The Urinary System
The urinary system includes:

- Kidneys
- Ureters
- Urinary bladder
- Urethra
Functions of the urinary system

- Excretion of metabolic wastes
- Regulation of ion, salt and water concentration of body fluid
- Synthesis
The number of lobes in a kidney equals the number of medullary pyramids.
Cortex: outer layer, granular appearance (due to many corpuscles)

Medulla: darker striped appearance (due to tubules)
- Subdivided into distinct renal pyramids, terminating with a papilla.
- Separated by renal columns from the cortex.

Pelvis: Expanded proximal part of ureter
Nephron = functional unit of the kidney

1. Renal Corpuscle
   (Glomerulus + Bowman’s Capsule)

2. Proximal Convoluted Tubule (PCT)

3. Loop of Henle (LOH)

4. Distal Convoluted Tubule (DCT)
Production of urine

Glomerular filtration

Tubular Reabsorption

Tubular Secretion
The glomerulus - a tuft of capillaries composed of 10 to 20 capillary loops

The renal or Bowman’s capsule - a double-layered epithelial cup

- The glomerular capillaries are supplied by an afferent arteriole and are drained by an efferent arteriole
- Endothelial cells have fenestrations (blood cells can’t go through)
- Vascular pole – a part of glomerulus where aff. arteriole enters and eff. arteriole exits
Renal Corpuscle

A-arteriole; b-parietal layer of BC; c-PCT; d-podocyte (visceral layer of BC)
Renal Capsule

- Two layers – external (parietal) and internal (visceral)
- Space between the two layers – urinary (Bowmen’s space)
- From urinary space the filtrate enters PST
Internal layer of capsule - podocytes

**Podocytes** — a type of epithelial cells:

- have long primary processes and interdigitating foot processes (**pedicles**) which grasp capillaries like fingers
- **Filtration slits** – spaces between the pedicles
Glomerulus and Bowman’s Capsule

- Afferent arteriole
- Efferent arteriole
- Glomerular capsular space
- Parietal layer of glomerular capsule
- Proximal convoluted tubule
- Glomerular capillary covered by podocyte-containing visceral layer of glomerular capsule
- Cytoplasmic extensions of podocytes
- Filtration slits
- Foot processes of podocyte
- Podocyte cell body
- Glomerular capillary endothelium (podocyte covering and basement membrane removed)
- Fenestrations (pores)
Filtration barrier

1. Fenestrated Capillary Endothelium
2. Basement membrane
3. Filtration Slits between pedicles of podocytes in the visceral layer of Bowman’s capsule
4. The volume of ultrafiltrate is about 180 L/day

Albuminuria (presence of significant amounts of albumin in the urine) or hematuria (presence of significant amounts of red blood cells in the urine) indicate physical or functional damage to the GBM.
The renal corpuscle contains an additional group of cells called **mesangial cells**. **Functions:**

- **Phagocytosis** - remove trapped residues and aggregated proteins from the GBM and filtration slit diaphragm, thus keeping the glomerular filter free of debris.
- **Structural support.**
- **Modulation of glomerular distension** - Mesangial cells have contractile properties.
Tubular Reabsorption

- Absorption of water, ions, glucose, amino acids and proteins back to the blood
- 85% - in the proximal convoluted tubules
Tubular Secretion

- Some substances (K, H, ammonium, creatinine, some medicine and etc.) exit from surrounding capillaries into the lumen of tubules
Proximal tubules & descending thick tubule

- Microvilli
- Glycocalyx

Distal convoluted tubule & ascending thick tubule

Thin limb of Henle (ascending & descending)

- Don’t confuse it with capillary (vasa recta or peritubular capillary plexus)

Collecting duct & collecting tubules

- Principal cells
- Intercalating cells

Vasa recta & peritubular capillary plexus

- RBCs
Proximal Convoluted Tubule

• **Reabsorption:**
  – 65% ions of Na, Cl and water,
  – 80% ions of P and **bicarbonate**, 80% of Ca,
  – 100% glucose
  – 100% protein
  – 50% urea

• **Secretion:**
  – H+ и NH4+, creatinine, acetylcholine, dopamine, adrenalin, histamine
  – Fatty acids, bile acids, penicillin
Kidney Cortex – PCT (P) & DCT (D)
Loop of Henle

- Concentration of urine due to reabsorption of water and NaCl

- **Countercurrent multiplication:**
  - Descending part is permeable to water and impermeable to Na⁺:
    - Water leaves the tubule into the interstitium
  - Ascending part is impermeable to water and permeable to Na⁺:
    - Na⁺, Cl⁻, K⁺ leave the tubule into the interstitium

