BANGABANDHU SHEIKH MUJIBUR RAHMAN SCIENCE & TECHNOLOGY UNIVERSITY

A Presentation on **Physiology of Kidney**

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Introduction

The word kidney derived from Latin word “renes”. The kidneys are a pair of bean-shaped organs on either side of your spine, below your ribs and behind your belly. It is found on the left and right sides of the body in vertebrates. They are located at the back of the abdominal cavity in the retroperitoneal space. In adults they are about 11 centimeters or about 4 or 5 inches long, roughly the size of a large fist.

They receive blood from the paired renal arteries; blood exits into the paired renal veins. Each kidney is attached to a ureter, a tube that carries excreted urine to the bladder.

The kidneys' job is to filter your blood. They remove wastes, control the body's fluid balance, and keep the right levels of electrolytes. All of the blood in your body passes through them several times a day.



Kidneys

Blood comes into the kidney, waste gets removed, and salt, water, and minerals are adjusted, if needed. The filtered blood goes back into the body. Waste gets turned into urine, which collects in the kidney's pelvis - a funnel-shaped structure that drains down a tube called the ureter to the bladder.

Each kidney has around a million tiny filters called nephrons. You could have only 10% of your kidneys working, and you may not notice any symptoms or problems.

If blood stops flowing into a kidney, part or all of it could die. That can lead to kidney failure.

The Physiology of Kidney

Renal physiology is the study of the physiology of the kidney. Generally renal physiology is referred as the study of kidney function. This encompasses all functions of the kidney, including maintenance of acid-base balance; regulation of fluid balance; regulation of sodium, potassium, and other electrolytes; clearance of toxins; absorption of glucose, amino acids, and

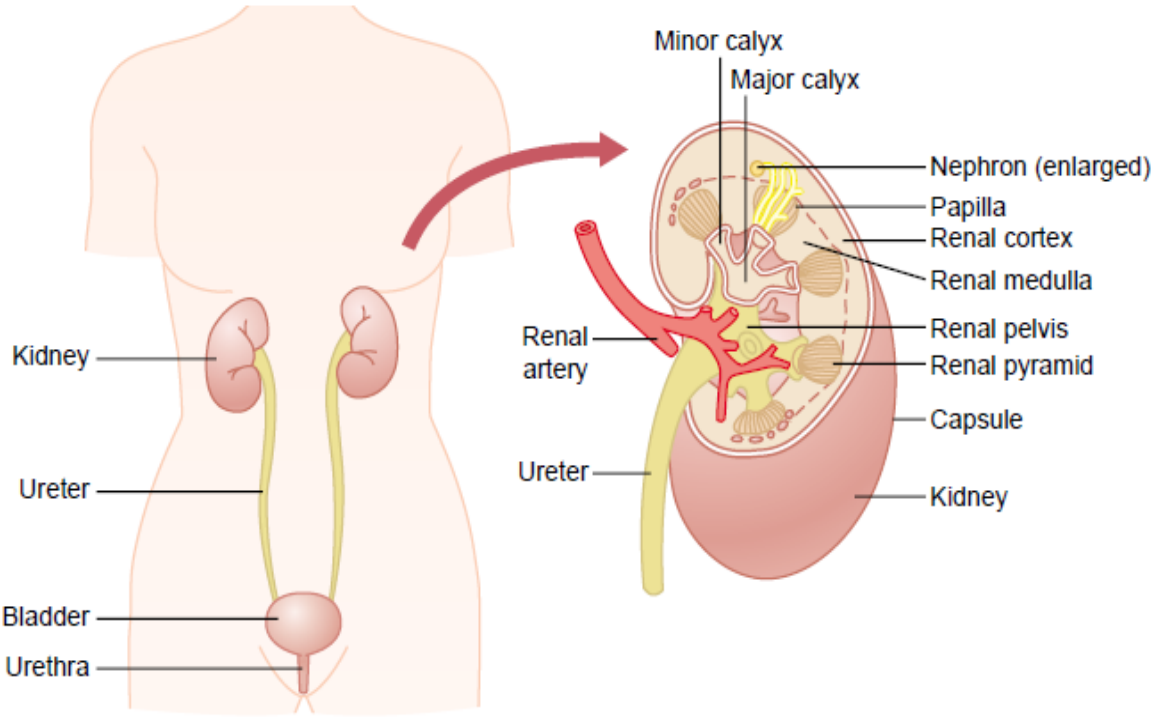
other small molecules; regulation of blood pressure; production of various hormones, such as erythropoietin; and activation of vitamin D.
Much of renal physiology is studied at the level of the nephron, the smallest functional unit of the kidney. Each nephron begins with a filtration component that filters the blood entering the kidney. This filtrate then flows along the length of the nephron, which is a tubular structure lined by a single layer of specialized cells and surrounded by capillaries.

The major functions of these lining cells are the reabsorption of water and small molecules from the filtrate into the blood, and the secretion of wastes from the blood into the urine.

Proper function of the kidney requires that it receives and adequately filters blood. This is performed at the microscopic level by many hundreds of thousands of filtration units called renal corpuscles, each of which is composed of a glomerulus and a Bowman's capsule. A global assessment of renal function is often ascertained by estimating the rate of filtration, called the **glomerular filtration rate (GFR)**.

Anatomy of kidney

The two kidneys lie on the posterior wall of the abdomen, outside the peritoneal cavity. Each kidney of the adult human weighs about **150 grams** and is about the size of a clenched fist. The medial side of each kidney contains an indented region called the **hilum** through which pass the renal artery and vein, lymphatic, nerve supply, and ureter, which carries the final urine from the kidney to the bladder, where it is stored until emptied. The kidney is surrounded by a tough, fibrous **capsule** that protects its delicate inner structures.



Basic Anatomy of Kidney

If the kidney is bisected from top to bottom, the two major regions that can be visualized are the outer **cortex** and the inner region referred to as the **medulla.**

Renal cortex

The renal cortex is the outer part of the kidney. It contains the glomerulus and convoluted tubules.

The renal cortex is surrounded on its outer edges by the renal **capsule**, a layer of fatty tissue. Together, the renal cortex and capsule house and protect the inner structures of the kidney.

Renal medulla

The renal medulla is the smooth, inner tissue of the kidney. It contains the loop of Henle. The medulla is divided into multiple cone-shaped masses of tissue called **renal pyramids**.

Renal pyramids

Renal pyramids are small structures that contain strings of nephrons and tubules. These tubules transport fluid into the kidney. This fluid then moves away from the nephrons toward the inner structures that collect and transport urine out of the kidney.

Collecting Ducts

There's a collecting duct at the end of each nephron in the renal medulla. This is where filtered fluids exit the nephrons. Once in the collecting duct, the fluid moves on to its final stops in the renal pelvis.

Renal pelvis

The renal pelvis is a funnel-shaped space in the innermost part of the kidney. It functions as a pathway for fluid on its way to the bladder

Calyces

The first part of the renal pelvis contains the calyces. These are small cup-shaped spaces that collect fluid before it moves into the bladder. This is also where extra fluid and waste become urine.

Hilum

The hilum is a small opening located on the inner edge of the kidney, where it curves inward to create its distinct beanlike shape. The renal pelvis passes through it, as well as the:

- Renal artery. This brings oxygenated blood from the heart to the kidney for filtration.
- Renal vein. This carries filtered blood from the kidneys back to the heart.
- Ureter
- The ureter is a tube of muscle that pushes urine into the bladder, where it collects and exits the body.

