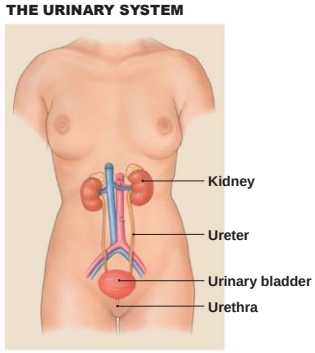
About this Chapter

- Anatomy of the urinary system
- Overview of kidney function
- Filtration
- Reabsorption
- Secretion
- Excretion
- Micturition

Functions of the Kidneys

- Regulation of extracellular fluid volume and blood pressure
- Regulation of osmolarity
- Maintenance of ion balance
- Homeostatic regulation of pH
- Excretion of wastes
- Production of hormones

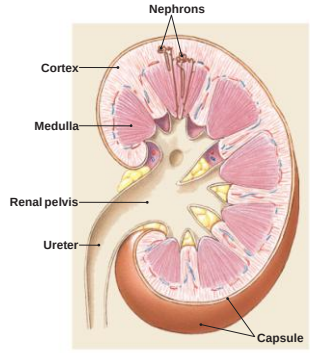
Anatomy: The Urinary System



(a) The urinary system

Figure 19-1a

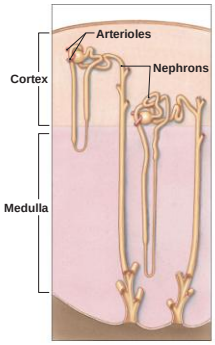
Anatomy: The Urinary System



(c) The kidney, in cross section.

Figure 19-1c

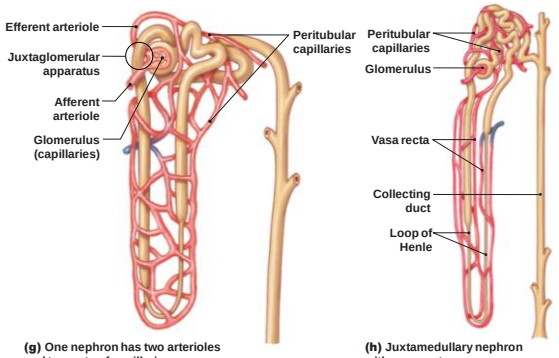
Anatomy: The Urinary System



(i) Some nephrons dip deep into the medulla.

Figure 19-1i

Anatomy: The Urinary System



(g) One nephron has two arterioles and two sets of capillaries.

(h) Juxtamedullary nephron with vasa recta

Figure 19-1g–h

Anatomy: The Urinary System

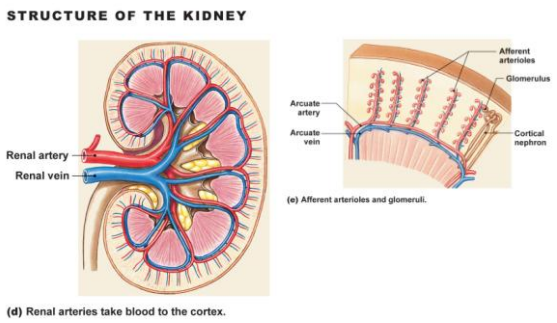


Figure 19-1d–e

Anatomy: The Urinary System

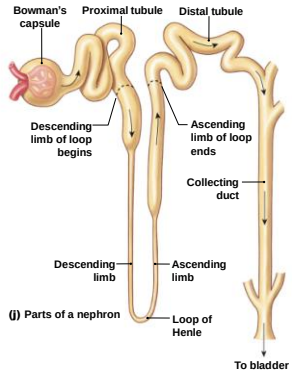


Figure 19-1j

Kidney Function

- Filtration, reabsorption, secretion, and excretion

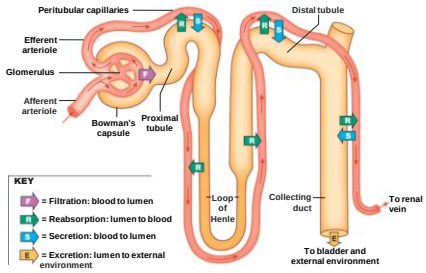


Figure 19-2

Kidney Function

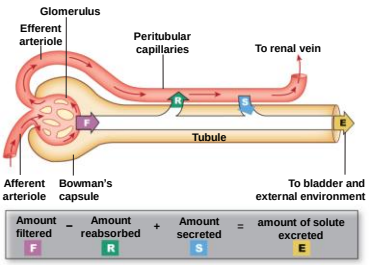
Table 19-1 Changes in Filtrate Volume and Osmolarity Along the Nephron