- The medullary interstitium around the tubules is “salty”. The osmolarity is higher then in the lumen
Distal Convoluted Tubule

- **Reabsorption**: 10% ions of Na, Cl, Ca and bicarbonate
Collecting ducts

- Are mainly in the medulla

- **Reabsorption of water (5-25%)**
  - Aquaporins – special canals for water.
  - ADH regulates the number of aquaporins and reabsorption of water
Cross section of Kidney Medulla
Kidney Medulla (Collect tubules and loops)

- Thin limb of Henle (ascending & descending)
- Collecting duct & collecting tubules
- Principal cells
- Intercalating cells
- Don't confuse it with capillary (vasa recta or peritubular capillary plexus)
Blood Supply

The kidneys are highly vascular organs; they receive approximately 25% of the cardiac output.
Kidney Medulla – Vasa Recta (VR)
LM – injected kidney vascular system

Rete mirabile

Efferent arteriole

Afferent arteriole

Rete mirabile
Two Types of Nephrons

- **Cortical nephrons** (85%) located mostly in the cortex of kidney, produce "standard" urine.

- **Juxtamedullary nephrons** (15%), located close to the medulla - responsive to ADH, can produce concentrated urine due to longer Loops of Henle.
Endocrine functions of the kidney

• Secretion:
  - Renin
  - Erythropoietin

• Activation:
  - Vit D
Juxtaglomerular Apparatus

- Regulates blood pressure by activating the renin–angiotensin–aldosterone system

- Located near the vascular pole of each renal corpuscle

- Includes:
  - macula densa
  - extraglomerular mesangial cells
  - juxtaglomerular cells
Kidney Juxtaglomerular Complex

MD = macula densa

JGC = juxtaglomerular cells
Renal Corpuscle and Macula Densa

- Macula densa
- Bowman's capsule
JG Cells

Macula densa

Renin granules in JG cells
Renin – Angiotensin – Aldosterone System

- Macula densa senses low fluid flow or low Na⁺ concentration
- Juxtaglomerular cells secrete renin
- Angiotensin-converting enzyme (ACE) in pulmonary blood
- Kidney releases enzyme renin into blood
- Liver releases angiotensinogen into blood
- Enzyme reaction to Angiotensin I
- Enzyme reaction to Angiotensin II
- Stimulates adrenal cortex to secrete Aldosterone
- Widespread vasoconstriction
- ADH causes aquaporins to move to the collecting duct plasma membrane, which increases water reabsorption
- Na⁺ uptake on the apical cell membrane in the distal convoluted tubule and collecting ducts
- Aldosterone stimulates Na⁺ uptake on the apical cell membrane in the distal convoluted tubule and collecting ducts
Erythropoietin (EPO)

- Synthesized by endothelial cells of the peritubular capillaries in the renal cortex.
- Regulates red blood cell formation in the bone marrow in response to decreased blood oxygen concentration.
Excretion of urine

Collecting ducts within each renal papilla release urine into minor calyx → major calyx → renal pelvis → ureter → urinary bladder → urethra
Urinary tract

- Mucosa, submucosa, muscularis externa, adventitia

- Mucosa – transitional epithelium + lamina propria

- Transitional epithelium lines minor and major calices, renal pelvis, urether, bladder and proximal part og urethra
Transitional epithelium
Urethers

- Inner longitudinal muscular fiber
- Outer circular muscular fibers
- Contraction of longitudinal fibers in the proximal part of ureter keeps the lumen open for the passage of urine from the bladder
- Peristalsis of muscular fibers propels the urine down the ureter
Ureter – folded mucus membrane

Transitional Epithelium
Nephrolithiasis (kidney stones)

Occurs when urine becomes too concentrated and substances crystallize. Symptoms arise when stones begin to move down ureter causing intense pain.

Kidney stones may form in the pelvis, calyces, or in the ureter. (Rarely in the bladder.)
Urinary Bladder

3 layers in the wall:

 ✓ Mucosa – transitional epithelium
  organ is expandable
  mucous prevents cells from contact
  with urine

 ✓ Muscularis (detrusor muscle)
  3 layers of smooth muscle (outer
  longitudinal, circular, inner
  longitudinal)
  circular fibers form internal urethral
  sphincter

 ✓ Adventitia/
  serosa on the
  superior surface
Bladder – Transitional Epithelium
Thank you for attention

Manneken Pis Fountain Brussels, 1619