic bones on the midline in front; the bony eminence under the pubic hair.

Trigone - A triangular space, esp. one at the base of the bladder, between the two openings of the ureters and the urethra.

Tubule - A small tube or canal.

Ureter - The tube that carries urine from the kidney to the bladder. It originates in the pelvis of the kidney and terminates in the posterior base of the bladder.

Urethra - The tube for the discharge of urine extending from the bladder to the outside.

Urinary bladder - A muscular, membranous, distensible reservoir that holds urine situated in the pelvic cavity. It receives urine from the kidneys through the ureters and discharges it from the body through the urethra.

Urine - The fluid and dissolved solutes (including salts and nitrogen-containing waste products) that are eliminated from the body by the kidneys.

Anatomy of the Kidneys

The kidneys are two fist-sized bean-shaped organs situated on either side of the vertebral column in the posterior abdomen, just below the level of the diaphragm.

Most individuals have two kidneys, each one between the level of the twelfth thoracic and third lumbar vertebrae.

The right kidney lies under the liver and is located slightly lower than the left kidney. This general area, known as the retroperitoneal space, provides protection to the kidneys with nearby flank and back muscles, fat, and fascia (Jarvis, 2016; Venes, 2017).

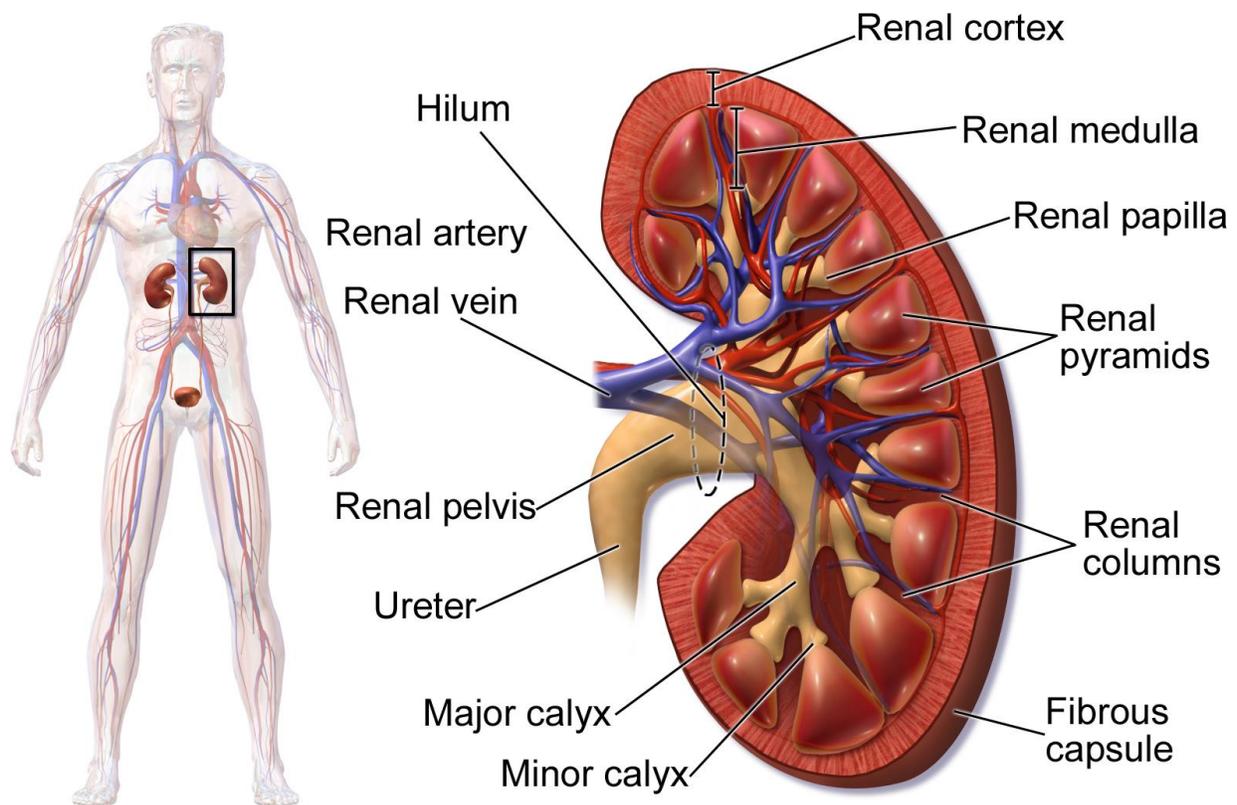
Each kidney is covered by a thin smooth fibrous membrane called a renal capsule. The renal capsule acts as a protective layer and contains pain receptors. It also serves to prevent kidney swelling.

The kidney is divided into two main areas:

- Renal cortex: A light outer area
- Renal medulla: A darker inner area

Within the medulla there are eight or more cone-shaped sections known as renal pyramids. The areas between the pyramids are called renal columns.