LOCATION IN NEPHRON	VOLUME OF FLUID	OSMOLARITY OF FLUID
Bowman's capsule	180 L/day	300 mOsM
End of proximal tubule	54 L/day	300 mOsM
End of loop of Henle	18 L/day	100 mOsM
End of collecting duct (final urine)	1.5 L/day (average)	50–1200 mOsM

Table 19-1

Kidney Function

- The urinary excretion of substance depends on its filtration, reabsorption, and secretion



The Filtration Fraction

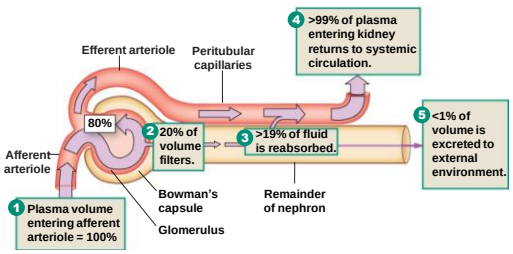
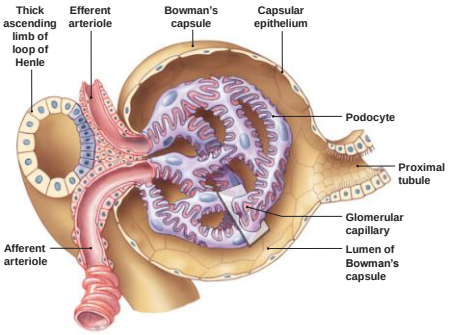


Figure 19-4

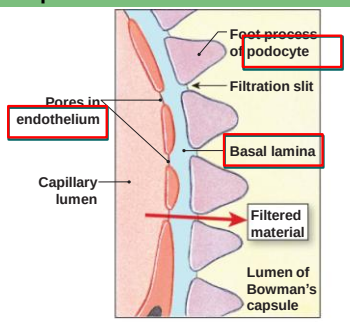
The Renal Corpuscle



(a) The epithelium around glomerular capillaries is modified into podocytes.

Figure 19-5a

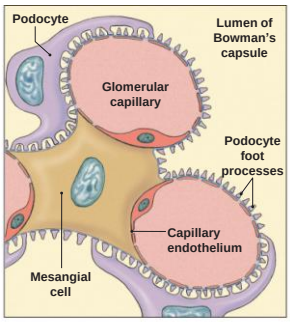
The Renal Corpuscle



(d) Filtered substances pass through endothelial pores and filtrationslits.

Figure 19-5d

The Renal Corpuscle



Mesangial cell:
- Can contract
- Cytokines

(c) Podocyte foot processes surround each capillary, leaving slits through which filtration takes place.

Figure 19-5c

Filtration Pressure

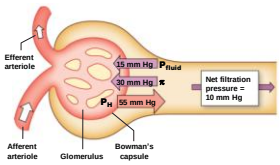
Depends on

1) **hydrostatic pressure (Blood Pressure)**

and is opposed by

2) **colloid osmotic pressure**
3) **capsule fluid pressure created in Bowmans capsule**

Volume of filtrate that enters Bowman's Capsule = GFR



P_H	–	π	–	P_{fluid}	=	net filtration pressure
55	–	30	–	15	=	10mm Hg

KEY

P_H = Hydrostatic pressure

π = Colloid osmotic pressure gradient due to proteins in plasma but not in Bowman's capsule

