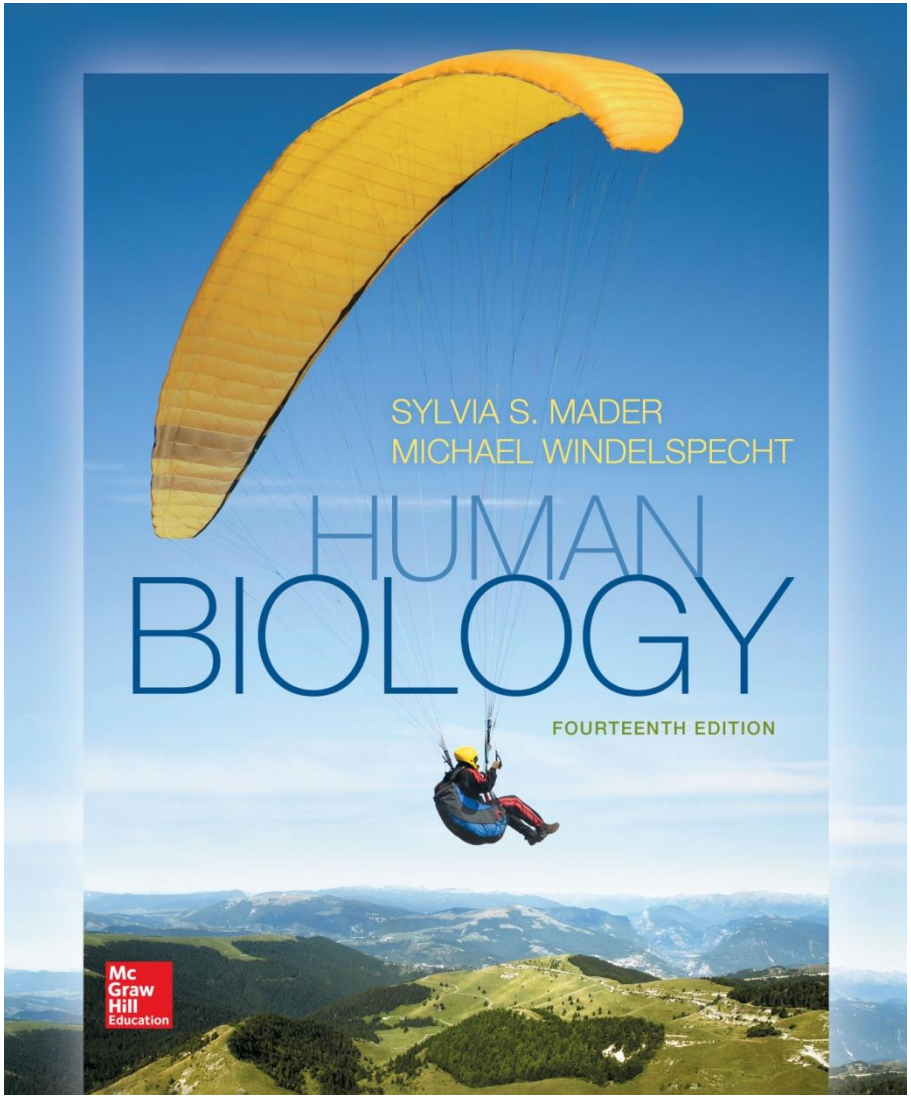
Chapter 11
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.



Urinary System

Points to ponder

- What are the parts and functions of the urinary system?
- What is the macroscopic and microscopic structure of the kidney?
- What are the three processes in urine formation?
- How is the kidney involved with regulating water-salt and acid-base balance of blood?
- What are the common disorders of the kidney?
- How can kidney failure be treated?
- How is the kidney involved with maintaining homeostasis along with other body systems?

What are the organs of the urinary system?