The hilum of the kidney is the entry site for the renal nerves and artery. It is also the exit site for the ureter and renal vein. Lymphatic vessels enter and exit through the hilum as well.



Kidney Anatomy

Anatomy of the Renal Parenchyma

The renal parenchyma (specialized tissue) contains three main areas:

- **The renal cortex:** the cortex is the outer rim of the kidney; it contains all of the glomeruli and approximately 85% of the nephron tubules. The cortex is the portion of the kidney that is metabolically active; aerobic metabolism occurs here and glucose and ammonia are formed (Scanlon, 2019).
- **The medulla:** the medulla is the middle portion of the kidney that contains 8-18 renal pyramids. The pyramids consist of collecting ducts, collecting tubules, and long loops of Henle. Columns of tissue from the renal cortex extend down into the medulla between the pyramids. These columns of tissue contain much of the kidney's blood vessels (including the interlobar arteries) and nerves (Scanlon, 2019).
- **The renal pelvis:** the renal pelvis is positioned within the renal sinus and composed of cuplike structures called calices. The renal pelvis is a large collection area that drains urine from the collecting ducts of the nephrons via the renal papillae. Minor (smaller) calices open into major (larger) calices and urine flows through the renal pelvis and into the ureter (Scanlon, 2019).

Test Yourself

All of the glomeruli are located in the

- A. Renal pelvis
- B. Renal cortex**
- C. Medulla

Rationale: The renal cortex: the cortex is the outer rim of the kidney; it contains all of the glomeruli and approximately 85% of the nephron tubules.

Anatomy of the Nephron

Each anatomic segment of the nephron has unique characteristics and specialized functions that enable selective transport of solutes and water.

Through sequential events of reabsorption and secretion along the nephron, tubular fluid is progressively processed into final urine for excretion.

Each nephron is composed of blood flow structures and urine flow structures.

Collecting tubule:

Secretes hydrogen and potassium, influenced by antidiuretic hormone (vasopressin) for water reabsorption (Jarvis, 2016; Venes, 2017).

Distal convoluted tubule:

Responds to the hormone aldosterone, secretes hydrogen and potassium, reabsorbs sodium, water, urea, and chloride.

Ascending loop of Henle:

Impermeable to water and produces a hypo-osmotic filtrate and a high interstitial osmolality by actively reabsorbing potassium, chloride and sodium.

Descending loop of Henle:

Permeable to water; reabsorbs filtered water and produces a concentrated filtrate to the ascending loop of Henle.

Proximal convoluted tubule:

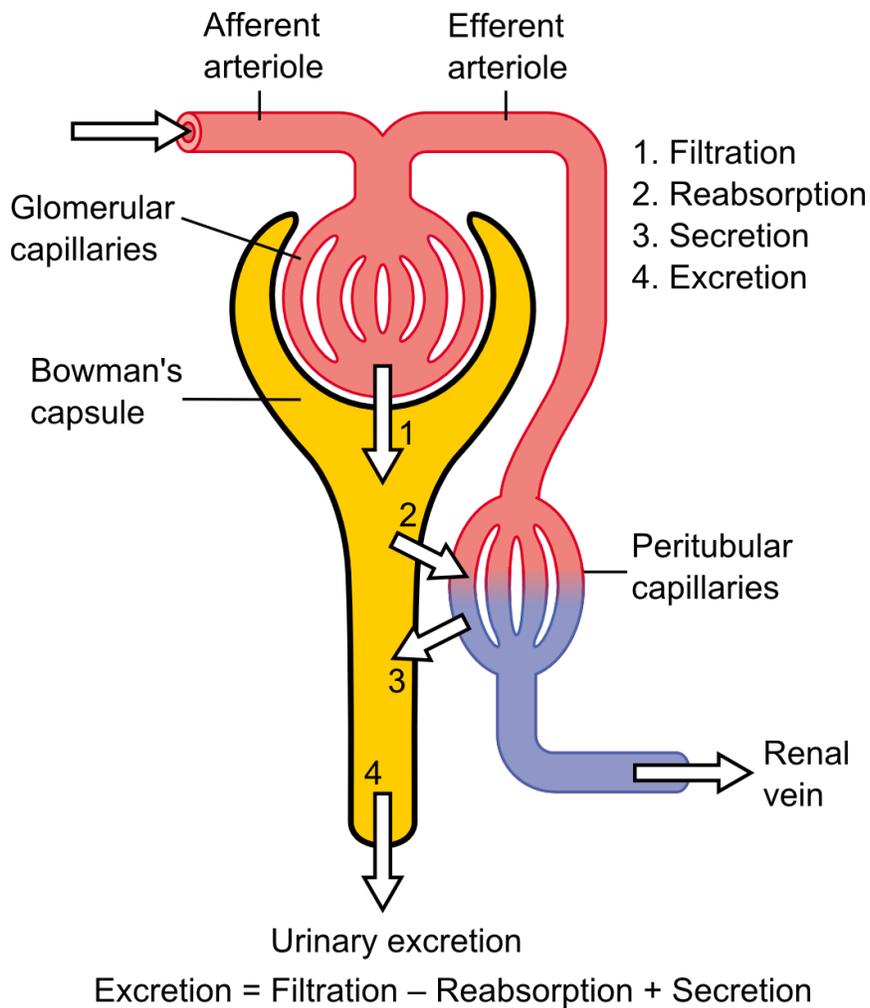
Responsible for the reabsorption of approximately two thirds of the filtered water, electrolytes and all of the vitamins, bicarbonate, glucose and amino acids that have been filtered (Jarvis, 2016).