Nephron (The Functional Unit)

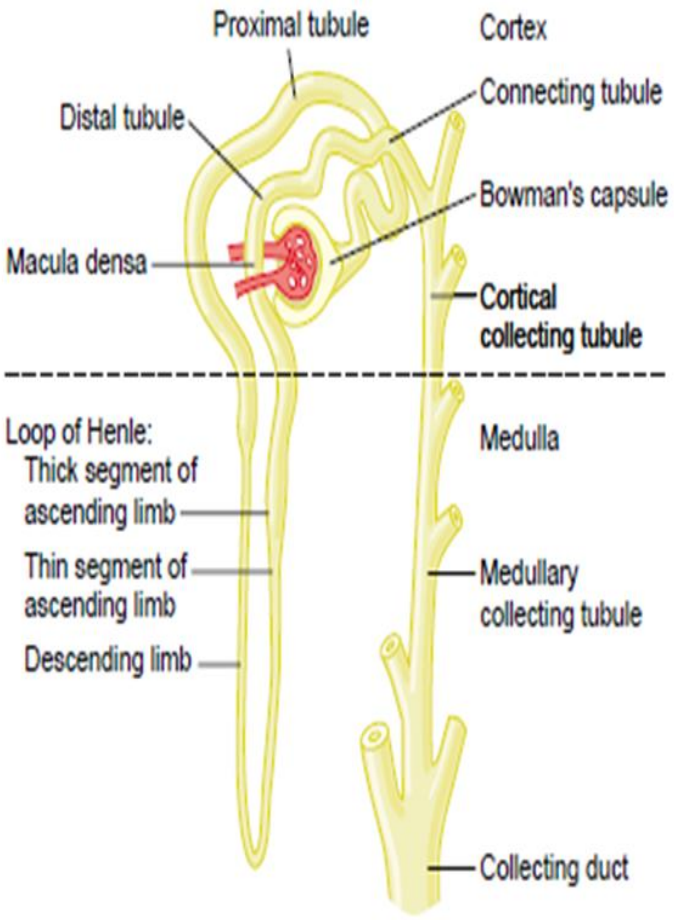
The nephron is the structural and functional unit of the kidney. Each adult kidney contains around **one million** nephrons. The nephron utilizes four processes to alter the blood plasma which flows to it: **filtration, reabsorption, secretion, and excretion**.

The kidney cannot regenerate new nephrons. Therefore, with renal injury, disease, or normal aging, there is a gradual decrease in nephron number. After age 40, the number of functioning

nephrons usually decreases about 10 per cent every 10 years; thus, at age 80, many people have 40 per cent fewer functioning nephrons than they did at age 40. This loss is not life threatening because adaptive changes in the remaining nephrons allow them to excrete the proper amounts of water, electrolytes, and waste products. Each nephron contains-

- a tuft of glomerular capillaries called the glomerulus, through which large amounts of fluid are filtered from the blood
- a long tubule in which the filtered fluid is converted into urine on its way to the pelvis of the kidney.

The glomerulus contains a network of branching and anastomosing glomerular capillaries that, compared with other capillaries, have high hydrostatic pressure (about 60 mm Hg). The glomerular capillaries are covered by epithelial cells, and the total glomerulus is encased in Bowman's capsule. Fluid filtered from the glomerular capillaries flows into Bowman's capsule and then into the proximal tubule, which lies in the cortex of the kidney.



Nephron

From the proximal tubule, fluid flows into the loop of Henle, which dips into the renal medulla. Each loop consists of a descending and an ascending limb. The walls of the descending limb and the lower end of the ascending limb are very thin and therefore are called the thin segment of the loop of Henle. After the ascending limb of the loop has returned partway back to the cortex, its wall becomes much thicker, and it is referred to as the thick segment of the ascending limb.

At the end of the thick ascending limb is a short segment, which is actually a plaque in its wall, known as the macula densa. The macula densa plays an important role in controlling nephron function. Beyond the macula densa, fluid enters the distal tubule, which, like the proximal tubule, lies in the renal cortex. This is followed by the connecting tubule and the cortical collecting tubule, which lead to the cortical collecting duct.

The initial parts of **8 to 10** cortical collecting ducts join to form a single larger collecting duct that runs downward into the medulla and becomes the medullary collecting duct. The collecting

ducts merge to form progressively larger ducts that eventually empty into the renal pelvis through the tips of the renal papillae. In each kidney, there are about **250** of the very large collecting ducts, each of which collects urine from about **4000** nephrons.

Structure of Nephron

Each nephron is basically composed of two part.

1. Renal corpuscle
2. Renal tubules

Renal corpuscle

The front end of the nephron is renal corpuscle. The renal corpuscle is the site of the filtration of blood plasma. It is situated at renal cortex. The renal corpuscle consists of two part

I. Bowman's capsule
II. Glomerulus

The renal corpuscle has two poles – a vascular pole and a urinary pole. The arterioles from the renal circulation enter and leave the glomerulus at the vascular pole. The glomerular filtrate leaves the Bowman's capsule at the renal tubule at the urinary pole.

Bowman's Capsule

The Bowman's capsule, also called the glomerular capsule, surrounds the glomerulus. It is composed of a visceral inner layer formed by specialized cells called **podocytes**, and a parietal outer layer composed of simple **squamous epithelium**. Fluids from blood in the glomerulus are filtered through the visceral layer of podocytes, resulting in the glomerular filtrate.

The glomerular filtrate next moves to the renal tubule, where it is further processed to form urine. The different stages of this fluid are collectively known as the tubular fluid.

Glomerulus

The glomerulus is the network known as a tuft, of filtering capillaries located at the vascular pole of the renal corpuscle in Bowman's capsule. Each glomerulus receives its blood supply from an afferent arteriole of the renal circulation. The glomerular blood pressure provides the driving force for water and solutes to be filtered out of the blood plasma, and into the space in Bowman's capsule called Bowman's space.

Only about a fifth of the plasma is filtered in the glomerulus. The rest passes into an efferent arteriole. The diameter of the efferent arteriole is smaller than that of the afferent, and this difference increases the hydrostatic pressure in the glomerulus.

Renal tubules

The renal tubule is the portion of the nephron containing the tubular fluid filtered through the glomerulus. After passing through the renal tubule, the filtrate continues to the collecting duct system.

The components of the renal tubule are:

- Proximal convoluted tubule (lies in cortex and lined by simple cuboidal epithelium with brush borders which help to increase the area of absorption greatly.)
- Loop of Henle (hair-pin like, i.e. U-shaped, and lies in medulla)

- Descending limb of loop of Henle
- Ascending limb of loop of Henle
    - The ascending limb of loop of Henle is divided into 2 segments: Lower end of ascending limb is very thin and is lined by simple squamous epithelium. The distal portion of ascending limb is thick and is lined by simple cuboidal epithelium.
    - Thin ascending limb of loop of Henle
    - Thick ascending limb of loop of Henle (enters cortex and becomes - distal convoluted tubule.)
- Distal convoluted tubule
- Collecting Duct

Blood from the efferent arteriole, containing everything that was not filtered out in the glomerulus, moves into the peritubular capillaries, tiny blood vessels that surround the loop of Henle and the proximal and distal tubules, where the tubular fluid flows. Substances then reabsorb from the latter back to the blood stream.

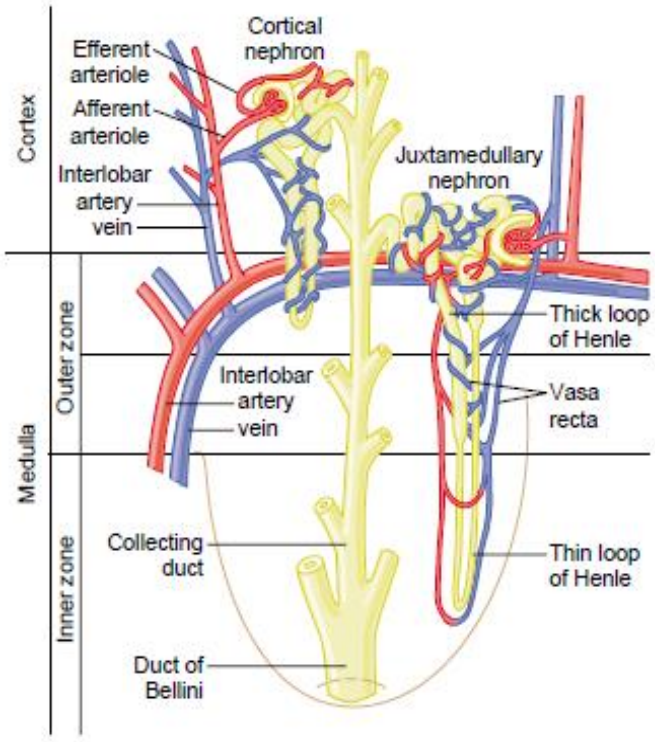
The peritubular capillaries then recombine to form an efferent venule, which combines with efferent venules from other nephrons into the renal vein, and rejoins the main bloodstream.

