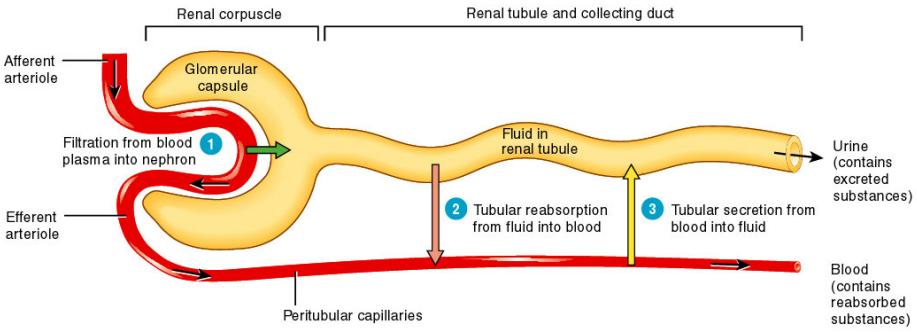
RENAL PHYSIOLOGY

TUBULAR FUNCTIONS IN URINE FORMATION

Fig. 26.07



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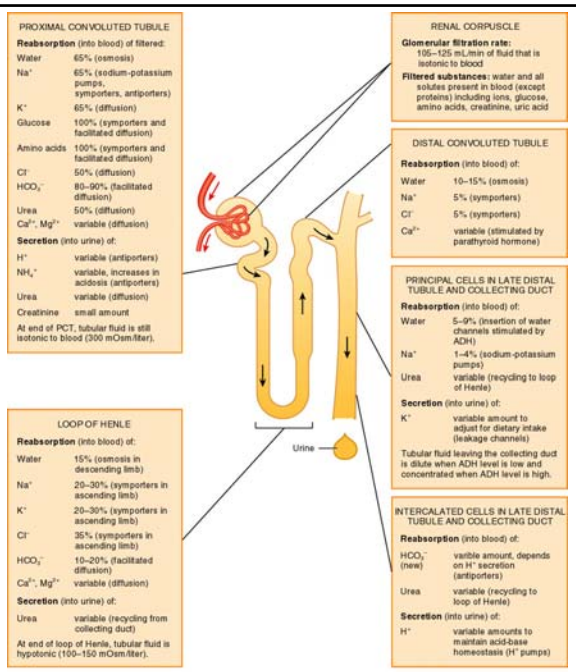

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Different Types of Substances undergo transport

- glucose, amino acids, protein
- Na, K, Cl, HCO3, Ca, Mg

- Urea, uric acid, creatinine, sulfates, phenols

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How much of the filtered load is reabsorbed in the PCT

- 67% reabsorbed
  - Filtered water
  - Na
  - Cl
  - K
  - Urea
- 100% reabsorbed
  - Glucose
  - amino acids
  - small filterable proteins
  - HCO3

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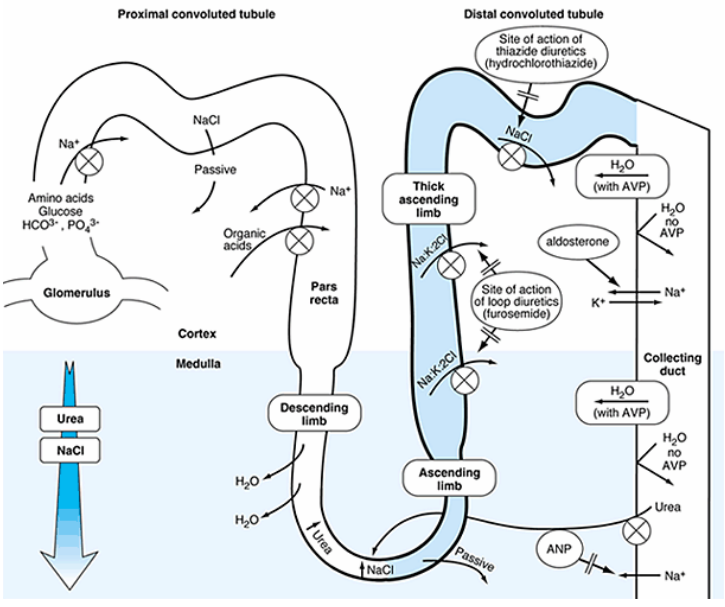

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Tubular Reabsorption

1. Ultrafiltration
2. Reabsorption

GFR-125ml/min

180 liters/day enter renal tubules

– 1-1.5 liters/day
– 178 liters are reabsorbed

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Reabsorptive Mechanism

- Active
  – if it goes against an electro-chemical gradient
  – work is performed
  – energy is utilized
- Passive
  – substance is reabsorbed migrates from tubular lumen to peritubular fluid down an electro-chemical gradient
  – no energy utilized

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Active Transport

- Transport maxima
  - fixed amount of substance/minute
  - reflection of the saturation of the system (energy, carrier)
  - (glucose, phosphate, sulfate, malate, lactate, beta-hydroxybutyrate, aceto-acetate, Vitamin C
- Gradient- time limitation
  - against electrochemical gradient
  - not limited in their reabsorption per unit time but rather are limited to
    - extent of the gradient that could be established in the duration of time that the fluid is in contact with the epithelium
    - the greater the gradient, the longer the time of contact → the greater the amount reabsorbed
  - (Sodium, Chlorides, Bicarbonates)

