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Teach Yourself
Human Physiology in 24 Hours

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1/50

Kidney and Nephronal Physiology

Rapid Learning Tutorial Series

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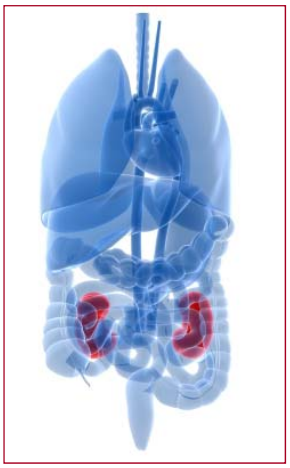
Learning Objectives

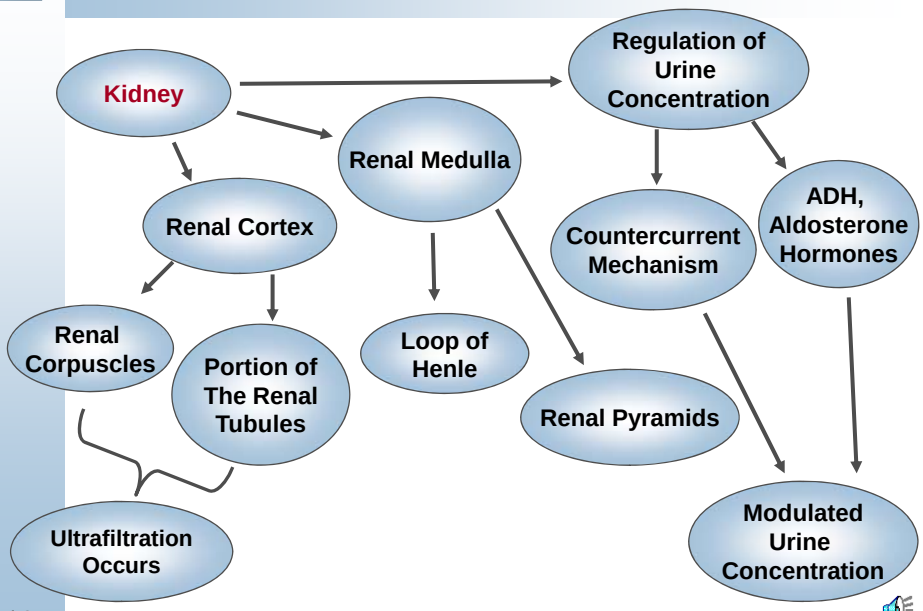
By completing this tutorial, you will learn about:



- the anatomical and functional overview of the renal system.
- the structure of nephrons.
- functional processes of the nephron and kidneys.
- regulation of urine concentration and volume.
- typical content of urine.
- how urine is excreted.
- kidney function tests and dialysis.

