**Urinary System**

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**Functions of Urinary System:**

1. excretion – excrete wastes
2. regulate blood volume and blood pressure by:
   a. adjusting water loss in urine
   b. releasing erythropoietin
   c. releasing renin
3. regulate plasma concentrations of Na+, K+, Cl-
4. helping to stabilize blood pH by controlling excretion of H+ and HCO3-
5. Assist liver with detoxifying poisons

**Main Organs:** kidneys form urine send it through urinary tract (ureter → urinary bladder → urethra)

**Urinary Tract Organs**

**Ureters:**
- tubes carry urine from renal pelvis of kidney to bladder
- inner lining is mucosa: epithelial tissue
- middle layer is smooth muscle
- peristaltic contractions roughly every 30 seconds
- outer layer visceral peritoneum

**Urinary Bladder:**
- muscular sac, posterior to pubic symphysis
- lies anterior to the uterus in females
- held in place via peritoneum & ligaments (middle & lateral umbilical ligaments)
- trigone: triangular region with openings for urethra – works as a funnel
- neck of bladder contains internal urethral sphincter: involuntary
- innervated by both sympathetic and parasympathetic divisions of ANS
- lining is mucosa consisting of epithelial tissue
- muscularis layer is smooth muscle: forms detrusor muscle: contracts to expel urine
- detrusor muscle also prevents urine from flowing back into ureters
- distends: muscles stretch (can hold up to 1 L)
- when empty collapses into folds called

**Urethra:**
- drains urine from urinary bladder to outside
- female: urethra: anterior to vagina
- male urethra longer and subdivided into:
  1.) prostatic urethra:
  2.) membranous urethra: very short segment in floor of pelvic cavity
  3.) penile urethra:

**Micturition Reflex: voiding or urination**

1.) distension in urinary bladder activates stretch receptors (reflex)
2.) afferent fibers in pelvic nerves carry impulses to spinal cord & to thalamus to cerebral cortex of brain
   so become aware of urge.
3.) stimulates parasymp. fibers which cause contraction of bladder & relaxation of internal sphincter.

**Incontinence:**
- from stretched or damaged sphincter muscles: increased intra-abdominal pressure causes urine to leak
- damage to CNS, spinal cord or nerves to urinary bladder

**Urinary Retention:** occurs in males due to enlarged prostate gland (prostatic hypertrophy)

**Kidneys:**
- bean shaped
- T12 - L3:
- medial indentation termed - hilus: leads into renal sinus
- renal blood vessels, ureters,
- adrenal gland is found superior to each kidney
- held in place via peritoneum & connective tissue

**3 layers of connective tissue surround each kidney**

1. renal capsule: innermost layer, directly attaches to kidney
   covers outer surface of kidney (layer of collagen)
2. adipose capsule:
3. renal fascia: dense irregular connective tissue
   anchors kidney to surrounding structures – fuses with peritoneum

**Sectional Anatomy of Kidney**

**Cortex, Medulla, Pelvis**

1. Renal Cortex:
2. Renal Medulla:
   - contains renal (medullary) pyramids
   - papilla: rounded tip – faces renal pelvis
   - base: flat portion – faces cortex
   - each renal pyramid forms renal lobe
   - each renal lobe contains nephrons which make urine
3. Renal Pelvis:
   formed from the minor and major calyces (minor calyx, major calyx)
   funnel shaped area
   collects

   pyelitis: infection of renal pelvis (usually from untreated UTI)

   pyelonephritis: infection of kidney
   ● Signs/symptoms: high fever, intense pain on affected side, vomiting, diarrhea, blood and pus
     in urine
   ● Tx: intense antibiotic therapy

