

Physiology of Urinary system

By

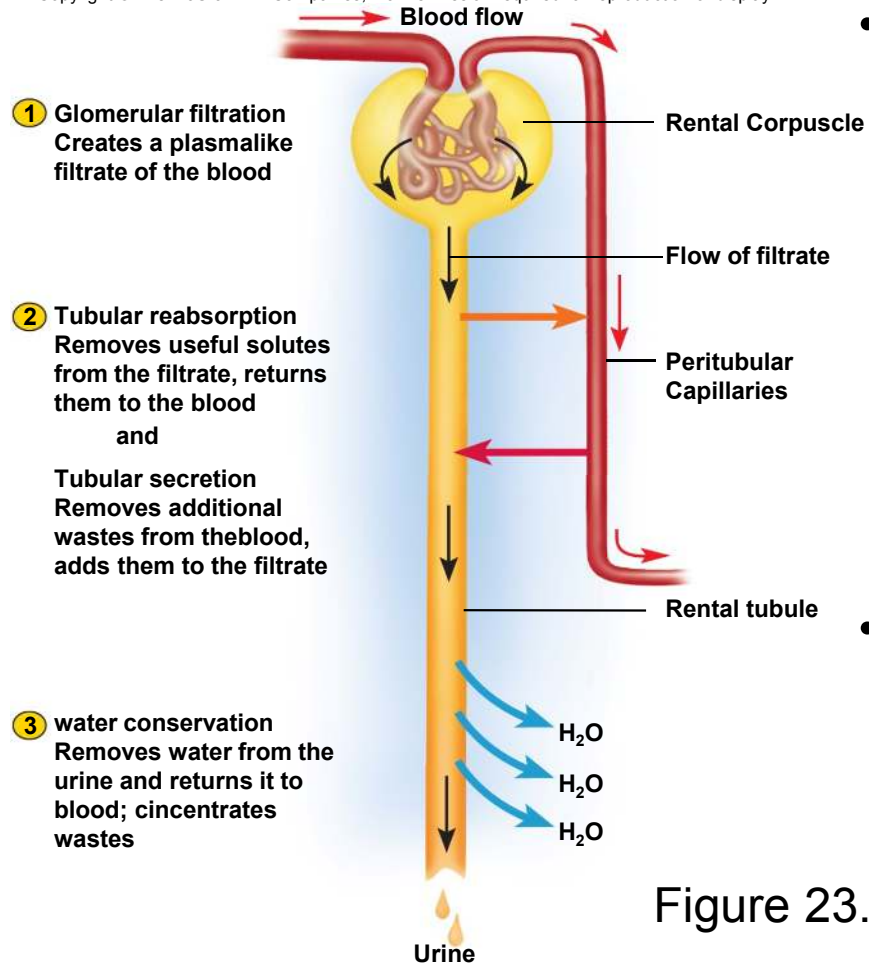
Dr. Mossa M. Marbut

Dr. Hassan Y. Hassan

3rd Year/ Lecture 3

Urine Formation II: Tubular Reabsorption and Secretion

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



- conversion of glomerular filtrate to urine involves the removal and addition of chemicals by tubular reabsorption and secretion
 - occurs through PCT to DCT
 - tubular fluid is modified
- steps involved include:
 - tubular reabsorption
 - tubular secretion
 - water conservation

Figure 23.9

Proximal Convoluted Tubule

- **PCT reabsorbs about 65% of glomerular filtrate**, removes some substances from the blood, and **secretes** them into the tubular fluid for disposal in urine
 - **prominent microvilli** and great length
 - abundant mitochondria provide ATP for active transport
 - PCTs alone account for about 6% of one's resting ATP and calorie consumption
- **tubular reabsorption** – process of reclaiming water and solutes from the tubular fluid and returning them to the blood
- **two routes of reabsorption**
 - **transcellular route**
 - substances pass through the cytoplasm of the PCT epithelial cells and out their base
 - **paracellular route**
 - substances pass between PCT cells
 - junctions between epithelial cells are quite leaky and allow significant amounts of water to pass through
 - **solvent drag** – water carries with it a variety of dissolved solutes
- taken up by **peritubular capillaries**