- Kidneys (2) – bean-shaped, fist-sized organ where urine is formed
- Ureters (2) – small, muscular tubes that carry urine from the kidneys to the bladder
- Bladder (1) – expandable organ that stores urine until it is expelled from the body
- Urethra (1) – tube (longer in men than women) that carries urine from the bladder to the outside of the body

Overview of the urinary system

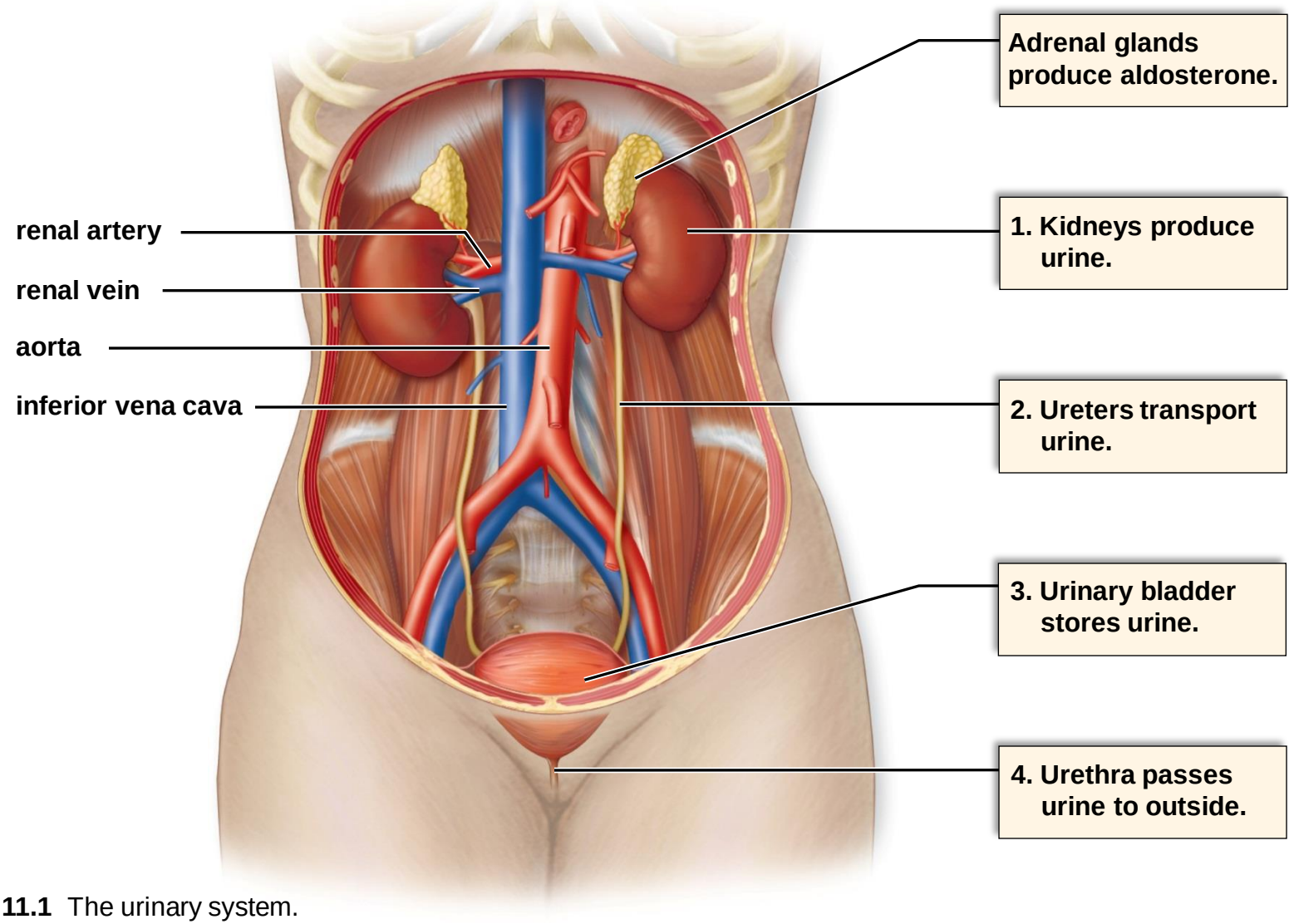


Figure 11.1 The urinary system.