Bowman's capsule:

The funnel shaped upper end of the proximal convoluted tubule that receives glomerular filtrate. When paired with the glomerulus it is also referred to as the renal corpuscle (Jarvis, 2016).

The Glomerulus:

Tightly coiled capillaries that filter fluid from the blood into the Bowman capsule. The basement membrane of the glomerulus prevents platelets, leukocytes, red blood cells and plasma proteins from passing through (Jarvis, 2016; Venes, 2017).



Function of the Nephron

The functional unit of the kidney is the nephron. Each kidney contains more than one million nephrons that perform all filtration, secretory, and reabsorption functions. Metabolic end products, unwanted substances or excessive ions such as potassium, sodium, hydrogen or chloride are cleansed from the blood plasma by the nephrons (Jarvis, 2016; Venes, 2017).

Healthy nephrons accomplish three major functions:

- Filtration of water soluble substances
- Reabsorption of filtered water, electrolytes and nutrients

- Secretion of excess substances or waste into the filtrate

Did You Know?

The speed of filtration in the glomerulus is known as the glomerular filtration rate (GFR). GFR is determined by filtration pressure and the amount of permeable surface area of the glomerular membrane. GFR is one method of assessing renal function. An average GFR is approximately 125 milliliters per minute (Scanlon, 2019).

Structure and Function of the Nephron

Tubule Part	Tubule Function
Proximal convoluted tubule	<ul style="list-style-type: none"> • Actively reabsorbs NaCl (sodium chloride) • Passively reabsorbs water • Reabsorbs 60-80% of filtrate • Reabsorbs glucose, amino acids, phosphates, potassium, and uric acid • Maintains acid-base balance by reabsorbing bicarbonate and secreting hydrogen ions • Secretes foreign substances into the filtrate
Loop of Henle	<ul style="list-style-type: none"> • Concentrates and dilutes urine • Descending limb is permeable only to water • Ascending limb is impermeable to water and acts as an active NaCl pump
Distal convoluted tubule	<ul style="list-style-type: none"> • Reabsorbs water, NaCl, and bicarbonate • Maintains acid base balance by secreting hydrogen ions • Site of ADH (anti-diuretic hormone) and aldosterone mechanisms of action (ADH influences water re-absorption and aldosterone influences sodium re-absorption)

Test Yourself

Which part of the tubule concentrate and dilutes urine?

- A. Loop of Henle**
- B. Proximal convoluted tubule
- C. Distal convoluted tubule

Rationale: Loop of Henle •Concentrates and dilutes urine •Descending limb is permeable only to water
•Ascending limb is impermeable to water and acts as an active NaCl pump

The Adrenal Glands

On the top of each kidney lies the adrenal gland, a small triangle shaped gland also known as the suprarenal gland.

Conveniently located, the adrenal glands influence the kidneys by regulating the level of sodium excreted into the urine (Jarvis, 2016; Venes, 2017).

The Ureters

The kidneys dispose of waste and extracellular fluid (urine) by gravity flow via the ureters. There are two ureters, one for each kidney. The ureters are narrow mucosa lined fibromuscular tubes that utilize peristaltic action to propel and drain urine into the urinary bladder. Each ureter has three layers.

Anatomy of the Ureters

The ureters enter the bladder through the detrusor muscle and travel under the bladder mucosa prior to emptying into the body of the bladder. As the bladder fills with urine and expands, pressure increases against the walls of the bladder. The pressure causes the ureters to close off at the ureter-bladder junction. This valvular closing mechanism prevents a back flow of urine back into the kidneys (Jarvis, 2016; Venes, 2017).

The wall of the ureter is made up of three layers. The outer layer is a supporting layer of fibrous connective tissue called the fibrous coat. The middle layer, the muscular coat, is made up of inner circular and outer longitudinal smooth muscle. This layer provides peristalsis to propel the urine. The inner layer is the mucosa and it is comprised of epithelium and is continuous with the lining of the renal pelvis and the urinary bladder. The mucosal layer secretes mucus that coats and protects the surface of the cells.

Anatomy of the Bladder

The bladder is located behind the symphysis pubis below the peritoneum (Scanlon, 2019). The urinary bladder is a hollow muscular sac that provides a holding area for urine until it is excreted through the urethra. Since the bladder is made up of mostly muscle, it can stretch and contract in relation to the amount of urine being stored. The capacity of a normal adult bladder is approximately 450 to 500 mL of urine. To expel the urine, the average adult will void approximately five to nine times per day with a volume of about 100 to 300 mL per void (Scanlon, 2019).

