Histology of the Urinary System
Lecture Objectives

- Describe the normal microscopic appearance of the different parts of the kidney including cortex, medulla, juxtaglomerular apparatus and the distribution of the vasculature within the kidney.
- List the different parts of the nephron with the details of each part.
- Describe the microscopical appearance of the ureter, urinary bladder and urethra.
- Compare the histological appearance of the distended and contracted bladder.
Internal Anatomy of the Kidneys

• Parenchyma of kidney
  – Renal cortex = superficial layer of kidney
  – Renal medulla
    • inner portion consisting of 8-18 cone-shaped renal pyramids separated by renal columns
    • renal papilla point toward center of kidney
  – Medullary rays, parallel arrays of tubules penetrate the cortex from the base of the medullary pyramids

• Drainage system fills renal sinus cavity
  – minor & major calyces empty into the renal pelvis which empties into the ureter
  – minor calyces collect urine from the papillary ducts of the papilla
Nephrons

- A *nephron* consists of a renal corpuscle where fluid is filtered, and a renal tubule into which the filtered fluid passes.
- Renal corpuscle = site of plasma filtration
  - glomerulus is capillaries where filtration occurs
  - glomerular (Bowman’s) capsule is double-walled epithelial cup that collects filtrate
Nephrons

• A renal tubule consists of:
  – proximal convoluted tubule (PCT)
  – loop of Henle (nephron loop)
  – distal convoluted tubule (DCT)

• Distal convoluted tubules of several nephrons drain into a single collecting duct and many collecting ducts drain into a small number of papillary ducts.
Nephrons

- The loop of Henle consists of:
  - thick descending limb
  - thin descending limb
  - thin ascending limb
  - thick ascending limb
Nephrons: Types

- There are two types of nephrons that have differing structure and function
  - A cortical nephron
    - glomerulus in the outer portion of the cortex
    - short loop of Henle
      - penetrates only into the outer region of the medulla
  - A juxtamedullary nephron
    - glomerulus deep in the cortex close to the medulla
    - long loop of Henle stretches through the medulla and almost reaches the renal papilla
80-85% of nephrons are cortical nephrons
Renal corpuscles are in outer cortex and loops of Henle lie mainly in cortex
• 15-20% of nephrons are juxtamedullary nephrons
• Renal corpuscles close to medulla and long loops of Henle extend into deepest medulla enabling excretion of dilute or concentrated urine
Renal Corpuscle

- Renal Corpuscle is about 200 μm in diameter
- Consists of:
  - *Bowman’s capsule* surrounds capsular (urinary) space
    - podocytes cover capillaries to form visceral layer
    - simple squamous cells form parietal layer of capsule
  - *Glomerular capillaries* arise from afferent arteriole & form a ball before emptying into efferent arteriole
    - Fenestrated endothelial cells constitute the capillaries
- Renal corpuscle have a *vascular pole* where the afferent arteriole enters and the efferent arteriole leaves, and a *urinary pole* where proximal convoluted tubule begins
Glomerular Capsule

- The *glomerular capsule* consists of visceral and parietal layers.
- The *parietal layer* consists of simple squamous epithelium supported by basal lamina and thin layer of reticular fibers.
  - Near the urinary pole the epithelium becomes cuboidal or low columnar.
- The *visceral layer* consists of modified simple squamous epithelial cells called *podocytes*. 
Glomerular Capsule

- Podocytes have cell body from which arise several primary processes
  - Each primary process gives rise to many secondary processes (pedicels)
  - Only the secondary processes have direct contact with the basal lamina
  - Filtration slits, is a 25 nm wide elongated spaces between the secondary processes
    - Filtration slits are covered by 6 nm thick diaphragm
- A thick basement membrane (0.1 µm) separates the capillaries endothelium and the podocytes
  - Lamina densa covered by lamina rara on each side
  - Basement membrane is selectively permeable for macromolecules
Glomerular Capillaries

- Glomerular capillaries have **mesangial cells** adhere to their walls.
- Mesangial cells are contractile cells and have receptors for angiotensin II, so it can reduce the glomerular flow.
- Mesangial cells contain also receptors for natriuretic factor produced by the cardiac atria cells causing vasodilation and relaxes mesangial cells.
- Mesangial cells also have several functions:
  - Support the glomerulus
  - Produce extracellular matrix
  - Immune response
  - Outside the glomerulus in the vascular pole, form the **extraglomerular mesangial cells**, which is part of the extraglomerular apparatus.
Proximal convoluted tubules

- Longer than the distal convoluted tubule, thus seen more near the renal corpuscle in the cortex
- Consists of **cuboidal cells**
- Acidophilic cytoplasm, numerous elongated mitochondria
- **Brush border**, abundant microvilli
- **Large cells**, 3-5 surround each tubule
- Lateral interdigitation connecting lateral walls of cells, difficult to distinguish boundaries between adjacent cells
- Basal infoldings with mitochondria (basal striations), characteristic of cells with active ionic transport
Proximal convoluted tubules

• Functions
  – Resorption of 80% water, electrolytes through Na⁺, K⁺-ATPase
  – Resorption of 100% glucose and amino acids
  – Protein resorption: apical canaliculi connecting microvilli increase the absorption of macromolecules by pinocytosis.
    • Vacuoles and lysosomes are more abundant in the apical portion of the cytoplasm
  – Secretion of creatinine and organic acids and bases, so pH modification
Loop of Henle