What are the functions of the urinary system?

1. Excretion of metabolic wastes
2. Maintenance of water-salt balance
3. Maintenance of acid-base balance
4. Hormone secretion: renin and erythropoietin (EPO)
5. Reabsorb filtered nutrients and synthesize vitamin D

1. Excretion

- Mostly of nitrogenous wastes
  - Urea is made by the breakdown of amino acids in the liver.
  - Uric acid is made by the breakdown of nucleotides.
  - Creatinine is made by muscle cells from the breakdown of creatine phosphate.

2 and 3. Maintenance of water-salt and acid-base balance

- These are homeostatic mechanisms.
- Water-salt balance helps to maintain blood pressure.
- The kidneys excrete hydrogen ions and reabsorb bicarbonate ions; this acid-base balance helps maintain a blood pH of 7.4 .

4. Hormone secretion

- Renin – secreted by the kidneys to allow the adrenal glands to secrete aldosterone to help regulate water-salt balance

- Erythropoietin – secreted by the kidneys to stimulate red blood cell production when blood oxygen is low

5. Reabsorb filtered nutrients and synthesize vitamin D

- The urinary system is responsible for reabsorbing filtered nutrients.

- Vitamin D is a molecule that promotes calcium absorption from the digestive tract.

How does the urinary bladder work?

- It stores urine, sphincters keep it closed.
- Expandable wall contains a middle layer of circular fibers of smooth muscle and 2 layers of longitudinal smooth muscle.
- Lining of transitional epithelium allows expansion of mucosa.
- Filling activates stretch receptors which signal to spinal cord.

