

Urinary System Organization

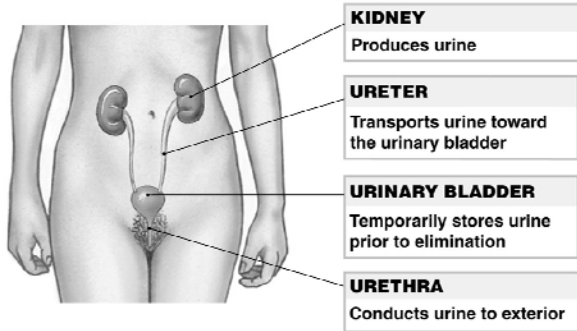
The Golden Rule: The Job of The Urinary System is to Maintain the Composition and Volume of ECF... remember this & all else will fall in place!

Functions of the Urinary System

- Eliminate organic wastes
- Regulate plasma ion levels
- Regulate blood volume and blood pressure
 - Adjust water loss
 - Release cardiovascular hormones
- Stabilize blood pH
- Conserve nutrients

Urinary System Organization

The Components of the Urinary System

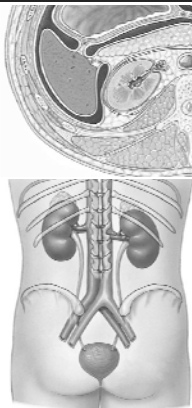


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The Kidneys

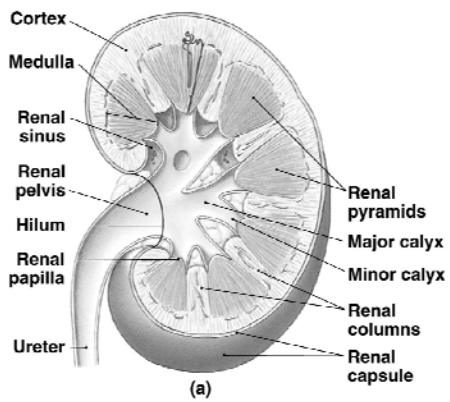
Anatomy of the Kidney

- Location:
 - *retroperitoneal*
- Left kidney superior to right
 - Left kidney superior aspect at T11
 - Right kidney superior aspect between T11 & T12
- Fibrous capsule surrounds the kidney
- Renal artery & vein, renal nerve and ureter enter & exit at hilum (another generic term...)



The Kidneys

The Structure of the Kidney

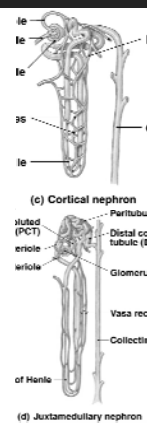


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The Kidneys

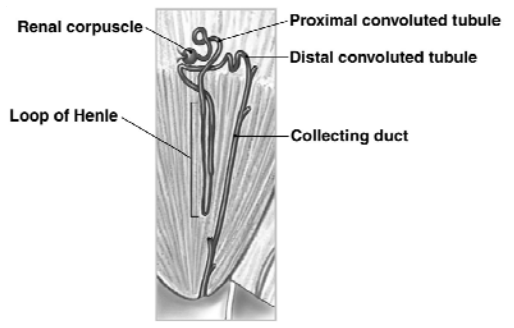
Internal Anatomy of the Kidney

- *Nephrons*
 - **functional units of kidney!**
 - Urine produced by nephrons
 - About a *million* nephrons per kidney
 - Two types of nephrons
 - Cortical (short loops)
 - Juxtamedullary (long loops)
- Renal *pelvis*
 - Urine collects here from *calyces*
 - Input from two *major calyces*
 - Each major calyx is fed by four to five *minor calyces*
 - Urine leaves pelvis to *ureter*



