Ch 19: The Kidneys

*Homeostatic regulation of*
ECF volume and BP
Osmolarity
  - 290 mOsm
Ion balance
  - Na+ and K+, etc.
pH (acid-base balance
Excretion of wastes & foreign substances
Hormone production
  - EPO
  - Renin

Functional unit of kidneys: ??
Five Processes of Urinary System

1. Filtration,
2. Reabsorption,
3. Secretion,
4. Excretion
5. Micturition

Related by equation:

\[ E = F - R + S \]

180 L / day filtered, >99% reabsorbed,

1.5 L/day excreted
1) Filtration

= Movement of fluid from blood to lumen of nephron (rel. nonspecific process)

Once in lumen – consider it outside body

Composition of filtrate?
1) Filtration, cont’d: Passage across 3 Barriers

1. Capillary endothelium is fenestrated

2. Basal lamina
   1. Filters proteins

3. Bowman’s capsule epithelium (visceral layer), including podocytes

Some small molecules (Ca^{2+}, low m.w. fatty acids) bind to plasma proteins \( \rightarrow ? \)

Fig 19-4
Cause of Filtration

Three types of pressures are at work:

- **Hydrostatic pressure in capillaries** (see exchange in tissues)
- **Osm. P_{capillaries} > Osm. P_{Bowman's capsule}**
- **Hydrostatic fluid P from presence of fluid in Bowman's capsule**

Net (?) **driving pressure**: ~ 10 mmHg

![Diagram of filtration process](image)
GFR = Glomerular Filtration Rate

Describes filtration efficiency: Amount of fluid filtered per unit of time

Average GFR ~ 180 L/day!

Filtration Coefficient is influenced by
1. Net filtration pressure
2. Available surface area of glomerular capillaries

GFR is closely regulated to remain constant over range of BPs (80 - 180 mm Hg)
Goal is to control blood flow though both afferent and efferent arterioles – via ?
Regulation of GFR

Several mechanisms provide close control of GFR:

- Filtration Pressure (BP)
  - Hydrostatic, colloid
  - Resistance in afferent vs. efferent arterioles
- Tubuloglomerular feedback
  - JG Apparatus
- Hormones and ANS
  - Angiotensin II (vasoconstrictor)
  - Prostaglandins (vasodilator)
Regulation of GFR via Tubuloglomerular Feedback

As GFR ↑, flow through DCT ↑

Macula densa cells: release paracrines

juxtaglomerular cells (smooth muscle fibers from afferent arteriole): contract

Thus GFR ↓
2) Tubular Reabsorption (99% of filtrate)

Highly selective and variable

Amount of filtrate / day?
Urine production / day?
% reabsorbed?

Mostly transepithelial transport (examples: Sodium and glucose)

Reabsorption may be active (Na⁺, glucose) or passive (urea)

Figs 19-12/13
2) Tubular Reabsorption (99% of filtrate)

- May be active
  - Na\(^+\) transport
  - Recall Antiports and Symports
- or Passive (think concentration and osmotic gradients)
  - Paracellular
  - E.g., urea
- Transcytosis
  - Proteins

**Fig 19-11**

Filtrate is similar to interstitial fluid.

1. Na\(^+\) is reabsorbed by active transport.
2. Electrochemical gradient drives anion reabsorption.
3. Water moves by osmosis, following solute reabsorption.
4. Concentrations of other solutes increase as fluid volume in lumen decreases. Permeable solutes are reabsorbed by diffusion.
**Na⁺ Reabsorption in PCT: Transepithelial Transport**

**Apical:** Leak channels for Na⁺. Movement down conc. gradient.

**Basolateral:** Na⁺/K⁺ ATPase.

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**Fig 19-12**

1. Na⁺ enters cell through open channels, moving down its electrochemical gradient.
2. Na⁺ is pumped out the basolateral side of cell by the Na⁺-K⁺-ATPase.
Passive Urea Reabsorption

$\text{Na}^+ \text{ actively reabsorbed}$

$\text{H}_2\text{O}$ follows passively

$\uparrow [\text{urea}] \Rightarrow \text{passive reabsorption}$

(diffusion into blood)
Saturation of Renal Transport

Saturation = Maximum rate of transport (t_m)

Same 3 characteristics as discussed in mediated transport

Transport maximum determined by

1. **Saturation** → Renal Threshold
2. Specificity
3. Competition

(Fig 19-15d)
3) Secretion

- 2nd route of entry (from ECF) into tubules for selected molecules

- Mostly transepithelial transport \((\text{analogous to reabsorption})\). Depends mostly on active membrane transport systems

- Provides mechanism for rapid removal of substances (most important for \(H^+\), \(K^+\), foreign organic ions and drugs such as penicillin etc.)
4) Excretion = Urine Output

- Excretion of excess ions, H₂O, toxins, “foreign molecules” “nitrogenous waste” (NH₄⁺, urea)
- Depends on Filtration, Reabsorption, Secretion
  - \( E = F - R + S \)
- Direct measurement of F, R, S impossible
  - infer from comparison of blood & urinalysis
- For any substance: (Renal) Clearance = plasma volume completely cleared of that substance per minute
  - Typically expressed as ml/min
Clinical Importance of GFR and Clearance

- **GFR** is an indicator for overall kidney function.
- **Clearance** → non-invasive way to measure GFR
  - Inulin (research use)
    - Neither secreted nor reabsorbed
  - Creatinine (clinically useful)
- If a substance is filtered and reabsorbed but not secreted ⟷ clearance rate < GFR
- If a substance is filtered and secreted but not reabsorbed ⟷ clearance rate > GFR
5. Micturition

Spinal cord integration: 2 simultaneous efferent signals

In infant just simple spinal reflex

Later: learned reflex under conscious control from higher brain centers

Various subconscious factors affect reflex
Renal Failure & Artificial Kidney

Symptoms when < 25% functional nephrons

due to:
1. Kidney infections
2. Chemical poisoning (lead, paint-thinner) etc.

Hemodialysis:
3/week 4-8h/session
Alternative: CAPD

Continuous Ambulatory Peritoneal Dialysis
Manneken Pis in Brussels

the end