A triangular area called the trigone is formed by three openings in the floor of the urinary bladder. Two openings are from the ureters and form the base of the trigone. Small flaps of mucosa cover over these openings and act as valves that allow urine to enter the bladder but prevent it from backing up into the ureters. The third opening, at the apex of the trigone, is the opening into the urethra. A band of the detrusor muscle encircles this opening to form the internal urethral sphincter.

Parts of the Bladder

The bladder has two main parts: the neck and the body. Urine is deposited by the ureters into the body of the bladder where it is collected. The body of the bladder is made up of smooth muscle known as the detrusor muscle. The muscle extends throughout the bladder allowing it to contract and empty out urine in one contraction. The body also has a mucosal lining with folds known as rugae. Rugae allow the detrusor muscle to distend without friction as urine collects (Jarvis, 2016; Venes, 2017).

The neck of the bladder is comprised of detrusor muscle and elastic tissue. This portion of the detrusor muscle is called the internal sphincter. The bladder neck also holds the posterior urethra.

Bladder Function

Normal bladder function relies on the sympathetic and parasympathetic parts of the autonomic nervous system.

The sympathetic nervous system innervates the bladder and urethra and make up what is known as the hypogastric nerve.

The parasympathetic nervous system controls bladder contractions and the passage of urine. Motor fibers are innervated from the parasympathetic system, the sympathetic system innervates the blood vessels and it is thought that pain and a full sensation may also be transmitted (Jarvis, 2016; Venes, 2017).

Anatomy of the Urethra

The urethra is a passageway leading from the bladder to the urinary meatus. Urine travels through the urethra to be discharged from the body.

The urethra has a smooth muscle sphincter that allows voluntary control over urination. In males, the urethra is much longer and extends through the prostate gland and penis to the urinary meatus.

Three segments make up the male urethra:

- The prostatic urethra
- The membranous urethra
- The penile urethra

The male urethra also serves as a passageway for sperm.

In females, the urethra is located behind the symphysis pubis and is anterior to the vagina. The female urethra is much shorter than in the male (Jarvis, 2016; Venes, 2017).

Test Yourself

True or false: The function of the bladder relies on both the sympathetic and parasympathetic parts of the autonomic nervous system?

Answer: True

Rationale: Normal bladder function relies on the sympathetic and parasympathetic parts of the autonomic nervous system.

Renal Hemodynamics and Blood Pressure Influence

Blood supply to the kidneys and renal function are directly related. Twenty percent of the body's cardiac output, or approximately 1,200 mL of blood per minute, flow through the kidneys. The kidneys are very sensitive to this as well. The kidneys are capable of extracting oxygen very efficiently from the blood it receives (Burns & Delgado, 2019). However, it is the flow rate that keeps the kidneys filtering the blood.

The cortex or outer layer of the kidneys receives four-fifths of the blood flow, while the medulla, or innermost portion of the kidneys, receive only one-fifth of the blood flow (Burns & Delgado, 2019). This is important because the nephrons (the functional units of the kidneys) are located in the cortex.

Renal Hemodynamics and BP Influence, con't

The kidneys are capable of auto-regulating the amount of blood they receive through the afferent arteriole. The afferent arteriole is responsible for maintaining a constant supply of blood to the kidney. These arterioles normally maintain a MAP (mean arterial pressure) of 80-180 mmHg to the kidney despite changes in the body's MAP (Burns & Delgado, 2019). When there is an increase in renal artery pressure, the afferent arterioles vasoconstrict. When there is a decrease in renal artery pressure, the afferent arterioles dilate to allow more blood flow to the kidneys.

Additionally, the blood flow to the kidneys may be impacted by neural mechanisms. For example, when there is a decrease in systemic MAP, the baroreceptors in the carotid sinus and aortic arch increase sympathetic activity. In other words, they cause the release of epinephrine into the vascular system. Epinephrine decreases renal blood flow by vasoconstricting the afferent and efferent arterioles. You

may get the same effect through other sympathetic stimulatory factors such as anxiety, stress, exercise, and fear. However, because the afferent arterioles are capable of auto-regulation, these neural mechanisms are dulled (Burns & Delgado, 2019).