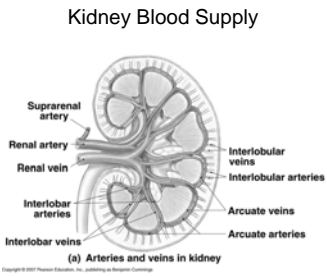
The Kidneys

The Structure of the Kidney's Functional Portion – The Nephron



The Kidneys

- Renal artery
 - Interlobar arteries
 - Arcuate arteries
 - Interlobular arteries
 - Afferent arteriole – to nephron
 - Efferent arteriole –from nephron
 - Interlobular veins
 - Arcuate veins
 - Interlobar veins
- Renal Vein



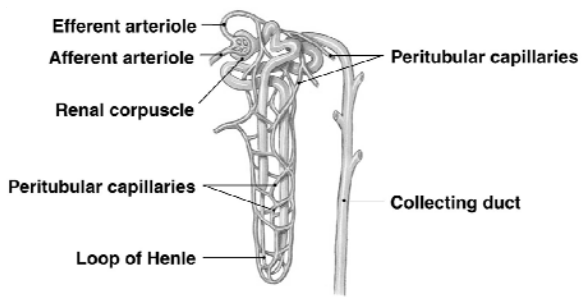
The Kidneys

Blood Supply to the Nephron

- Afferent arteriole
 - Branch of interlobular artery
- Glomerulus
- Efferent arteriole
- Peritubular capillaries
- *Vasa recta – only on juxtamedullary nephrons*

The Kidneys

The Blood Supply to the Kidneys

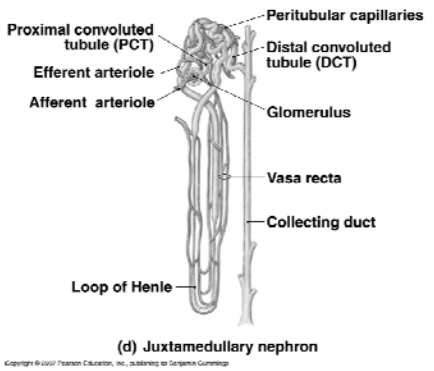


(c) Cortical nephron

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The Kidneys

The Blood Supply to the Kidneys



The Kidneys

The Nephron

- Basic functional unit of the kidney
- Two parts to the nephron
 - Renal *corpuscle*
 - Used in glomerular filtration
 - Renal *tubule*
 - Used in tubular secretion and reabsorption
- Feeds into *collecting system*

The Kidneys

Pathway of fluid (resulting in urine) through the Nephron

- First, *filtered* in the renal corpuscle
 - *Urine* begins as *filtrate*
- Next, filtrate flows into *renal tubule*
 - First, into the *proximal convoluted tubule* (PCT)
 - Next, the *loop of Henle*
 - Finally, the *distal convoluted tubule* (DCT)
- Last, exits to *collecting duct*

The Kidneys

A Representative Nephron and the Collecting System

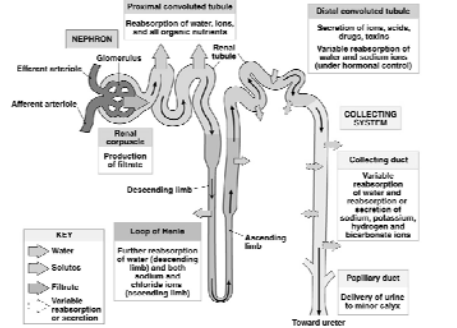


Figure 18-5

The Kidneys

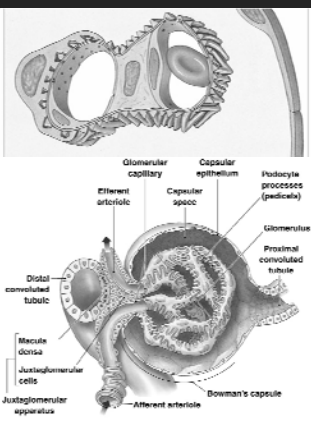
Functions of the Nephron

- Production of *filtrate*
 - Glomerulus
- Reabsorption of *nutrients*
 - PCT (only location... impact???)
- Reabsorption of *water and ions*
 - PCT, DCT, collecting duct
- Secretion of ions, drugs, toxins, acids
 - DCT, collecting duct