3/50

Concept Map



4/50

Anatomical and Functional Overview of the Renal System

1. Function of the Renal System
2. Anatomy of the Kidney

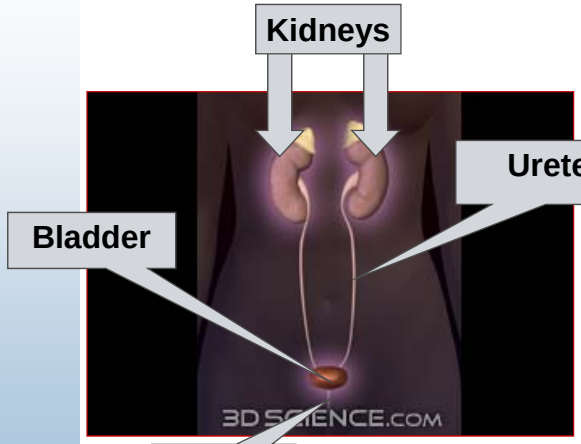
5/50

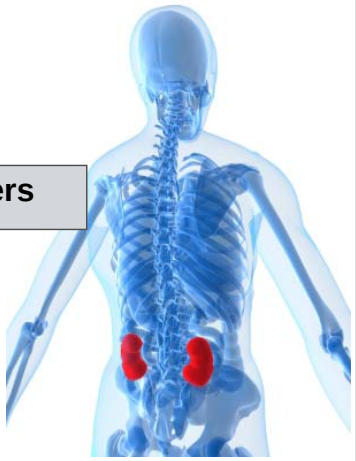
Functions of the Renal System

The primary function of the kidneys is to eliminate wastes from the body, but there are a number of other functions performed by this system: (1) regulate blood pH, (2) regulate ion concentration, (3) assist in vitamin D synthesis, and (4) regulate blood volume.

6/50

Renal System Anatomy

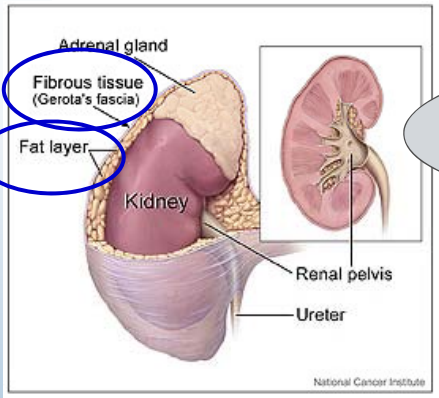




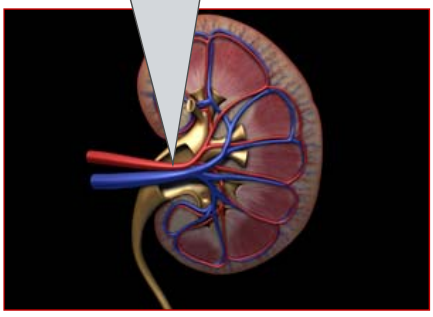
Retroperotineal Location of Kidneys

7/50

Kidney – External Anatomy



Hilum – where vessels and ureters enter kidney



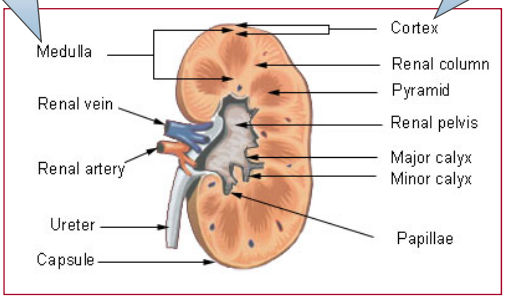
The kidneys are covered by a protective fibrous tissue layer, overlying a fat layer. Situated on top of each kidney are the adrenal glands.

8/50

Kidney – Internal Anatomy

The medulla is the inner portion of the kidney. It contains the renal pyramids and the nephrons.

The cortex is the outer portion of the kidney that surrounds the renal medulla.



During urine formation, the nephrons drain into the minor calyx, into the major calyx, out the renal pelvis, and into the ureter.

9/50

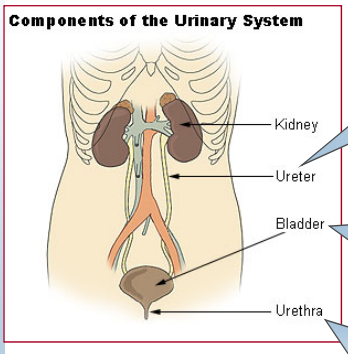
Question: Challenge

In renal physiology, what is the kidney Hilum?

In renal physiology, the Hilum is where the renal artery and renal vein enter the kidney.

10/50

Ureters, Bladder, and Urethra



The **ureters** are hollow, muscular tubes. The filtrate fluid drains from the kidneys to the bladder.

The **bladder** functions by collecting and storing urine until it is eliminated from the body.

The **urethra** is a hollow tube leading from the bladder to the body surface, for the external elimination of urine.

