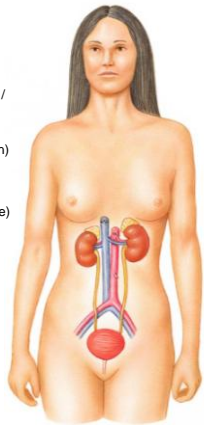


Urinary System:

Kidneys ain't just for pee'in

- Regulate blood volume / blood pressure (renin)
- Regulate red blood cell formation (erythropoietin)
- Stabilize blood pH
- Metabolize vitamin D to active form (Ca⁺⁺ uptake)

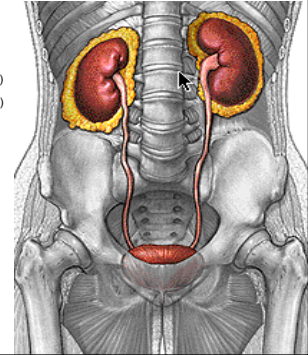


Major Functions of Urinary System:

- 1) Removal of organic waste products from fluids (excretion)
- 2) Discharge of waste products into the environment (elimination)
- 3) Homeostatic regulation of the volume / solute concentration of blood plasma

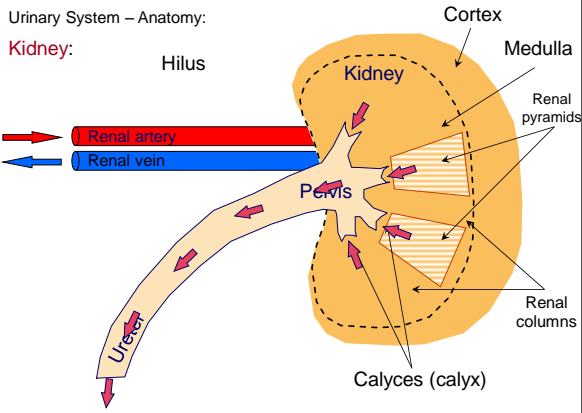
Urinary System – Anatomy:

- 1) **Kidneys** (retroperitoneal)
 - Renal capsule (collagen fibers)
 - Adipose capsule (support / protection)
 - Renal fascia (fibrous layer – anchoring)
- 2) **Ureters**
- 3) **Urinary bladder**
- 4) **Urethra**



Urinary System – Anatomy:

Kidney:



Urinary System – Anatomy:

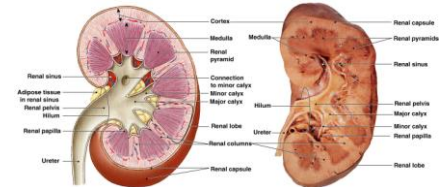
Blood Supply to Kidneys:

- 1/4 of cardiac output delivered to kidneys
- $0.25 \times 5 \text{ L / min} = 1.25 \text{ L / min}$ (kidneys only 0.5% of total body mass)

Nerve Supply to Kidneys:

- Sympathetic nervous system

 - 1) Adjust rate of urine formation (change blood flow / pressure)
 - 2) Adjust overall blood pressure / volume (renin release)



Urinary System – Anatomy:

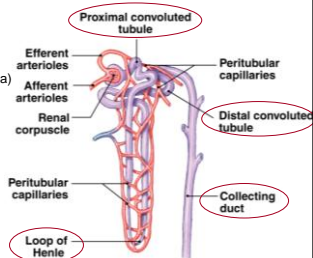
Nephron: Functional unit of the kidney (urine formation)

- ~ 1 million / kidney
 - Filter ~ 200 L of blood plasma / day
 - Produce ~ 1 - 1.5 L of urine / day
- } 99% of filtrate returned to blood

Nephron Anatomy:

- 1) **Glomerulus**
 - Network of capillaries
 - Tightly wound coil (↑ surface area)
- 2) **Tubule**
 - Location of filtrate / urine

Peritubular Capillaries
(Portal System)
Reabsorb materials from tubule of nephron

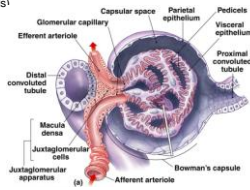
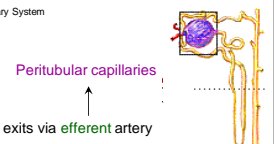


