

The Urinary System
Presented By:
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Kidney Functions

- Filter 200 liters of blood daily, allowing toxins, metabolic wastes, and excess ions to leave the body in urine
- Regulate volume and chemical makeup of the blood
- Maintain the proper balance between water and salts, and acids and bases

Other Renal Functions

- Gluconeogenesis during prolonged fasting
- Production of rennin to help regulate blood pressure and erythropoietin to stimulate RBC production
- Activation of vitamin D

Other Urinary System Organs

- Urinary bladder – provides a temporary storage reservoir for urine
- Paired ureters – transport urine from the kidneys to the bladder
- Urethra – transports urine from the bladder out of the body

Kidney Location and External Anatomy

- The bean-shaped kidneys lie in a retroperitoneal position in the superior lumbar region and extend from the twelfth thoracic to the third lumbar vertebrae
- The right kidney is lower than the left because it is crowded by the liver
- The lateral surface is convex and the medial surface is concave, with a vertical cleft called the renal hilus leading to the renal sinus
- Ureters, renal blood vessels, lymphatics, and nerves enter and exit at the hilus

Layers of Tissue Supporting the Kidney

- Renal capsule – fibrous capsule that prevents kidney infection
- Adipose capsule – fatty mass that cushions the kidney and helps attach it to the body wall

- Renal fascia – outer layer of dense fibrous connective tissue that anchors the kidney

Kidney Location and External Anatomy

Internal Anatomy

- A frontal section shows three distinct regions
 - Cortex – the light colored, granular superficial region
 - Medulla – exhibits cone-shaped medullary (renal) pyramids
 - Pyramids are made up of parallel bundles of urine-collecting tubules
 - Renal columns are inward extensions of cortical tissue that separate the pyramids
 - The medullary pyramid and its surrounding capsule constitute a lobe

Internal Anatomy

- Renal pelvis – flat, funnel-shaped tube lateral to the hilus within the renal sinus

Internal Anatomy

- Major calyces – large branches of the renal pelvis
 - Collect urine draining from papillae
 - Empty urine into the pelvis
- Urine flows through the pelvis and ureters to the bladder

Internal Anatomy

Blood and Nerve Supply

- Approximately one-fourth (1200 ml) of systemic cardiac output flows through the kidneys each minute
- Arterial flow into and venous flow out of the kidneys follow similar paths
- The nerve supply is via the renal plexus

The Nephron

- Nephrons are the structural and functional units that form urine, consisting of:
 - Glomerulus – a tuft of capillaries associated with a renal tubule
 - Glomerular (Bowman's) capsule – blind, cup-shaped end of a renal tubule that completely surrounds the glomerulus

The Nephron

- Renal corpuscle – the glomerulus and its Bowman's capsule
- Glomerular endothelium – fenestrated epithelium that allows solute-rich, virtually protein-free filtrate to pass from the blood into the

glomerular capsule

The Nephron

Anatomy of the Glomerular Capsule

- The external parietal layer is a structural layer
- The visceral layer consists of modified, branching epithelial podocytes
- Extensions of the octopus-like podocytes terminate in foot processes
- Filtration slits – openings between the foot processes that allow filtrate to pass into the capsular space

Renal Tubule

- Proximal convoluted tubule (PCT) – composed of cuboidal cells with numerous microvilli and mitochondria
 - Reabsorbs water and solutes from filtrate and secretes substances into it

Renal Tubule

- Loop of Henle – a hairpin-shaped loop of the renal tubule
 - Proximal part is similar to the proximal convoluted tubule
 - Proximal part is followed by the thin segment (simple squamous cells) and the thick segment (cuboidal to columnar cells)
- Distal convoluted tubule (DCT) – cuboidal cells without microvilli that function more in secretion than reabsorption

Renal Tubule

Connecting Tubules

- The distal portion of the distal convoluted tubule nearer to the collecting ducts

Connecting Tubules

- Two important cell types are found here
 - Intercalated cells
 - Cuboidal cells with microvilli
 - Function in maintaining the acid-base balance of the body
 - Principal cells
 - Cuboidal cells without microvilli
 - Help maintain the body's water and salt balance

Nephrons

- Cortical nephrons – 85% of nephrons; located in the cortex
- Juxtamedullary nephrons:
 - Are located at the cortex-medulla junction

- Have loops of Henle that deeply invade the medulla
- Have extensive thin segments
- Are involved in the production of concentrated urine

Nephrons

Capillary Beds of the Nephron

- Every nephron has two capillary beds
 - Glomerulus
 - Peritubular capillaries
- Each glomerulus is:
 - Fed by an afferent arteriole
 - Drained by an efferent arteriole

Capillary Beds of the Nephron

- Blood pressure in the glomerulus is high because:
 - Arterioles are high-resistance vessels
 - Afferent arterioles have larger diameters than efferent arterioles
- Fluids and solutes are forced out of the blood throughout the entire length of the glomerulus