P_{fluid} = Fluid pressure created by fluid in Bowman's capsule

Autoregulation of Glomerular Filtration Rate

- GFR remains relatively constant

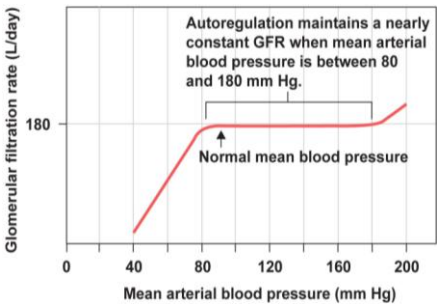


Figure 19-7

Filtration

- Resistance changes in renal arterioles alter renal blood flow and **GFR**

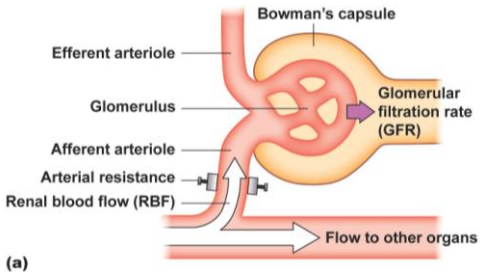


Figure 19-8a

Influences on GFR

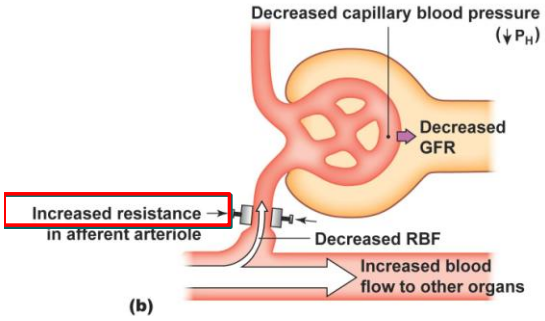


Figure 19-8b

Filtration

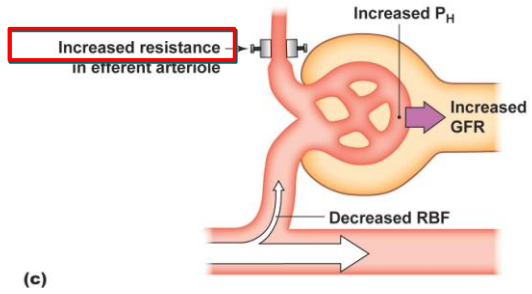


Figure 19-8c

GFR Regulation

Autoregulation (Instrinsic local responses)

1. Myogenic response
   - Stretch smooth muscle cells they contract
   - High BP causes arteriole constriction = ↓GFR
   - Low BP – no contraction - ??
2. Tubuloglomerular feedback
   - Paracrine control (juxtaglomerular apperatus)

Extrinsic (Non-local) Response

3. Hormones and autonomic neurons (SNS)

Juxtaglomerular Apparatus

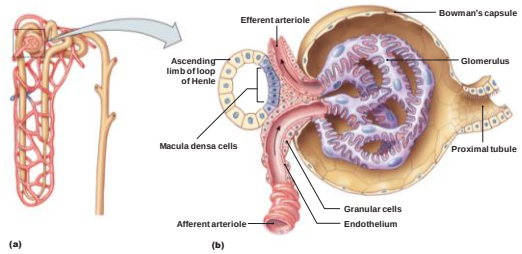
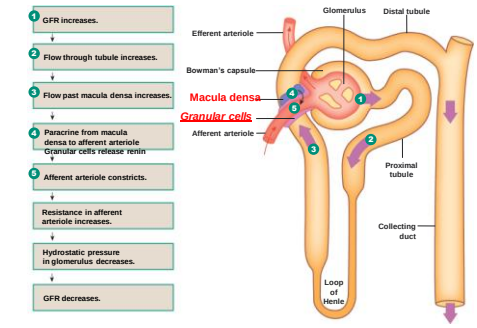


Figure 19-9

Tubuloglomerular Feedback



PLAY **Interactive Physiology® Animation: Urinary System: Glomerular Filtration**

Figure 19-10

GFR Regulation

Extrinsic (Non-local) Response

Can influence GFR

- Sympathetic neurons innervate the arterioles
  - If LOW BP or hemorrhage
    - Sympathetic vasoconstriction
      - GFR is reduced (conserves fluids)
- Hormones
  - Angiotensin II – Vasoconstrictor! Increases BP & GFR