Control of the urinary bladder

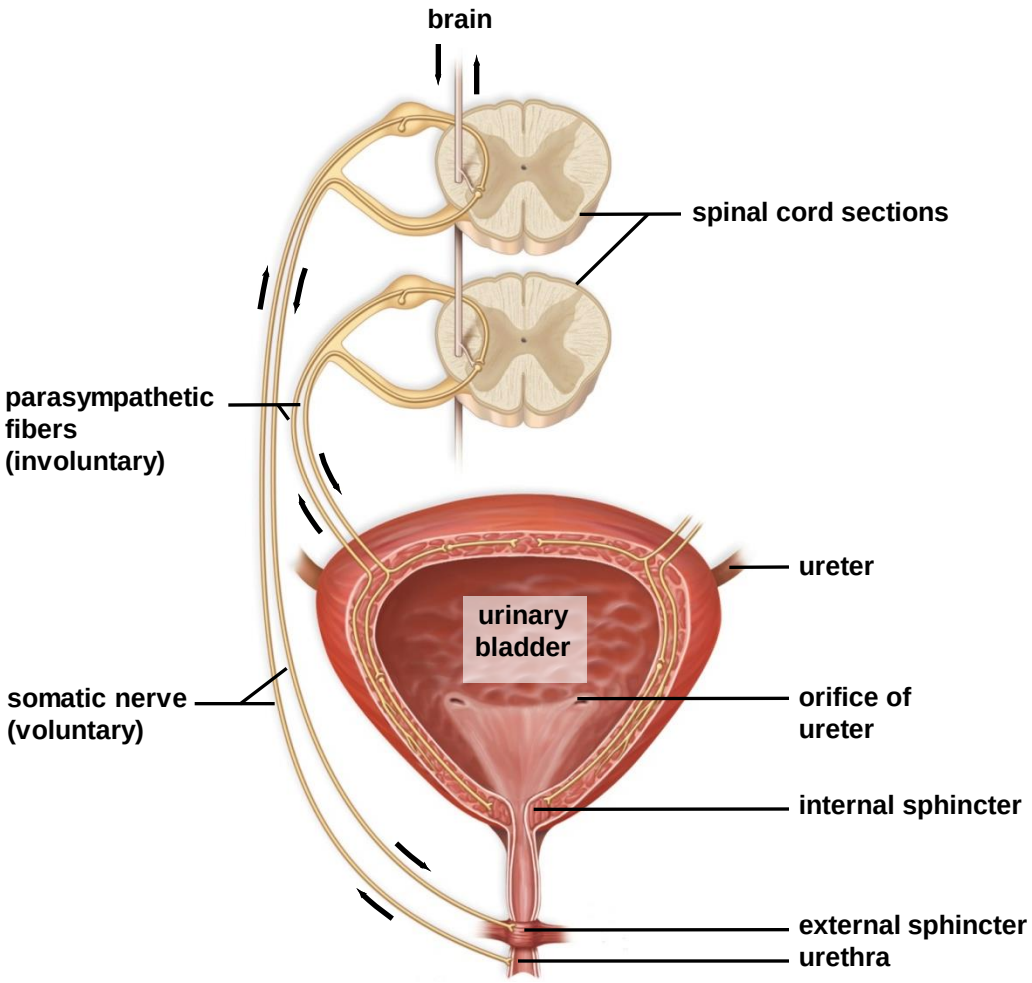


Figure 11.2 Sensory impulses trigger a desire to urinate.

What are the 3 regions of the kidney?

- Renal cortex – an outer granulated layer
- Renal medulla – cone-shaped tissue masses called renal pyramids
- Renal pelvis – central cavity that is continuous with the ureter

