

CHAPTER 26

URINARY SYSTEM

CHAPTER OVERVIEW: This chapter describes the location, structure and functions of the organs of the urinary system and their constituent parts. The process of urine formation is described in detail. The nervous and cellular mechanisms responsible for determining the final composition of urine are explained in detail and urine composition is related to the homeostatic control of blood and interstitial fluid composition.

OUTLINE (two or three fifty-minute lectures):
Seeley, A&P, 5/e

Lect. Object.	Topic Outline, Chapter 26	Figures & Tables	Transparenc Acetates
1	I. Urinary System, p. 861	System Interactions, p.896 Clinical Focus, p.861 Fig. 26.1, p.861	TA-535
2	A. Kidneys <ol style="list-style-type: none"> 1. General Size <ol style="list-style-type: none"> a. 11 cm X 5 cm X 3 cm b. 130 g 2. Located in Renal Fat Pad 3. Internally -Hilum to Renal Sinus <ol style="list-style-type: none"> a. Renal Artery b. Renal Vein c. Ureter 4. Outer Region = Cortex 5. Inner Region = Medulla <ol style="list-style-type: none"> a. Renal Pyramids b. Medullary Rays c. Renal Columns 6. Tube System from Pyramids <ol style="list-style-type: none"> a. Renal Papillae b. Minor Calyces c. Major Calyces d. Renal Pelvis e. Ureter 	Fig. 26.2, p.862	TA-536
3	<ol style="list-style-type: none"> 7. Functional Unit is the Nephron <ol style="list-style-type: none"> a. Juxtamedullary and Cortical Nephrons 8. Renal Corpuscle <ol style="list-style-type: none"> a. Glomerulus and Fenestrated Capillaries <ol style="list-style-type: none"> 1). Afferent Arteriole 2). Efferent Arteriole b. Bowman's Capsule <ol style="list-style-type: none"> 1). Parietal Layer 2). Podocytes of Visceral Layer 9. Filtration Membrane <ol style="list-style-type: none"> a. Capillary Epithelium (Fenestrated) b. Basement Membrane c. Podocytes and Filtration Slits 	Fig. 26.3, p.863	TA-537
	<ol style="list-style-type: none"> 8. Renal Corpuscle <ol style="list-style-type: none"> a. Glomerulus and Fenestrated Capillaries <ol style="list-style-type: none"> 1). Afferent Arteriole 2). Efferent Arteriole b. Bowman's Capsule <ol style="list-style-type: none"> 1). Parietal Layer 2). Podocytes of Visceral Layer 	Fig. 26.4, p.865	TA-538
	<ol style="list-style-type: none"> 9. Filtration Membrane <ol style="list-style-type: none"> a. Capillary Epithelium (Fenestrated) b. Basement Membrane c. Podocytes and Filtration Slits 	Fig. 26.4c,d, p.865	TA-538
	<ol style="list-style-type: none"> 10. Juxtaglomerular Apparatus <ol style="list-style-type: none"> a. Modified Smooth Muscle Cells = Juxtaglomerular Cells b. Macula Densa Cells of Distal Convoluted Tubule 	Fig. 26.4b, p.865	TA-538
	<ol style="list-style-type: none"> 11. Tubules <ol style="list-style-type: none"> a. Proximal Convoluted Tubule <ol style="list-style-type: none"> 1). 14 cm Long X 60 μ m 2). Simple Cuboidal Epithelium with Microvilli b. Loops of Henle <ol style="list-style-type: none"> 1). Descending Limb - Simple Cuboidal to Simple Squamous Epithelium 2). Ascending Limb - Simple Squamous to Simple Cuboidal 	Fig. 26.5, p.866	TA-539