Reabsorption

Reabsorption may be active or passive

- Transepithelial transport
  - Substances cross both apical and basolateral membrane
- Paracellular pathway
  - Substances pass through the junction between two adjacent cells

About Reabsorption

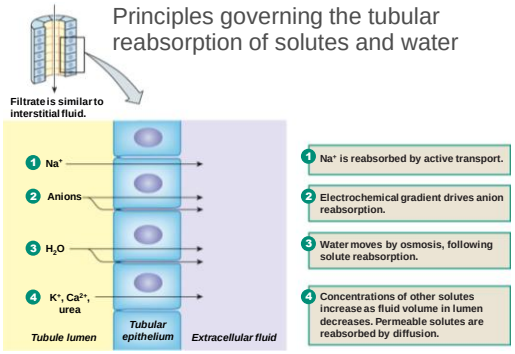


Figure 19-11, steps 1–4

Reabsorption

- Sodium reabsorption in the proximal tubule

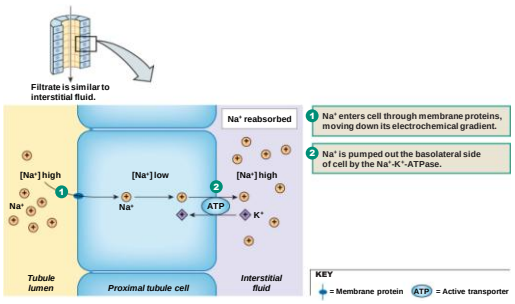
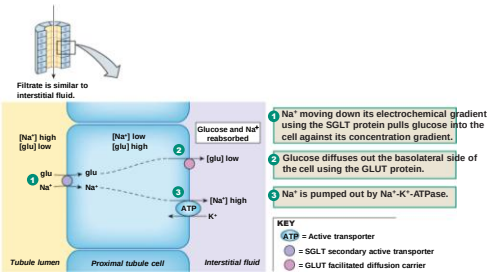


Figure 19-12

Reabsorption

- Sodium-linked glucose reabsorption in the proximal tubule



Reabsorption

- Urea
  - Passive reabsorption by diffusion
    - i.e., must have concentration gradient
- Plasma proteins
  - Most proteins are not in filtrate!!!!!!!!!!!!!!!!!!!!!!!!
  - But tiny ones enter proximal tubule cells by endocytosis
    - digested by lysosomes
- Peritubular Capillary pressure favor reabsorption:

P**H** in caps = 10; Colloid osmotic Pressure in Caps = 30

Difference of 20 favors reabsortion

Reabsorption

- Saturation of mediated transport can occur and influence reabsorption

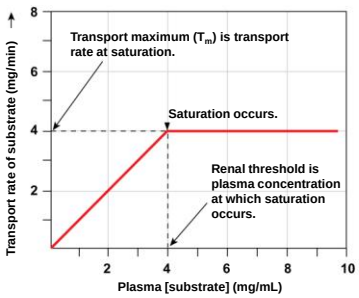


Figure 19-14

Reabsorption

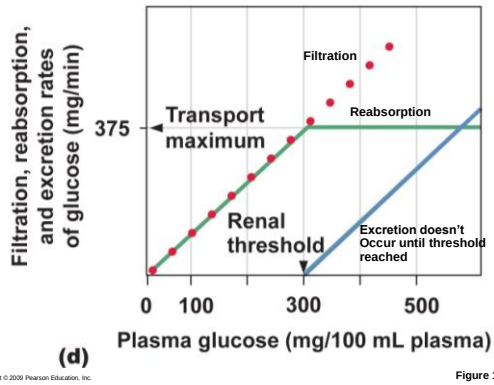


Figure 19-15d

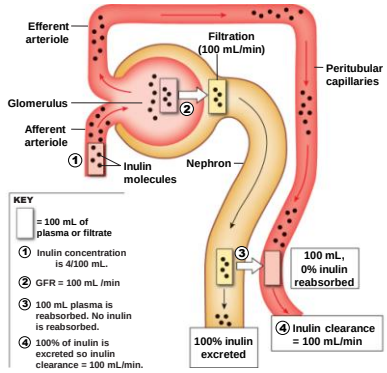
Secretion

- Transfer of molecules from extracellular fluid into lumen of the nephron tubule
  - Active process
- Important in homeostasis of
  - K^+ and H^+
- Increasing secretion enhances nephron excretion