11/50

Nephron – Functional Unit of the Kidney

1. **Nephron**
2. **Renal Corpuscle**

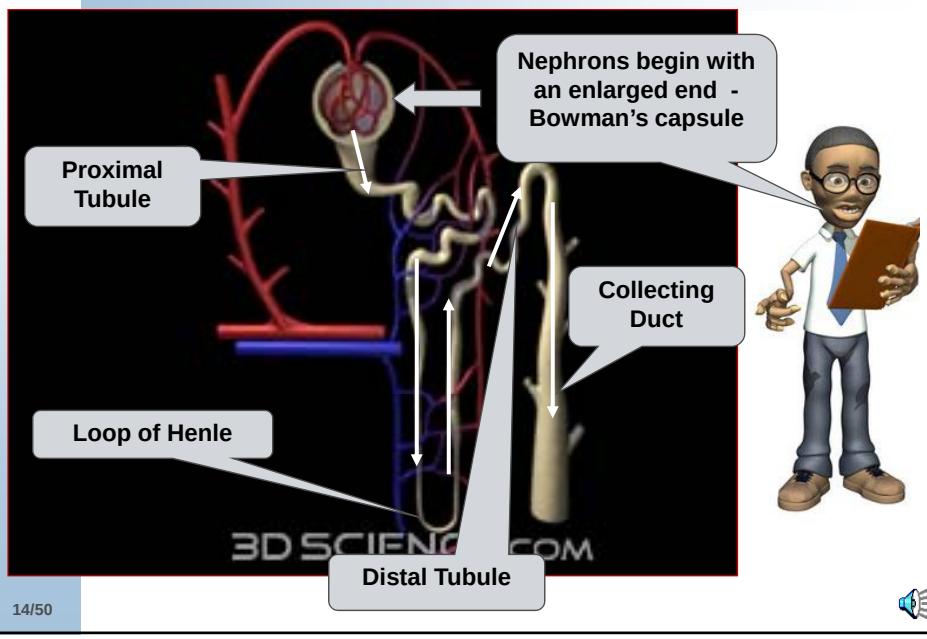
12/50

Location of Nephrons

The nephrons are tubular structures, which are the functional unit of the kidneys. There are over 1 million in each kidney. All the nephrons drain towards the center of the kidney into the collecting duct system. The nephron perfoms almost all of the kidneys functions, including reabsorption and secretion of certain solutes and ions. Nephrons are classified into two groups:(1) The Juxtamedullary apparatus extends into the medulla, and (2) Cortical, which do not extend into medulla.

13/50

Structure of Nephrons



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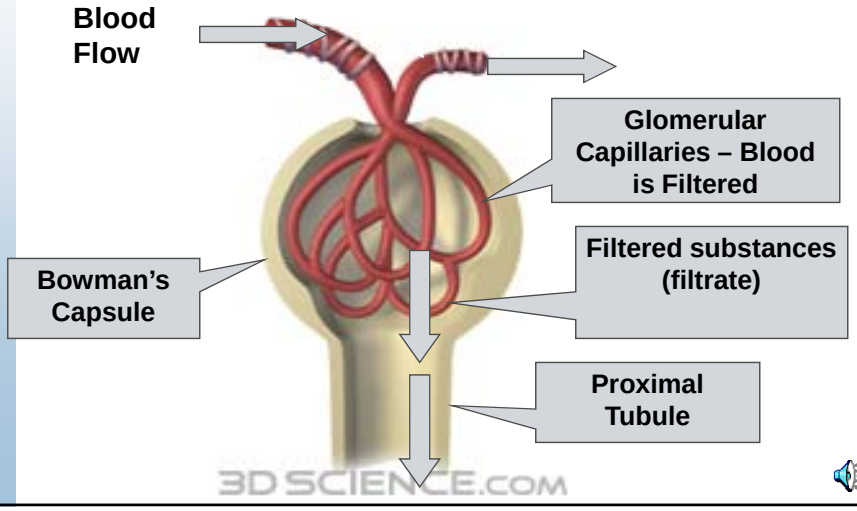
Renal Corpuscle

The renal corpuscle is made up of Bowman's Capsule and the glomerulus. The renal corpuscle connects the nephron to the glomerulus, which is a specialized capillary.