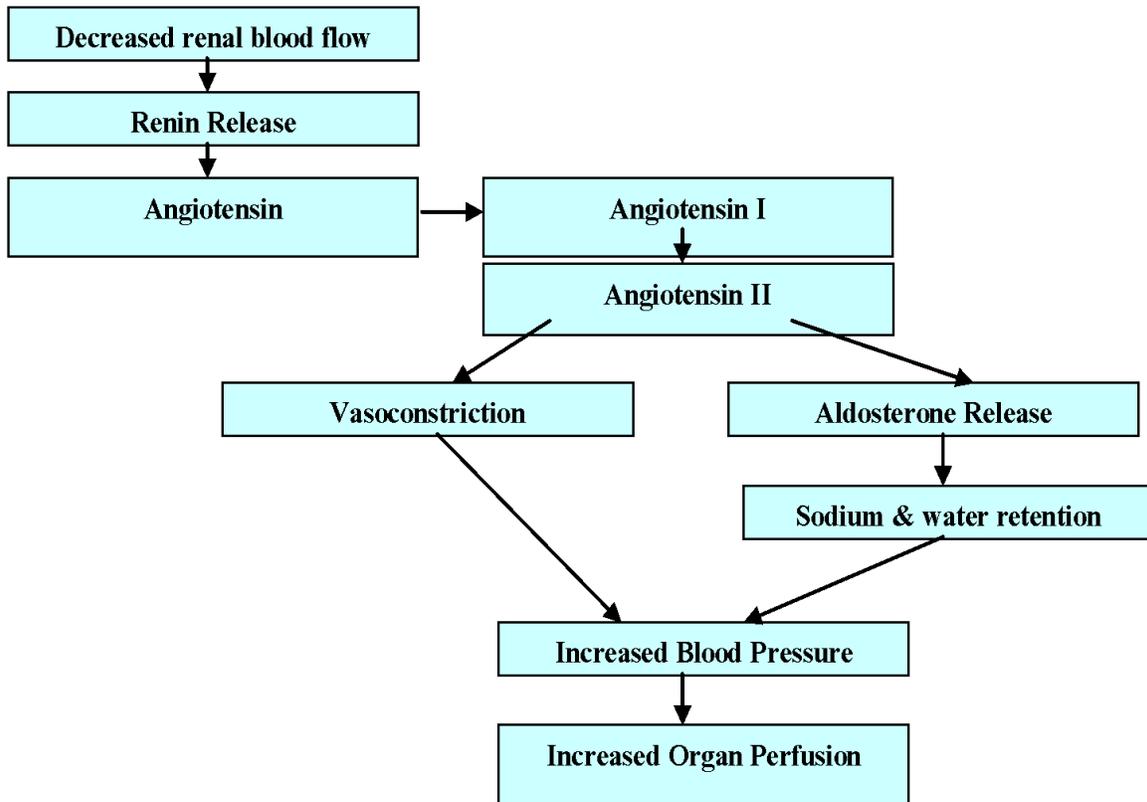
Hormonal Influence

Hormones also play a part in the amount of blood that reaches the kidneys. Renal prostaglandins cause vasoconstriction or vasodilation. The major hormonal player in renal hemodynamics is the renin-angiotensin-aldosterone system (RAAS). When the kidneys sense a decrease in blood pressure, the renin-angiotensin-aldosterone system is activated. This system has the net effect of increasing organ perfusion and arterial blood pressure. It is very effective in regulating blood volume, cardiac and vascular function, and arterial pressure.

When the system is activated due to a pathologic condition, such as heart failure, the system itself is pathologic to the body, resulting in increased blood pressure that will usually be damaging over time (Scanlon, 2019).

Renin-Angiotensin-Aldosterone System

The mechanism of the system is summarized below



Test Yourself

Blood to the kidneys is auto-regulated through which structure?

- A. Nephron
- B. Afferent arteriole**
- C. Efferent arteriole

Rationale: The kidneys are capable of auto-regulating the amount of blood they receive through the afferent arteriole

Urinary System Innervation

The primary innervation of the urinary system is mostly supplied by the autonomic nervous system. The parasympathetic and sympathetic nervous system both innervate the kidney; however, the sympathetic nervous system exerts more effect (Jarvis, 2016). Sensory nervous system fibers are located in all sections of tubules and in the afferent and efferent arterioles. The sensory nervous system is involved in:

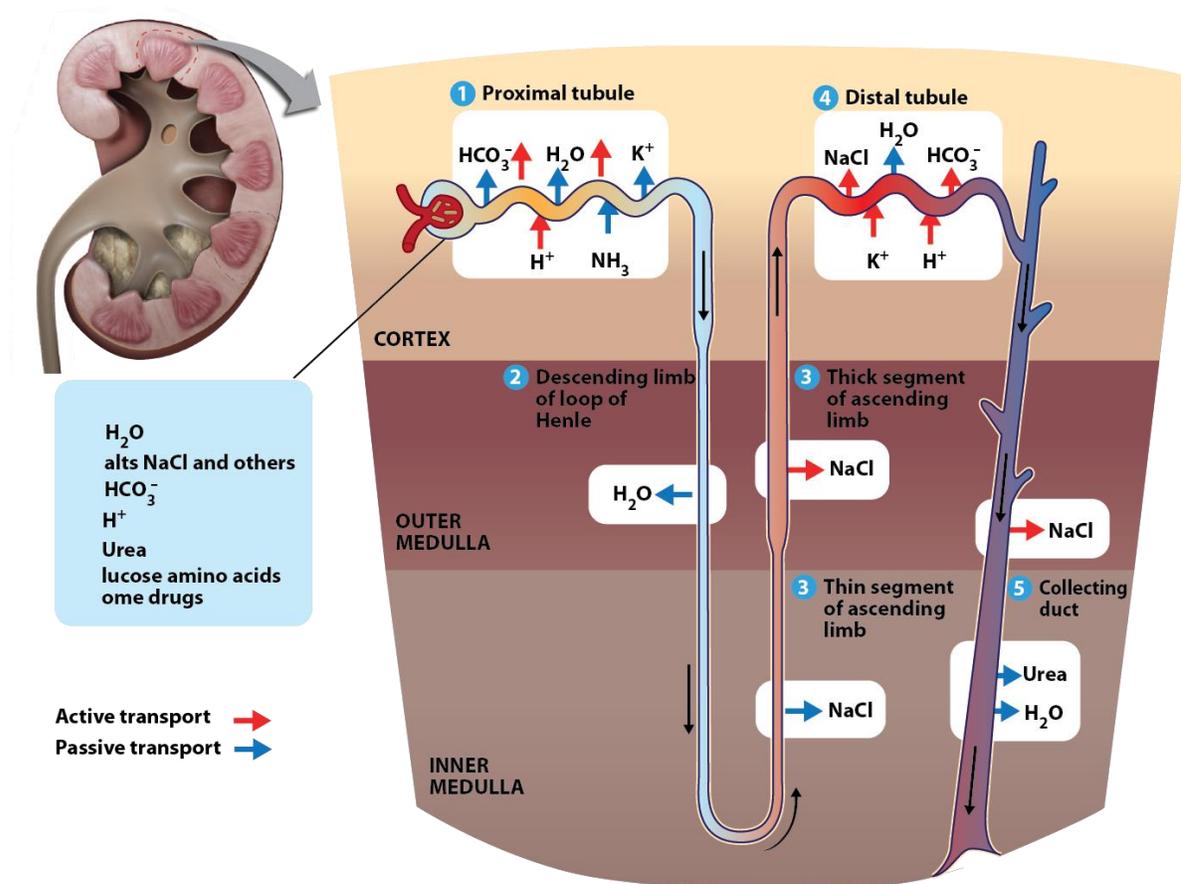
- Increased sodium reabsorption within the proximal tubule.
- Constriction of efferent and afferent arterioles.
- Afferent arteriole constriction, extreme reduction in renal blood flow, and decrease of glomerular filtration.

Functions of the Kidney: Urine Formation

The kidneys are responsible for urine formation, filtration and elimination of waste products, and regulation of fluids and electrolytes. The kidneys are also vital in maintaining the acid-base balance in the body. Hormone production and synthesis of vitamin D are also essential kidney functions (Scanlon, 2019).

Urine formation is directly related to the glomerular filtration rate (GFR). Urine formation involves filtration, reabsorption, and secretion. Refer also to previous section on the nephron.

- Filtration is the transfer of dissolved substances and water and mostly occurs due to hydrostatic pressure in the glomerular capillaries. Fluid is filtered out of the capillaries when the hydrostatic pressure pushes blood against the walls of the capillaries (Scanlon, 2019).
- Reabsorption occurs by active and passive transport. Passive transport is accomplished via the process of osmosis and diffusion. Active transport requires energy (such as the sodium/potassium pump) and a substance to carry the molecules (Scanlon, 2019).
- Secretion is the movement of a substance from the capillaries that is not needed by the body (Scanlon, 2019).



Osmosis:

Osmosis is the passive movement of water from an area of low solute concentration to an area of higher concentration.

Diffusion:

Diffusion is the passive movement of solute from an area of high concentration to an area of low concentration.

Urine Excretion

Normal urine output in a 24 hour time period is approximately 1.5 liters (Scanlon, 2019).

Urine is composed of:

- Water
- Toxins
- Drugs
- Vitamins
- Hormones and byproducts
- Nitrogen based waste such as ammonia, creatinine, uric acid, and urea
- Ions such as sodium, potassium, chloride, calcium, hydrogen, sulfate, bicarbonate and phosphate

Urine output can be affected by many factors; however, over-hydration usually results in increased urine output and dehydration or diminished cardiac output will result in decreased urine output.