Different Types of Nephron

Although each nephron has all the components described earlier, there are some differences, depending on how deep the nephron lies within the kidney mass. In this case they are divided inti two types-

1. Cortical Nephrons
2. Juxtamedullary Nephrons

Those nephrons that have glomeruli located in the outer cortex are called cortical nephrons; they have short loops of Henle that penetrate only a short distance into the medulla.



Different Types of Nephron

About 20 to 30 per cent of the nephrons have glomeruli that lie deep in the renal cortex near the medulla and are called juxtamedullary nephrons. These nephrons have long loops of Henle that dip deeply into the medulla, in some cases all the way to the tips of the renal papillae. The vascular structures supplying the juxtamedullary nephrons also differ from those supplying the cortical nephrons. For the cortical nephrons, the entire tubular system is surrounded by an extensive network of peritubular capillaries. For the juxtamedullary

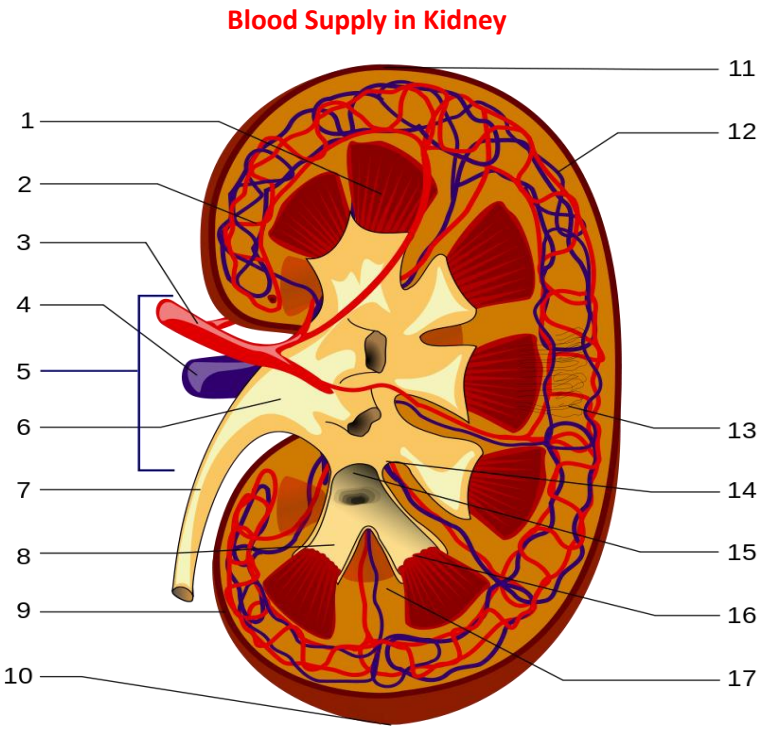
nephrons, long efferent arterioles extend from the glomeruli down into the outer medulla and then divide into specialized peritubular capillaries called vasa recta that extend downward into the medulla, lying side by side with the loops of Henle. Like the loops of Henle, the vasa recta return toward the cortex and empty into the cortical veins. This specialized network of capillaries in the medulla plays an essential role in the formation of a concentrated urine.

Functions of Nephron

- A nephron is responsible for removing waste products, stray ions, and excess water from the blood
- Remove excess water, wastes and other substances from your blood.
- Return substances like sodium, potassium or phosphorus whenever any of these substances run low in your body.
- Filtration of all type of element of blood without protein by glomerulus
- Constant the value of P^h of blood

Renal Blood Supply

Blood flow to the two kidneys is normally about 22 per cent of the cardiac output, or 1100 ml/min. The renal artery enters the kidney through the hilum and then branches progressively to form the interlobar arteries, arcuate arteries, interlobular arteries (also called radial arteries) and afferent arterioles, which lead to the glomerular capillaries, where large amounts of fluid and solutes (except the plasma proteins) are filtered to begin urine formation. The distal ends of the capillaries of each glomerulus coalesce to form the efferent arteriole, which leads to a second capillary network, the peritubular capillaries, that surrounds the renal tubules.



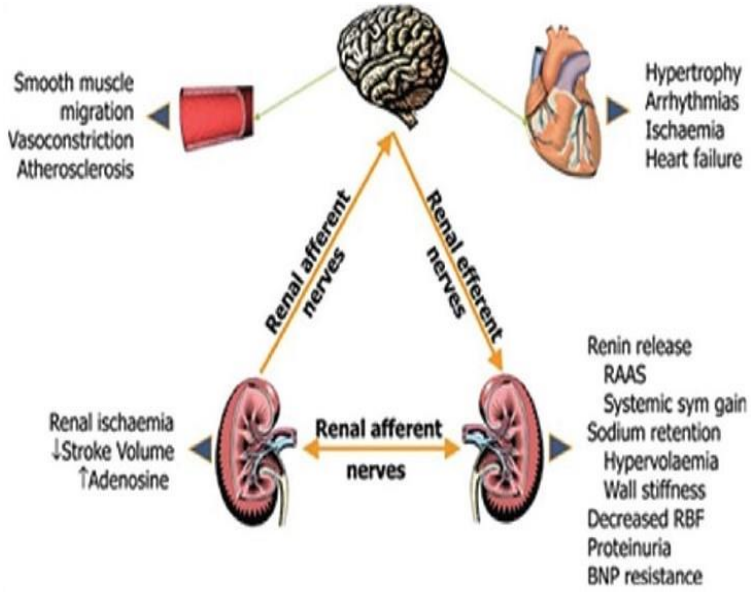
1.Renal pyramid 2. Interlobular artery 3. Renal artery 4. Renal vein 5. Renal hilum 6. Renal pelvis 7. Ureter 8. Minor calyx 9. Renal capsule 10. Inferior renal capsule 11. Superior renal capsule 12. Interlobular vein 13. Nephron 14. Renal sinus 15. Major calyx 16. Renal papilla 17. Renal column

The renal circulation is unique in that it has two capillary beds, the glomerular and peritubular capillaries, which are arranged in series and separated by the efferent arterioles, which help regulate the hydrostatic pressure in both sets of capillaries. High hydrostatic pressure in the glomerular capillaries (about 60 mm Hg) causes rapid fluid filtration, whereas a glomerular filtration, tubular reabsorption, or both in response to body homeostatic demands.

The peritubular capillaries empty into the vessels of the venous system, which run parallel to the arteriolar vessels and progressively form the interlobular vein, arcuate vein, interlobar vein, and renal vein, which leaves the kidney beside the renal artery and ureter.

Nerve Supply

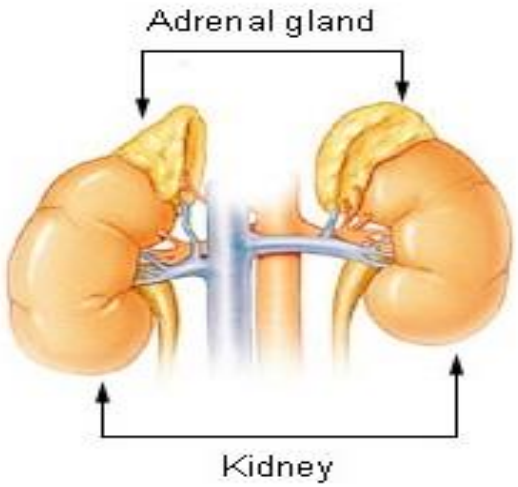
The kidney and nervous system communicate via the renal plexus, whose fibers course along the renal arteries to reach each kidney.