	Epithelium		
	c. Distal Convoluted Tubule		
	1). Shorter than Proximal Tubule		
	2). Smaller Cuboidal Cells, Fewer Microvilli	Fig. 26.5d, p.866	TA-539
	d. Collecting Ducts		
	1). Simple Cuboidal Epithelium		
	2). Form Medullary Ray		
	3). Extend Through Tip of Renal Pyramid		
4	B. Arteries and Veins of the Kidney	Fig. 26.6, p.867	TA-540
	1. Renal Artery		
	2. Segmental Arteries		
	3. Interlobar Arteries		
	4. Arcuate Arteries		
	5. Interlobular Arteries		
	6. Afferent Arterioles		
	7. Glomerular Capillaries		
	8. Efferent Arterioles		
	9. Peritubular Capillaries & Vasa Recta	Fig. 26.6b, p.867	TA-540
	10. Interlobular Veins		
	11. Arcuate Veins		
	12. Interlobar Veins		
	13. Renal Veins		
	C. Ureters and Urinary Bladder	Fig. 26.7, p.868	TA-541
	1. Two Ureters, One from Each Renal Pelvis to Urinary Bladder		
	2. Trigone Region of Bladder		
	a. Ureters Enter Urinary Bladder Posteriorly		
	b. Urethra Leaves Anteriorly	Predict Quest. 1	
	3. Transitional Epithelium		
	4. Urethral Sphincters		
	a. Internal - Smooth Muscle		
	b. External - Skeletal Muscle		
	II. Urinary Production	Clinical Focus, p.879 Clinical Focus, p.891 Fig. 26.8, p.869 Table 26.1, p.869	TA-542
	A. Filtration		
	1. Renal Fraction = % of Cardiac Output Passing through Kidneys, 12-30 %	Table 26.2, p.870	
	2. Renal Blood Flow Rate - Vol. (ml) of Blood Passing through Kidney per min.		
	3. Filtration Fraction = % of Plasma becoming Filtrate, about 1 %		
	4. Glomerular Filtration Rate (GFR) = ml of Filtrate Formed per min, about 125 ml / min		
	5. About 99 % of Filtrate Volume Reabsorbed in Nephron	Predict Quest. 2	
5	6. Filtration Barrier		
	a. 100 to 1000 Times More Permeable than Typical Capillary		
	b. Molecular Diameters # 7 nm or Molecular Weights to 40,000 Daltons	Predict Quest. 3; Clinical Note, p.870	
6	7. Filtration Pressure, about 10 mm Hg	Fig. 26.9, p.871	TA-543
	a. Glomerular Capillary Pressure Promotes Filtration (+60 mm Hg)	Predict Quest. 4	
	1). Decreased by Constriction of Afferent Arteriole		
	2). Increased by Constriction of Efferent Arteriole		
	b. Colloid Osmotic Pressure Resists filtration (-32 mm Hg)		
	c. Capsule Pressure Resists Filtration (-18 mm Hg)		
7	B. Tubular Reabsorption	Table 26.1, p.869 Table 26.3, p.872 Fig. 26.8, p. 869	TA-542
	1. Movement from Filtrate Back into Blood		
	a. 99 % of Water Reabsorbed		
	b. 40-60 % of Urea		
	2. Endocytosis		

