Glomerular Capillary Blood Pressure

- Fluid pressure exerted by blood within glomerular capillaries
- Depends on
  - Contraction of the heart
  - Resistance to blood flow offered by afferent and efferent arterioles
- Major force producing glomerular filtration
- 55 mm Hg
<table>
<thead>
<tr>
<th><strong>Plasma-colloid Osmotic Pressure</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Caused by unequal distribution of plasma proteins across glomerular membrane</td>
<td></td>
</tr>
<tr>
<td>• Opposes filtration</td>
<td></td>
</tr>
<tr>
<td>• 30 mm Hg</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Bowman’s Capsule Hydrostatic Pressure</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Pressure exerted by fluid in initial part of tubule</td>
<td></td>
</tr>
<tr>
<td>• Tends to push fluid out of Bowman’s capsule</td>
<td></td>
</tr>
<tr>
<td>• Opposes filtration</td>
<td></td>
</tr>
<tr>
<td>• 15 mm Hg</td>
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</tbody>
</table>
Glomerular Filtration Rate

- Net filtration pressure = glomerular capillary blood pressure – (plasma-colloid osmotic pressure + Bowman’s capsule hydrostatic pressure)
  - e.g. 55 mm Hg – (30 mm Hg + 15 mm Hg) = 10 mm Hg

- Glomerular filtration rate (GFR)
  - Depends on
    - Net filtration pressure, which is only regulated by changing glomerular capillary hydrostatic pressure
      - 180 liters/day
      - 125 ml/min
      - 99% reabsorbed
      - 1% forms excreted urine
      - 1.25 ml/min

(b) Arteriolar vasodilation increases the GFR
**Glomerular Filtration Rate**

- Controlled adjustments in GFR
  1. Glomerular capillary blood pressure is maintained at 55mmHg
     - Two major control mechanisms
       1. **Autoregulation** (aimed at preventing spontaneous changes in GFR)
          - Myogenic mechanism controls afferent arteriole
          - Tubuloglomerular feedback from macula densa of juxtaglomerular apparatus (TGF) controls afferent arteriole
       2. **Extrinsic sympathetic control** (aimed at long-term regulation of arterial blood pressure)
          - Mediated by sympathetic nervous system input to afferent arterioles
          - Baroreceptor reflex
          - Controls afferent arteriole in emergency

**Autoregulation of Glomerular Filtration Pressure and Rate**

**MYOGENIC MECHANISM** to regulate filling of glomerulus (more filling = more pressure = more filtration)

- Arterial Pressure
- Stretch on Wall of Afferent Arteriole
- Cell Ca++ Permeability
- Intracell. Ca++ contraction force... radius
- Increase Resistance
- **glomerular capillary filling**

Automatically “turning down” the faucet filling a sink to keep sink volume and pressure constant
AUTOREGULATION OF GRP and GFR: Tubuloglomerular feedback from macula densa of juxtaglomerular apparatus (TGF) controls afferent arteriole

1 = increase filling

2 = decrease emptying

3 Results in support of GFP+ GFR
Tubular Reabsorption

- Involves the transfer of substances from tubular lumen into peritubular capillaries
- Highly selective and variable process
- Involves transepithelial transport
  - Reabsorbed substance must cross five barriers
    - Must leave tubular fluid by crossing luminal membrane of tubular cell
    - Must pass through cytosol from one side of tubular cell to the other
    - Must cross basolateral membrane of the tubular cell to enter interstitial fluid
    - Must diffuse through interstitial fluid
    - Must penetrate capillary wall to enter blood plasma

To be reabsorbed (to move from the filtrate to the plasma), a substance must cross five distinct barriers:

1. the luminal cell membrane
2. the cytosol
3. the basolateral cell membrane
4. the interstitial fluid
5. the capillary wall

Fig. 13-9, p. 391
Tubular Reabsorption

- Passive reabsorption
  - No energy is required for the substance’s net movement
  - Occurs down electrochemical or osmotic gradients
- Active reabsorption
  - Occurs if any one of the steps in transepithelial transport of a substance requires energy
  - Movement occurs against electrochemical gradient

Na⁺ Reabsorption

- An active Na⁺ - K⁺ ATPase pump in basolateral membrane is essential for Na⁺ reabsorption
- Of total energy spent by kidneys, 80% is used for Na⁺ transport
- Na⁺ is not reabsorbed in the descending limb of the loop of Henle
- Water follows reabsorbed sodium by osmosis which has a main effect on blood volume and blood pressure
Reabsorption of other stuff