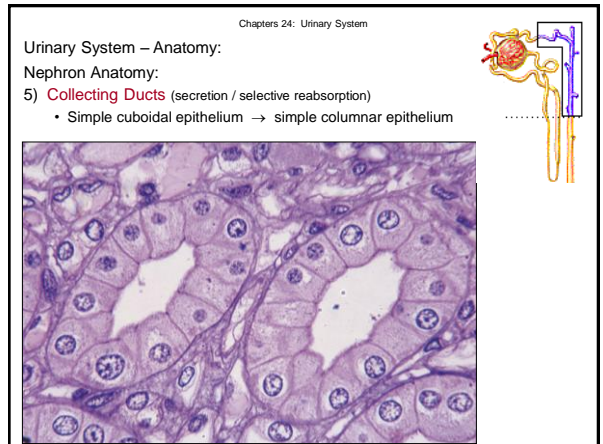
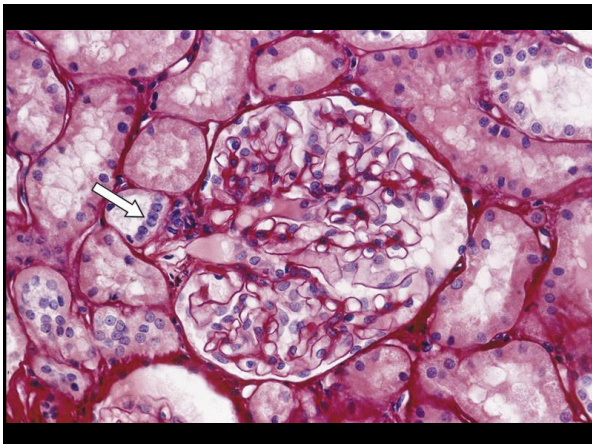
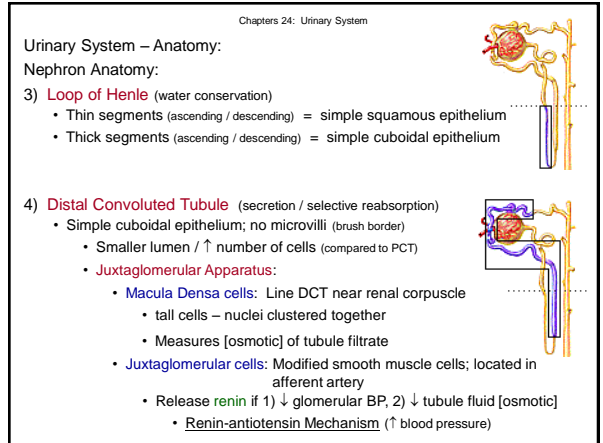
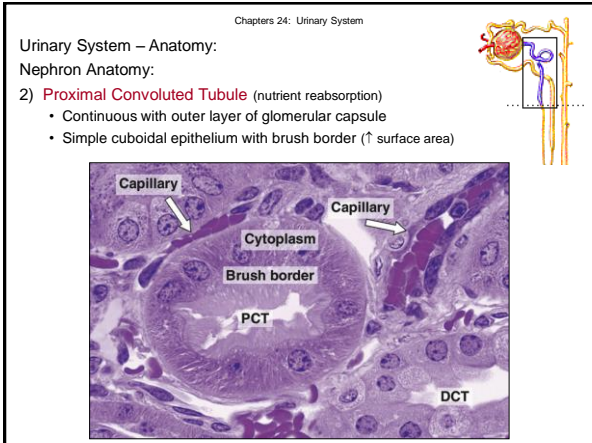
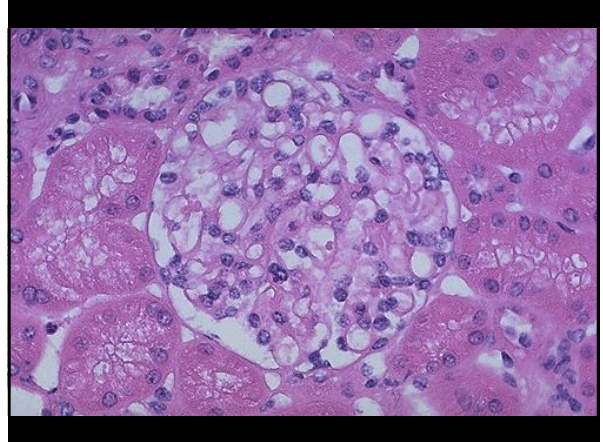
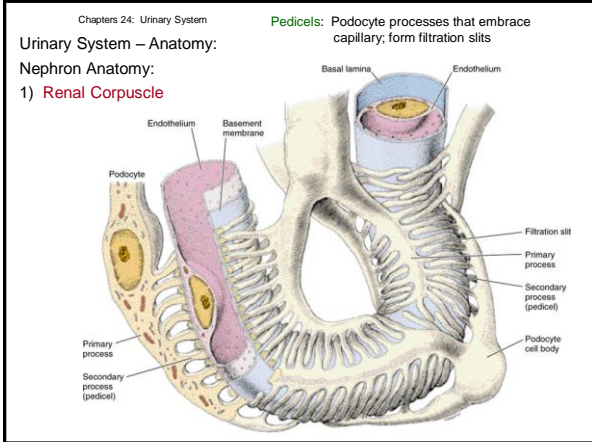
Urinary System – Anatomy:

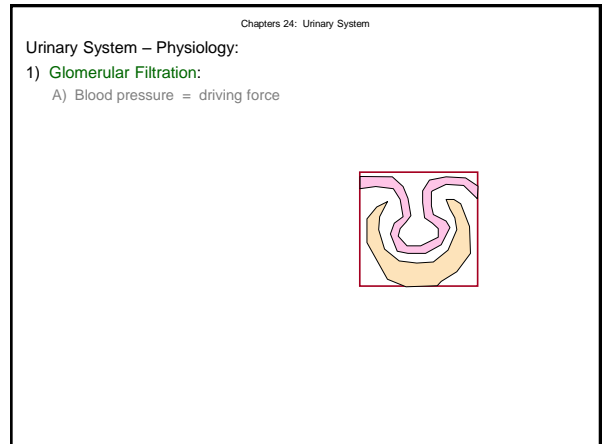
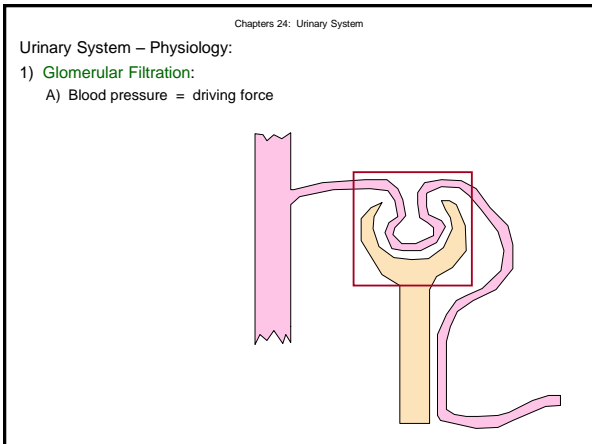
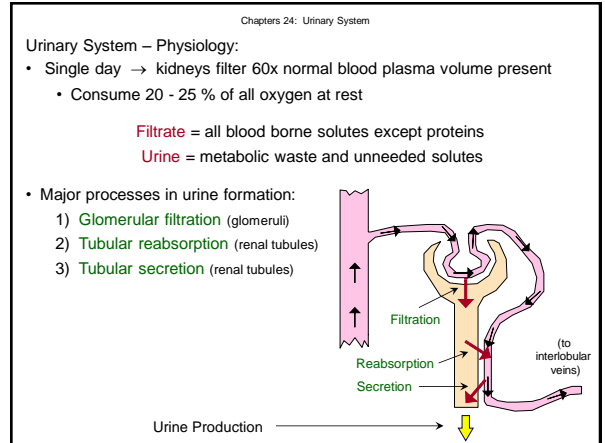
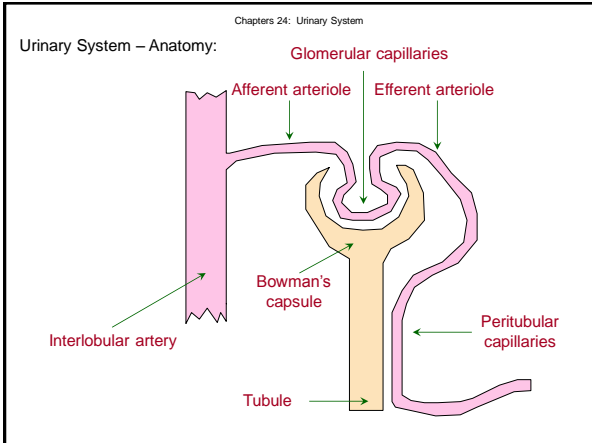
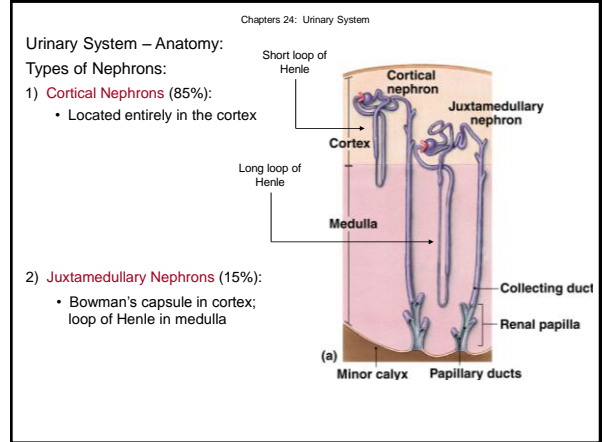
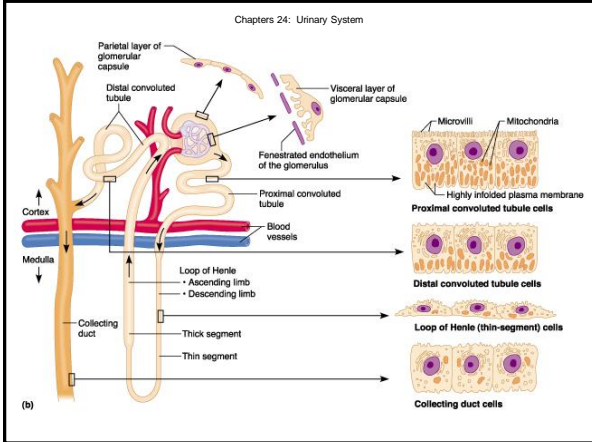
Nephron Anatomy:

- 1) **Renal Corpuscle** (filtration)
 - A) **Glomerulus**
 - Blood enters via afferent artery and exits via efferent artery
 - Fenestrated endothelium
 - B) **Glomerular Capsule** (Bowman's Capsule)
 - Expanded proximal end of nephron (surrounds glomerulus)
 - Outer layer = simple squamous epithelium
 - Inner layer = Podocytes (foot cells)

Peritubular capillaries







Chapters 24: Urinary System

Urinary System – Physiology:

1) **Glomerular Filtration:**

A) Blood pressure = driving force

Glomerular Hydrostatic Pressure

Colloid Osmotic Pressure

Capsular Hydrostatic Pressure

Net Filtration Pressure = $55 \text{ mm Hg} - (15 \text{ mm Hg} + 30 \text{ mm Hg})$

Chapters 24: Urinary System

Urinary System – Physiology:

1) **Glomerular Filtration:**

A) Blood pressure = driving force

Glomerular Hydrostatic Pressure

Colloid Osmotic Pressure

Capsular Hydrostatic Pressure

Net Filtration Pressure = 10 mm Hg

Chapters 24: Urinary System

Glomerular capsule

Net outward pressure

Key:

- \uparrow = Glomerular (blood) hydrostatic pressure (55 mm Hg)
- \uparrow = Blood colloid osmotic pressure (30 mm Hg)
- \uparrow = Capsular hydrostatic pressure (15 mm Hg)

Chapters 24: Urinary System

Urinary System – Physiology:

1) **Glomerular Filtration:**

A) Blood pressure = driving force

B) Molecules Filtered < 3 nm Diameter

- Water, glucose, amino acids, ions, nitrogenous waste (cells / proteins too large)

Chapters 24: Urinary System

Urinary System – Physiology:

1) **Glomerular Filtration:**

A) Blood pressure = driving force

B) Molecules Filtered < 3 nm Diameter

- Water, glucose, amino acids, ions, nitrogenous waste (cells / proteins too large)

Pores in endothelium

Capillary lumen

Pedicles of podocytes

Lamina densa

Capsular space

Filtration slit

Capillary endothelial cell

Basement Membrane

Podocytes

Filtration slits

Water, glucose, amino acids, ions, nitrogenous waste

Filtration membrane

Chapters 24: Urinary System

Urinary System – Physiology:

Creatinine Clearance Test

- Metabolite of creatine phosphate
- Eliminated in urine (not reabsorbed...)