The Kidneys

Parts of the Renal Corpuscle

- **Glomerulus**
 - Knot of interconnected capillaries with a spherical shape
- **Bowman's capsule**
 - Encloses glomerulus with squamous epithelium
- **Afferent arteriole**
 - Blood supply to glomerulus
- **Efferent arteriole**
 - Blood drainage from glomerulus



The Kidneys

Glomerulus Anatomy

- Glomerular capillaries covered by *podocytes*
 - Narrow slits separate foot processes of podocytes
- Capsular space surrounds glomerulus
 - Filtrate accumulates here
 - Bounded by Bowman's capsule

The Kidneys

Proximal Convoluted Tubule

- Reabsorbs critical substances from filtrate
 - Nutrients (e.g., glucose, amino acids)
 - Ions
 - Proteins
- Releases them into surrounding interstitial fluid
- Enter peritubular capillaries and return to blood stream

The Kidneys

Loop of Henle

- *Descending* limb
 - Permeable to water
- *Ascending* limb
 - Impermeable to water and solutes

The Kidneys

Distal Convoluted Tubule (DCT)

- Transport activities
 - Actively secretes substances *into* urine
 - Actively reabsorbs sodium *from* urine
- *Juxtaglomerular apparatus*
 - Releases *renin, erythropoietin*
 - Located at start of DCT

The Kidneys

Collecting Ducts

- Receive urine from nephrons
- Merge into *papillary ducts*
 - Delivers urine to *minor calyx*
- Adjust final osmotic pressure of urine
 - By reabsorbing water
 - By transporting ions

Principles of Urine Production

Primary Purpose of Urine Production

- Excretion of dissolved solutes
 - Metabolic wastes
 - Urea
 - Creatinine
 - Uric acid
 - Excess ions

Processes in Urine Formation to meet the primary purpose

- Filtration
- Reabsorption
- Secretion

Principles of Urine Production

Filtration at the Glomerulus

- Blood pressure forces fluid and dissolved substances across the endothelial wall of glomerular capillaries into the capsular space
- Glomerular filtration rate (GFR) depends on blood pressure
- Any change in blood pressure affects filtration

Principles of Urine Production

Renin Release

- Decline in filtration pressure (blood pressure) triggers renin release
 - Released by juxtaglomerular apparatus
- Renin leads to increased blood volume and blood pressure
- GFR returns toward normal
- Restores *homeostasis*

Principles of Urine Production

Key Note

Roughly **180 liters** of filtrate is produced at the glomeruli each day. That represents 70 times the total plasma volume. Almost all of that fluid volume must be reabsorbed to avoid fatal dehydration.

Principles of Urine Production

Tubular Reabsorption/Secretion

- PCT reabsorbs 60–70% of filtrate
 - Nutrients
 - Sodium, other ions
 - Water
- Releases them into venous drainage for return to the blood stream
- Also, PCT secretes substances into tubular fluid

Principles of Urine Production

Tubular Reabsorption/Secretion (cont'd)

- Loop of Henle
 - Reclaims water, ions from filtrate
 - Ascending limb pumps out sodium and chloride ions
 - Descending limb absorbs water
 - Interstitial osmotic pressure pulls water from tubular fluid
 - Urea concentration rises as fluid is lost

Principles of Urine Production

Tubular Reabsorption/Secretion (cont'd)

- Distal Convoluted Tubule (DCT)
 - Performs final adjustment
 - Secretes or reabsorbs ions
 - Reabsorbs sodium in exchange for secreted potassium and hydrogen ions
 - *Aldosterone* increases sodium reabsorption and potassium loss

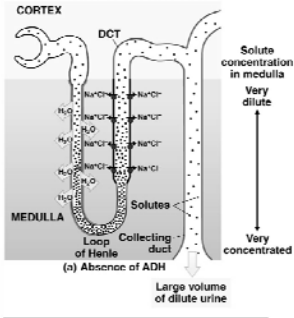
Principles of Urine Production

Control by *Antidiuretic Hormone* (ADH)