Input from the sympathetic nervous system triggers vasoconstriction in the kidney, thereby reducing renal blood flow. The kidney also receives input from the parasympathetic nervous system, by way of the renal branches of the vagus nerve; the function of this is yet unclear. Sensory input from the kidney travels to the T10-11 levels of the spinal cord and is sensed in the corresponding dermatome. Thus, pain in the flank region may be referred from corresponding kidney.

Gland Above Kidney

The adrenal glands (also known as suprarenal glands) are endocrine glands that produce a variety of hormones including adrenaline and the steroids aldosterone and cortisol. They are found above the kidneys. Each gland has an outer cortex which produces steroid hormones and an inner medulla. The adrenal cortex itself is divided into three zones: zona glomerulosa, the zona fasciculata and the zona reticularis.



The adrenal cortex produces three main types of steroid hormones: **mineralocorticoids, glucocorticoids,** and **androgens.** Mineralocorticoids (such as **aldosterone**) produced in the zona glomerulosa help in the regulation of **blood pressure and electrolyte balance**. The glucocorticoids cortisol and corticosterone are synthesized in the zona fasciculata; their functions include the regulation of **metabolism and immune system suppression**. The innermost layer of the cortex, the zona reticularis, produces androgens that are converted to fully functional **sex hormones** in the gonads and other target organs. The production of steroid hormones is called steroidogenesis, and involves a number of reactions and processes that take place in cortical cells.

Function of Kidney

kidneys serve multiple functions, including:

- Excretion of metabolic waste products and foreign chemicals
- Regulation of water and electrolyte balances
- Regulation of body fluid osmolality and electrolyte concentrations
- Regulation of arterial pressure
- Regulation of acid-base balance
- Secretion, metabolism, and excretion of hormones
- Gluconeogenesis

Excretion of Metabolic Waste Products, Foreign Chemicals

The kidneys are the primary means for eliminating waste products of metabolism that are no longer needed by the body. These products include urea (from the metabolism of amino acids), creatinine (from muscle creatine), uric acid (from nucleic acids), end products of hemoglobin breakdown (such as bilirubin), and metabolites of various hormones. These waste products must be eliminated from the body as rapidly as they are produced. The kidneys also eliminate most toxins and other foreign substances that are either produced by the body or ingested, such as pesticides, drugs, and food additives.

Regulation of Water and Electrolyte Balances

For maintenance of homeostasis, excretion of water and electrolytes must precisely match intake. If intake exceeds excretion, the amount of that substance in the body will increase. If intake is less than excretion, the amount of that substance in the body will decrease. Intake of water and many electrolytes is governed mainly by a person's eating and drinking habits, requiring the kidneys to adjust their excretion rates to match the intake of various substances.

Within 2 to 3 days after raising the sodium intake, renal excretion also increases to about 300 mEq/day, so that a balance between intake and output is re-established. However, during the 2 to 3 days of renal adaptation to the high sodium intake, there is a modest accumulation of sodium that raises extracellular fluid volume slightly and triggers hormonal changes and other compensatory responses that signal the kidneys to increase their sodium excretion.

The capacity of the kidneys to alter sodium excretion in response to changes in sodium intake is enormous. Experimental studies have shown that in many people, sodium intake can be increased to 1500 mEq/ day (more than 10 times normal) or decreased to 10 mEq/day (less than one tenth normal) with relatively small changes in extracellular fluid volume or plasma sodium concentration. This is also true for water and for most other electrolytes, such as chloride, potassium, calcium, hydrogen, magnesium, and phosphate ions. In the next few chapters, we discuss the specific mechanisms that permit the kidneys to perform these amazing feats of homeostasis.

Regulation of Arterial Pressure

The kidneys play a dominant role in long-term regulation of arterial pressure by excreting variable amounts of sodium and water. The kidneys also contribute to short-term arterial pressure regulation by secreting vasoactive factors or substances, such as renin, that lead to the formation of vasoactive products (e.g., angiotensin II).

Regulation of Acid-Base Balance

The kidneys contribute to acid-base regulation, along with the lungs and body fluid buffers, by excreting acids and by regulating the body fluid buffer stores. The kidneys are the only means of eliminating from the body certain types of acids, such as sulfuric acid and phosphoric acid, generated by the metabolism of proteins.

Regulation of Erythrocyte Production

The kidneys secrete erythropoietin, which stimulates the production of red blood cells. One important stimulus for erythropoietin secretion by the kidneys is hypoxia. The kidneys normally account for almost all the erythropoietin secreted into the circulation. In people with severe kidney disease or who have had their kidneys removed and have been placed on hemodialysis, severe anemia develops as a result of decreased erythropoietin production.

Regulation of 1,25–Dihydroxyvitamin D3 Production

The kidneys produce the active form of vitamin D, 1,25- dihydroxyvitamin D3 (calcitriol), by hydroxylating this vitamin at the "number 1" position. Calcitriol is essential for normal calcium deposition in bone and calcium reabsorption by the gastrointestinal tract. Calcitriol plays an important role in calcium and phosphate regulation.

Glucose Synthesis

The kidneys synthesize glucose from amino acids and other precursors during prolonged fasting, a process referred to as gluconeogenesis. The kidneys' capacity to add glucose to the blood during prolonged periods of fasting rivals that of the liver. With chronic kidney disease or acute failure of the kidneys, these homeostatic functions are disrupted, and severe abnormalities of body fluid volumes and composition rapidly occur. With complete renal failure, enough potassium, acids, fluid, and other substancesmaccumulate in the body to cause death within a few days, unless clinical interventions such as hemodialysis are initiated to restore, at least partially, the body fluid and electrolyte balances.

Urine Formation

The rates at which different substances are excreted in the urine represent the sum of three renal processes,

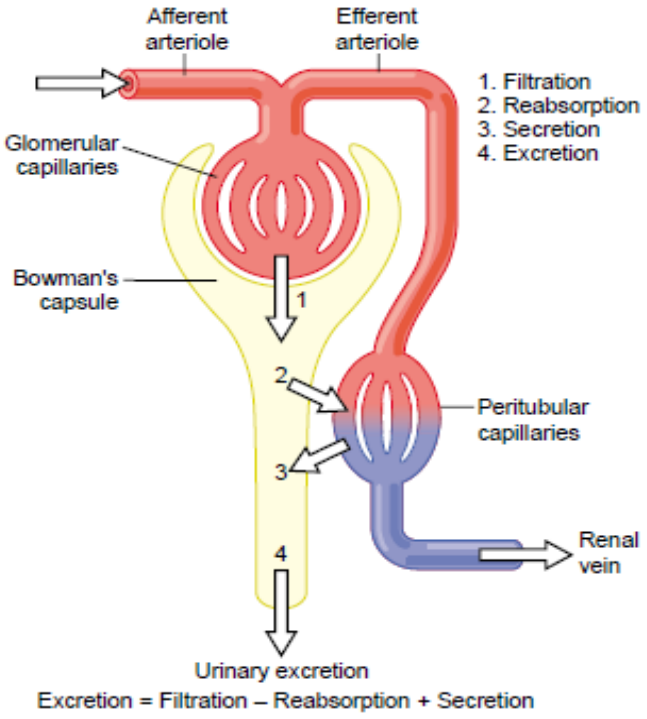
(1) glomerular filtration,
(2) reabsorption of substances from the renal tubules into the blood,
(3) secretion of substances from the blood into the renal tubules.