Sodium Chloride

- **sodium reabsorption** is the key to everything else
 - creates an osmotic and electrical gradient that drives the reabsorption of water and other solutes
 - most abundant cation in filtrate
 - creates steep concentration gradient that favors its diffusion into the epithelial cells
- **two types of transport proteins** in the apical cell surface are responsible for sodium uptake
 - symports that simultaneously bind Na^+ and another solute such as glucose, amino acids or lactate
 - a Na^+ - H^+ antiport that pulls Na^+ into the cell while pumping out H^+ into tubular fluid
- sodium is prevented from accumulating in the epithelial cells by **Na^+ - K^+ pumps** in the basal surface of the epithelium
 - pumps Na^+ out into the extracellular fluid
 - picked up by peritubular capillaries and returned to the blood stream
 - ATP consuming active transport pumps
 - **secondary active transport** – Na^+ transporting symports in apical cell membrane do not consume ATP, are considered an example of secondary active transport for their dependence on the Na^+ - K^+ pumps at the base of the cell
- negative **chloride ions** follow the positive sodium ions by electrical attraction
 - various antiports in the apical cell membrane that absorb Cl^- in exchange for other anions they eject into the tubular fluid – K^+ - Cl^- symport

Reabsorption in the PCT

Other Electrolytes

- **potassium, magnesium, and phosphate ions** diffuse through the paracellular route with water
- **phosphate** is also cotransported into the epithelial cells with Na^+
- some **calcium** is reabsorbed through the paracellular route in the PCT, but most Ca^{+2} occurs later in the nephron
- **glucose** is cotransported with Na^+ by **sodium-glucose transport (SGLT) proteins**.
- **urea** diffuses through the tubule epithelium with water – reabsorbs 40 – 60% in tubular fluid
 - kidneys remove about half of the urea from the blood - creatinine is not reabsorbed at all

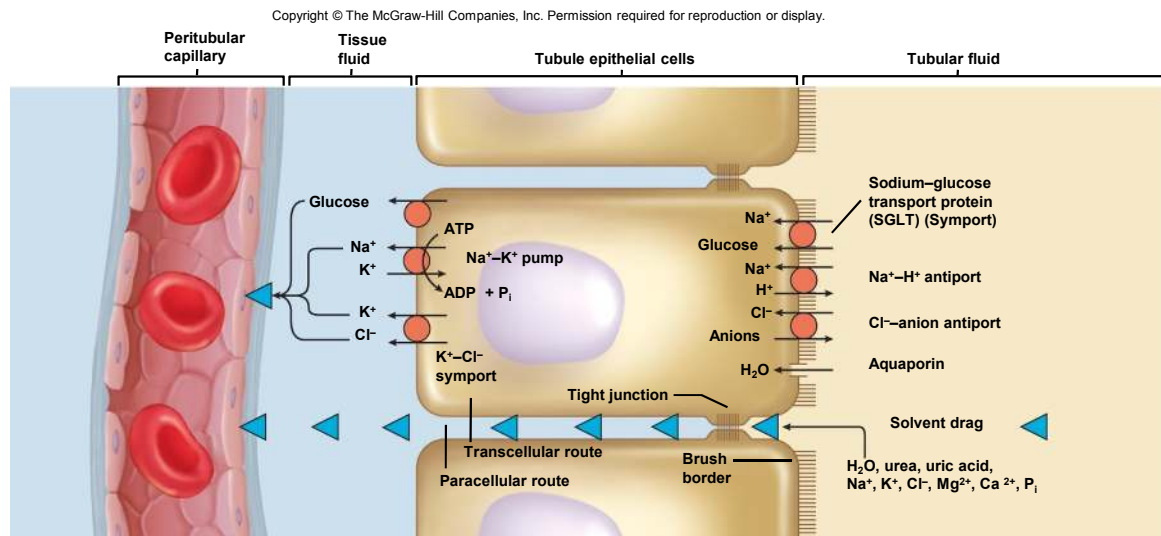


Figure 23.16

Water Reabsorption

- kidneys reduce 180 L of glomerular filtrate to 1 or 2 liters of urine each day
- two-thirds of water in filtrate is reabsorbed by the PCT
- reabsorption of all the salt and organic solutes makes the tubule cells and tissue fluid hypertonic
 - water follows solutes by osmosis through both paracellular and transcellular routes through water channels called **aquaporins**
 - in PCT, water is reabsorbed at constant rate called **obligatory water reabsorption**

Uptake by the Peritubular Capillaries

- after water and solutes leave the basal surface of the tubular epithelium, they are reabsorbed by the peritubular capillaries
 - reabsorbed by osmosis and solvent drag
- three factors promote osmosis into the capillaries
 - accumulation of reabsorbed fluid around the basolateral sides of epithelial cell creates **high interstitial fluid pressure** that drives water into the capillaries
 - narrowness of efferent arterioles **lowers blood hydrostatic pressure** in peritubular capillaries so there is less resistance to absorption
 - proteins remain in blood after filtration, which **elevates colloid osmotic pressure**
 - high COP and low BHP in the capillaries and high hydrostatic pressure in the tissue fluid, the balance of forces in the peritubular capillaries favors absorption