- Regulates water loss
 - DCT, collecting tubule, collecting duct made permeable to water by ADH
 - Water then exits to interstitial fluid and remains in the body
 - Urine becomes concentrated (low in water, high in solute)
 - The higher the ADH level, the more concentrated the urine

Principles of Urine Production

The Effects of ADH on the DCT and Collecting Duct



KEY

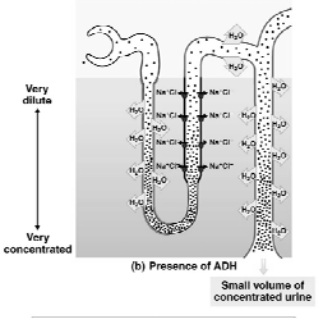
Na^+Cl^- Solute	Water permeable	Water impermeable
H_2O Solute	Solute permeable	Solute impermeable
H_2O Solute	Water permeable	Water impermeable
H_2O Solute	Solute impermeable	Solute permeable
H_2O Solute	Water permeable	Water impermeable
H_2O Solute	Solute permeable	Solute impermeable
H_2O Solute	Water permeable	Water impermeable
H_2O Solute	Solute impermeable	Solute permeable

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Figure 18-7(a)

Principles of Urine Production

The Effects of ADH on the DCT and Collecting Duct



KEY

Na^+Cl^- Solute	Water permeable	Water impermeable
H_2O Solute	Solute permeable	Solute impermeable
H_2O Solute	Water permeable	Water impermeable
H_2O Solute	Solute impermeable	Solute permeable
H_2O Solute	Water permeable	Water impermeable
H_2O Solute	Solute permeable	Solute impermeable
H_2O Solute	Water permeable	Water impermeable
H_2O Solute	Solute impermeable	Solute permeable

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Figure 18-7(b)

Principles of Urine Production

Water Balance in the Kidney

- More than 99% of water is reabsorbed from the filtrate by the renal tubules
- Water content of normal urine ranges from 93% to 97%

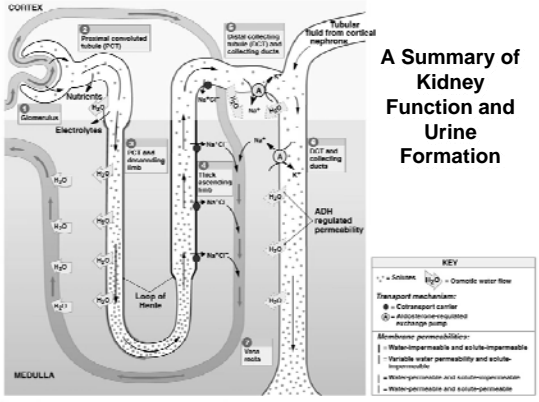
Principles of Urine Production

TABLE 18-3 General Characteristics of Normal Urine

CHARACTERISTIC	NORMAL RANGE
pH	4.5–8 (average: 6.0)
Specific gravity (density of urine/density of pure water)	1.003–1.030
Osmotic concentration (Osmolarity) (number of solute particles per liter; for comparison, fresh water ≈ 5 mOsm/L, body fluids ≈ 300 mOsm/L and sea water ≈ 1000 mOsm/L)	855–1335 mOsm/L
Water content	93–97%
Volume	700–2000 ml/day
Color	Clear yellow
Odor	Varies with composition
Bacterial content	None (sterile)

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Principles of Urine Production



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Figure 18-8

Principles of Urine Production

Key Note

Reabsorption depends on diffusion, osmosis, and active transport. If the mechanism of water reabsorption is “water follows salt” (*actually water follows any ion*) it is said to be **obligatory** reabsorption. If water reabsorption is mediated by water channels it is called **facultative** reabsorption. Many of these processes are regulated by local or hormonal mechanisms. Secretion is a selective, carrier-mediated process.