1) **Glomerular Filtration:**

A) Blood pressure = driving force

B) Molecules Filtered < 3 nm Diameter

- Water, glucose, amino acids, ions, nitrogenous waste (cells / proteins too large)

C) **Glomerular filtration rate (GFR):**

- Volume of fluid filtered into Bowman's capsule / minute
- Normal adult = 120-150 ml / min
- Factors governing filtration rate:
 - Surface area (65 m² / kidney)
 - Filtration membrane permeability
 - Net filtration pressure (\downarrow 20% GHP = no filtration)

Relatively fixed...

• Control of GFR

1) Autoregulation: Local changes in afferent / efferent arteriole diameters

- Reduced blood flow (\downarrow GHP) = Dilation of afferent arteriole
- Relaxation of glomerular capillaries
- Constriction of efferent arteriole

Increased blood flow (\uparrow GHP)

Chapters 24: Urinary System

Urinary System – Physiology:

1) Glomerular Filtration:

A) Blood pressure = driving force

B) Molecules Filtered < 3 nm Diameter

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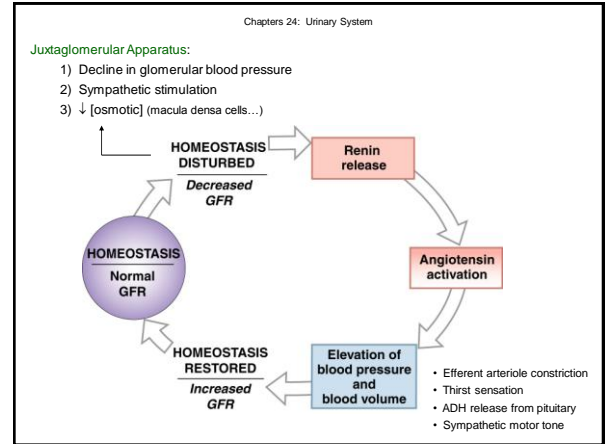
Relatively fixed...

• Control of GFR

- Autoregulation: Local changes in afferent / efferent arteriole diameters
- Hormonal Regulation: Renin-angiotensin mechanism...

Creatinine Clearance Test

- Metabolite of creatine phosphate
- Eliminated in urine (not reabsorbed...)

$$\text{Rate (ml/min)} = \frac{\text{Amount cleared in urine (mg/h)}}{\text{Amount in blood (mg/dl)}}$$


Chapters 24: Urinary System

Urinary System – Physiology:

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Relatively fixed...

• Control of GFR

- Autoregulation: Local changes in afferent / efferent arteriole diameters
- Hormonal Regulation: Renin-angiotensin mechanism...
- Autonomic Regulation: Sympathetic innervation
 - Associated with vasoconstriction of afferent arteriole (over-rides local control)

Creatinine Clearance Test

- Metabolite of creatine phosphate
- Eliminated in urine (not reabsorbed...)

$$\text{Rate (ml/min)} = \frac{\text{Amount cleared in urine (mg/h)}}{\text{Amount in blood (mg/dl)}}$$

Chapters 24: Urinary System

Urinary System – Physiology:

2) Tubular Reabsorption:

- Return of fluid from renal tubules to blood
- ~ 80% of water & solutes reabsorbed at **proximal convoluted tubule**

A) Active processes:

- Chemicals moved against gradient
- Requires ATP (pumps in epithelial cell membranes)

B) Passive processes:

- Chemicals move down gradients

Chapters 24: Urinary System

Urinary System – Physiology:

2) Tubular Reabsorption:

Assisting movement into blood:

- Highly permeable basement membrane
- Low blood pressure and high [protein] in capillary

Transport Maximums (T_m)

- Diabetes

Key:

- Primary active transport (red arrow)
- Secondary active transport (dashed red arrow)
- Passive transport (diffusion) (blue arrow)
- Protein carrier (purple circle)
- Ion channel (blue square)