Anatomy of the kidney

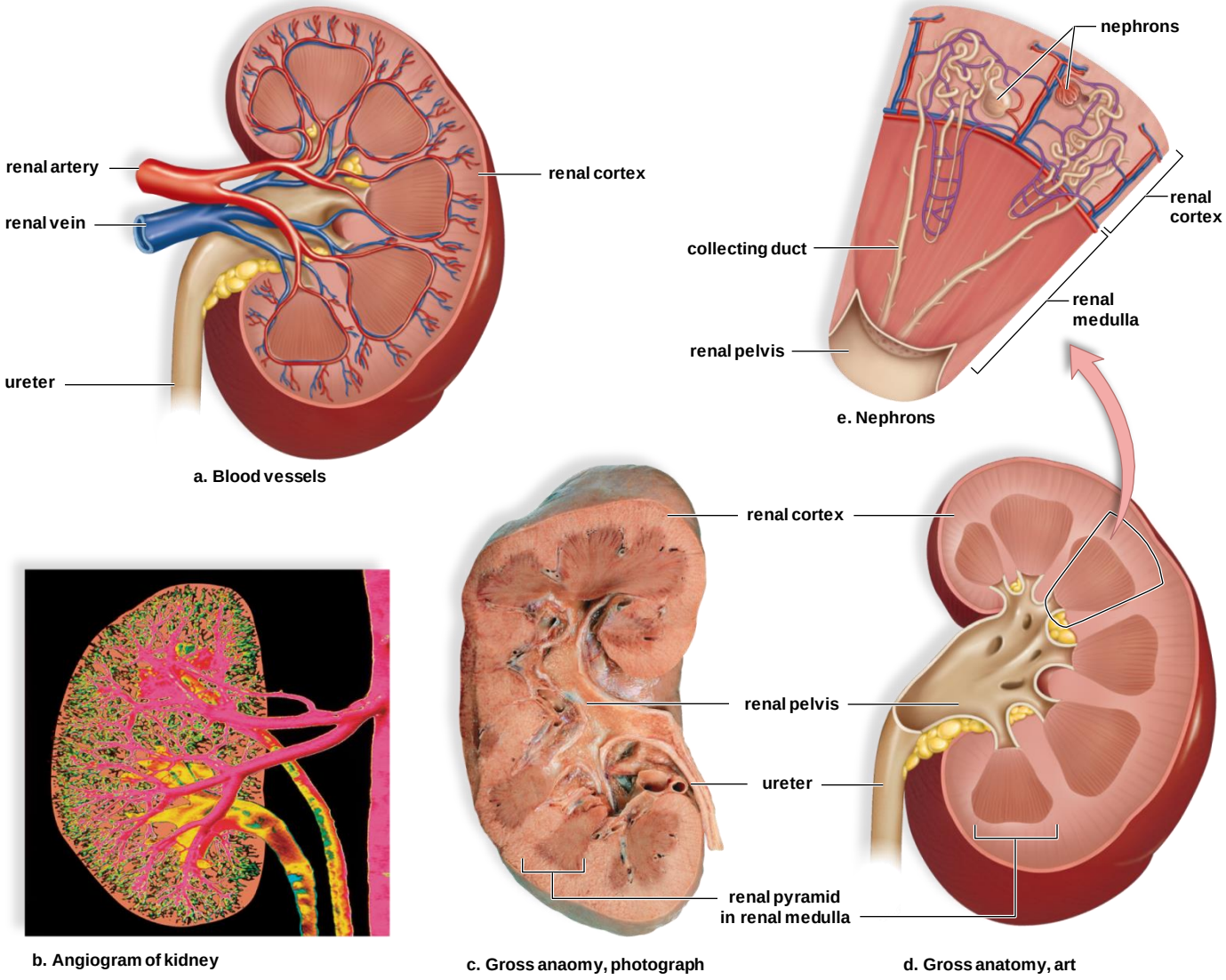


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Figure 11.3 The anatomy of a human kidney.

What are nephrons?

- Microscopic functional unit of the kidney that produces urine
- > 1 million per kidney

What are nephrons?