Expressed mathematically,

Urinary excretion rate = Filtration rate- Reabsorption rate + Secretion rate

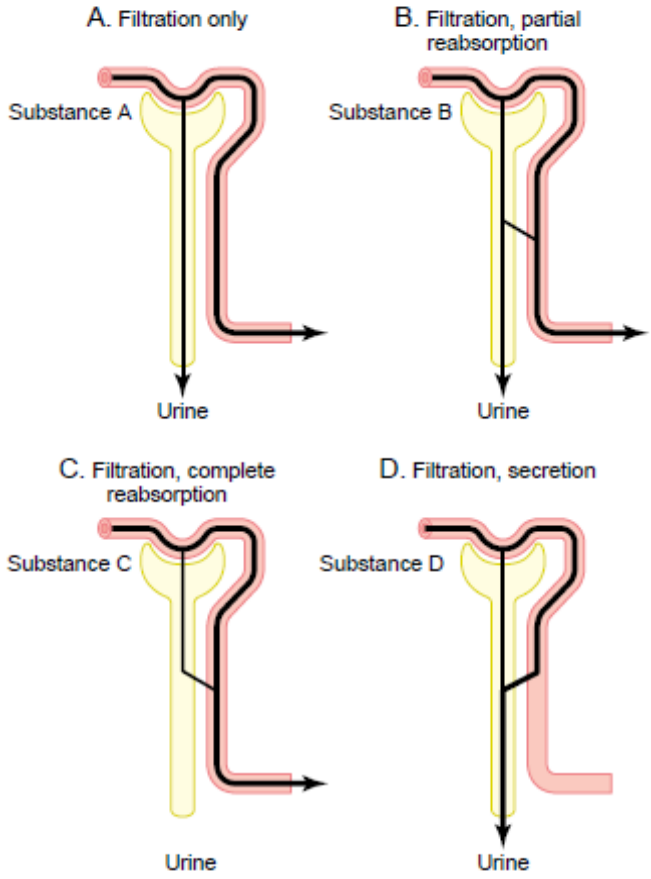
Urine formation begins when a large amount of fluid that is virtually free of protein is filtered from the glomerular capillaries into Bowman's capsule.

Most substances in the plasma, except for proteins, are freely filtered, so that their concentration in the glomerular filtrate in Bowman's capsule is almost the same as in the plasma. As filtered fluid leaves Bowman's capsule and passes through the tubules, it is modified by reabsorption of water and specific solutes back into the blood or by secretion of other substances from the peritubular capillaries into the tubules.



The substance shown in panel A is freely filtered by the glomerular capillaries but is neither reabsorbed nor secreted. Therefore, its excretion rate is equal to the rate at which it was filtered. Certain waste products in the body, such as creatinine, are handled by the kidneys in this manner, allowing excretion of essentially all that is filtered.

In panel B, the substance is freely filtered but is also partly reabsorbed from the tubules back into the blood. Therefore, the rate of urinary excretion is less than the rate of filtration at the glomerular capillaries. In this case, the excretion rate is calculated as the filtration rate minus the reabsorption rate. This is typical for many of the electrolytes of the body.



In panel C, the substance is freely filtered at the glomerular capillaries but is not excreted into the urine because all the filtered substance is reabsorbed from the tubules back into the blood. This pattern occurs for some of

the nutritional substances in the blood, such as amino acids and glucose, allowing them to be conserved in the body fluids.

The substance in panel D is freely filtered at the glomerular capillaries and is not reabsorbed, but additional quantities of this substance are secreted from the peritubular capillary blood into the renal tubules. This pattern often occurs for organic acids and bases, permitting them to be rapidly cleared from the blood and excreted in large amounts in the urine. The excretion rate in this case is calculated as filtration rate plus tubular secretion rate.

For each substance in the plasma, a particular combination of filtration, reabsorption, and secretion occurs. The rate at which the substance is excreted in the urine depends on the relative rates of these three basic renal process.

Why Are Large Amounts of Solutes Filtered and Then Reabsorbed by the Kidneys?

One might question the wisdom of filtering such large amounts of water and solutes and then reabsorbing most of these substances. One advantage of a high GFR is that it allows the kidneys to rapidly remove waste products from the body that depend primarily on glomerular filtration for their excretion. Most waste products are poorly reabsorbed by the tubules and, therefore, depend on a high GFR for effective removal from the body.

A second advantage of a high GFR is that it allows all the body fluids to be filtered and processed by the kidney many times each day. Because the entire plasma volume is only about 3 liters, whereas the GFR is about 180 L/day, the entire plasma can be filtered and processed about 60 times each day. This high GFR allows the kidneys to precisely and rapidly control the volume and composition of the body fluids.

Glomerular Filtration—The First Step in Urine Formation

Filtration, which takes place at the renal corpuscle, is the process by which cells and large proteins are retained while materials of smaller molecular weights are filtered from the blood to make an ultra-filtrate that eventually becomes urine. The kidney generates 180 liters of filtrate a day. The process is also known as hydrostatic filtration due to the hydrostatic pressure exerted on the capillary walls.

Composition of the Glomerular Filtrate

Urine formation begins with filtration of large amounts of fluid through the glomerular capillaries into Bowman's capsule. Like most capillaries, the glomerular capillaries are relatively impermeable to proteins, so that the filtered fluid (called the glomerular filtrate) is essentially protein-free and devoid of cellular elements, including red blood cells. The concentrations of other constituents of the glomerular filtrate, including most salts and organic molecules, are similar to the concentrations in the plasma.

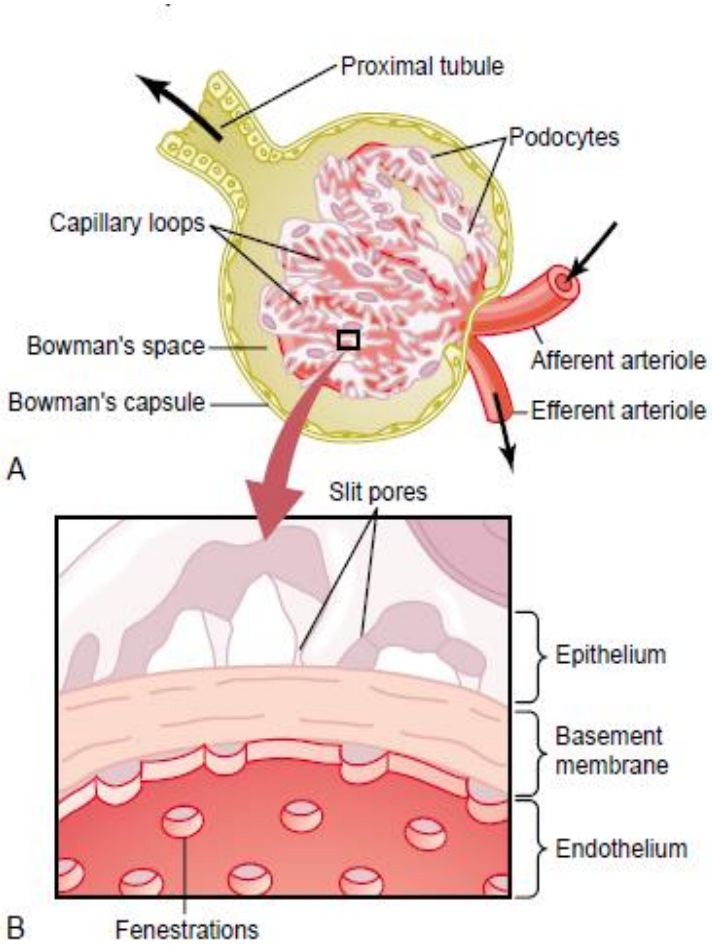
Exceptions to this generalization include a few low-molecular-weight substances, such as calcium and fatty acids, that are not freely filtered because they are partially bound to the plasma proteins. Almost one half of the plasma calcium and most of the plasma fatty acids are bound to proteins, and these bound portions are not filtered through the glomerular capillaries.

GFR Is About 20 Per Cent of the Renal Plasma Flow

As in other capillaries, the GFR is determined by-

(1) The balance of hydrostatic and colloid osmotic forces acting across the capillary membrane.

(2) The capillary filtration coefficient (Kf), the product of the permeability and filtering surface area of the capillaries.