   Blood and Nerve Supply: (p. 955) kidneys receive 20-25% of cardiac output
   blood leaves heart to aorta – aortic arch – thoracic aorta – abdominal aorta:
   renal arteries enter thru hilus branch into
   ↓ segmental (lobar) arteries
   ↓ interlobar arteries (pyramids to cortex)
   ↓ arcuate arteries (arch along boundary of cortex & medulla)
   ↓ interlobular arteries (supply cortex)
   ↓ afferent arteriole (takes blood into glomerulus)
   ↓ glomerulus (capillary network)
   ↓ efferent arteriole (drains blood from glomerulus)
   ↓ peritubular capillaries (surround nephron tubules)
   ↓ venules
   ↓ interlobular veins
   ↓ arcuate veins
   ↓ interlobar veins
   ↓ renal vein

   Blood Flow through kidney assessed by giving PAH (para-aminohippuric acid)
   PAH is removed from blood by nephrons and eliminated in urine
   compare plasma concentration with amount in urine

   Renal plexus: ANS:
   - sympathetic stimulation controls blood vessels: vasoconstriction/vasodilation

   Nephrons:
   each kidney contains
   consists of
   1. glomerular (Bowman's) capsule (surrounds glomerulus)
      note Renal Corpuscle is Bowman's capsule & glomerulus
   2. proximal convoluted tubule (PCT)
   3. Loop of Henle – descending & ascending limbs
   4. distal convoluted tubule (DCT)

5. collecting duct.

Adaptations for each region:
1. glomerulus:

   Glomerulus:
   afferent arteriole:
   efferent arteriole:
   fenestrated capillaries
   Surrounded by Bowman's Capsule
   parietal epithelium: outer wall of capsule

2. Proximal Convoluted Tubule:
   - simple cuboidal epithelium
   - have microvilli

3. Loop of Henle: descending & ascending limbs
   - lower part of descend limb (thin segment) contains simple squamous epithel. and is very permeable to
   - ascending limb thick segment:
   4. Distal Convoluted Tubule:
      - simple cuboidal epithelial cells
      - lack
      - better suited for

Two types of Nephrons:
1. Cortical Nephrons:

2. Juxtamedullary Nephrons:

Juxtaglomerular Apparatus: regulates BP & rate of filtrate formation
point of contact between
juxtaglomerular (JG) cells in afferent arteriole:
- smooth muscle cells
- contain
- mechanoreceptors:
macula densa:
- contains chemoreceptors (osmoreceptors) respond

**Principles of Renal Physiology**

- 47 gallons fluid/day only 1% becomes urine
- nephrons form the urine
- excrete wastes (urea, creatinine, uric acid) wastes are in blood, nephron filters them out of blood to eliminate them in urine

**Basic Processes of Urine Formation**

1. **Filtration:** hydrostatic pressure forces water/solutes out of blood into nephron (Bowman’s capsule)
2. **Reabsorption:** removal of water/solutes from filtrate back into blood
3. **Secretion:** transport of solutes from peritubular capillaries back into filtrate

Reabsorption and Secretion use the following methods of transport:
- osmosis
- diffusion
- carrier-mediated transport: requires carrier protein – if saturate carrier protein cannot transport molecule (termed transport maximum or Tm) which indicates renal threshold
  - if renal threshold reached for reabsorption cannot reabsorb the substance and it is lost in urine
- facilitated diffusion
- active transport
- cotransport
- countertransport

1. **Glomerular Filtration**

filtration is passive

filtration membrane:
- glomerular blood pressure is 50 mmHg vs 35 at arterial end of capillary bed

**Filtration Membrane**
- porous w/ 3 layers:
  1. Fenestrated capillaries
  2. Visceral membrane of podocytes

**Net Filtration Pressure (NFP)**

\[ \text{NFP} = \text{G.H.P.} - (\text{G.O.P.} + \text{Cs.H.P.}) \]

- G.H.P. = glomerular hydrostatic pressure: (50 mmHg) – dependent on
- G.O.P. = glomerular osmotic pressure: (25 mmHg) – dependent on

\[ \text{NFP} = 50 - (25 + 15) \]

\[ \text{NFP} = 10 \text{ mmHg} \]

**Glomerular Filtration Rate (GFR)**

- amount of fluid filtered from blood into kidney per minute – 125 ml/minute

1. total surface area for filtration
2. permeability of filtration membrane
3. NFP

or if there is decreased filtrate and flow:

- renal autoregulation: regulates diameter

**Regulation of Glomerular Filtration**

A. Intrinsic: kidneys (renal) autoregulation

- kidney regulate glomerular filtration thru monitoring
  - if flow rapid (large amounts of filtrate prod.)