- Glucose and amino acids are reabsorbed by sodium-dependent, secondary active transport.
- Electrolytes other than Na\(^+\) that are reabsorbed by the tubules have their own independently functioning carrier systems within the proximal tubule.
- The reabsorption of water in the proximal tubule increases the concentration of urea in the tubule, as water is lost from the tubule. This produces a concentration gradient for urea from the tubule into the interstitial fluid.
- Generally, unwanted waste products are not reabsorbed.
### Tubular Secretion

- Transfer of substances from peritubular capillaries into the tubular lumen
- Involves transepithelial transport (steps are reversed)
- Kidney tubules can selectively add some substances to the substances already filtered

<table>
<thead>
<tr>
<th>Tubular Secretion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Most important substances secreted by the tubules:</strong></td>
</tr>
<tr>
<td>- $H^+$</td>
</tr>
<tr>
<td>◦ Important in regulating acid-base balance</td>
</tr>
<tr>
<td>◦ Secreted in proximal, distal, and collecting tubules</td>
</tr>
<tr>
<td>- $K^+$</td>
</tr>
<tr>
<td>◦ Keeps plasma $K^+$ concentration at appropriate level to maintain normal membrane excitability in muscles and nerves</td>
</tr>
<tr>
<td>◦ Secreted only in the distal and collecting tubules under control of aldosterone</td>
</tr>
<tr>
<td>- Organic ions</td>
</tr>
<tr>
<td>◦ Accomplish more efficient elimination of foreign organic compounds from the body</td>
</tr>
<tr>
<td>◦ Secreted only in the proximal tubule</td>
</tr>
</tbody>
</table>
Urine Excretion

- Depending on the body’s state of hydration, the kidneys secrete urine of varying concentrations.
- Too much water in the ECF establishes a hypotonic ECF.
- A water deficit establishes a hypertonic ECF.
- A large, vertical osmotic gradient is established in the interstitial fluid of the medulla (from 100 to 1200 mosm/liter to 1200 mosm/liter). This increase follows the hairpin loop of Henle deeper and deeper into the medulla.
- This osmotic gradient exists between the tubular lumen and the surrounding interstitial fluid.

**Table 13-2** Summary of Transport Across Proximal and Distal Portions of the Nephron

<table>
<thead>
<tr>
<th>PROXIMAL TUBULE</th>
<th>Reabsorption</th>
<th>Secretion</th>
</tr>
</thead>
<tbody>
<tr>
<td>65% of filtered Na⁺ actively reabsorbed, not subject to control</td>
<td>Variable H⁺ secretion, depending on acid-base status of body</td>
<td>Organic ion secretion; not subject to control</td>
</tr>
<tr>
<td>Cl⁻ follows passively</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All filtered glucose and amino acids reabsorbed by secondary active transport; not subject to control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable amounts of filtered PO₄³⁻ and other electrolytes reabsorbed; subject to control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65% of filtered H₂O osmotically reabsorbed; not subject to control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% of filtered urea passively reabsorbed; not subject to control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Almost all filtered K⁺ reabsorbed; not subject to control</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DISTAL TUBULE AND COLLECTING DUCT</th>
<th>Reabsorption</th>
<th>Secretion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Na⁺ reabsorption, controlled by aldosterone; Cl⁻ follows passively</td>
<td>Variable H⁺ secretion, depending on acid-base status of body</td>
<td></td>
</tr>
<tr>
<td>Variable H₂O reabsorption, controlled by vasopressin</td>
<td>Variable K⁺ secretion, controlled by aldosterone</td>
<td></td>
</tr>
</tbody>
</table>
Role of Vasopressin

- Vasopressin-controlled, variable water reabsorption occurs in the final tubular segments.
- 65 percent of water reabsorption is obligatory in the proximal tubule. In the distal tubule and collecting duct it is variable, based on the secretion of ADH.
- The secretion of vasopressin increases the permeability of the tubule cells to water. An osmotic gradient exists outside the tubules for the transport of water by osmosis.
- Vasopressin is produced in the hypothalamus and stored in the posterior pituitary. The release of this substance signals the distal tubule and collecting duct, facilitating the reabsorption of water.
- Vasopressin works on tubule cells through a cyclic AMP mechanism.
- During a water deficit, the secretion of vasopressin increases. This increases water reabsorption.
- During an excess of water, the secretion of vasopressin decreases. Less water is reabsorbed. More is eliminated.