The glomerular capillaries have a much higher rate of filtration than most other capillaries because of a high glomerular hydrostatic pressure and a large Kf. In the average adult human, the GFR is about 125 ml/min, or 180 L/day. The fraction of the renal plasma flow that is filtered (the filtration fraction) averages about 0.2; this means that about 20 per cent of the plasma flowing through the kidney is filtered through the glomerular capillaries. The filtration fraction is calculated as follows:

Filtration fraction = GFR/Renal plasma flow

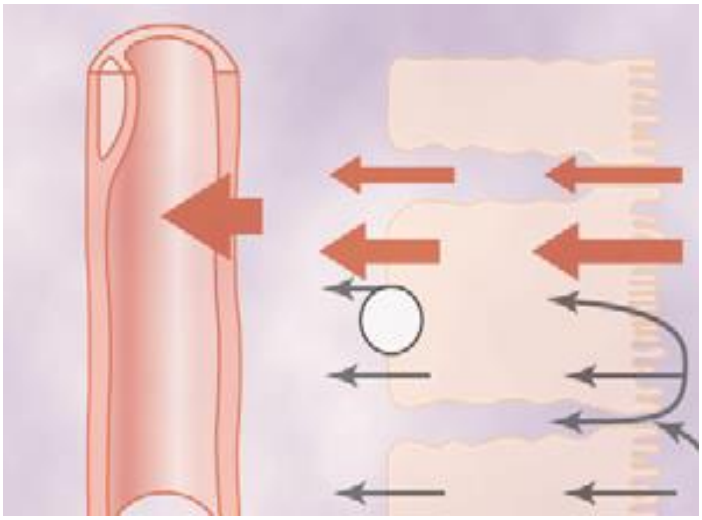
Factor Affecting to GRF

There are many factor that affect to the rate of GRF. They are-

- Filterability of Solutes Is Inversely Related to Their Size.
- Negatively Charged Large Molecules Are Filtered Less Easily Than Positively Charged Molecules of Equal Molecular Size.
- Increased Bowman's Capsule Hydrostatic Pressure Decreases GFR
- Increased Glomerular Capillary Filtration Coefficient Increases GFR
- Increased Glomerular Capillary Colloid Osmotic Pressure Decreases GFR
- Increased Glomerular Capillary
- Hydrostatic Pressure Increases GFR
- Increased Glomerular Capillary Hydrostatic Pressure Increases GFR

Reabsorption by the Renal Tubules (2nd step)

As the glomerular filtrate enters the renal tubules, it flows sequentially through the successive parts of the tubule—the proximal tubule, the loop of Henle, the distal tubule, the collecting tubule, and, finally, the collecting duct—before it is excreted as urine. Along this course, some substances are selectively reabsorbed from the tubules back into the blood, whereas others are secreted from the blood into the tubular lumen. Eventually, the urine that is formed and all the substances in the urine represent the sum of three basic renal processes—glomerular filtration, tubular reabsorption, and tubular secretion—as follows:



Urinary excretion = Glomerular filtration - Tubular reabsorption+ Tubular secretion

For many substances, reabsorption plays a much more important role than does secretion in determining the final urinary excretion rate. However, secretion accounts for significant amounts of potassium ions, hydrogen ions, and a few other substances that appear in the urine.

Location of Reabsorption	Reabsorbed Nutrient	Notes
Early proximal tubule	Glucose (100%) amino acids (100%) bicarbonate (90%) Na^+ (65%) Cl^- (65%) phosphate (65%) and H2O (65%)	• PTH will inhibit phosphate reabsorption. • AT II stimulates Na^+, H_2O and $HCO3^-$ reabsorption
Thin descending loop of Henle	H_2O	• Reabsorbs via medullary hypertonicity and makes urine hypertonic.
Thick ascending loop of Henle	Na^+ (10–20%) K^+, Cl^- indirectly induces para cellular reabsorption of Mg^{2+}, Ca^{2+}	• This region is impermeable to H_2O and the urine becomes less concentrated as it ascends.
Early distal convoluted tubule	Na^+, Cl^-	• PTH causes Ca^{2+} reabsorption.

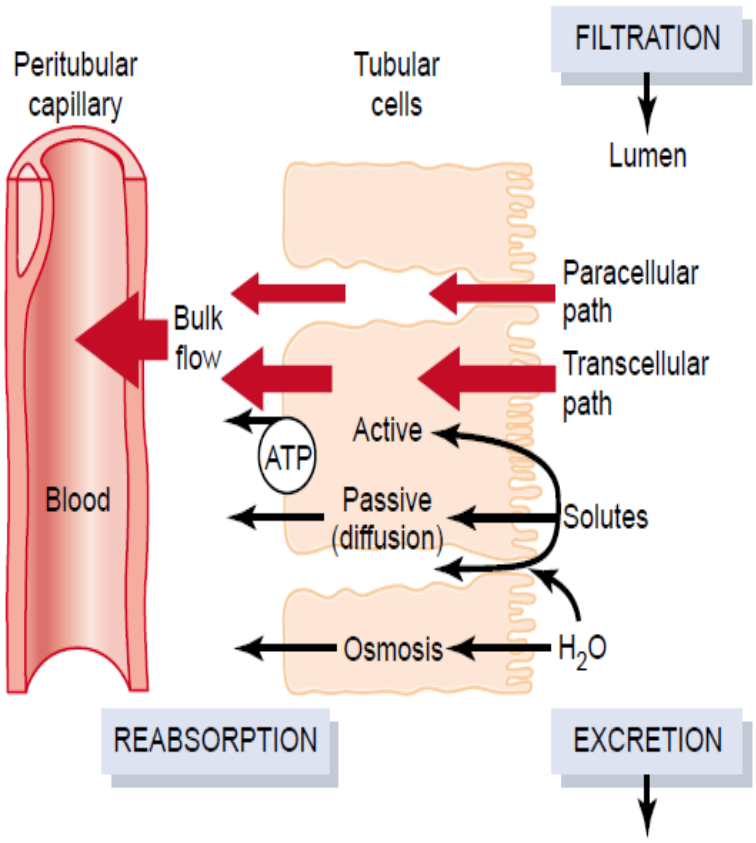
Early distal convoluted tubule	Na^+ (3–5%), H_2O	• Na+ is reabsorbed in exchange for K+, and H+, which is regulated by aldosterone. • ADH acts on the V2 receptor and inserts aquaporins on the luminal side

Tubular Reabsorption Is Selective and Quantitatively Large

Table shows the renal handling of several substances that are all freely filtered in the kidneys and reabsorbed at variable rates. The rate at which each of these substances is filtered is calculated as

Filtration = Glomerular filtration rate* Plasma concentration

This calculation assumes that the substance is freely filtered and not bound to plasma proteins. For example, if plasma glucose concentration is 1 g/L, the amount of glucose filtered each day is about 180 L/day ¥ 1 g/L, or 180 g/day. Because virtually none of the filtered glucose is normally excreted, the rate of glucose reabsorption is also 180 g/day.



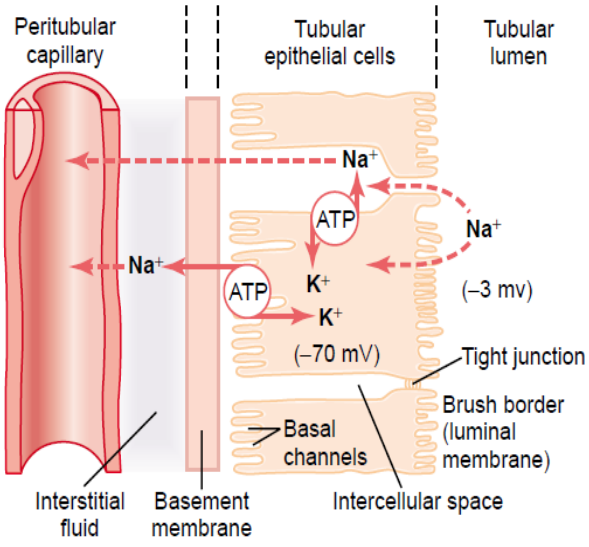
Unlike glomerular filtration, which is relatively nonselective (that is, essentially all solutes in the plasma are filtered except the plasma proteins or substances bound to them), tubular reabsorption is highly selective. Some substances, such as glucose and amino acids, are almost completely reabsorbed from the tubules, so that the urinary excretion rate is essentially zero. Many of the ions in the plasma, such as sodium, chloride, and bicarbonate, are also highly reabsorbed, but their rates of reabsorption and urinary excretion are variable, depending on the needs of the body. Certain waste products, such as urea and creatinine, conversely, are poorly reabsorbed from the tubules and excreted in relatively large amounts.