• **Thick descending limb** (60 μm)
  – Cytology
    • Similar to proximal convoluted tubules
    • Slightly fewer microvilli
    • Less basolateral interdigitation
    • Mitochondria are smaller and more randomly oriented
  – Function: Na\(^+\) and H2O reabsorption

• **Thin tubule** (12 μm)
  – Cytology: Simple squamous epithelium
  – Function
    • Descending limb: permeable to H2O and salt
    • Ascending limb: impermeable to H2O, permeable to salt and urea
    • Concentration of the urine
Loop of Henle

• Thick ascending limb
  – Cytology
    • Cuboidal cells with apical nuclei
    • Numerous basal infoldings with larger mitochondria
    • Few and short microvilli
    • Macula densa, part of juxtaglomerular apparatus
  – Function
    • Cl\(^-\) and Na\(^+\) transport into basolateral spaces
    • Establish a salt concentration gradient in medulla for urine concentration
Distal convoluted tubule

- **Cytology**
  - Same as thick ascending limb of loop of Henle
  - Cells are flatter and smaller than those of proximal convoluted tubules, so more cells will appear in cross section

- **Function**
  - Na\(^+\) reabsorption, Ka\(^+\) secretion (aldosterone)
  - Reabsorption of bicarbonate, hydrogen secretion, pH increases
  - Conversion of ammonia to ammonium ions
Collecting tubules and ducts

- **Types**
  - Connecting tubule: 40 µm in diameter, in cortex
  - Cortical duct: medullary rays
  - Medullary duct: medulla
  - Papillary duct (of Bellini): 200 µm in diameter, apex

- **Epithelium: cuboidal to columnar cells**
  - Principal cells: light stained cells, cilium, short microvilli, basal infoldings, permeable to H2O (H2O channel, in the presence of antidiuretic hormone)
  - Intercalated cells: dark stained cells, microplicae (folds), H⁺ secretion, bicarbonate reabsorption. Absent in inner medulla
Juxtaglomerular Apparatus

- Senses and regulates blood flow and composition
- Structure where afferent arteriole makes contact with ascending limb of loop of Henle
- Consists of three cell types
  - **juxtaglomerular cells**: modified muscle cells in arteriole, renin secretion
  - **macula densa**: sense NaCl concentration, regulates renin release. It is thickened part of ascending limb
  - **the extraglomerular mesangial cells**: unknown function
• Regulation of blood flow by renin
  Stimulation → JG cells → Renin →
  Angiotensinogen → Angiotensin I (lung) →
  Angiotensin II → Aldosterone (Adrenal
cortex) → Na⁺, Cl⁻ uptake (DCT)
Blood & Nerve Supply of Kidney

- Abundantly supplied with blood vessels
  - receive 25% of resting cardiac output via renal arteries
- Functions of different capillary beds
  - glomerular capillaries where filtration of blood occurs
    - vasoconstriction & vasodilation of afferent & efferent arterioles produce large changes in renal filtration
  - peritubular capillaries that carry away reabsorbed substances from filtrate
  - vasa recta supplies nutrients to medulla without disrupting its osmolarity form
- The nerve supply to the kidney is derived from the renal plexus (sympathetic division of ANS). Sympathetic vasomotor nerves regulate blood flow & renal resistance by altering arterioles
Urinary bladder & Urinary passages

• Bladder and urinary passages store and conduct urine to the exterior
• All have the same histological structure:
  • The mucosa
    – Transitional epithelium
    – Lamina propria
  • Dense woven sheath of smooth muscle
    – Calyces, renal pelvis and ureters: helical arrangement
    – Distal part of ureter: longitudinal
    – Bladder: run in every direction
    – Bladder neck:
      • Internal longitudinal. Distal to bladder neck become circular
        – Surround prostatic urethra
        – Extend to external urethral meatus in women
      • Middle circular: ends at the bladder neck
      • Outer longitudinal layer: continue to the prostate in men and to the external urethral meatus in women
  • Adventitia
  • Serosa: upper part of the bladder
A. Empty bladder
B. Full bladder
Urethra

- **Male urethra**: consists of four parts
  - Prostatic urethra
    - Close to bladder, and ducts of prostate gland opens into it
    - Transitional epithelium
    - Dorsal and distal part have verumontanum (elevation protrudes into its interior)
      - Closed tube (prostatic utricle) opens into the tip with no known function
    - Ejaculatory ducts open on the sides of the verumontanum
  - Membranous urethra
    - 1 cm, surrounded by the external urethra sphincter (striated muscle)
    - Stratified or pseudostratified columnar epithelium
  - Bulbous and pendulous parts of urethra
    - Located in the corpus spongiosum of the penis
    - Lumen dilates distally forming the fossa navicularis
    - Pseudostratified columnar with stratified squamous areas
    - Litter’s glands: mucous glands found along the entire urethra and mostly in the pendulous part
- **Female urethra**
  - 4-5 cm long tube, lined by stratified squamous epithelium and areas of pseudostratified columnar epithelium
  - The mid part is surrounded by external urethral sphincter