Transport Maximum of Glucose

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

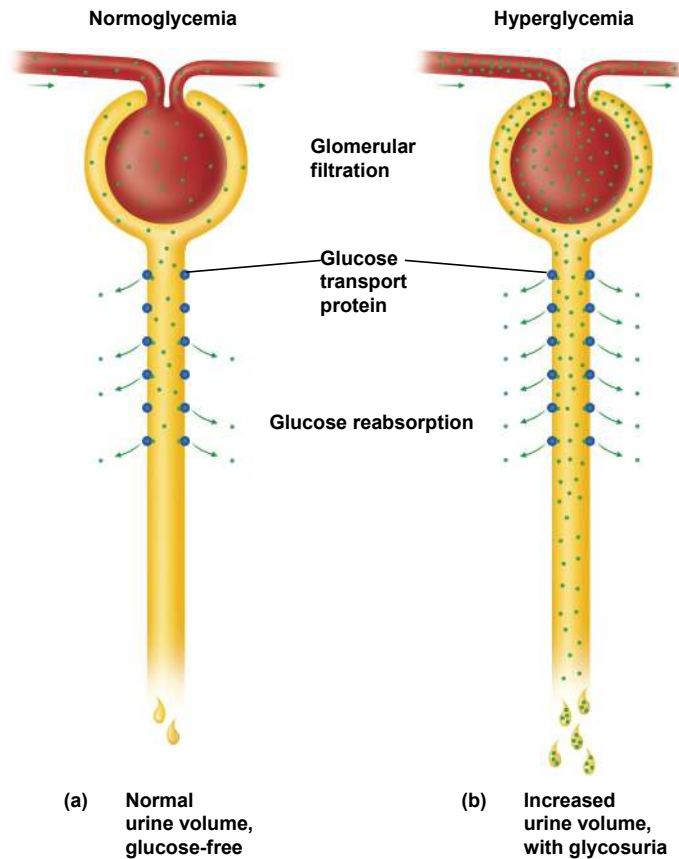


Figure 23.18

- there is a limit to the amount of solute that the renal tubules can reabsorb
- limited by the **number of transport proteins** in the plasma membrane
- if all transporters are occupied as solute molecules pass
 - excess solutes appear in urine
- **transport maximum** is reached when transporters are saturated
- each solute has its own transport maximum
 - any blood glucose level above 220 mg/dL results in **glycosuria**

Tubular Secretion

- **tubular secretion** – process in which the renal tubule extracts chemicals from the capillary blood and secretes them into tubular fluid
- two purposes in proximal convoluted tubule and nephron loop
 - **waste removal**
 - urea, uric acid, bile acids, ammonia, catecholamines, prostaglandins and a little creatinine are secreted into the tubule
 - secretion of uric acid compensates for its reabsorption earlier in PCT
 - clears blood of pollutants, morphine, penicillin, aspirin, and other drugs
 - explains need to take prescriptions 3 to 4 times/day to keep pace with the rate of clearance
 - **acid-base balance**
 - secretion of hydrogen and bicarbonate ions help regulate the pH of the body fluids

Function of Nephron Loop

- **primary function of nephron loop** is to generate salinity gradient that enables collecting duct to concentrate the urine and conserve water
- electrolyte reabsorption from filtrate
 - thick segment reabsorbs 25% of Na^+ , K^+ , and Cl^-
 - ions leave cells by active transport and diffusion
 - NaCl remains in the tissue fluid of renal medulla
 - water can not follow since thick segment is impermeable
 - tubular fluid very dilute as it enters distal convoluted tubule

DCT and Collecting Duct

- fluid arriving in the DCT still contains about 20% of the water and 7% of the salts from glomerular filtrate
 - if this were all passed as urine, it would amount to 36 L/day
- DCT and collecting duct reabsorb variable amounts of water salt and are regulated by several hormones
 - **aldosterone, atrial natriuretic peptide, ADH, and parathyroid hormone**
- **two kinds of cells** in the DCT and collecting duct
 - **principal cells**
 - most numerous
 - have receptors for hormones
 - involved in salt and water balance
 - **intercalated cells**
 - involved in acid/base balance by secreting H^+ into tubule lumen and reabsorbing K^+