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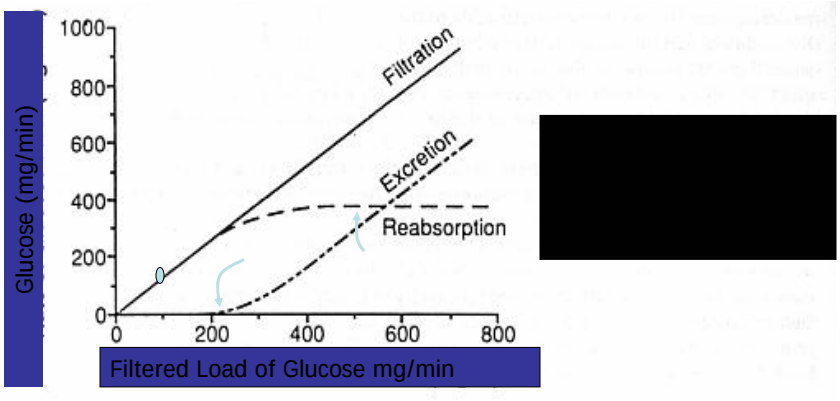
Glucosuria



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Passive Transport

- diffusion along or down an electro-chemical gradient
- water, urea, chlorides moves from lumen to peritubular fluid because
  - electrochemical
  - osmotic gradient
- no energy is spent

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Quantification of Tubular Reabsorption

calculated by subtracting the amount excreted per minute from the filtered amount within the same period of time.

- $QR = Q_F - Q_E$

  $QR = (GFR \times P_X) - (U_X \times V)$

- gauging the reabsorptive capacity of the tubules

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Urine Flow rate= 1ml/min

Urine Concentration of Sodium (UNa) = 70 mEq/L= 70 µEq/ml

Plasma sodium Concentration = 140 mEq/L= 140 µEq/ml

GFR (inulin clearance)= 100ml/min

$QR = (GFR \times P_X) - (U_X \times V)$

100 X 140= 14000 µEq/min

70 X 1= 70 µEq/min

14,000 µEq/min – 70 µEq/min = 13,930 µEq/min

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Factors Affecting Tubular Reabsorption

- Rate of flow along the tubules
- Osmotic pressure of the fluid in the tubules
- Changes in the endocrine activity of posterior pituitary lobe and the adrenal cortex
  - AVP (ADH) increase reabsorption of fluid DT, and CD.
  - Mineralocorticoids increase reabsorption of Na, Cl, H2O in the distal convoluted tubules

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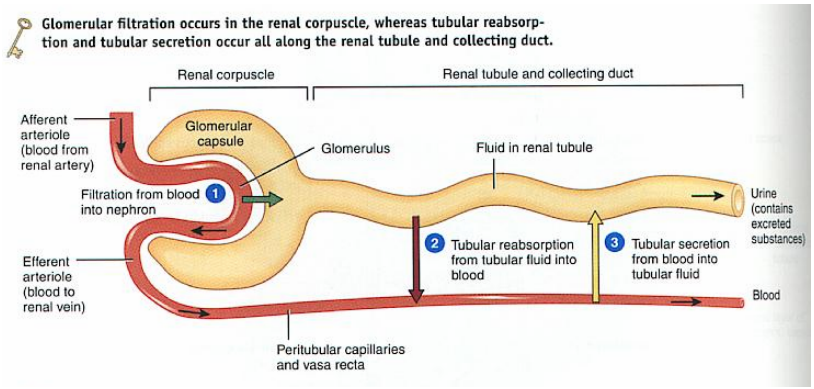

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TUBULAR SECRETION

- Nature of Tubular secretion
- Active Secretion by Tm-Limited Mechanisms
- Active Secretion by Gradient-time- limited Mechanism
- Passive Tubular Secretion
- Quantification of Tubular Secretion

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Nature of Tubular Secretion

- resembles reabsorption
  - difference orientation of movement
- Three Types of Secretory Mechanism
  - absolute limitation of transport capacity (Active)
  - gradient time limitation of transport capacity (Active)
  - diffusion of materials down gradients of concentration (Passive)

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Active Secretion by Tm- Limited Mechanisms:

- heterogenous group *(carboxylic acids {phenol red, hippurate, creatinine, p-aminohippurate PAH, penicillin, chlorothiazide}, glucoronides, urological contrast agents {diodrast, uroselectan, topax, neo-iopax, and skiodan})*
- strong organic bases *(guanidine, thiamine, choline, histamine, piperidine, darstine, priscoline and hexamethonium*

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Active Secretion by Gradient-time-limited Mechanisms

- secretion of H ion is active
- secretion of K ions involves active accumulation in tubular cells
  - *same carrier that transport hydrogen ions*
- transport of both ions appears to be gradient dependent
  - *if intracellular K ions is high, H ions is low, K occupies the transport mechanism to the exclusion of H ion*
- Same mechanism reabsorbed sodium
  - *reabsorbed in exchange for either H+ or K+ ions (Distal T, CD)*

