Renal (Urinary) System

Chapter 17

Function
Maintains homeostasis in ECF
• Removing metabolic waste (except CO₂)
  – e.g. ammonia, urea, uric acid
• Removing foreign compounds
  – e.g. drugs, food additives, pesticides
• Regulating salt concentrations, fluid volume, and pH

Anatomy
• Kidneys (2)
  – process plasma into urine
• Ureters (2)
  – tubes that carry urine to bladder
• Urinary bladder
  – storage of urine
• Urethra
  – carries urine to exterior

Anatomy
• Cortex
  – outer granular region
• Medulla
  – inner striated region
  – renal pyramids
• Renal Pelvis
  – central collecting cavity
• Renal artery and vein

Anatomy
• Nephron
  – 1 million per kidney
  – functional unit of the kidney
  – smallest unit capable of forming urine

Vascular Component
• Renal Artery
• Afferent Arteriole
• Glomerulus
• Efferent Arteriole
• Peritubular Capillaries
• Venules
• Renal Vein

Fig 17.1

Fig 17.2

Fig 17.2

Fig 17.5
Nephron

Tubular Component
- forms urine
- Bowman’s capsule
- Proximal Convoluted Tubule
- Loop of Henle
- Distal Convoluted Tubule
- Collecting duct

Urine Formation

- Urine - water and waste solutes
- Nephrons conduct three processes to convert blood plasma into urine
  1. filtration
     - filter blood plasma to retain cells/proteins
  2. reabsorption
     - remove valuable materials from filtrate
  3. secretion
     - transfer additional wastes to filtrate

Filtration

- Occurs in the glomerulus
  - Fenestrated capillaries
    - 3 layers of podocytes form capillary walls
    - Small pores (fenestrae)
  - filters plasma
    - proteins + cells stay in blood
    - forms ultrafiltrate

- Filtration driven by blood pressure
- Glomerular filtration is non-selective
  - Small particles pass (glucose, Na⁺, urea, H₂O)
  - Large ones do not
- 20% of plasma enters tubule
  - plasma filtered 65x/day

Reabsorption

- Occurs in remainder of nephron tubule
- Selective movement of substances from tubule into plasma
  - Return of valuable substances to peritubular caps
- Active or passive
  - Passive (no energy)
  - Active transport (requires energy)

Secretion

- Also occurs in tubules
- Additional materials transported from plasma in peritubular capillaries into tubule
  - excess K⁺, Ca²⁺ and H⁺, uric acid
  - foreign compounds
- By passive diffusion or active carrier transport
Proximal Tubule

Proximal Tubule Reabsorbs:
- 2/3 of plasma Na⁺
- 2/3 of plasma Cl⁻
- 2/3 of plasma H₂O
- 100% of plasma glucose

Active Transport in the Proximal Tubule
- Na⁺ actively transported from cell to blood
- Creates Na⁺ gradient favoring Na⁺ flow from lumen
- Na⁺ gradient used to transport glucose against concentration gradient (cotransport)
- Glucose diffuses into blood passively

Passive Reabsorption in the Proximal Tubule
- Cl⁻ to be reabsorbed passively along electrical gradient
- Water reabsorbed along osmotic gradient

Acid Base Balance
- Proximal tubule also secretes H⁺ and absorbs HCO₃⁻ – used to regulate pH
- with ↓ pH, ↑ H⁺ secretion and HCO₃⁻ reabsorption

Loop of Henle
- Kidneys produce a hyperosmotic urine – less H₂O than blood plasma
- concentrating mechanism occurs in the Loop of Henle

Loop of Henle
- Countercurrent Multiplication – generates osmotic gradient that draws H₂O out of the tubules to be reabsorbed – due to active reabsorption of Na⁺ & Cl⁻
Loop of Henle

- **descending limb**
  - permeable to water
  - no active transport
- **ascending limb**
  - impermeable to water
  - lined w/ Na⁺-K⁺ pumps

Distal Convoluted Tubule and Collecting Duct

- Secretion of K⁺ and H⁺
- Reabsorption of Na⁺ and water
- Generation of hyperosmotic urine
  - final ~8% of water and Na⁺ reabsorbed

Hormonal Regulation of Reabsorption

- **Aldosterone**
  - increases Na⁺ reabsorption and K⁺ secretion by distal & collecting tubules
  - ↑ salt retention and BP (H₂O retention)
- **ADH**
  - induces implantation of aquaporins (water channels) into tubule cell membranes
  - ↑ permeability of Distal and Collecting tubules to water
  - ↑ H₂O reabsorption = ↓ urine volume

Triggering of Aldosterone Release

- release induced by *juxtaglomerular apparatus*
  - region of afferent arteriole that comes into contact w/ ascending limb of Loop of Henle
- releases *renin* (enzyme) into blood in response to ↓BP
- renin converts *angiotensinogen* → *angiotensin I*
Triggering of Aldosterone Release

- angiotensin I converted to angiotensin II (fully activated) by angiotensin converting enzyme in lungs
- angiotensin II stimulates aldosterone release

Urination

- Ureters
  - transfer urine to pelvic region
- Urinary Bladder
  - Stores urine
  - smooth muscle, stretchable walls
- Two sphincters
  - internal urethral sphincter (involuntary)
  - external urethral sphincter (voluntary)

Urination Reflex:
- Stretch receptors in bladder wall → spinal cord
  - efferents to smooth muscle → contraction
- Internal sphincter relaxes
- External sphincter relaxes