DCT and Collecting Duct

- **aldosterone** - the “salt-retaining” hormone
 - steroid secreted by the adrenal cortex
 - when blood Na^+ concentration falls or
 - when K^+ concentration rises
 - or drop in blood pressure → renin release → angiotensin II formation → stimulates adrenal cortex to secrete aldosterone
- **functions of aldosterone**
 - acts on thick segment of nephron loop, DCT, and cortical portion of collecting duct
 - stimulates the reabsorption of more Na^+ and secretion of K^+
 - water and Cl^- follow the Na^+
 - net effect is that the body retains NaCl and water
 - helps maintain blood volume and pressure
 - the urine volume is reduced
 - the urine has an elevated K^+ concentration

DCT and Collecting Duct

- **atrial natriuretic peptide (ANP)** - secreted by atrial myocardium of the heart in response to high blood pressure
- has four actions that result in the excretion of more salt and water in the urine, thus reducing blood volume and pressure
 - dilates afferent arteriole, constricts efferent arteriole - \uparrow GFR
 - inhibits renin and aldosterone secretion
 - inhibits secretion of ADH
 - inhibits NaCl reabsorption by collecting duct

DCT and Collecting Duct

- **antidiuretic hormone (ADH)** secreted by posterior lobe of pituitary
- in response to dehydration and rising blood osmolarity
 - stimulates hypothalamus
 - hypothalamus stimulates posterior pituitary
- action - make collecting duct more permeable to water
 - water in the tubular fluid reenters the tissue fluid and bloodstream rather than being lost in urine

DCT and Collecting Duct

- **parathyroid hormone (PTH)** secreted from parathyroid glands in response to calcium deficiency (**hypocalcemia**)
 - acts on PCT to increase phosphate excretion
 - acts on the thick segment of the ascending limb of the nephron loop, and on the DCT to increase calcium reabsorption
 - increases phosphate content and lowers calcium content in urine
 - because phosphate is not retained, the calcium ions stay in circulation rather than precipitating into the bone tissue as calcium phosphate
 - PTH stimulates calcitriol synthesis by the epithelial cells of the PCT

Summary of Tubular Reabsorption and Secretion

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

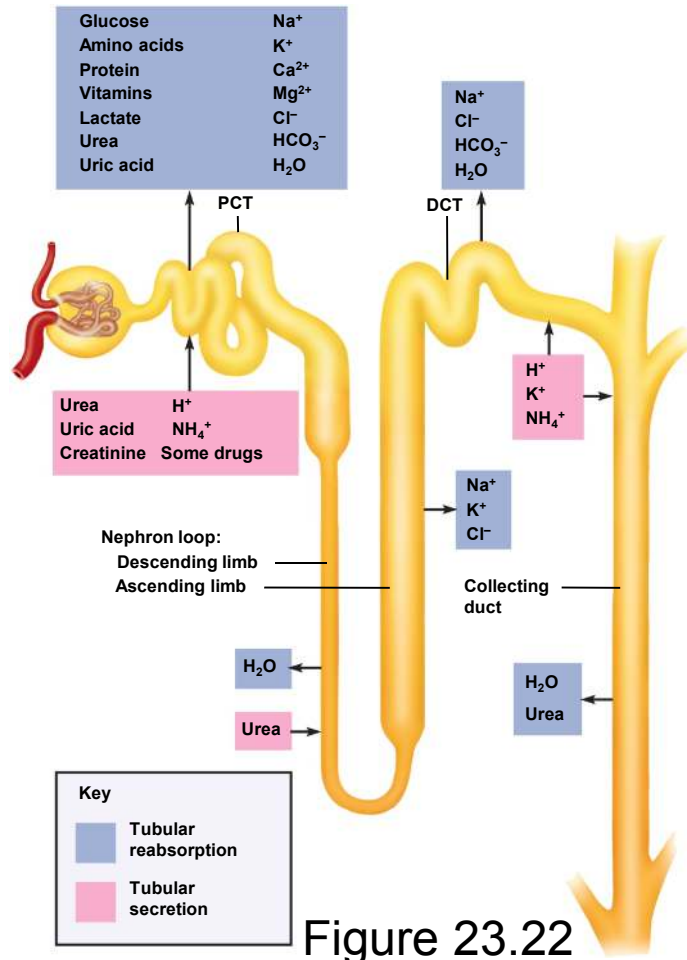


Figure 23.22

- **PCT** reabsorbs 65% of glomerular filtrate and returns it to peritubular capillaries
 - much reabsorption by osmosis & cotransport mechanisms linked to active transport of sodium
- **nephron loop** reabsorbs another 25% of filtrate
- **DCT** reabsorbs Na^+ , Cl^- and water under hormonal control, especially aldosterone and ANP
- the tubules also extract drugs, wastes, and some solutes from the blood and **secrete** them into the tubular fluid
- **DCT** completes the process of determining the chemical composition of urine
- collecting duct conserves water