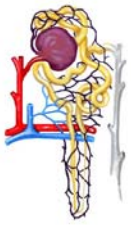
15/50

Vasa Recta

In addition to the glomerulus, a specialized set of vessels, the Vasa recta, surround the Loop of Henle. These vessels function to maintain the gradients necessary for countercurrent exchange.

16/50

Functional Processes of the Nephron and Kidney

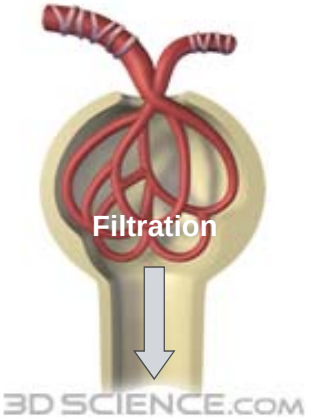


1. Filtration and Reabsorption
2. Secretion
3. Excretion

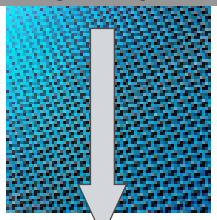
17/50

Filtration

Filtration in the kidney refers to the movement of substances from the glomerular capillary into the nephron. This is due to the pressure exerted by the blood entering Bowman's Capsule, which forces water and dissolved components through the glomerulus to form filtrate.



Proteins and cells are too large to filter through the pores.



Glucose, water, sodium are filtered through the pores into nephrons.

18/50

Question: Challenge

What is the vasa recta?

The vasa recta is a specialized set of vessels that surround the Loop of Henle. These vessels function to maintain the gradients necessary for countercurrent exchange.

19/50

Reabsorption

Reabsorption is the process whereby the filtrate produced in the glomerulus is reabsorbed through the renal tubule. Approximately 99% of all the filtrate is reabsorbed and this includes: water, sodium, glucose, magnesium, etc. The reabsorption process is specific to the changing needs of the body.

20/50

Secretion

Tubular secretion performs the opposite function of reabsorption. Specifically, it adds materials to the filtrate from the bloodstream. These materials are usually unwanted substances, such as H+ and toxins, as well as urea.

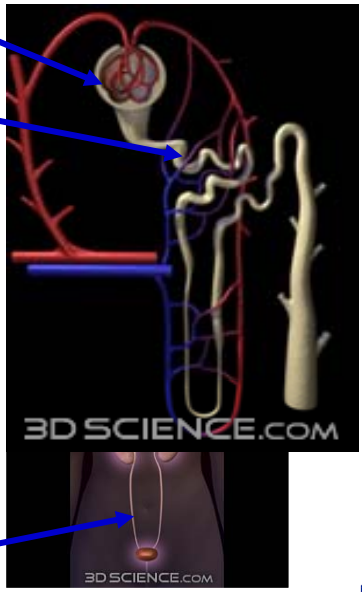
21/50

Excretion

Glomerulus

Nephron

Excretion is the elimination of urine from the body. Urine formation actually begins with filtrate formation in the glomerulus; a total of 180 L/day is filtered. Next, approximately 99% of the filtrate is reabsorbed. The filtrate to be excreted as urine is transported through the minor and major calyx and the renal pelvis into the ureters and bladder, to be eliminated through the urethra.

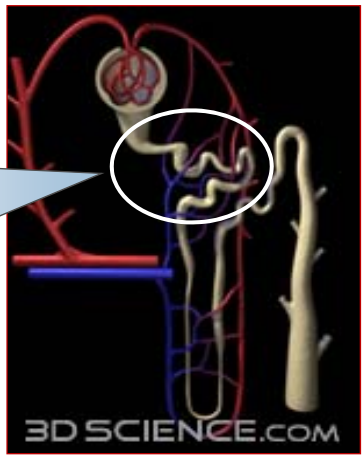


Ureters

22/50

Function of the Proximal Tubule

The **Proximal Tubule is responsible for reabsorption.** Normally, 100% of the filtered glucose is reabsorbed. The proximal tubule contains epithelial cells with microvilli, which increase the surface area for reabsorption. This fluid in the proximal tubule is isotonic compared to plasma.