Excretion

- Excretion = filtration – (reabsorption + secretion)
- **Clearance**
  - Rate at which a solute disappears from the body by excretion or by metabolism
  - Non-invasive way to measure GFR
  - Inulin and creatinine used to measure GFR
    - A non-invasive way to measure GFR

Inulin Clearance is equal to GFR



GFR

- Filtered load of X = $[X]_{plasma} \times$ GFR
- Filtered load of inulin = excretion rate of inulin
- GFR = excretion rate of inulin/$[inulin]_{plasma}$ = inulin clearance
- GFR = inulin clearance

Excretion

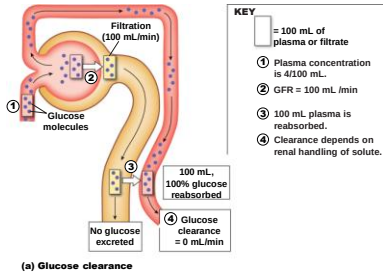
Table 19-2 Renal Handling of Solutes

For any molecule *X* that is freely filtered at the glomerulus:	Renal handling of *X* is:
Filtration is greater than excretion	Net reabsorption of *X*
Excretion is greater than filtration	Net secretion of *X*
Filtration and excretion are the same	No net reabsorption or secretion
Clearance of *X* is less than inulin clearance	Net reabsorption of *X*
Clearance of *X* is equal to inulin clearance	*X* is neither reabsorbed nor secreted.
Clearance of *X* is greater than inulin clearance	Net secretion of *X*

Table 19-2

Excretion

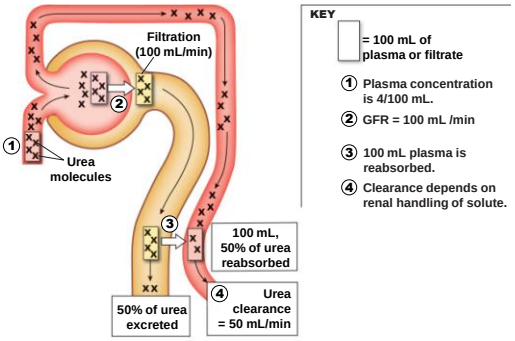
- The relationship between clearance and excretion



(a) Glucose clearance

Figure 19-17a

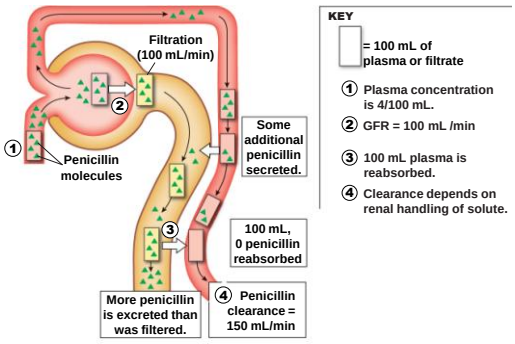
Excretion



(b) Urea clearance

Figure 19-17b

Excretion

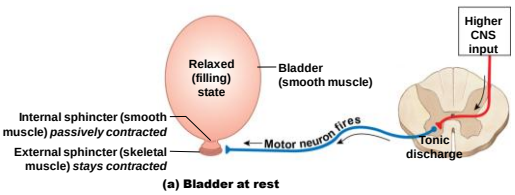


(c) Penicillin clearance

Figure 19-17c

Micturition

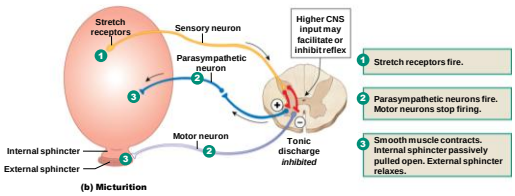
- The storage of urine and the micturition reflex



(a) Bladder at rest

Figure 19-18a

Micturition



(b) Micturition

Figure 19-18b