	3. Active Transport and Cotransport Mechanisms		
	4. Transport in the Proximal Tubule	Fig. 26.10a, p.873	TA-544
	a. Most Reabsorption of Nutrients and Ions		
	Total Volume of Filtrate Reduced by 65 % Apical Membrane		
	Contains Carrier Molecules		
8	5. Transport in the Loop of Henle	Fig. 26.11, p. 874	TA-545
9	a. Thin Descending Limb		
10	b. Thick Ascending Limb	Fig. 26.12, p. 875	TA-546
	6. Transport in the Distal Tubule and Collecting Duct	Fig. 26.13, p. 876	TA-547
	a. Active Transport of Na ⁺ and Cl ⁻		
	b. Impermeable to Water in Absence of ADH	Predict Quest. 5	
	c. Final 19 % of Water Reabsorbed when ADH Present	Clinical Note, p.877	
	7. Changes in the Concentration of Solute in the Nephron		
10	C. Tubular Secretion		
	1. Active or Passive Movement into Filtrate Across Proximal or Distal	Table 26.4, p.877	
	Convuluted Tubules	Fig. 26.14, p. 878	TA-548
	2. Normal Cellular Products - Ex. Ammonia		
	3. Drugs and Toxins - Ex. Penicillin, PAH		
12	D. Urine Concentration Mechanism		
	1. Medullary Concentration Gradient	Fig. 26.15, p.880	TA-549
	a. 300 mOsmol in Cortex		
	b. 1200 mOsmol in Deepest Medulla		
	2. Counter-Current System Maintains Gradient		
11	a. Vasa Recta		
	b. Loop of Henle		
	c. Variable Permeability to Urea		
	3. Urea Contributes to High Medullary Concentration	Fig. 26.16, p. 881	TA-550
	1. Summary of Changes in Filtrate Volume and	Table 26.3, p. 872	TA-363
	Concentration	Clinical Note, p.882	
	a. Decrease in Filtrate Volume	Fig. 26.17, p. 883	
	b. Increase in Filtrate Osmolality		
	c. Marked Change in Filtrate		
	Composition		
13	III. Regulation of Urine Concentration and Volume		
	A. Hormonal Mechanisms	Fig. 26.13, p. 876	TA-547
	1. Antidiuretic Hormone (ADH)		
	a. From Anterior Pituitary		
	b. Targets Distal Convuluted Tubules and Collecting Ducts		
	c. Action is to Increase Cell Permeability to Water		
	d. Secretion Increased when	Predict Quest. 6	
13	2. Renin-Angiotensin-Aldosterone		
	a. Renin from Juxtaglomerular Apparatus when		
	1). Na ⁺ in DCT Decreased		
	2). BP in Afferent Arteriole Decreased		
	b. Renin Converts Angiotensinogen to Angiotensin I		
	c. Angiotensin Converting Enzyme (ACE) Converts Angiotensin		
	I to Angiotensin II		
	d. Actions of Angiotensin II		
	1). Potent Vasoconstrictor		
	2). Increases Aldosterone Secretion		
	e. Aldosterone From Adrenal Cortex		
	f. Targets Distal Convuluted Tubules and Collecting Ducts	Fig. 26.18, p.885	TA-552
	g. Action Increases Active Transport of Na ⁺ and Cl ⁻ into Blood	Predict Quest. 7	
	h. Aldosterone Secretion Increased When		
	1). Blood Na ⁺ Increased		
	3. Other Hormones		
	a. Atrial Natriuretic Hormone Source Right Atrium of Heart		
	b. Action is Decreased ADH Secretion		
	c. Prostaglandins and Kinins - Precise Roles as Yet Unclear		