Chapters 24: Urinary System

Urinary System – Physiology:

2) Tubular Reabsorption:

- Absorptive capabilities of tubules:

Substance	Proximal Convoluted Tubule	Loop of Henle	Distal Convoluted Tubule & Collecting Duct
Glucose	100%		
Amino acids	100%		
Na ⁺	~ 70%	~ 25%	(hormone dependent)
Water	~ 70%	~ 25%	(hormone dependent)
HCO ₃ ⁻	~ 90%		
Cl ⁻	~ 50%	~ 35%	(hormone dependent)

TABLE 26-2 Significant Differences Between Solute Concentrations in Urine and Plasma

Solute	Urine	Plasma
Urea (mg/L)	147.5	138.4
Potassium (K ⁺) (mEq/L)	47.5	4.4
Chloride (Cl ⁻) (mEq/L)	153.3	105
Bicarbonate (HCO ₃ ⁻) (mEq/L)	1.8	27

METABOLITES AND NUTRIENTS (mg/dL)

Glucose	0.000	90
Lipids	0.000	400
Amino acids	0.000	4.2
Proteins	0.000	7.5 g/dL

Chapters 24: Urinary System

Urinary System – Physiology:

2) **Tubular Reabsorption:**

- Non-reabsorbed substances:
 - 1) Urea (~ 21 g / day)
 - Result of amino acid breakdown
 - 2) Creatinine (~ 1.8 g / day)
 - Result of creatine phosphate breakdown
 - 3) Uric Acid (~ 480 mg / day)
 - Result of nucleotide breakdown
- Not reabsorbed because:
 - A) Lack protein carriers
 - B) Not lipid soluble
 - C) Too large to pass through membrane pores

Solute	Urine	Plasma
Urea	300	10–20
Creatinine	120	1–1.5
Ammonia	50	<0.1
Uric acid	40	3

Chapters 24: Urinary System

Urinary System – Physiology:

3) **Tubular Secretion:**

- Movement of material from capillary / tubule cells to filtrate
- Functions:
 - A) Eliminating substances not in filtrate (e.g., antibiotics)
 - B) Eliminating substances reabsorbed (e.g., urea)
 - C) Eliminating excess K^+ (exchanged for Na^+)
 - D) Balancing pH (H^+ / HCO_3^- ; dependent on pH of peritubular blood)

Chapters 24: Urinary System

Urinary System – Physiology:

Regulation of Urine Volume / Concentration:

Osmolality: (Osml)

of solute particles dissolved in 1 L of water

Units:

- **Osml** = 1 mole of non-ionizing substance in 1 L of water
 - 1 mole glucose dissolved in 1 L water = 1 Osmol
 - 1 mole of NaCl dissolved in 1 L water = 2 Osmol
- **mOsml** = 0.001 Osmol

Chapters 24: Urinary System

Urinary System – Physiology:

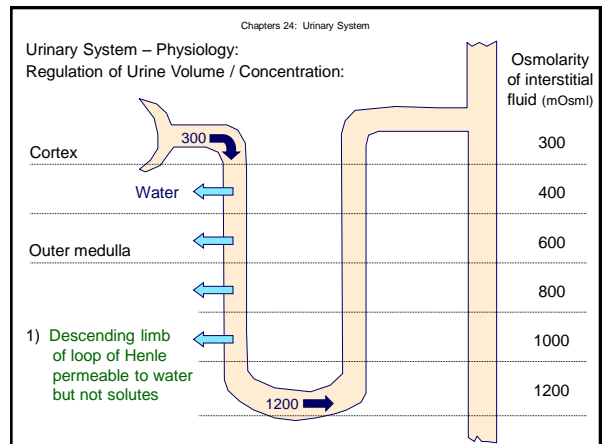
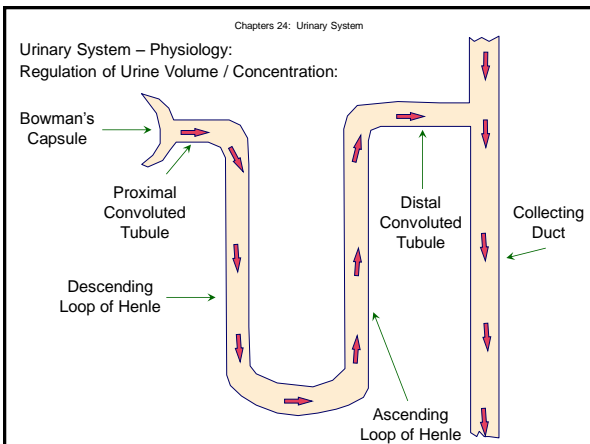
Regulation of Urine Volume / Concentration:

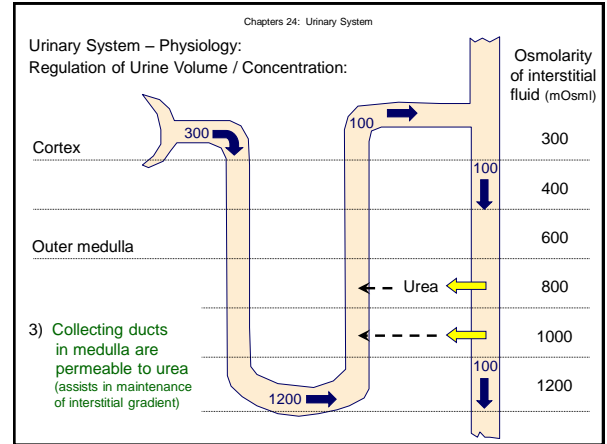
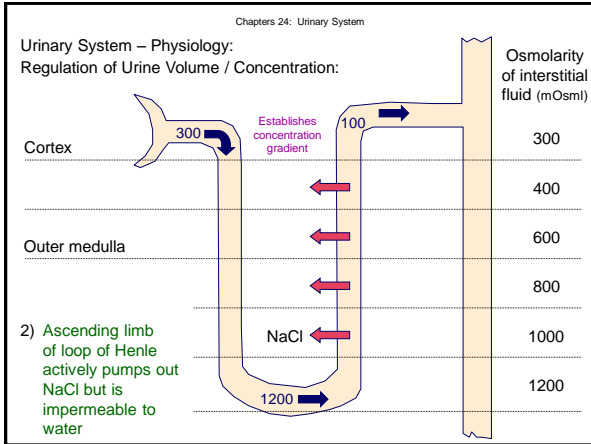
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Chapters 24: Urinary System

Urinary System – Physiology:
Regulation of Urine Volume / Concentration:

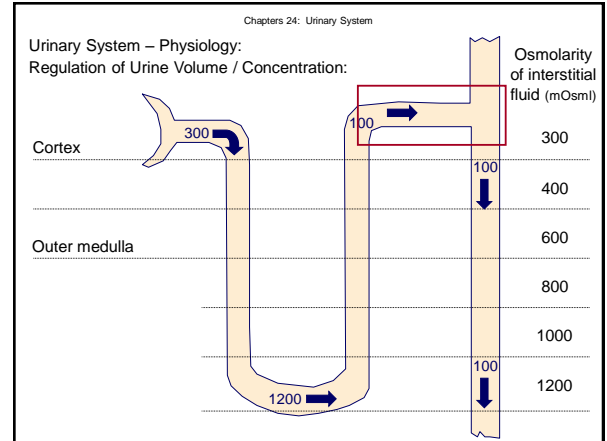
Formation of Dilute Urine (~ 100 mOsm):

- 15 – 19 ml fluid / min produced (~ 22.5 L urine / day)
- Collecting ducts impermeable to water
- **Diuretics** = Chemicals that enhance urinary output
 - Used to treat various medical conditions (e.g., hypertension)

Formation of Concentrated Urine (~ 1200 mOsm):

- 1.0 ml fluid / min produced (~ 1.5 L urine / day)
- Hormonally controlled (facultative water reabsorption)

1) **Antidiuretic Hormone (ADH)**



Chapters 24: Urinary System

Urinary System – Physiology:
Regulation of Urine Volume / Concentration:

↓ urine volume
↑ urine concentration

Alcohol

Activation of osmoreceptors in hypothalamus

↑ osmolarity of blood

ADH (posterior pituitary)

Water channels open in distal tubule and collecting duct

peritubular capillary ~300 mosm

collecting duct ~100 mosm

ADH

water

Chapters 24: Urinary System

Urinary System – Physiology:
Regulation of Urine Volume / Concentration:

Formation of Dilute Urine (~ 100 mOsm):

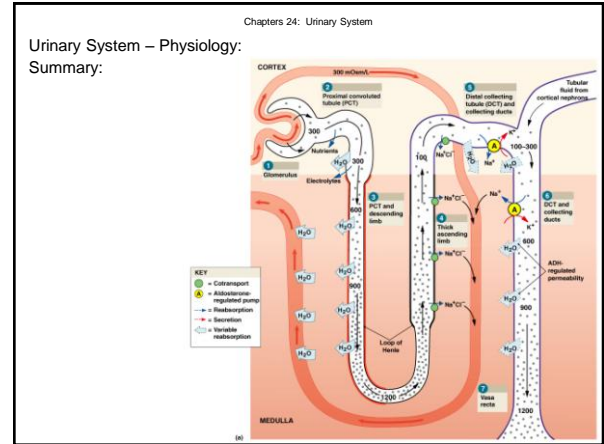
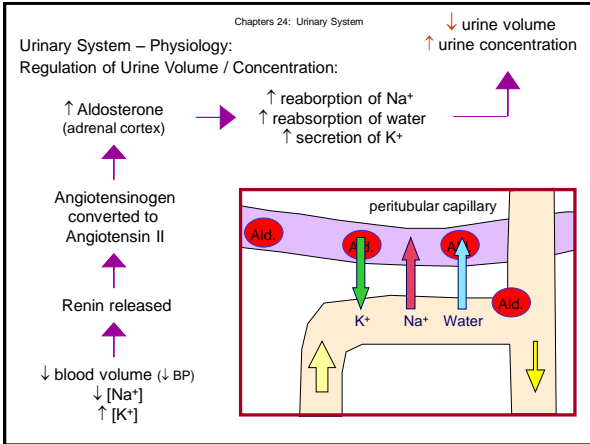
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Formation of Concentrated Urine (~ 1200 mOsm):

- 1.0 ml fluid / min produced (~ 1.5 L urine / day)
- Hormonally controlled (facultative water reabsorption)

1) **Antidiuretic Hormone (ADH)**

2) **Aldosterone**



Chapters 24: Urinary System

Urinary System – Physiology:
Composition of Urine:

- 95% water
- 5% solutes
 - Nitrogenous wastes (urea > creatinine > uric acid)
 - Ions (Na⁺; K⁺; phosphates; sulfates)

Produced by flora in large intestine (absorbed in colon)

Physical Characteristics of Urine:

- 1) **Color & Transparency**
 - Dilute = clear / pale yellow; Conc. = deep yellow (urobilin)
- 2) **Odor**
 - Fresh = slight odor; Old = ammonia odor (bacterial metabolism)
- 3) **pH**
 - Acidic (pH ~ 6)

Chapters 24: Urinary System

Urinary System – Physiology:
Urine Transport, Storage, and Elimination:

- 1) **Ureters:** Convey urine from kidney to bladder
 - Movement = Peristalsis
- Histology:
 - Mucosa (Transitional epithelium)
 - Smooth muscle layer (longitudinal / circular)
 - Adventitia

➤ **Kidney Stones**

Chapters 24: Urinary System

Urinary System – Physiology:
Urine Transport, Storage, and Elimination:

- 2) **Bladder:** Collapsible, muscular sack → urine storage
 - Retroperitoneal (maximum capacity ~ 1 L)
- Histology:
 - Mucosa (Transitional epithelium)
 - Smooth muscle layer (**Detrusor muscle**)
 - Adventitia / serosa

Trigone
Triangular area bounded by ureter openings and urethral exit

Chapters 24: Urinary System

Urinary System – Physiology:
Urine Transport, Storage, and Elimination:

- 3) **Urethra:** Opening to external environment
 - Distinct between sexes
- Histology:
 - Mucosa (Stratified epithelium – transitional / columnar / squamous)
 - Mucin-secreting cells present
 - Lamina propria anchors to surrounding structures

Urinary System – Physiology:
Urine Transport, Storage, and Elimination:

If not acknowledged,
relaxation for ~ 1 hr.

Micturition (urination):

Incontinence:
Inability to control urination
voluntarily (e.g., spinal cord injury)