Therefore, by controlling the rate at which they reabsorb different substances, the kidneys regulate the excretion of solutes independently of one another, acceptability that is essential for precise control of the composition of body fluids.

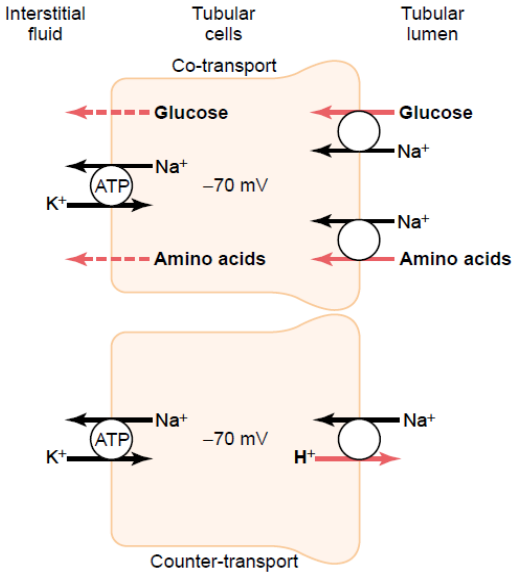
Mechanism of Tubular Reabsorption

There are many types of mechanisms for tubular reabsorption. They are including-

- Active transport
  - I. Primary active transport
  - II. Secondary active transport
- Passive transport



Basic Mechanism of Active Transport



Secondary Active Transport

Passive Water Reabsorption by Osmosis Is Coupled Mainly to Sodium Reabsorption

When solutes are transported out of the tubule by either primary or secondary active transport, their concentrations tend to decrease inside the tubule while increasing in the renal interstitium. This creates a concentration difference that causes osmosis of water in the same direction that the solutes are transported, from the tubular lumen to the renal interstitium. Some parts of the renal tubule, especially the proximal tubule, are highly permeable to water, and water reabsorption occurs so rapidly that there is only a small concentration gradient for solutes across the tubular membrane.

A large part of the osmotic flow of water occurs through the so-called tight junctions between the epithelial cells as well as through the cells themselves. The reason for this, as already discussed, is that the junctions between the cells are not as tight as their name would imply, and they allow significant diffusion of water and small ions. This is especially true in the

proximal tubules, which have a high permeability for water and a smaller but significant permeability to most ions, such as sodium, chloride, potassium, calcium, and magnesium.

As water moves across the tight junctions by osmosis, it can also carry with it some of the solutes, a process referred to as solvent drag. And because the reabsorption of water, organic solutes, and ions is coupled to sodium reabsorption, changes in sodium reabsorption significantly influence the reabsorption of water and many other solutes.

In the more distal parts of the nephron, beginning in the loop of Henle and extending through the collecting tubule, the tight junctions become far less permeable to water and solutes, and the epithelial cells also have a greatly decreased membrane surface area. Therefore, water cannot move easily across the tubular membrane by osmosis. However, antidiuretic hormone (ADH) greatly increases the water permeability in the distal and collecting tubules.

Thus, water movement across the tubular epithelium can occur only if the membrane is permeable to water, no matter how large the osmotic gradient. In the proximal tubule, the water permeability is always high, and water is reabsorbed as rapidly as the solutes. In the ascending loop of Henle, water permeability is always low, so that almost no water is reabsorbed, despite a large osmotic gradient. Water permeability in the last parts of the tubules—the distal tubules, collecting tubules, and collecting ducts—can be high or low, depending on the presence or absence of ADH.

Active Secretion (3rd step)

Secretion is the reverse of reabsorption: molecules are transported from the peritubular capillary through the interstitial fluid, then through the renal tubular cell and into the ultrafiltrate.

This is happened in the proximal convoluted tubules. From capillaries some unusable material are secreted into proximal convoluted tubules like urea, creatinine etc. In distal convoluted tubules Hydrogen, potassium and ammonia are secreted.

Hydrogen, creatinine, and drugs are removed from the blood and into the collecting duct through the peritubular capillary network.

Tubular secretion is the transfer of materials from peritubular capillaries to the renal tubular lumen; it is the opposite process of reabsorption. This secretion is caused mainly by active transport and passive diffusion.

Usually only a few substances are secreted, and are typically waste products. Urine is the substance leftover in the collecting duct following reabsorption and secretion.

Mechanisms of Secretion

The mechanisms by which secretion occurs are similar to those of reabsorption, however these processes occur in the opposite direction.

- **Passive diffusion**—the movement of molecules from the peritubular capillaries to the interstitial fluid within the nephron.
- **Active transport**—the movement of molecules via ATPase pumps that transport the substance through the renal epithelial cell into the lumen of the nephron.

Renal secretion is different from reabsorption because it deals with filtering and cleaning substances from the blood, rather than retaining them. The substances that are secreted into the tubular fluid for removal from the body include:

- Potassium ions (K+)
- Hydrogen ions (H+)
- Ammonium ions (NH4+)
- Creatinine
- Urea
- Some hormones
- Some drugs (e.g., penicillin)

Many pharmaceutical drugs are protein-bound molecules that Diagram showing the basic physiologic mechanisms of the kidney and the three steps involved in urine formation. Arely filtration, reabsorption, secretion, and excretion. are easily secreted, which is why urine testing can detect the exposure to many types of drugs. Tubular secretion occurs throughout the different parts of the nephron, from the proximal convoluted tubule to the collecting duct at the end of the nephron.

Path of Urine Production and Secretion Mechanism

Afferent vain ⟶ Glomerulus ⟶ Sac of Bowman's capsule ⟶ Renal tubules ⟶ Collecting ducts ⟶ Renal pelvis ⟶ Ureter ⟶ Urine Bladder ⟶ Urine tubules ⟶ Excretory pore ⟶ Excretion

Transport of Urine into the Bladder

Urine that is expelled from the bladder has essentially the same composition as fluid flowing out of the collecting ducts; there are no significant changes in the composition of urine as it flows through the renal calyces and ureters to the bladder.

Urine flowing from the collecting ducts into the renal calyces stretches the calyces and increases their inherent pacemaker activity, which in turn initiates peristaltic contractions that spread to the renal pelvis and then downward along the length of the ureter, thereby forcing urine from the renal pelvis toward the bladder.

The walls of the ureters contain smooth muscle and are innervated by both sympathetic and parasympathetic nerves as well as by an intramural plexus of neurons and nerve fibers that extends along the entire length of the ureters. As with other visceral smooth muscle, peristaltic contractions in the ureter are enhanced by parasympathetic stimulation and inhibited by sympathetic stimulation.

The ureters enter the bladder through the detrusor muscle in the trigone region of the bladder. Normally, the ureters course obliquely for several centimeters through the bladder wall. The normal tone of the detrusor muscle in the bladder wall tends to compress the ureter, thereby preventing backflow of urine from the bladder when pressure builds up in the bladder during micturition or bladder compression. Each peristaltic wave along the ureter increases the pressure within the ureter so that the region passing through the bladder wall opens and allows urine to flow into the bladder.

In some people, the distance that the ureter courses through the bladder wall is less than normal, so that contraction of the bladder during micturition does not always lead to complete occlusion of the ureter. As a result, some of the urine in the bladder is propelled backward into the ureter, a condition called vesicoureteral reflux. Such reflux can lead to enlargement of the ureters and, if severe, can increase the pressure in the renal calyces and structures of the renal medulla, causing damage to these regions.

Amount of Urine Excreted

In general, a healthy man excretes1.5L of urine. But some reason that effect on this amount. If we take liquid food more than the amount of the production of urine is more. Salty food increases the production of urine. In diabetes and nephritis, the amount of urine production increase. Some material called diuretics increase the rate of urine production. E.g. water, salty water, tea, coffee etc.