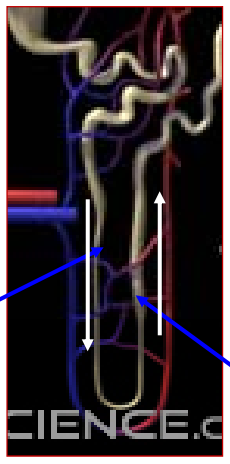


23/50

Function of the Loop of Henle

The Loop of Henle can be divided into 2 functional regions: Descending Limb and the Ascending Limb. In the **Descending Limb**, fluid travels down the descending limb towards the medulla. Water moves out of the descending limb, resulting in hyper-osmotic fluid.

In the **Ascending Limb**, fluid travels towards the cortex. In this region of the nephron, Na+ and Cl- are actively transported out of the limb. This leads to dilute or hypo-osmotic fluid entering the collecting tubule.



Descending Limb

Ascending Limb

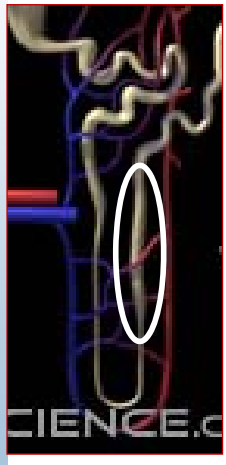
24/50

Regulation of Urine Concentration and Volume

1. Urine Concentration
2. Hormones Involved

25/50

Dilute Urine

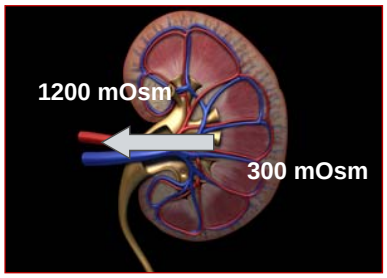


When there are no hormones released for reabsorption, a large volume of dilute urine is produced. This occurs by the nephron containing dilute fluid, after the ascending limb, which then proceeds out of the kidney for excretion.

26/50

Processes to Concentrate Urine

Increasing Osmolarity from the Cortex to the Medulla



During times of low water intake, the kidneys can conserve water by increasing the volume of reabsorbed fluid. This is accomplished by the Countercurrent Mechanism. The countercurrent mechanism establishes an osmolarity gradient in which the osmolarity increases from the cortex towards the medulla. The maximum osmolarity of 1200 mOsm occurs in the Loop of Henle and, as the flitrate passes through the collecting tubule, water moves out into the interstitial fluid space and eventually returns to the rest of the body.

27/50

Question: Challenge

What is the countercurrent mechanism in nephron physiology?

The countercurrent mechanism establishes an osmolarity gradient in which the osmolarity increases from the cortex towards the medulla. The maximum osmolarity of 1200 mOsm occurs in the Loop of Henle and, as the flitrate passes through the collecting tubule, water moves out into the interstitial fluid space and eventually returns to the rest of the body.

28/50

Antidiuretic Hormone (ADH)

Antidiuretic hormone, or vasopressin, is a hormone released from the posterior pituitary gland to act on the kidneys. When water must be conserved, ADH is released and causes water channels to be inserted, and this leads to water reabsorption from the distal tubule and the collecting tubule.

