Urinary System
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Urinary System Objectives

• Describe the histologic features of the kidneys, ureters and bladder.
• Describe the structures that comprise the renal filtration barrier and their role in formation of glomerular filtrate (provisional urine).
• Describe the role of the loop of Henle in concentrating urine.
More Urinary System Objectives

• Describe how aldosterone and antidiuretic hormone (ADH) affect the renal tubules.

• Trace the pathway of urine flow along the nephron and urinary tract.
Urinary System Lecture Outline

• Introduction
• Kidneys
• Ureters
• Urinary bladder
• Urethra
Urinary System Lecture Outline

• Introduction
Functions of the Urinary System

• Filtration & excretion of cellular wastes from blood

• Regulation of fluid and electrolyte balance by selective reabsorption and excretion of water and solutes

• Production of the hormones renin and erythropoietin
Urinary System Lecture Outline

• Introduction

• Kidneys
  • Anatomic parts
Major Anatomic Parts of the Kidney

Parenchyma
- Cortex
  - Renal corpuscles
  - Medullary rays
- Medulla
  - Renal pyramids
- Renal columns

Renal sinus
- Renal pelvis
- Major and minor calyces
- Nerves and vessels
- Connective tissues
Fibrous capsule
Minor calyces
Blood vessels entering renal parenchyma
Renal sinus
Major calyces
Renal pelvis
Fat in renal sinus
Minor calyces
Ureter
Cortex
Medulla (pyramid)
Papilla of pyramid
Renal column (of Bertin)
Medullary rays
Urinary System Lecture Outline

- Introduction
- Kidneys
  - Anatomic parts
  - Blood flow
Blood Supply to the Kidney

Most important for you to know
Blood Flow in the Kidney

Afferent arteriole

\[ \downarrow \]

Glomerular capillaries

\[ \downarrow \]

Efferent arteriole

or

Peritubular capillaries

Supply cortical nephrons and proximal and distal convoluted tubules

Vasa recta

Supply juxtamedullary nephrons, structures in the medulla, and then loop back to cortex-medullary boundary
Blood Supply to a Renal Corpuscle

- Interlobular artery
  - Afferent arteriole
  - Glomerulus
  - Efferent arteriole

- Cortical nephron
  - Juxtamedullary nephron
- Peritubular capillaries (associated with convoluted tubules)
- Vasa recta (associated with nephron loop)
- Arcuate vessels
- Interlobular vein
- Nephron loop
- Collecting duct
- Cortex
- Medulla
Urinary System Lecture Outline

- Introduction
- Kidneys
  - Anatomic parts
  - Blood flow
  - The corpuscle
What’s a Renal Corpuscle?

A renal corpuscle consists of three things:

**Glomerulus**
- A tuft of capillaries

**Bowman’s capsule**
- The container that surrounds the glomerulus
- Two layers: visceral (inner) and parietal (outer)

**Urinary space**
- The space between the two layers of Bowman’s capsule (where urine collects)
Vascular and urinary poles
Capillaries (blue) and podocytes (green)
Interdigitating secondary foot processes
Glomerular capillaries & podocyte

- Foot processes
- Podocyte

Filtration membrane:
- Basement membrane
- Fenestrated capillary endothelium

Filtration slits

Capillary lumen
Podocytes

- Podocytes have a central cell body with primary processes.
- Each primary process gives rise to secondary processes called pedicels (foot processes) that embrace the glomerular capillaries.
- Foot processes from different podocytes interdigitate. Spaces between pedicels are called filtration slits. A little diaphragm covers each filtration slit.
Mesangial Cells

- In addition to podocytes and glomerular capillary endothelial cells, mesangial cells are a third cell type present in the glomerulus.

- Functions of mesangial cells:
  - Physical support for glomerulus.
  - Phagocytosis of proteins and other debris from the glomerular basal lamina.
  - Secretion of cytokines and other substances for immune defense and repair.
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  • Blood flow
  • The corpuscle
  • The nephron
What’s a nephron?

Nephrons are the functional units of the kidney. They are the things that produce urine.

A nephron includes:

• The renal corpuscle
• Tubules
  • proximal convoluted tubule
  • loop of Henle
  • distal convoluted tubule
This whole thing (including all the tubes except blood vessels) is the nephron!
The three things that comprise the filter are:

- Fenestrated endothelial cells of the glomerular capillaries
- Glomerular basal lamina
- Filtration slits between foot processes (covered with a diaphragm)
Filtration barrier

Filtration slits

Urinary space

Capillary lumen

Fenestrated endothelial cells

Glomerular basal lamina
The Glomerular Basal Lamina

- Made from fused basal laminae of endothelial cells and podocytes.
- Lamina densa is a physical barrier (particles larger than 10 nm can’t easily cross).
- Lamina rara is a charge barrier (negatively charged proteins with a molecular weight greater than albumin can’t easily cross).
How does stuff get from blood into urine?

- Hydrostatic pressure within the capillaries pushes water (and particles of the proper size, weight, and charge) from blood through the GBL into the urinary space.

