COUNTER CURRENT MECHANISM

• KIDNEYS HAVE
  – MECHANISMS FOR EXCRETING EXCESS WATER
  – MECHANISMS FOR EXCRETING EXCESS SOLUTES

Obligatory Urine Volume

\[
\text{600 mOsm/day} = 0.5 \text{ L/day} \\
\text{1200 mOsm/1.} 
\]
NEPHRON TYPES

- Superficial (cortical) [85 %]
  - Capable of forming dilute urine
- Juxtamedullary [15 %]
  - Capable of forming concentrated (> 300 mOsm/kg) urine

1-2 % Blood Flows Through Juxta Medullary Nephrons
NEPHRON TYPES

- Cortical Nephrons have
  - Peritubular Capillaries
- Juxtamedullary Nephron have
  - Vasa Recta
EXCRETION LIMITS

- At least 600 mmol must be excreted each day
  - minimum volume = 600/1200 = 0.5 L
  - maximum volume = 20 L

NEPHRON TYPES
Cortical and Juxtamedullary Nephrons

1-2 % Blood Flows Through Juxta Medullary Nephrons
COUNTER CURRENT MECHANISM

- LOOPS OF HENLE OF JUXTA MEDULLARY NEPHRONS establish hyperosmolality of interstitium of medulla. They are called COUNTER CURRENT MULTIPLIERS

- VASA RECTA maintain hyperosmolality established by counter current multipliers. They are called COUNTER CURRENT EXCHANGERS
Table 28-1

Summary of Tubule Characteristics—Urine Concentration

<table>
<thead>
<tr>
<th>Active NaCl Transport</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H₂O</td>
</tr>
<tr>
<td>Proximal tubule</td>
<td>++</td>
</tr>
<tr>
<td>Thin descending limb</td>
<td>0</td>
</tr>
<tr>
<td>Thin ascending limb</td>
<td>0</td>
</tr>
<tr>
<td>Thick ascending limb</td>
<td>++</td>
</tr>
<tr>
<td>Distal tubule</td>
<td>+</td>
</tr>
<tr>
<td>Cortical collecting</td>
<td>+</td>
</tr>
<tr>
<td>tube</td>
<td></td>
</tr>
<tr>
<td>Inner medullary</td>
<td>+</td>
</tr>
<tr>
<td>collecting duct</td>
<td></td>
</tr>
</tbody>
</table>

0, minimal level of active transport or permeability; +, moderate level of active transport or permeability; ++, high level of active transport or permeability; +ADH, permeability to water or urea is increased by ADH.
LOOP OF HENLE

<table>
<thead>
<tr>
<th>Descending Loop</th>
<th>Ascending Loop</th>
</tr>
</thead>
<tbody>
<tr>
<td>highly permeable to water</td>
<td>impermeable to water</td>
</tr>
<tr>
<td>impermeable to Na⁺</td>
<td>permeable to Na⁺ (mediated by Na⁺/K⁺/2Cl⁻ apical carrier - inhibited by furosemide (Lasix))</td>
</tr>
<tr>
<td>water exit promoted</td>
<td>Na⁺/K⁺-ATPase actively pumps out sodium of cell into interstitium</td>
</tr>
</tbody>
</table>

Buildup of solute concentration into the renal medulla

1. Active transport of sodium ions and co-transport of potassium, chloride, and other ions out of the thick portion of the ascending limb of the loop of Henle into the medullary interstitium
2. Active transport of ions from the collecting ducts into the medullary interstitium
3. Facilitated diffusion of large amounts of urea from the inner medullary collecting ducts into the medullary interstitium
4. Diffusion of only small amounts of water from the medullary tubules into the medullary interstitium, far less than the reabsorption of solutes into the medullary interstitium
Role of DCT & CT in Excreting a Concentrated Urine

Urea contributes about 40 to 50 per cent of the osmolality (500-600 mOsm/L) of the renal medullary interstitium when the kidney is forming a maximally concentrated urine.
ROLE OF UREA IN MAKING A HYPEROSMOTIC RENAL MEDULLARY INTERSTITIUM AND CONCENTRATED URINE

About 40 to 50% of the osmolarity (500-600 mOsm/L) of the renal medullary interstitium when the kidney is forming a maximally concentrated urine.

A specific urea transporter UT-AI, is activated by ADH.