29/50

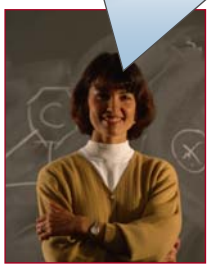
Aldosterone

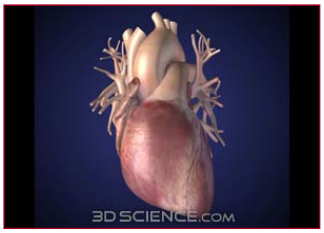
Aldosterone is released from the adrenal glands (which are attached to the kidneys), specifically from the adrenal cortex. Aldosterone causes the kidneys to increase sodium and water reabsorption, which leads to an increase in blood volume and blood pressure.

30/50

Atrial Natriuretic Hormone (ANH)

The **Atrial natriuretic hormone** serves as a signal from the heart to the kidneys. It is released from the atria when blood pressure is high, and it reduces water reabsorption in the kidneys. As more water is excreted, this results in a decrease in blood volume and a subsequent decrease in blood pressure.





31/50

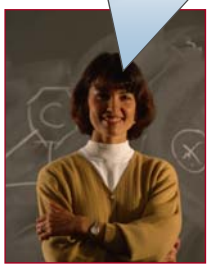
Urine Content

1. **Normal Components of Urine**
2. **Tubular Maximum**

32/50

Substances Normally Present in Urine

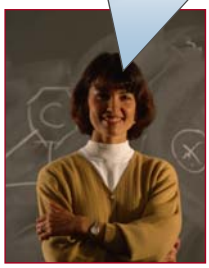
Urine is a highly regulated fluid; it is normally bright yellow and normally made up of the following: (1) 95% or more Water, (2) Sodium, (3) Potassium, (4) Sulfur, (5) Hydrogen Ions, (6) Urea, (7) Creatinine, and (8) Ammonia.



33/50

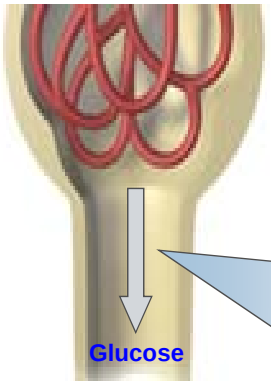
Substances Not Normally Present in Urine

Normally, the urine should not contain glucose, proteins, or red blood cells. Proteins and red blood cells are normally too large to leave the glomerular blood flow. Discoloration of the urine or the presence of protein and glucose is a sign of abnormal function.



34/50

Tubular Maximum

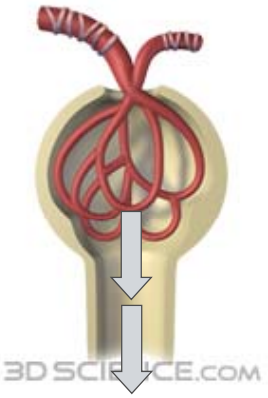


Tubular reabsorption of molecules and ions occurs at a maximum rate. The protein mechanisms involved in reabsorbing a molecule, such as glucose, can only reabsorb glucose at a certain amount per unit of time. If the blood concentration is too high, some fraction of the glucose will be excreted out of the body. In uncontrolled diabetes, for example, excess glucose in the bloodstream will lead to glucose being excreted in the urine.

35/50

Diabetes and Tubular Maximum

In uncontrolled diabetes, higher than normal blood glucose levels occur. This leads to greater than normal glucose being filtered in the glomerulus. Therefore, glucose levels in the nephron exceed tubular maximum and this causes glucose to be excreted in the urine. The excreted glucose can be easily detected on urine test strips.



Glucose Excreted in the Urine

36/50

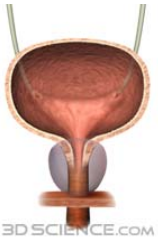
Question: Challenge

What is meant by tubular maximum?

Tubular reabsorption of molecules and ions occurs at a maximum rate. The protein mechanisms involved in reabsorbing a molecule, such as glucose, can only reabsorb glucose at a certain amount per unit of time. If the blood concentration is too high, some fraction of the glucose will be excreted out of the body. In uncontrolled diabetes, for example, excess glucose in the bloodstream will lead to glucose being excreted in the urine.

