## Terms - Alphabetical

**Aquaporins** – A membrane protein that allows the transport of water across a cell membrane

**Calcitriol** – Active form of Vitamin D

**Defecation** – Removal of feces

**Detrusor Muscle** – Smooth muscle in the wall of the bladder

**Internal Urethral Sphincter** – A ring of muscle that controls the flow of urine

**Juxtaglomerular Cells** – Cells in the kidney that synthesize, store, and secretes renin when blood pressure decreases

**Erythropoietin** – Stimulates bone marrow to produce red blood cells

**Excretion** – Remove urine from body

**External Urethral Sphincter** -A ring of muscle that can be voluntarily controlled to contract and prevent urination

**Macula Densa** – An area of cells that line the upper portion of the ascending loop of henle that detects sodium levels and regulated blood vessel diameter to regulate blood pressure

**Nephron** – The functional unit of the kidney

## Terms - Alphabetical (cont)

**Peritubular Capillaries** – Small blood vessels that surround the nephron

**Renal Capsule** – Outermost connective tissue layer of the kidney

**Rugae** – Folds in the stomach lining – is collapsed and stretched out as bladder fills

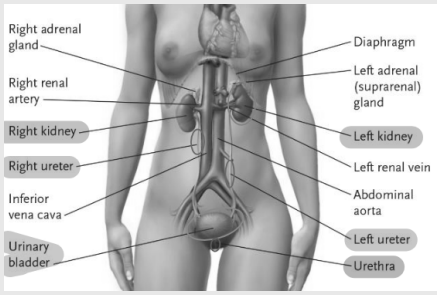
**Transitional Epithelium** – Cells that can change shape

## Overview

• Regulates blood water and ion composition
• Excretes waste products of metabolism
• The kidneys are the most important regulator of
blood pressure.
• Produces renin – renin-angiotensin system
• Regulates blood pH by excreting excess H+ ions
• The kidneys also release two hormones:
**Calcitriol** – tells small intestine to make calcium
**Erythropoietin**

Increase in salt -> increases water -> Increases blood volume -> increases blood pressure

## Organs




## Organs

**2 Kidneys** – Bean shaped, where urine is formed
•Regulates blood volume and blood pressure
•Produce hormones
•Excrete wastes

**2 Ureters** – Muscular tubes that carry urine from kidneys to bladder

**1 Bladder** – Expandable organ that stores urine until released from the body

**1 Urethra** – Tube that carries urine from bladder to outside of the body

**Note: Highlighted in the picture above.**

## Kidneys

•Primary organ of excretion

•Covered by renal capsule

•Adipose tissue on outside

•**Renal Medulla** – Middle Layer

• **Renal Cortex** – Outer Layer

•**Renal Pelvis** – Forms ureter

•Renal Calyces

## Layers of the Bladder Wall

*Stretchy as it fills with urine*

**Inner mucosal layer** – Cubed shaped cells stretch and flatten

•Includes transitional epithelium

•Forms folds or rugae

**Middle muscular layer**

•Three layers of smooth muscle

•Called detrusor muscle

**Outer layer**

• Superior surface – serous membrane of peritoneum

• Remaining surface – covered by fibrous coating

## Urethra

**Internal Urethral Sphincter** – ring of muscle that opens and closes

•Smooth muscle surrounding the opening to the urethra

•Opening and closing is under **involuntary control**

## Urethra (cont)

**External Urethral Sphincter**

•Skeletal muscle surrounding the urethra below the internal urethral sphincter

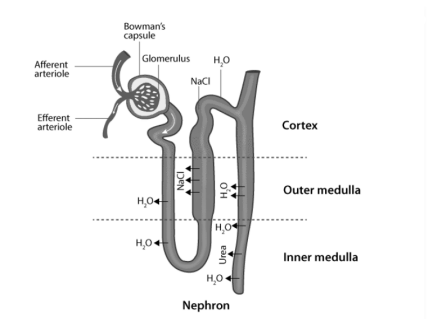
•Under **voluntary control**

## Excretion

Mostly of nitrogenous wastes (metabolic wastes):

> •Urea made by the break down of amino acids
>
> •Uric acid made by the break down of nucleotides
>
> •Creatinine made by muscle cells from the breakdown of creatine phosphate

## Nephrons




• Are the structural and functional units of the kidney. Each kidney has over 1 million of these units.

• Produces urine

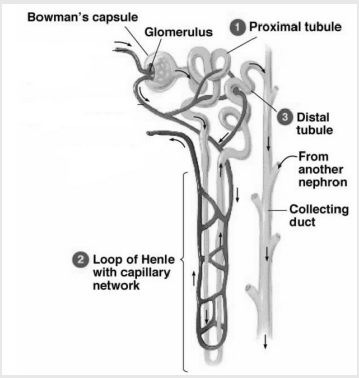
• Has blood supply with 2 capillary areas (glomerular and peritubular)

• Each nephron consists of a **glomerulus**, which is a knot of capillaries and a **renal tubule**.