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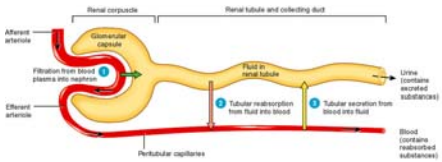
Passive Tubular Secretion

- weak bases (quinine, quinacrine, procaine etc) secreted by “diffusion trapping”
- two weak acids are secreted in the same manner
- Renal tubules are <u>permeable</u> to undissociated weak bases and undissociated weak acids and are <u>impermeable</u> to the cationic and anionic forms
- passive secretion of weak bases, and weak acids (salicylic acid, phenobarbital)



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Quantification of Tubular Secretion

- secreted by the renal tubules also filtered through the glomerulus.

Rate of Excretion= rate of filtration + rate of tubular secretion

Rate of Secretion= rate of excretion – rate of filtration

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REGULATION OF THE ACID-BASE BALANCE OF THE BODY

Three Major Factors Help Maintain pH

- Chemical buffers (blood physiology)
- Respiratory Regulatory Mechanism (respiratory physiology)
- Kidneys eliminate excess acids and bases

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Regulation of pH by the Kidneys

- body produces excess acids→ excrete acid, and by returning bicarbonate
- pH 5.5- 6.5 urine
- pH 7.35- 7.45 plasma

- **<u>Kidney Compensate by:</u>**
  1. The reabsorption of bicarbonate
  2. Acidification of phosphate buffer salts
  3. The secretion of ammonia

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The Reabsorption of Bicarbonates

- normally all bicarbonates are reabsorbed in exchange of hydrogen ions
- hydrogen ions are available in tubular cells
  - cell $CO_2 + H_20 \rightarrow (CA)\ H_2CO_3 \rightarrow H + HCO_3$
  - urine $H + HCO_3 \rightarrow H_2CO_3 \rightarrow H_2O + CO_2$
    - water excreted
    - carbon dioxide reabsorbed
    - sodium ions (from urine→ tubular cells
    - $Na + HCO_3 \rightarrow Na_2HCO_3$

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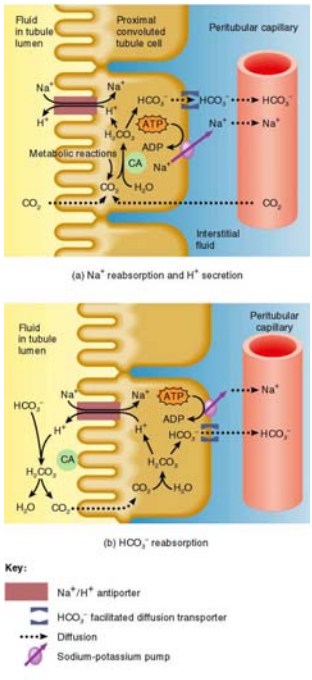
Fig. 26.13



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Acidification of Phosphate Buffer Salts

- exchange between hydrogen ion and sodium salt monohydrogen phosphate (Na_2HPO4)
- $Na_2HPO4 \rightarrow Na + NaHPO_4$
- H ions from tubular cells unite with $NaHPO_4 \rightarrow NaH_2PO4 \rightarrow$ excreted
- hydrogen ion is removed from the body

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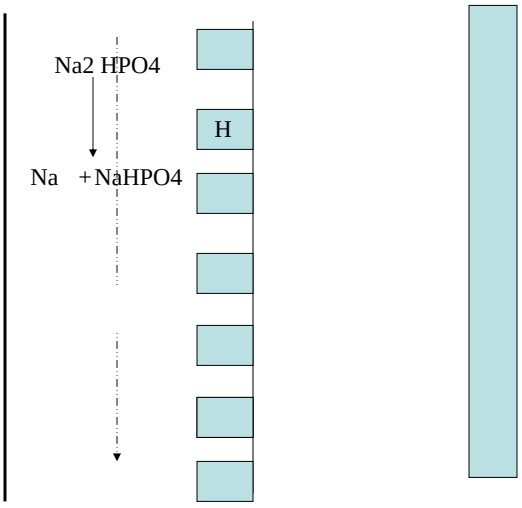

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The Secretion of Ammonia

- Ammonia is formed in the renal tubular cells from the oxidation of amino acids, glutamine by the enzyme glutaminase
  - free NH_3 unite with hydrogen ion converted into ammonium ion NH_4 → excreted as ammonium chloride → Hydrogen ion is excreted
  - ammonia can also be converted to urea

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ACIDOSIS

- Urine pH 4.5
- Bicarbonate excretion may diminished or disappear
- Excretion of titratable acid, ammonium salt and Chloride excretion increases
- Excretion of Sodium and Potassium decreases

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ALKALOSIS

- Urine pH 8.0
- Bicarbonate excretion increase
- Excretion of titratable acid, ammonium salt and Chloride excretion decrease
- Excretion of Sodium and Potassium increase

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Thank You!