More information:

- Normal urine output is about 1500 mL/24h
- Anuria is 0-100mL/24h
- Oliguria is 100-400mL/24h
- Polyuria is more than 2500mL/24h

(Scanlon, 2019)

Interactive Activity

Match the name of the process with the correct description

Osmosis	A. Transfer of dissolved substances and water; mostly occurs due to hydrostatic pressure
Diffusion	B. Movement of a substance from the capillaries that is not needed
Filtration	C. The passive movement of solute from an area of high concentration to an area of low concentration
Reabsorption	D. The passive movement of water from an area of low solute concentration to an area of higher concentration
Secretion	E. Occurs by active and passive transport

Answers: Filtration= A; Secretion= B; Diffusion= C; Osmosis= D; Reabsorption= E

Creatinine and Blood Urea Nitrogen

Creatinine

Excretion of metabolic waste products in the urine can be measured to determine how well the kidneys are functioning. Serum creatinine, a waste product of muscle metabolism, can be used to measure renal function because it is excreted only by the kidneys. The amount of creatinine produced per day is constant and dependent upon the body's muscle mass. It is freely filtered so that production should equal excretion. Because of this, measuring one's serum creatinine is a very reliable indicator of renal function (Scanlon, 2019).

Blood Urea Nitrogen

Blood urea nitrogen is a waste product from protein metabolism. It is filtered and reabsorbed along the length of the entire kidney (Scanlon, 2019). It is not as reliable at measuring kidney function because it is dependent upon:

- Urine flow
- Renal blood flow
- Catabolism
- Protein metabolism
- Drugs
- Diet

Fluid Regulation

The body has several mechanisms for regulating fluids. One of the first ways the body regulates fluid is via the hypothalamus. The hypothalamus is the body's thirst center. When cells in the hypothalamus become dehydrated, it causes the brain to tell you that you are thirsty, so you drink more water.

Antidiuretic hormone (ADH) is also made in the hypothalamus, and released from the posterior pituitary. The release of ADH is stimulated by increased serum osmolarity.

Once released, ADH works on the distal and collecting tubules of the kidneys to reabsorb water. Additionally, remember that the Loop of Henle's major function is to concentrate or dilute urine based upon osmolarity as well (Scanlon, 2019).

Electrolytes and Factors Influencing Excretion and Re-Absorption

Electrolyte	Factors Influencing Excretion and Re-absorption
Sodium	<ul style="list-style-type: none">• As GFR increases, sodium re-absorption decreases – so more is excreted• As GFR decreases, sodium re-absorption increases – so less is excreted• When aldosterone is released, it caused the kidneys to reabsorb sodium
Potassium	<ul style="list-style-type: none">• Elevations in potassium levels• High urine flow (increased intake or diuretics) increase potassium excretion• Aldosterone
Calcium	<ul style="list-style-type: none">• Parathyroid hormone – PTH - (stimulated by decrease in Ca)• Vitamin D (stimulate Ca absorption from GI tract)
Phosphate	<ul style="list-style-type: none">• PTH (inhibits re-absorption of phosphorus)• GFR (as GFR increases, phosphate re-absorption decreases and vice versa)
Magnesium	<ul style="list-style-type: none">• Sodium dependant
Chloride	<ul style="list-style-type: none">• Acid Base Balance. In acidosis, bicarbonate is reabsorbed while chloride is excreted. In alkalosis, bicarbonate is excreted, while chloride is reabsorbed

Acid-Base Balance

The renal system is one of three major acid-base balance systems in the body. If a metabolic acid begins to build up in the body, the kidneys increase acid excretion mechanisms to eliminate the excess. If the amount of acid in the body is too low, the kidneys decrease the excretion of acid from the body (Scanlon, 2011). If the body's pH increases, the kidney excretes bicarbonate. If the pH decreases, the kidney retains bicarbonate (Scanlon, 2019).

The renal system usually responds to acid base imbalances within 48 hours. Although the renal response is much slower in comparison to the speedy response by the respiratory system (minutes), the renal response is much more powerful (Burns & Delgado, 2019). The renal response to acidosis results in the

kidneys secreting more hydrogen ions in the form of water (H₂O), dihydrogen phosphate (H₂PO₄), and ammonium chloride (NH₄Cl). Acidosis also results in reabsorption of more bicarbonate ions and production of ammonia to accommodate hydrogen ion excretion.