1. Myogenic Mech.: responds to pressure changes
  - smooth muscle contracts when stretched if systemic BP increases,
  - so it keeps glomerular pressure
  - if systemic BP falls, causes


A. Controlled by Macula Densa cells of juxtaglomerular apparatus

- in distal tubules respond to slow flowing filtrate and/or osmotic signals
  - but if flow is fast or high osmolarity, will release

B. Renin-Angiotensin Mech. (hormonal)

- juxtaglomerular cells release renin cause angiotensinogen to release angiotensin I which is converted to angiotensin II powerful vasoconstrictor
  - (angiotensin II constrict efferent arteriole to increase glomerular blood pressure)

  - also causes adrenal cortex to release
  - travels to CNS to release ADH
Factors trigger release of renin:
1. Decreased stretch of JG cells
2. Macula Densa cells cause vasodilation
3. Sympathetic nervous system

C. Extrinsic (Autonomic): sympathetic nervous system
- stress or emergency
  - symp. fibers → epinephrine causes
  - triggers the release of renin by JG cells

2. Tubular Reabsorption
filtrate contains same as blood plasma except urine:
need to get stuff from filtrate back into blood so it doesn’t become urine and is lost
begins when filtrate enters proximal tubules and is moved thru

- glucose, AA reabsorbed cotransport with Na
- active transport: ion pumps for Na⁺, K⁺, HCO₃⁻, Mg²⁺, PO₄³⁻
- passive reabsorption of: water, urea, Cl⁻ and lipid soluble molecules
- Na⁺ reabsorbed several ways

Solute Drag: substances reabsorbed because water reabsorption increases their concentration in the filtrate (creates a concentration gradient for them).

Nonreabsorbed Substances: because
- urea, creatinine, uric acid

Different Regions of Tubules and What They Absorb:
- Proximal Convoluted Tubule: most involved in reabsorption absorbs

Loop of Henle:
Distal tubule:
- Aldosterone: controls

3. Tubular Secretion
blood secretes molecules back into tubule (filtrate)
2nd chance for
H & K are both secreted in exchange for Na
compete for secretion
Important because:
1. Disposing of
2. Eliminating
3. Getting
4. Controlling
when pH decreases:
when pH increases:

Regulation of Urine Concentration and Volume: Loop of Henle
countercurrent mechanism:

- osmolarity of filtrate in prox. convoluted tubule is osmolarity as filtrate moves from cortex to medulla
1. Descending limb:
   - impermeable to
   - permeable to
2. Ascending limb:
   - impermeable to
   - permeable to
3. Collecting tubules in deep medullary regions:
   - permeable to
as urine passes thru deep medullary regions,

4. Vasa recta acts as countercurrent exchange:
   - maintains osmotic gradient
   - found near 

   establishes a concentration gradient that will allow the passive reabsorption of water from the tubular fluid.

**Formation of Dilute Urine:**
- filtrate diluted as passes thru:
  - when ADH not released by posterior pituitary:

**Formation of Concentrated Urine:**
- ADH: decreases urine, by facultative water reabsorption:
- obligatory water reabsorption:

- release of ADH:

**Diuretics:**
- enhance osmotic diuretic:
  - alcohol:
  - caffeine:
  - drugs:

**Renal Clearance:**
- creatinine clearance test used to estimate GFR
- monitor creatinine in blood and amount in urine over 24 hr. period
- note RC of glucose = 0
- RC less than creatinine indicates some of it was reabsorbed