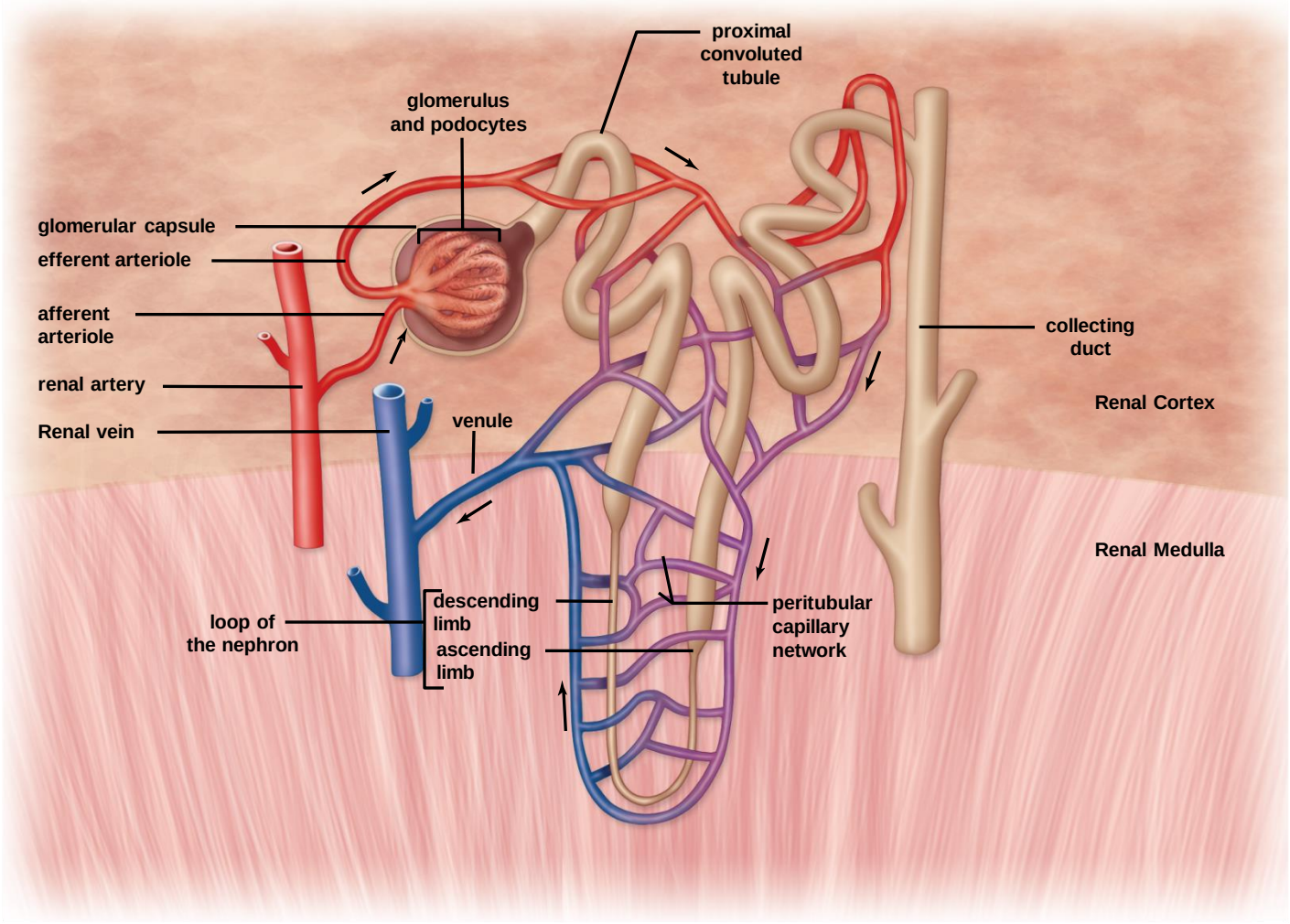

Figure 11.4 The structure of a nephron.

Anatomy of a nephron

- Glomerulus – a knot of capillaries inside the glomerular capsule where pores produce a blood filtrate
- Proximal convoluted tubule – epithelial layer with a brush border of microvilli to allow reabsorption of filtrate components
- Loop of nephron – U-shaped structure that has a descending limb to allow water to leave and an ascending limb that pushes out salt

Anatomy of a nephron

- Distal convoluted tubule – made of epithelial cells rich in mitochondria and thus is important for movement of molecules from the blood to the tubule (tubular secretion)

- Collecting ducts – several nephrons share a collecting duct which serve to carry urine to the renal pelvis

How does the nephron form urine?