13	<ul style="list-style-type: none"> B. Autoregulation <ul style="list-style-type: none"> 1. Results in Stable GFR 2. Largely Independent of Systemic Arteriolar BP 3. Involves Afferent and Efferent Arterioles <ul style="list-style-type: none"> a. Constriction of Afferent Arteriole Decreases Glomerular Capillary Pressure = Increased Filtration b. Constriction of Efferent Arteriole Increases Glomerular Capillary Pressure = Decreased Filtration 		
14	<ul style="list-style-type: none"> C. Effect of Sympathetic Stimulation on Kidney Function <ul style="list-style-type: none"> 1. Sympathetic Stimulation Constricts Afferent Arterioles 2. Decreases Renal Blood Flow 3. Decreases Filtrate Formation 4. Shock can Lead to Impairment of Blood Flow that Damages Kidney 		
	IV. Regulation of Urine Concentration and Volume	Fig. 26.19, p.887	TA-553
	<ul style="list-style-type: none"> 1. Regulation of Extracellular Fluid Osmolality 2. Regulation of Extracellular Fluid Volume <ul style="list-style-type: none"> a. Neural Mechanisms b. Renin-Angiotensin-Aldosterone Mechanism c. Atrial Natriuretic Hormone Mechanism d. Antidiuretic Hormone Mechanism 	Fig. 26.20a., p. 888	TA-554
15	V. Clearance and Tubular Maximum, p. 890		
	A. Plasma Clearance (ml/min) = Quantity of Urine Produced (ml/min) X [Concentration of Substance in Urine / Concentration of Substance in Plasma]	Clinical Note, p.891 Table 26.2, p.870	
	B. Clearance of a Substance Estimates GFR if <ul style="list-style-type: none"> 1. Substance Passes Freely Across Filtration Membrane 2. Substance not Reabsorbed Along Nephron 3. Substance not Secreted Along Nephron 4. Inulin = Polysaccharide with these Characteristics 	Predict Quest. 8	
	C. Clearance of a Substance Estimates Plasma Flow if <ul style="list-style-type: none"> 1. Substance Passes Across Filtration Membrane 2. Remaining Substance Secreted so Very Little Left in Blood Following Single Pass Through Kidneys 3. Para-Aminohippuric Acid has these Characteristics 	Predict Quest. 9	
	D. Blood Concentration Influences Clearance <ul style="list-style-type: none"> 1. Tubular Load = Total Amount of Substance Passing Through Filtration Membrane into Nephron per min. 2. Tubular Maximum = Maximum Rate of Active and Mediated Tubular Reabsorption of a Compound 3. When Tubular Load > Tubular Maximum, the Excess Passes into the Urine 	Fig. 26.21, p.892	
	VI. Urine Movement, p. 892	Clinical Note, p.892	
	A. Urine Flow Through the Nephron and Ureters <ul style="list-style-type: none"> 1. Pressure Gradient Forces Fluid from Plasma to Bowman's Capsule 2. Pressure Gradient from Bowman's Capsule to Renal Pelvis 3. Peristaltic Contraction of Circular Smooth Muscle in Ureters <ul style="list-style-type: none"> a. Forces Urine to Urinary Bladder b. Rate Once Every 2-3 min. c. Rate Increased by Parasympathetic Stimulation 4. Internal Bladder Pressure Increases <ul style="list-style-type: none"> a. Slowly from Volumes of 0-500 ml b. More Pronounced with Volume Increases Above 500 ml. 		
16	B. Micturition Reflex <ul style="list-style-type: none"> 1. Neural Reflex Initiated by Stretch of Bladder or Irritation of Bladder/Urethra 2. Afferent Paths to Sacral Region of Spinal Cord 3. Spinal and Cranial Integration 	Fig. 26.22, p. 893	TA-555
		Clinical Note, p.894	

- a. Reflex Integration in Spinal Cord Predominates in Infants
- b. Reflex Integration in Brainstem Predominates in Adults
- 4. Efferent Paths of Spinal Reflex in Parasympathetic Fibers
 - a. Increase Smooth Muscle Contraction in Bladder
 - b. Decrease Contraction in Internal Urethral Sphincter
- 5. Fibers from Motor Cortex
 - a. Control Voluntary Skeletal Muscle of External Urethral Sphincter
 - b. Conscious Override Develops by Age 2-3 yrs.

VII. Systems Pathology: Acute Renal Failure, p. 895

Predict Quest. 10

IMPORTANT CONSIDERATIONS: If there is a desire to cover the anatomical structures of the organs and the nephron in the laboratory, that frees up lecture time for clarifying the processes of urine formation and the hormonal controls on urine production and concentration. The three major segments are therefore the anatomy of the system, the processes and influences on urine formation, and the composition of final urine as a reflection of homeostatic needs.

The notion of countercurrent exchange mechanisms and the extracellular fluid concentration gradient in the medulla of the kidney will be totally new for most students. One problem is that most other examples of countercurrents, such as heat exchangers in refrigeration units and air conditioners, will also be unfamiliar to the students, so useful analogies are hard to come by.

SEE INSTRUCTOR'S MANUAL AND COURSE SOLUTIONS MANUAL FOR ADDITIONAL RESOURCES.