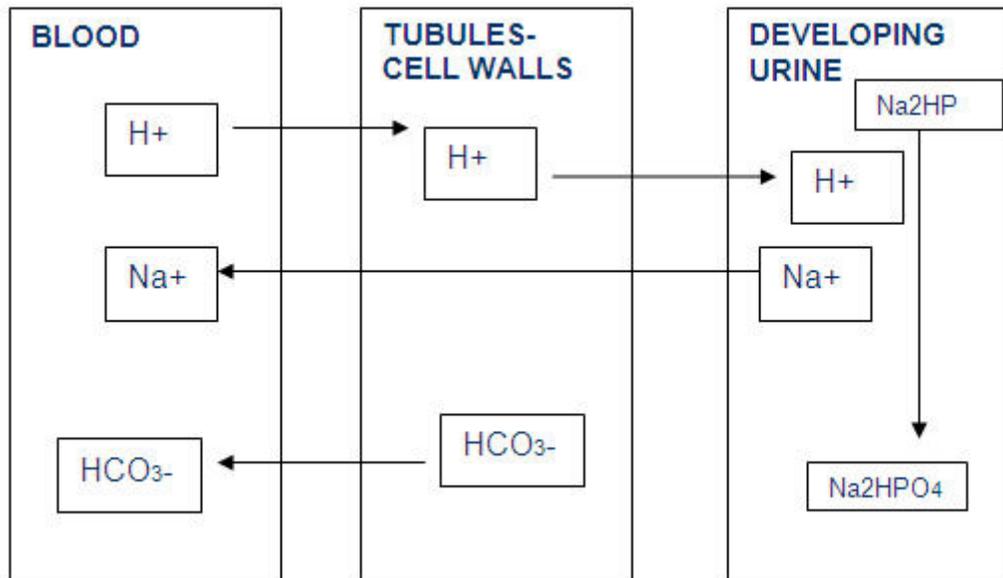
Acid-Base Balance

The renal response to alkalosis results in a decrease in hydrogen ion secretion. It results in an increase in secretion of bicarbonate, and a decrease in the production of ammonia (Burns & Delgado, 2019).

Imbalance	Hydrogen Ions	Bicarbonate	Ammonia
Acidosis	↑ secretion & excretion (H ₂ O, H ₂ PO ₄ , NH ₄ Cl)	↑ reabsorption, ↓ excretion	↑ production
Alkalosis	↓ secretion & excretion (H ₂ O, H ₂ PO ₄ , NH ₄ Cl)	↓ reabsorption, ↑ excretion	↓ production

Acid-Base Balance

Additional Information: Acid-Base Balance



H⁺ = Hydrogen

Na⁺ = Sodium

HCO₃⁻ = Hydrogen carbonate

Na₂HPO₄ = Sodium biphosphate or disodium hydrogen phosphate.

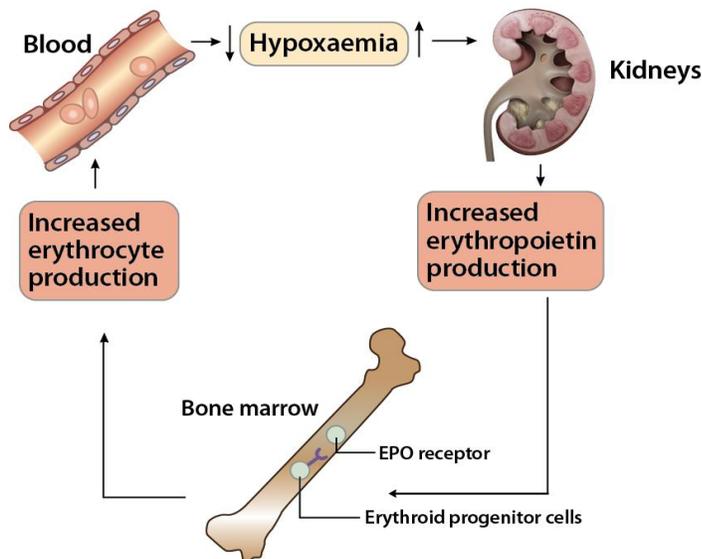
Erythropoietin and Vitamin D

Erythropoietin

The kidneys also secrete a hormone called erythropoietin that is involved in the formation of red blood cells. Erythropoietin is released into the bloodstream by the kidneys in response to a decrease in the concentration of hemoglobin in the blood (Scanlon, 2019).

Vitamin D

Vitamin D synthesis is also partially dependent on the kidneys. The kidney helps to process vitamin D from an inactive state to an active form that is a necessary co-factor for calcium absorption in the intestine and bone mineralization (Scanlon, 2019).



Test Yourself:

Which of the following affect bone mineralization?

- A. Excretion of acid from the body
- B. **Synthesis of vitamin D -**
- C. Secretion of erythropoietin

Rationale: Bone mineralization is affected by the synthesis of vitamin D.

Changes in the System due to Aging

As we age, our nephrons decrease in number. Additionally, the overall amount of kidney tissue decreases. Blood supply to the kidney can be impacted by atherosclerosis, and GFR decreases. The

elastic bladder loses some of its “spring” and becomes less distensible. The bladder muscles weaken, resulting in incomplete emptying when urinating. Prostatic changes in men may impede the outward flow of urine. For women, bladder or vaginal prolapse may also block the urethra. Because the bladder does not completely empty, aging persons have an increased risk for urinary tract infections.

Since the kidneys have so much reserve capacity, normal age-related changes do not impact our daily renal function. Illness, increased stressors, and multiple medications significantly increase the workload of the kidney and impact normal function. Elderly patients may also have impaired thirst mechanisms or intentionally decrease fluid intake to reduce bladder control issues. Bladder and prostate cancer are also more prevalent in older individuals (Jarvis, 2016; Scanlon, 2019).

Conclusion

The urinary system and kidneys play a vital role in metabolizing and expelling waste from the body.

Healthcare professionals with a basic understanding of the renal and urinary system will have the knowledge to recognize alterations that have the potential to adversely affect their patients.

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