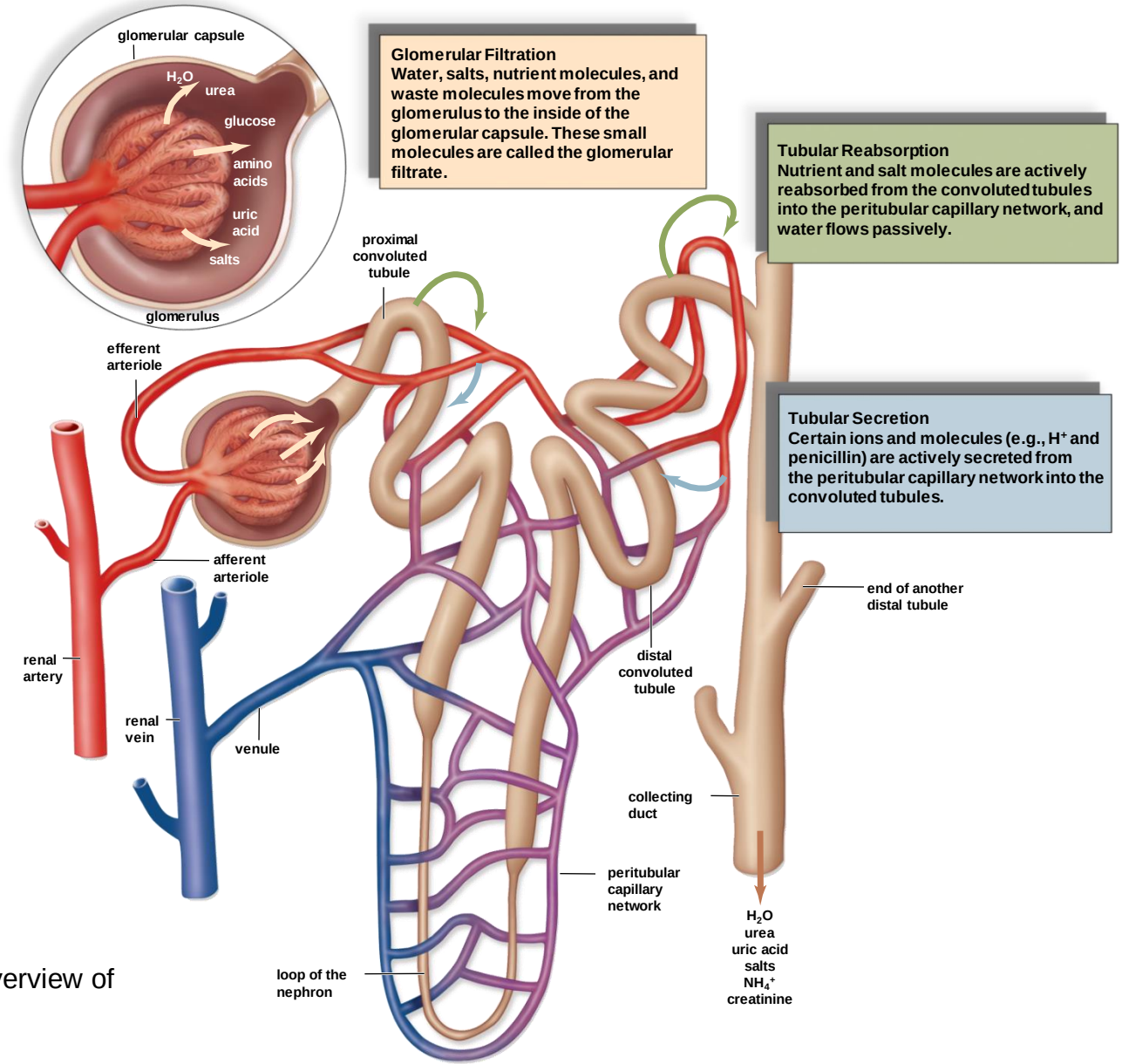

Figure 11.6 An overview of urine production.

What are the three processes in the formation of urine?

- Glomerular filtration
- Tubular reabsorption
- Tubular secretion

Glomerular filtration

- Water and small molecules move from the glomerulus to the glomerular capsule, while large molecules and formed elements remain in the glomerular blood.

Filterable Blood Components	Nonfilterabe Blood Components
Water	Formed elements (blood cells and platelets)
Nitrogenous wastes	Plasma proteins
Nutrients	
Salts(ions)	

Tubular reabsorption and secretion

- Many molecules and ions are reabsorbed from the nephron into the blood.
- Tubular secretion is a second way to remove substances such as drugs, H^+ and creatinine from the blood.

Reabsorbed Filtrate Components	Nonreabsorbed Filtrate Components
Most water	Some water
Nutrients	Much nitrogenous waste
Required salts (ions)	Excess salts (ions)