37/50

Urine Elimination



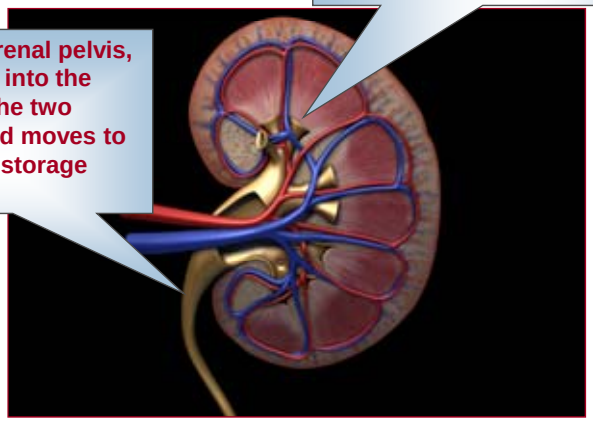
1. **Bladder**
2. **Micturition Reflex**

38/50

Kidneys and Ureters

Fluid drains from the nephrons into the minor and major calyx and, finally, into the renal pelvis.

Next, from the renal pelvis, the fluid drains into the ureters. From the two ureters, the fluid moves to the bladder for storage until excretion.

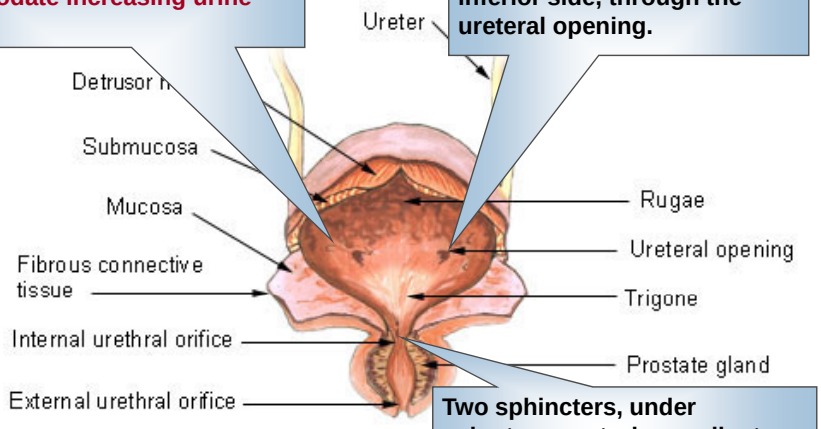


39/50

Bladder Function

The bladder stores up to 1L of fluid and can stretch to accommodate increasing urine volume.

The ureters open into the bladder in the posterior/ inferior side, through the ureteral opening.

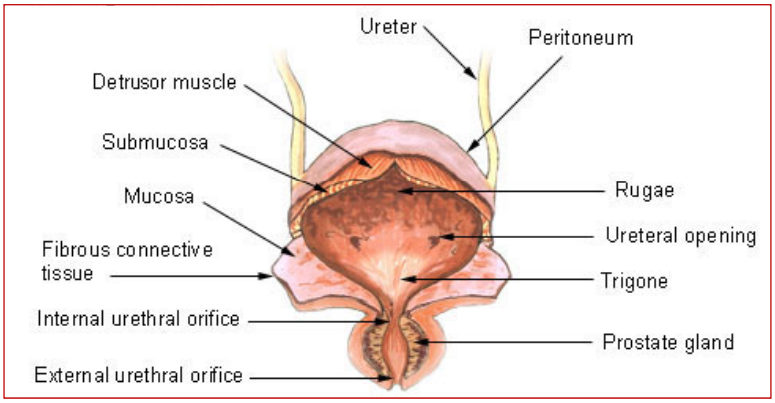


Two sphincters, under voluntary control, coordinate the release of urine from the bladder into the urethra.

40/50

Micturition Reflex

The micturition reflex refers to the processing of information sent from stretch receptors in the bladder (due to the bladder filling) to the lower region of the spinal cord. This impulse then passes to the cortex where they initiate a subconscious desire to urinate.