Capillary Beds

- Peritubular beds are low-pressure, porous capillaries adapted for absorption that:
 - Arise from efferent arterioles
 - Cling to adjacent renal tubules
 - Empty into the renal venous system
- Vasa recta – long, straight efferent arterioles of juxtamedullary nephrons

Capillary Beds

Vascular Resistance in Microcirculation

- Afferent and efferent arterioles offer high resistance to blood flow
- Blood pressure declines from 95mm Hg in renal arteries to 8 mm Hg in renal veins

Vascular Resistance in Microcirculation

- Resistance in afferent arterioles:
 - Protects glomeruli from fluctuations in systemic blood pressure
- Resistance in efferent arterioles:
 - Reinforces high glomerular pressure
 - Reduces hydrostatic pressure in peritubular capillaries

Juxtaglomerular Apparatus (JGA)

- Where the distal tubule lies against the afferent (sometimes efferent)

arteriole

- Arteriole walls have juxtaglomerular (JG) cells
 - Enlarged, smooth muscle cells
 - Have secretory granules containing renin
 - Act as mechanoreceptors

Juxtaglomerular Apparatus (JGA)

- Macula densa
 - Tall, closely packed distal tubule cells
 - Lie adjacent to JG cells
 - Function as chemoreceptors or osmoreceptors
- Mesangial cells:
 - Have phagocytic and contractile properties
 - Influence capillary filtration

Juxtaglomerular Apparatus (JGA)

Filtration Membrane

- Filter that lies between the blood and the interior of the glomerular capsule
- It is composed of three layers
 - Fenestrated endothelium of the glomerular capillaries
 - Visceral membrane of the glomerular capsule (podocytes)
 - Basement membrane composed of fused basal laminae of the other layers

Filtration Membrane

Filtration Membrane

Mechanisms of Urine Formation

- The kidneys filter the body's entire plasma volume 60 times each day
- The filtrate:
 - Contains all plasma components except protein
 - Loses water, nutrients, and essential ions to become urine
- The urine contains metabolic wastes and unneeded substances

Mechanisms of Urine Formation

- Urine formation and adjustment of blood composition involves three major processes
 - Glomerular filtration
 - Tubular reabsorption
 - Secretion

Glomerular Filtration

- Principles of fluid dynamics that account for tissue fluid in all

capillary beds apply to the glomerulus as well

- The glomerulus is more efficient than other capillary beds because:
 - Its filtration membrane is significantly more permeable
 - Glomerular blood pressure is higher
 - It has a higher net filtration pressure
- Plasma proteins are not filtered and are used to maintain oncotic pressure of the blood

Net Filtration Pressure (NFP)

- The pressure responsible for filtrate formation
- NFP equals the glomerular hydrostatic pressure (HP_g) minus the oncotic pressure of glomerular blood (OP_g) combined with the capsular hydrostatic pressure (HP_c)

Glomerular Filtration Rate (GFR)

- The total amount of filtrate formed per minute by the kidneys
- Factors governing filtration rate at the capillary bed are:
 - Total surface area available for filtration
 - Filtration membrane permeability
 - Net filtration pressure

Glomerular Filtration Rate (GFR)

- GFR is directly proportional to the NFP
- Changes in GFR normally result from changes in glomerular blood pressure

Glomerular Filtration Rate (GFR)

Regulation of Glomerular Filtration

- If the GFR is too high:
 - Needed substances cannot be reabsorbed quickly enough and are lost in the urine
- If the GFR is too low:
 - Everything is reabsorbed, including wastes that are normally disposed of

Regulation of Glomerular Filtration

- Three mechanisms control the GFR
 - Renal autoregulation (intrinsic system)
 - Neural controls
 - Hormonal mechanism (the renin-angiotensin system)

Intrinsic Controls

- Under normal conditions, renal autoregulation maintains a nearly constant glomerular filtration rate

- Autoregulation entails two types of control
 - Myogenic – responds to changes in pressure in the renal blood vessels
 - Flow-dependent tubuloglomerular feedback – senses changes in the juxtaglomerular apparatus

Extrinsic Controls

- When the sympathetic nervous system is at rest:
 - Renal blood vessels are maximally dilated
 - Autoregulation mechanisms prevail

Extrinsic Controls

- Under stress:
 - Norepinephrine is released by the sympathetic nervous system
 - Epinephrine is released by the adrenal medulla
 - Afferent arterioles constrict and filtration is inhibited
- The sympathetic nervous system also stimulates the renin-angiotensin mechanism

Renin-Angiotensin Mechanism

- Is triggered when the JG cells release renin
- Renin acts on angiotensinogen to release angiotensin I
- Angiotensin I is converted to angiotensin II
- Angiotensin II:
 - Causes mean arterial pressure to rise
 - Stimulates the adrenal cortex to release aldosterone
- As a result, both systemic and glomerular hydrostatic pressure rise

Renin Release

- Renin release is triggered by:
 - Reduced stretch of the granular JG cells
 - Stimulation of the JG cells by activated macula densa cells
 - Direct stimulation of the JG cells via β_1 -adrenergic receptors by renal nerves
 - Angiotensin II