<table>
<thead>
<tr>
<th>RC of urea</th>
<th>RC of sodium</th>
<th>creatinine</th>
</tr>
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<tbody>
<tr>
<td>RC &lt; 125 means:</td>
<td>RC = 0 indicates:</td>
<td>RC &gt; 125 means</td>
</tr>
</tbody>
</table>

**Aging and the Urinary System:**
- decrease in number of functional nephrons (30-40% loss between ages 25 – 85)
- reduction in GFR
- reduced sensitivity to ADH
- problems with micturition reflex

**Characteristics of Urine:**
- color:
- pH:

**Clinical Applications**

**Urinalysis:** Abnormal components of urine:
- hematuria
- glycosuria
- proteinuria (albuminuria)
- ketonuria
- pyuria
- azotemia

<table>
<thead>
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<th>Normal Renal Function Tests</th>
<th>Test</th>
<th>Normal Value</th>
<th>Interpretation</th>
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<tr>
<td>Color</td>
<td>Amber-yellow</td>
<td>Drugs and foods may change color</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>Clear</td>
<td>Pus and blood will make cloudy</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>4.6-8.0</td>
<td>Bacteria create an alkaline urine</td>
<td></td>
</tr>
</tbody>
</table>

**Specific gravity**
- Adult: 1.010-1.025
- Infant: 1.010-1.018

| Blood | Negative | Bleeding along urinary tract |

**Microscopic Urine**
- Bacteria: None
- Red blood cells: Negative
- White blood cells: Negative
- Crystals: Negative
- Fat: Negative
- Casts: Occasional

<table>
<thead>
<tr>
<th>MICROSCOPIC URINE</th>
<th>Bacteria</th>
<th>None</th>
<th>Detection</th>
</tr>
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<td>Microscopic Urine</td>
<td>Red blood cells</td>
<td>Negative</td>
<td>Bleeding along urinary tract</td>
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<tr>
<td>Microscopic Urine</td>
<td>White blood cells</td>
<td>Negative</td>
<td>Infection</td>
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<thead>
<tr>
<th>Urinary Chemistry</th>
<th>Bilirubin</th>
<th>Negative</th>
<th>Increases may cause dark orange color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urinary Chemistry</td>
<td>Urobilinogen</td>
<td>Negative</td>
<td>Increased in liver disease</td>
</tr>
<tr>
<td>Urinary Chemistry</td>
<td>Ketones</td>
<td>Negative</td>
<td>Increased in liver disease</td>
</tr>
<tr>
<td>Urinary Chemistry</td>
<td>Glucose</td>
<td>Negative</td>
<td>Increased in liver disease</td>
</tr>
<tr>
<td>Urinary Chemistry</td>
<td>Sodium</td>
<td>Negative</td>
<td>Increased in liver disease</td>
</tr>
<tr>
<td>Urinary Chemistry</td>
<td>Potassium</td>
<td>Negative</td>
<td>Increased in liver disease</td>
</tr>
<tr>
<td>Urinary Chemistry</td>
<td>Protein</td>
<td>Negative</td>
<td>Increased in liver disease</td>
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**Normal Serum Values**
- BUN: 8-25 mg/dl
- Creatinine: Male = 0.6-1.5 mg/dl, Female = 0.6-1.1 mg/dl

**Clinical Applications:**

- Elevated with diseased kidneys
- Elevated with diseased kidneys
- Elevated in renal failure
1. Kidney stones (renal calculi)

2. Urinary Tract Infections (UTIs)
   bacterial or fungal pathogens
   more common in females (shorter, close to anus, sexual intercourse can push bacteria into urethra)
   ● urethritis: inflammation of urethra
   ● cystitis: inflammation of urinary bladder
   ● dysuria:

3. Bladder cancer
   3X more prevalent in males
   spreads through adjacent lymph nodes/tissue quickly

4. Glomerulonephritis:
   antigen-antibody complexes clog up filtration membrane and filtration decreases

5. Renal Failure:
   Acute renal failure
   Chronic renal failure