41/50

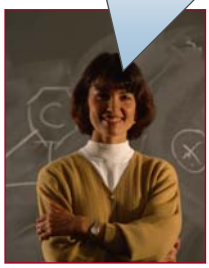
Kidney Function Tests and Dialysis

1. **Kidney Function tests**
2. **Kidney Transplant**

42/50

Typical Kidney Function Tests

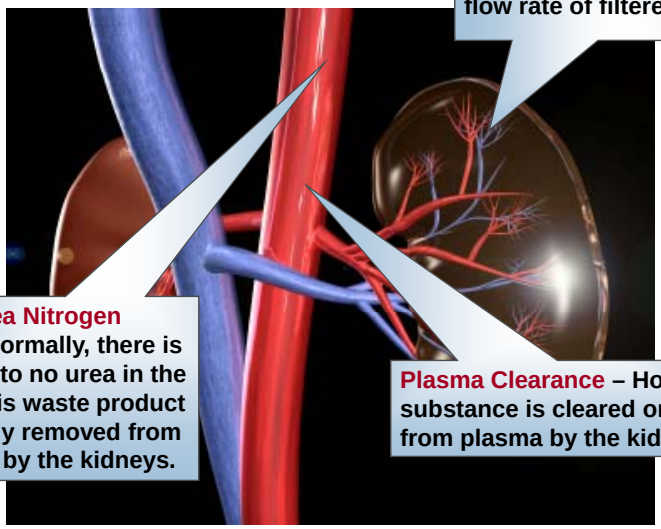
A **urinalysis** is a common test used in the doctor's office as part of yearly physicals or if a problem is suspected. A urinalysis tests for electrolyte levels and for the presence of proteins, glucose, blood cells, bacteria and immune cells. This test, along with others, can be used to asses overall kidney function.



43/50

Typical Kidney Function Tests (Continued)

Glomerular Filtration Rate (GFR) – is a measure of the flow rate of filtered fluid.



Blood Urea Nitrogen (BUN) – Normally, there is very little to no urea in the blood. This waste product is normally removed from the blood by the kidneys.

Plasma Clearance – How quickly substance is cleared or removed from plasma by the kidneys.

44/50

Kidney Donation and Transplant

Fact: Only one kidney is needed for life.

Approximately 10,000 kidney transplants are done in the U.S. each year.

People have the opportunity to make a choice to donate a kidney to another individual.

People may need a kidney transplant due to renal failure or severe glomerular damage.

45/50

Kidney Dialysis

Dialysis is an artificial means of filtering the blood. Blood flows through specialized membranes, similar in principle to glomerulur filtration. Waste products are filtered out and then the blood is returned into the patient's circulation.

46/50

Question: Challenge

Name 3 common kidney function tests.

(1) Blood Urea Nitrogen (BUN) – Normally, there is very little to no urea in the blood. This waste product is normally removed from the blood by the kidneys

(2) Plasma Clearance – How quickly substance is cleared or removed from plasma by the kidneys

(3) Glomerular Filtration Rate (GFR) is a measure of the flow rate of filtered fluid.

47/50

Learning Summary

Filtration, reabsorption, secretion, and excretion are the 4 major important renal functions.

BUN, plasma clearance, and GFR are several functional tests used to assess kidney function.

Urine formation begins in the kidneys with elimination occurring through the ureters, bladder, and urethra.

The renal system closely regulates blood volume and concentration.

Nephrons are the functional units of the kidneys.

48/50

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Congratulations

You have successfully completed the tutorial

Kidney and Nephronal Physiology

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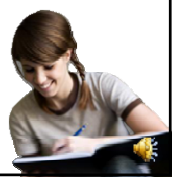
What's Next …

Step 1: Concepts – Core Tutorial (Just Completed)

→ **Step 2: Practice – Interactive Problem Drill**

Step 3: Recap – Super Review Cheat Sheet

Go for it!



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