Composition of Urine

Urine is straw colored and acidic liquid. The straw color is for the presence of urochrome. P^h of urine is 6.5.

Component	Percentage	Component	Percentage
Water	95%	Potassium	0.15%
Urea	2%	Magnesium	0.01%
Uric Acid	0.05%	Chloride	0.6
Creatinine	0.075%	Phosphate	0.27%
Sodium	0.35%	Sulfate	0.18%
Ammonium	0.04%	Extra	1.275%

Pain Sensation in the Ureters and the Ureterorenal Reflex

The ureters are well supplied with pain nerve fibers. When a ureter becomes blocked (e.g., by a ureteral stone), intense reflex constriction occurs, associated with severe pain. Also, the pain impulses cause a sympathetic reflex back to the kidney to constrict the renal arterioles, thereby decreasing urine output from the kidney. This effect is called the ureterorenal reflex and is important for preventing excessive flow of fluid into the pelvis of a kidney with a blocked ureter.

Hormonal Control for Urine Formation

Hormone	Site of Action	Effects
Aldosterone	Collecting tubules and ducts	Increase NaCl, H_2O reabsorption Increase K^+ secretion
Angiotension II	Proximal Tubule, Thick ascending loop of henle, distal tubule and collecting ducts	Increase NaCl, H_2O reabsorption Increase H^+ secretion
Anti Diuretic Hormone (ADH)	distal tubule, collecting tubules and collecting ducts	Increase H_2O reabsorption
Atrial Natriuretic Peptide	distal tubule, collecting tubules and collecting ducts	Decrease NaCl reabsorption
Parathyroid Hormone	Proximal tubules, Thick ascending loop of henle and distal tubule	Decrease $PO4^{--}$ reabsorption Increase Ca^{++} reabsorption

Renin–Angiotensin

Renin is an enzyme that is produced by the granular cells of the afferent arteriole at the JGA. It enzymatically converts angiotensinogen (made by the liver, freely circulating) into angiotensin I. Its release is stimulated by prostaglandins and NO from the JGA in response to decreased extracellular fluid volume.

ACE is not a hormone but it is functionally important in regulating systemic blood pressure and kidney function. It is produced in the lungs but binds to the surfaces of endothelial cells in the afferent arterioles and glomerulus. It enzymatically converts inactive angiotensin I into active angiotensin II. ACE is important in raising blood pressure. People with high blood pressure are sometimes prescribed ACE inhibitors to lower their blood pressure.

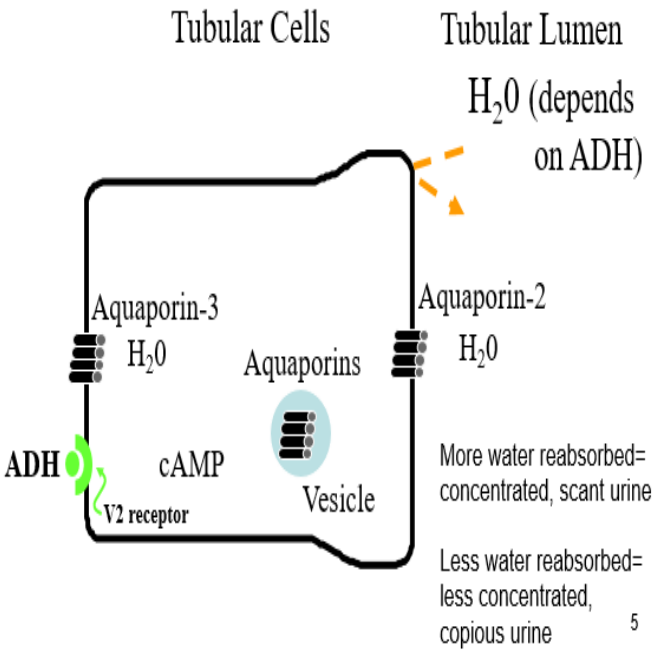
Angiotensin II is a potent vasoconstrictor that plays an immediate role in the regulation of blood pressure. It acts systemically to cause vasoconstriction as well as constriction of both the afferent and efferent arterioles of the glomerulus. In instances of blood loss or dehydration, it reduces both GFR and renal blood flow, thereby limiting fluid loss and preserving blood volume. Its release is usually stimulated by decreases in blood pressure, and so the preservation of adequate blood pressure is its primary role.

Aldosterone

Aldosterone, often called the "salt-retaining hormone," is released from the adrenal cortex in response to angiotensin II or directly in response to increased plasma K+. It promotes Na+ reabsorption by the nephron, promoting the retention of water. It is also important in regulating K+, promoting its excretion. (This dual effect on two minerals and its origin in the adrenal cortex explains its designation as a mineralocorticoid.) As a result, renin has an immediate effect on blood pressure due to angiotensin II–stimulated vasoconstriction and a prolonged effect through Na+ recovery due to aldosterone. At the same time that aldosterone causes increased recovery of Na+, it also causes greater loss of K+. Progesterone is a steroid that is structurally similar to aldosterone. It binds to the aldosterone receptor and weakly stimulates Na+ reabsorption and increased water recovery. This process is unimportant in men due to low levels of circulating progesterone. It may cause increased retention of water during some periods of the menstrual cycle in women when progesterone levels increase.

Antidiuretic Hormone (ADH)

Diuretics are drugs that can increase water loss by interfering with the recapture of solutes and water from the forming urine. They are often prescribed to lower blood pressure. Coffee, tea, and alcoholic beverages are familiar diuretics. ADH, a 9-amino acid peptide released by the posterior pituitary, works to do the exact opposite.



It promotes the recovery of water, decreases urine volume, and maintains plasma osmolarity and blood pressure. It does so by stimulating the movement of aquaporin proteins into the apical cell membrane of principal cells of the collecting ducts to form water channels, allowing the transcellular movement of water from the lumen of the collecting duct into the interstitial space in the medulla of the kidney by osmosis. From there, it enters the vasa recta capillaries to return to the circulation. Water is attracted by the high osmotic environment of the deep kidney medulla.

Kidney Disease

All of the vital functions the kidneys perform and the toxins they encounter, the kidneys are susceptible to various problems.

Some of these include:

- chronic kidney disease
- kidney failure
- kidney stones
- glomerulonephritis
- acute nephritis
- polycystic kidney disease
- urinary tract infections
- caliectasis
- acidosis
- uremia
- hydronephrosis
- pyelonephritis
- kidney cysts
- nephrotic syndrome
- azotemia

Symptoms of a kidney problem

Kidney conditions can cause a range of symptoms. Some common ones include:

- trouble sleeping
- fatigue
- inability to concentrate
- dry, itchy skin
- increased or decreased urination
- blood in urine
- foamy urine
- puffiness around the eyes
- foot or ankle swelling
- reduced appetite
- muscle cramps

If you notice any of these symptoms, contact your doctor. Depending on your symptoms, they may do some kidney function tests to make a diagnosis.

Tips for healthy kidneys

The kidneys are important organs that affect many other body parts, including the heart. Follow these tips to keep them working efficiently:

Avoid extra salt

Eating a lot of salty foods can disrupt the balance of minerals in the blood. This can make it harder for the kidneys to work properly. Try swapping out processed foods — which usually have a lot of added salt — for whole foods, such as:

- fresh fruits and vegetables
- lean cuts of meat
- nuts

Exercise

High blood pressure is a known risk factor for chronic kidney disease. Regular exercise, even for just 20 minutes a day, can help reduce blood pressure.

Stay hydrated

Drinking plenty of water helps the kidneys perform one of their most important functions: removing toxins. Learn more about how much water you should really be drinking every day.

Use medications with caution

Regularly taking certain over-the-counter medications, such as nonsteroidal anti-inflammatory drugs, can cause kidney damage over time. Occasionally taking them is fine, but work with your doctor to find alternatives if you have a condition that requires managing pain, such as arthritis.

Know the risk factors

Several things can increase your risk of developing a kidney condition. Make sure you regularly have your kidney function tested if you:

- have diabetes
- are obese
- have high blood pressure
- have a family history of kidney disease

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