• The tubule forms a cup shape around the glomerulus – called the **glomerular capsule** or **Bowman's capsule**

Glomerular capsule/Bowman's capsule is **different** from glomerulus.

## Anatomy of a Nephron




## Anatomy of a Nephron

**Glomerulus** – a knot of capillaries inside the glomerular capsule where pores produce a blood filtrate – located in the renal cortex.

**Proximal Convoluted Tubule** – Epithelial layer with a brush border of microvilli to allow reabsorption of filtrate components.

**Loop of Henle** – U-shaped structure that has a descending limb to allow water to leave and an ascending limb that pushes out salt.

## Anatomy of a Nephron (cont)

**Distal Convoluted Tubule** – Made of epithelial cells rich in mitochondria and thus is important for movement of molecules from the blood to the tubule (tubular secretion). Waste products are actively transported out of blood capillaries and into the tubule.

**Collecting Ducts** – Several nephrons share a collecting duct which serves to carry urine to the renal pelvis. Water continues to leave through the collecting ducts to be reabsorbed into the blood if ADH is present.

## Functions of the Nephron

**Filtration** – Fluid from the glomerular capillaries into Bowman's capsule.

**Reabsorption** - Fluid moves from nephron tubule back into the blood stream.

**Secretion** - Fluid moves from peritubular capillaries into the nephron tubule.

**Excretion** - Fluid moves from the nephron tubules to bladder to outside of the body.

Amount filtered – Amount reabsorbed + Amount secreted
= Amount of substance excreted.

## Formation of Urine

Formation of Urine

- 3 Processes:
- Glomerular Filtration
- Tubular Reabsorption
- Tubular Secretion

## Formation of Urine I

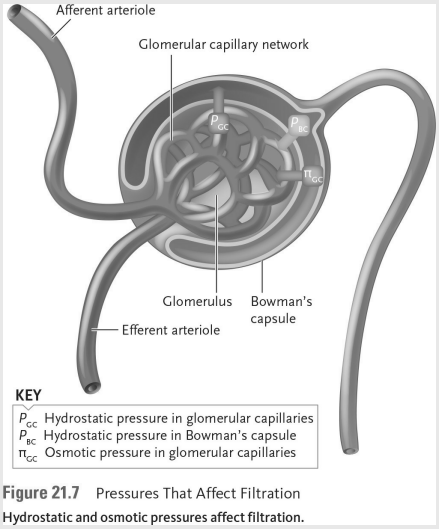



**Figure 21.7** Pressures That Affect Filtration
**Hydrostatic and osmotic pressures affect filtration.**

**Glomerular Filtration:**

• Filtration occurs in the renal corpuscles
• Water and small molecules move from the glomerulus to the Bowman's capsule while large molecules and blood cells remain in the glomerular blood.
- Afferent and efferent arteriole
• Substances are filtered out due to **high blood pressure**
• This pushes all plasma molecules (Water, Na+, Cl, glucose, nutrients) out of the capillaries & into the capsule. This is **Filtrate**.

## Formation of Urine II

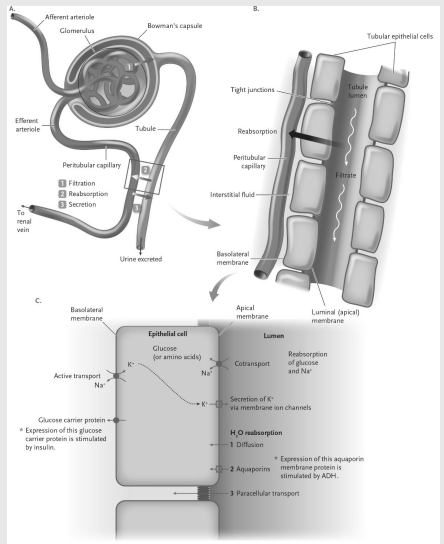



**Figure 21.9** Movement across the Tubule Epithelial Cell Membranes
(A) Filtration, reabsorption, and secretion. (B) Substances that are reabsorbed must move from the tubule lumen, through the epithelial cell, and into the bloodstream. (C) Substances cross the tubule epithelial cell membrane through various membrane transport proteins, carriers, or via diffusion.