Recirculation of urea

two special features of the renal medullary blood flow

- The medullary blood flow is low, accounting for less than 5 per cent of the total renal blood flow. This sluggish blood flow is sufficient to supply the metabolic needs of the tissues but helps to minimize solute loss from the medullary interstitium.
- The vasa recta serve as countercurrent exchangers, minimizing washout of solutes from the medullary interstitium.
COUNTER CURRENT EXCHANGERS

- Sluggish blood flow (1-2 %)
- Close proximity
- High permeability

A PASSIVE PROCESS
COUNTER CURRENT EXCHANGERS

COUNTER CURRENT MULTIPLIERS

Vasa recta

LOH

COUNTER CURRENT EXCHANGERS

Vasa recta

Interstitium

mOsm/L

mOsm/L

300

600

800

1000

1200

600

800

1000

1200

300

600

800

900
Table 28-2
Regulation of ADH Secretion

<table>
<thead>
<tr>
<th>Increase ADH</th>
<th>Decrease ADH</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ Plasma osmolarity</td>
<td>↓ Plasma osmolarity</td>
</tr>
<tr>
<td>↓ Blood volume</td>
<td>↑ Blood volume</td>
</tr>
<tr>
<td>↓ Blood pressure</td>
<td>↑ Blood pressure</td>
</tr>
<tr>
<td>Nausea</td>
<td></td>
</tr>
<tr>
<td>Hypoxia</td>
<td></td>
</tr>
<tr>
<td>Drugs:</td>
<td>Drugs:</td>
</tr>
<tr>
<td>Morphine</td>
<td>Alcohol</td>
</tr>
<tr>
<td>Nicotine</td>
<td>Clonidine (antihypertensive drug)</td>
</tr>
<tr>
<td>Cyclophosphamide</td>
<td>Haloperidol (dopamine blocker)</td>
</tr>
</tbody>
</table>
DISORDERS OF URINARY CONCENTRATING ABILITY

- Failure to Produce ADH: "Central" Diabetes Insipidus.
- Inability of the Kidneys to Respond to ADH: "Nephrogenic" Diabetes Insipidus.
DISORDERS OF URINARY CONCENTRATING ABILITY

- Inappropriate secretion of ADH (SIADH)

RENAI PHYSIOLOGY
MICTURITION

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It is the process by which the urinary bladder empties when it becomes filled

- Filling of bladder.
- Micturition reflex.
- Voluntary control.
Physiologic Anatomy and Nervous Connections of the Bladder

- Composed of
  1. Body
  2. Neck........post urethra (stretch receptors)
- External sphincter.
- Pelvic diaphragm.

A reservoir ... adult ... 250-400ml
DETRUSOR MUSCLE ... pr can rise upto 40-60 mmHg.
Mucosa... RUGAE ...TRIGONE

Nervous Connections of the Bladder
Nerve Supply

- **PELVIC NERVES** from sacral plexus mainly S2 and S3...both sensory and motor. The motor nerves transmitted in the pelvic nerves are **parasympathetic fibers**
- **PUDENDAL NERVE** contain skeletal motor fibers transmitted through the to the external bladder sphincter
- **SYMPATHETIC INNERVATION** from the sympathetic chain through the hypogastric nerves (L-2). Stimulate mainly the blood vessels and have little to do with bladder contraction. Some sensory nerve fibers for fullness and pain.
INNERVATION OF THE BLADDER

<table>
<thead>
<tr>
<th>Nerves</th>
<th>Characteristic</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvic nerves (parasympathetic fibers)</td>
<td>Both sensory and motor nerve fibers</td>
<td>Contraction of bladder</td>
</tr>
<tr>
<td>S-2 and S-3</td>
<td></td>
<td>The sensory fibers detect the degree of stretch in the bladder wall</td>
</tr>
<tr>
<td>Pudendal Nerve</td>
<td>somatic nerve</td>
<td>Fibers that innervate and control the voluntary skeletal muscle of the sphincter</td>
</tr>
<tr>
<td>Hypogastric Nerves</td>
<td>sympathetic innervation (L2)</td>
<td>Stimulate mainly the blood vessels and have little to do with bladder contraction. Sensory nerve fibers of the sympathetic nerves also mediate the sensation of fullness and pain.</td>
</tr>
</tbody>
</table>

FILLING OF BLADDER AND ITS TONE...

- 0 ... when empty.
- 30-50 ml ... 5-10 cm of water.
- 200 – 300 ml ... small additional rise of pr.
- Beyond 300 – 400 ml ... pr rises rapidly.
- Micturition waves... acute pr peaks superimposed on the tonic pr changes can range from few to > 100 cm of water caused by micturition reflex.
- Cystometryrogram.
CYSTOMETROGRAM
Micturition Reflex

- Completely AUTONOMIC SPINAL REFLEX.
- When bladder only partially filled, relax spontaneously after a fraction of a min. Detrusor muscle contraction stops ... pr falls to baseline.
- As bladder fills more ... reflexes increase in frequency and intensity.
- Positive feedback mechanism.
Bladder fills to capacity and overflows a few drops at a time through the urethra. This is called overflow incontinence.

**ABNORMALITIES OF MICTURITION**

<table>
<thead>
<tr>
<th>Lesion</th>
<th>ATOMIC BLADDER</th>
<th>AUTOMATIC BLADDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory nerve fibers from the bladder to the spinal cord and tabs dorsalis destroyed</td>
<td>Spinal Cord Damage Above the Sacral Region resulting in Spinal shock</td>
<td></td>
</tr>
<tr>
<td>Feature</td>
<td>return of excitability of micturition reflex until typical micturition reflexes returns &amp; then, periodic (but unannounced) bladder emptying occurs which may be controlled by scratching or tickling</td>
<td></td>
</tr>
</tbody>
</table>