Urinary System

- Renal artery
- Renal vein
- Hilum
- Inferior vena cava
- Kidney
- Abdominal aorta
- Ureter
- Urinary bladder
- Urethra
Location of Kidneys—Transverse Section

- Kidney
- Adipose tissue
- Parietal peritoneum
- Inferior vena cava
- Pancreas
- Spleen
- Small intestine
- Aorta
- Large intestine
- Stomach
Kidney

(a) Coronal section
- Renal cortex
- Renal medulla
- Renal pyramid
- Renal capsule
- Renal column
- Opening of renal calyx into renal pelvis
- Renal pelvis
- Renal papilla

(b) Diagrammatic magnification
- Minor calyx
- Major calyx
- Renal artery
- Renal vein
- Ureter
- Renal papilla
- Renal medulla
- Nephron
- Glomerular capsule
- Proximal convoluted tubule
- Distal convoluted tubule
- Papillary duct
- Nephron loop

(c) Single nephron and papillary duct
Glomerular capillary covered by podocyte-containing visceral layer of glomerular capsule

Glomerular capsular space

Proximal convoluted tubule

Parietal layer of glomerular capsule

Efferent arteriole

Afferent arteriole

Cytoplasmic extensions of podocytes

Filtration slits

Foot processes of podocyte

Podocyte cell body

Glomerular capillary endothelium (podocyte covering and basement membrane removed)

Fenestrations
Kidney — Single Nephron Tubule

- Distal convoluted tubule
- Collecting duct
- Proximal convoluted tubule
- Loop of Henle
Location of Juxtaglomerular Apparatus

- Glomerular capsule
- Glomerulus
- Afferent arteriole
- Distal convoluted tubule
- Proximal convoluted tubule
- Juxtaglomerular apparatus
- Efferent arteriole
- Nephron loop
Urethra

- Mucosal lining changes
  - Transitional-Pseudostratified-Stratified squamous ep.
- Internal urethral sphincter at bladder urethra junction (smooth muscle).
- External urethral sphincter (skeletal muscle) where passes through body wall.
- Shorter in females (~3-4cm) than males (~20cm)
- Carries urine out of the body through external urethral orifice
Renal Physiology

• ~1200 mL/min blood passes through glomeruli
  – 120-125 mL/min plasma filtered into the renal tubule.
  – = filtering your entire plasma vol. 60/day.

• Kidneys use 20-25% of all oxygen used while at rest
Urine Formation

- 1) Glomerular Filtration
- 2) Tubular Reabsorption
- 3) Tubular Secretion
Glomerular Filtration

- Glomerulus
- Glomerular capsule
- Efferent arteriole
- Afferent arteriole
- Podocyte cell body (visceral layer)
- Red blood cell
- Proximal tubule cell
- Foot processes of podocytes
- Parietal layer of glomerular capsule
- Capsular space
- Afferent arteriole
- Juxtaglomerular cells
- Macula densa cells of the distal tubule
- Efferent arteriole
- Lumens of glomerular capillaries
- Endothelial cell of glomerular capillary
- Mesangial cells between capillaries
- Renal corpuscle
- Juxtaglomerular apparatus

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Glomerular Filtration Rate

- Net Filtration Pressure (directly proportional)
- Membrane permeability
- Total filtration surface area
- 120-125 mL/min
GFR Regulation

• Too fast = nutrients lost
• Too slow = wastes not disposed of
• Control mechanisms
  – Intrinsic controls (renal autoregulation)
    • Myogenic mechanism
    • Tubular feedback mechanism
  – Extrinsic controls
    • Sympathetic NS controls
    • Renin angiotensin system
Renin-Angeotensin System

Angiotensin II Formation

Liver

Kidney

Angiotensinogen

Bloodstream

Renin

Angiotensin I

Angiotensin converting enzyme

Angiotensin II

Lung capillaries

Vasoconstriction

Increased aldosterone secretion

Increased ADH secretion

Increased thirst
Tubular Reabsorption

Key:
- Red = Primary active transport
- Blue = Passive transport

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Key:
- Red = Active transport
- Blue = Passive transport

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Diabetes Insipidus

• Impairs ADH regulation of water balance
• Caused by:
  – ADH deficiency
  – mutation in aquaporin gene
• Renal tubules fail to reabsorb water
• Treatment
  – High calorie diets
  – Lots of water
Tubular Secretion

• PCT & collecting ducts are the main sites of secretion
  – PCT = Ammonium ions (& other N wastes)
  – DCT = H+ ions may be secreted
  – Collecting ducts
    • K+, H+, HCO3- may be secreted
(a) Key:
- Red = Active transport
- Blue = Passive transport

(b)
Acidification of Urine

Blood → \( \text{HCO}_3^- \) → \( \text{H}_2\text{CO}_3 \) → Water + \( \text{CO}_2 \) → \( \text{H}_2\text{O} + \text{CO}_2 \) → \( \text{Na}^+ \) → \( \text{H}^+ \) → \( \text{H}_2\text{PO}_4^- \) → \( \text{NH}_3 \) → \( \text{H}^+ \) → \( \text{NH}_4^+ \)

Filtration → \( \text{HCO}_3^- \) + \( \text{H}^+ \) → \( \text{H}_2\text{CO}_3 \) → \( \text{H}_2\text{CO}_3 \) → \( \text{H}_2\text{O} + \text{CO}_2 \) → \( \text{Na}^+ \)
Renal Clearance

• \( \text{RC} = \frac{\text{UV}}{\text{P}} \)
  - \( \text{U} \) = conc. of substance in urine
  - \( \text{V} \) = flow rate of urine formation
  - \( \text{P} \) = conc. of substance in plasma

• Inulin \( \text{RC} = 125 \text{ml/min} \)
  - \( \text{RC} < 125 \) means some of X was reabsorbed
  - \( \text{RC} > 125 \) means some was secreted
## Urine Composition

<table>
<thead>
<tr>
<th>Substance</th>
<th>Plasma</th>
<th>Urine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (L/day)</td>
<td></td>
<td>1.4</td>
</tr>
<tr>
<td>Organic molecules (mg/dL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>3900–5000</td>
<td>0*</td>
</tr>
<tr>
<td>Glucose</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Urea</td>
<td>26</td>
<td>1820</td>
</tr>
<tr>
<td>Uric acid</td>
<td>3</td>
<td>42</td>
</tr>
<tr>
<td>Creatinine</td>
<td>1</td>
<td>196</td>
</tr>
<tr>
<td>Ions (mEq/L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na⁺</td>
<td>142</td>
<td>128</td>
</tr>
<tr>
<td>K⁺</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>103</td>
<td>134</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Specific gravity (g/ml)†</td>
<td></td>
<td>1.005–1.030</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>4.5–8.0</td>
</tr>
</tbody>
</table>

*Trace amounts of protein can be found in the urine.

†The specific gravity increases as the concentration of solutes in urine increase.
Urinalysis

• Folk remedies
• Hippocrates
• Diabetes