## Formation of Urine II

**Tubular Reabsorption:**

• Glomerular Capsule then becomes the Proximal Convoluted Tubule.
• Surrounded by peritubular capillary network
• Microvilli line lumen tubules to increase surface area
• 60-70% of reabsorption occurs in the proximal tubule for reabsorption
- Water, nutrients, salt, are reabsorbed
- Most metabolic wastes, some salt and some water are not reabsorbed
• Reabsorption can occur by diffusion, active transport or facilitated transport

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## Formation of Urine II (cont)

**Loop of Henle:**

In the **Renal Medulla**
• U-Shaped tubule
• Descending and ascending limb
• Mainly water and salt movement
• In the descending limb it's highly permeable to water due to aquaporins
• Water moves out of the tubule via osmosis
• In the ascending limb, the pores are designed so water cannot move through it
- Salt and K+ is actively transported out.

Note: Amino acids and Glucose are 100% reabsorbed
Glucose is not reabsorbed with high blood sugars or diabetes

## Formation of Urine III

**Tubular Secretion:**

•Distal Convoluted Tubule
•Hormonal regulation affects the remaining reabsorption of ions and water.
•Potassium, H+ ions, penicillin, creatinine (waste product) are actively transported out of the blood capillaries and into the tubule.
•Uric acid is also secreted into the tubules to be excreted in the urine. An excess of uric acid can cause gout or kidney stones

## Formation of Urine III (cont)

**Collecting Duct:**

•The distal tubule joins with the other distal tubules to form a collecting duct
•Water continues to leave through the collecting duct to be reabsorbed into the blood if ADH is present

## Antidiuretic Hormone

• Water absorption is regulated by antidiuretic hormone (ADH) which opens up more aquaporins in the collecting duct

• ADH is secreted by the pituitary gland when our fluid intake is low – at night, in the summer

## Juxtaglomerular Cells

• In the arteriole wall the granular cells – **Juxtaglomerular cells (JG)** – are enlarged smooth muscle cells that have secretory granules that contain the hormone renin – part of the renin-angiotensin system (RAS) – It increases Blood Pressure (increase salt and water)

• The JG cells are mechanoreceptors (they sense BP) in the afferent arteriole – responds to changes in blood pressure.

## Juxtaglomerular Cells (cont)

• The **macula densa** is a group of tall, closely packed cells located adjacent to the JG cells.

• The macula densa cells are chemoreceptors that respond to changes in NaCl content of the filtrate

• These cells work in tandem and are critical regulators of the blood pressure
- Measures sodium content
- Responds to changes in salt concentration

## Maintain acid-base Balance of Blood

•Homeostatic mechanism
•The kidneys maintain balance by excreting hydrogen ions and reabsorbing the bicarbonate ions
•This acid-base balance helps maintain a blood pH of 7.4.
•Narrow Range -> 7.35 – 7.45

**How is it Maintained:**

•Buffers are chemical or a combination of chemicals that can take up excess H+ (more acidic in blood) or excess OH-(more basic in blood)
•The respiratory centre in the brain can increase breathing rate if the buffers cannot maintain pH. The kidneys are responsible for maintaining blood pH.

## Kidney Disease

•Chronic Kidney Disease (CKD) is the most common disease and leads to kidney failure

•Primary causes are hypertension and diabetes.

• CKD is characterized by a gradual loss of kidney function

• Kidney function can be determined by the **glomerular filtration rate** (GFR). As kidney disease progresses, GFR decreases.

• Kidney function can also be determined by testing for urine albumin

• If urine contains protein, kidney damage is present

• Once kidney failure occurs, the only treatment options are **dialysis** or a **kidney transplant**.

## Kidney Stones

• Kidney Stones affect 10% of the population

• Most common cause is excess uric acid or calcium-oxalate precipitation• Most common cause is excess uric acid or calcium-oxalate precipitation

• Small stones often pass without treatment. Large kidney stones may need to be removed with surgery

## Overall Process

• Glomerular capsule holds the knot of capillaries called **glomerulus.**
• The capillaries allow fluid, waste product, ions, etc., to pass from the blood into the capsule. This is called **filtrate.** It's sent along the long renal tubule. – Glomerular Filtration

• The filtrate flows through the **proximal convoluted tubule (Renal Cortex)**that is made up of epithelial layer with a border of microvilli to allow reabsorption of filtrate components.
• Filtrate continues down to the **Loop of henle (dips into the Renal Medulla then back to the cortex)** where the descending limb pushes water out and the ascending limb pushes salt out. – **Tubular Reabsorption**

• Remaining filtrate goes to the **distal convoluted tubule and collecting ducts** where the filtrate is now officially urine. - **Tubular Secretion**

## Extra terms

**Aldosterone** - A steroid hormone made by the adrenal cortex (the outer layer of the adrenal gland). It helps control the balance of water and salts in the kidney by keeping sodium in and releasing potassium from the body. Too much aldosterone can cause high blood pressure and a build-up of fluid in body tissues.

**Angiotensin II** - Causes the muscular walls of small arteries (arterioles) to constrict (narrow), increasing blood pressure. Angiotensin II also triggers your adrenal glands to release aldosterone and your pituitary gland to release antidiuretic hormone

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