Principles of Urine Production

Vascular Control of Kidney Function

- Automatic regulation of filtration pressure by changes in diameter of afferent and efferent arterioles
- Autonomic regulation by sympathetic activation
 - Powerful vasoconstriction of afferent arterioles
 - Decreases GFR
 - Also, redirects blood flow to other organs

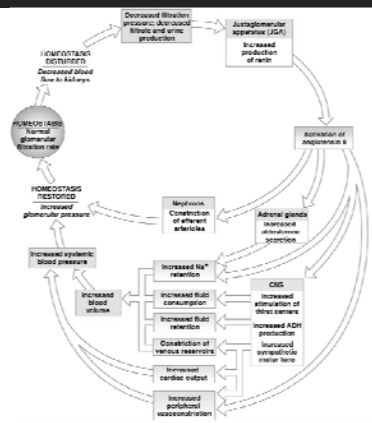
Principles of Urine Production

Hormonal Control of Kidney Function

- Angiotensin II
- Aldosterone
- ADH
- Atrial natriuretic peptide (ANP)

Principles of Urine Production

Roles of the Renin-Angiotensin System in the Regulation of GFR



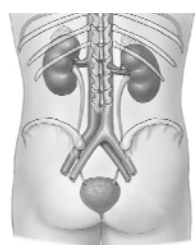
Transport, Storage, & Excretion

Transport and Storage of Urine

- Urine modification ends when fluid enters the renal pelvis
- Ureters, urinary bladder, urethra specialized for transport, storage, and excretion of urine

Transport, Storage, & Excretion

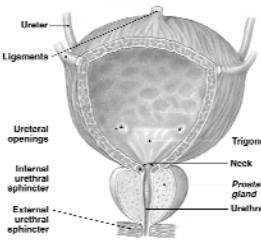
Ureters



- Ureters extend from renal pelvis to urinary bladder
- Smooth muscle in walls contract *peristaltically*
- Push urine toward bladder

Transport, Storage, & Excretion

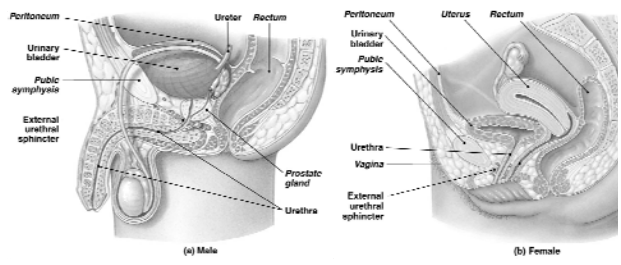
Urinary Bladder



- Distensible muscular sac for urine storage
- Internal features include
 - *Trigone*
 - *Neck*
 - *Internal urethral sphincter*
 - *Detrusor muscle*
- Contraction forces urine into urethra

Transport, Storage, & Excretion

Organs for the Conduction and Storage of Urine



Transport, Storage, & Excretion

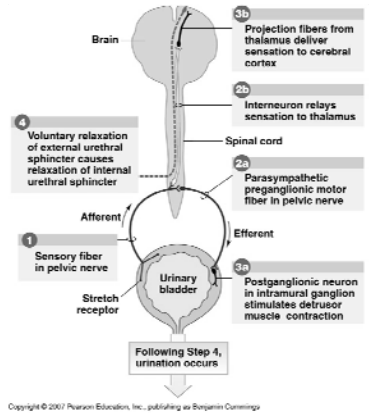
The Urethra

- Longer in males than females
- *External urethral sphincter* formed by a circular band of skeletal muscle of pelvic floor
- Under voluntary control

Transport, Storage, & Excretion

Micturition Reflex and Urination

- Urination coordinated by *micturition reflex*
 - Initiated by stretch receptors in the bladder wall
- Voluntary urination couples reflex with relaxation of external urinary sphincter
 - Permits internal urinary sphincter to open



Aging and the Urinary System

Age-Related Changes in Urinary System

- Loss of functional nephrons
- Reduced GFR
- Reduced response to ADH
- Urinary retention in men with prostate enlargement
- Drop in body water and mineral content
- Disorders of fluid, electrolyte, or acid-base balance