- Whatever enters the urinary space becomes provisional or temporary urine.

- It will be excreted as urine unless it is reabsorbed in the nephron.
Reabsorption vs. Secretion

- **Reabsorption** means a substance moves from the provisional urine into the blood.
- **Secretion** means a substance moves from blood into urine.
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• Introduction

• Kidneys
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  • Blood flow
  • The glomerulus
  • The nephron
  • The tubules
So many tubules! So little time.

- Proximal convoluted tubule and proximal straight tubule (= thick segment of descending limb)
- Thin segment of loop of Henle
- Distal straight tubule (= thick segment of ascending limb)
- Distal convoluted tubule
Proximal Tubules

• Proximal convoluted tubule merges with Bowman’s capsule, is super long and winds extensively

• Tons of mitochondria (so cells look more eosinophilic than other tubular cells)

• Brush border (microvilli): lumen looks “fuzzy”

• Main job: reabsorption of water, NaCl, glucose and amino acids.
Proximal convoluted tubules
Proximal straight tubule
Microvilli

Mitochondria
A General Principle

- Proximal tubular cells have numerous mitochondria and a basal plasma membrane with many deep invaginations.
- Important general principle: numerous mitochondria + invaginations of basal plasma membrane suggest a cell is involved in active ion transport.
The Loop of Henle

- Loop of Henle is in the medulla and is composed of thick and thin descending and ascending limbs.
- Important because it actively pulls ions out of the urine, creating high osmotic pressure in the connective tissue surrounding the loop.
- With this high osmotic pressure gradient, water passively leaves the urine as it goes through the medulla, creating a concentrated urine and preventing dehydration.
- The excess water is pulled into the vasa recta.
Different Nephrons have Different Loops

Juxtamedullary nephrons
- Close to the border of the cortex and medulla
- Have very long loops of Henle
- They make the connective tissue of the medulla hypertonic (so there’s high osmotic pressure and urine gets concentrated). Yay!

Cortical nephrons
- Located higher in the cortex
- Have very short loops of Henle.
Juxtamedullary nephron (long loop)

Cortical nephron (piddly loop)
Thin Segment of Loop of Henle

- Transition from proximal tubule to thin segment is abrupt.
- Brush border pretty much ends
- Simple squamous epithelium
- Nuclei bulge a little into lumen
- Surrounded by capillaries (vasa recta)
Distal Straight Tubule

- Transition from thin segment to distal straight tubule is abrupt.
- Simple cuboidal epithelium; cells smaller
- Brush border gone
- Re-enters cortex, returns to renal corpuscle and attaches to afferent arteriole at macula densa (function unclear)
- Juxtaglomerular apparatus cells are here too (make the hormone renin, which helps control blood pressure)
Distal straight tubule
Juxtaglomerular apparatus (makes renin) and macula densa (who knows what it does)
Distal Convoluted Tubule

- Begins at vascular pole of renal corpuscle
- Looks like distal straight tubule
- Function: finish concentrating urine
- Aldosterone (a hormone made by the adrenal glands) increases sodium reabsorption by the distal convoluted tubular cells. Water follows (in the collecting duct), and the urine becomes even more concentrated.
Distal convoluted tubules
Collecting Tubules

• Lined by simple cuboidal epithelium
• Cool-looking apical membrane bulges into lumen
• Sensitive to antidiuretic hormone (ADH), which is made by the hypothalamus and stored in the posterior pituitary.
• When there’s ADH around, special aquaporin channels (water channels) open up and allow water to pass through the cells.
• This helps concentrate urine.
Collecting ducts
What happens after the collecting ducts?

- Urine flows from collecting ducts in renal into the minor calyx, to the major calyx and to the renal pelvis.
- The minor and major calyces and renal pelvis are lined by transitional epithelium.
Urine flow from collecting ducts out to ureter

1. Collecting ducts in renal papilla
2. Minor calyx
3. Major calyx
4. Renal pelvis
5. Ureter
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What happens after urine leaves the kidney?
Ureters

• Ureters are paired ducts which conduct urine from the kidney to the bladder.

• Transitional epithelium lines the ureters which is cool, because it’s impermeable to water and ions.

• Two layers of smooth muscle are present in the wall; peristaltic contraction of the smooth muscle moves urine along the ureter.
The mucosa has lots of infoldings!

Ureter: super low-power view
Ureter: super low-power view
Ureter: transitional epithelium
Ureter: Umbrella cells
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• Urinary bladder
Bladder

• Expandable vessel for the storage of urine.
• Transitional epithelium lines the bladder (impermeable to water!)
• Composed of four layers, like ureters.
• Large bundles of smooth muscle in the wall.
Bladder: transitional epithelium and lamina propria
Bladder: muscularis externa (3 layers)
Bladder: umbrella cells
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Urethra

- The urethra conveys urine from the bladder to the exterior.
- Epithelium is variable along its length.
Urethra: Epithelium varies from stratified or pseudostratified columnar to stratified squamous
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