The urinary system and homeostasis

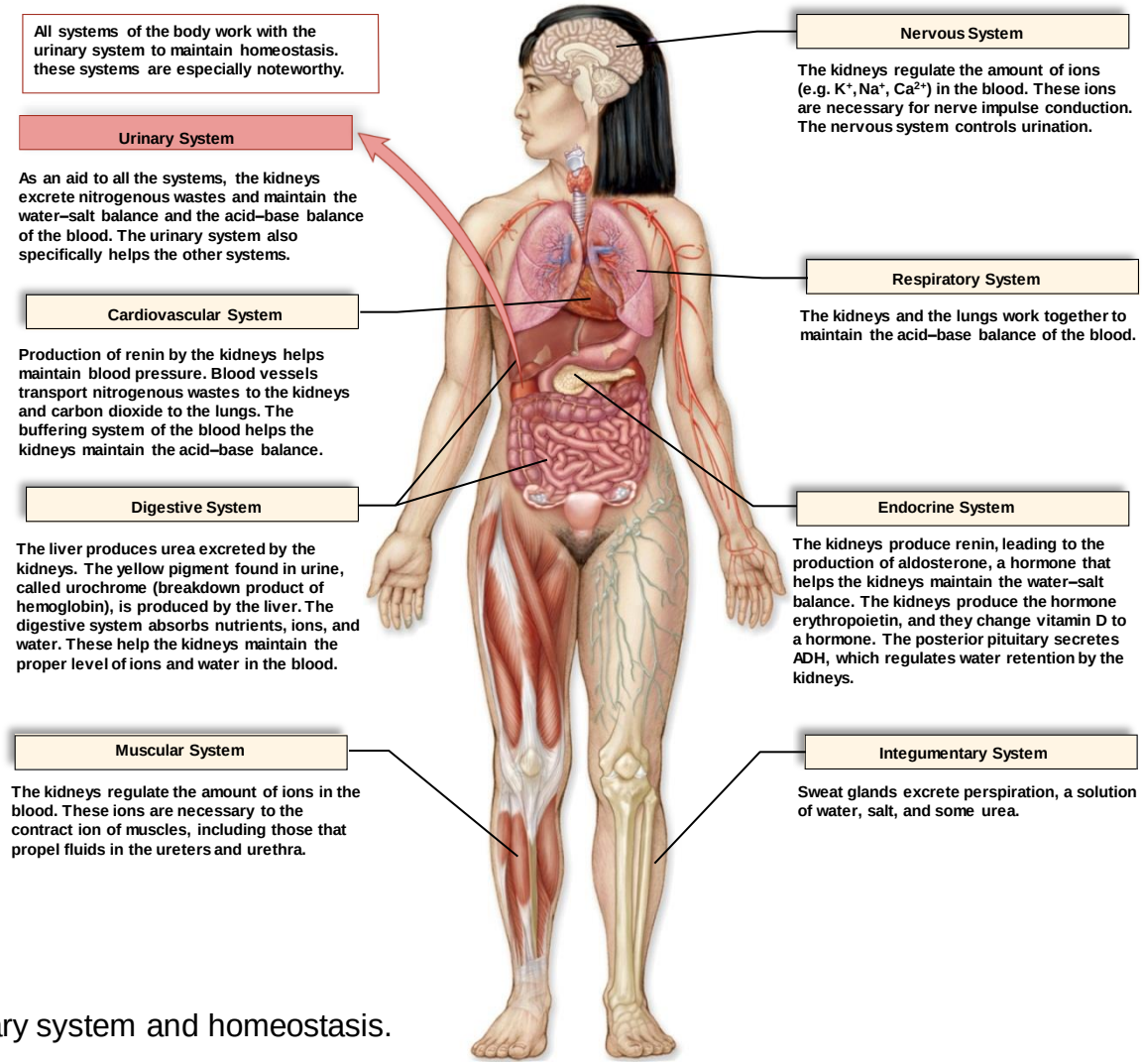

Figure 11.7 The urinary system and homeostasis.

How do the kidneys maintain homeostasis?

- Excrete wastes
  - Urea, creatinine, and uric acid
- Water-salt balance of blood
  - Helps regulate blood volume and pressure
- Acid-base balance of blood
  - Helps regulate pH
- Assistance to other systems
  - Endocrine, cardiovascular, skeletal, muscular, nervous, and digestive

What is the juxtaglomerular apparatus?

- Where the afferent arteriole and the distal convoluted tubule touch
- Secretes renin, which causes the release of aldosterone by the adrenal cortex

The juxtaglomerular apparatus

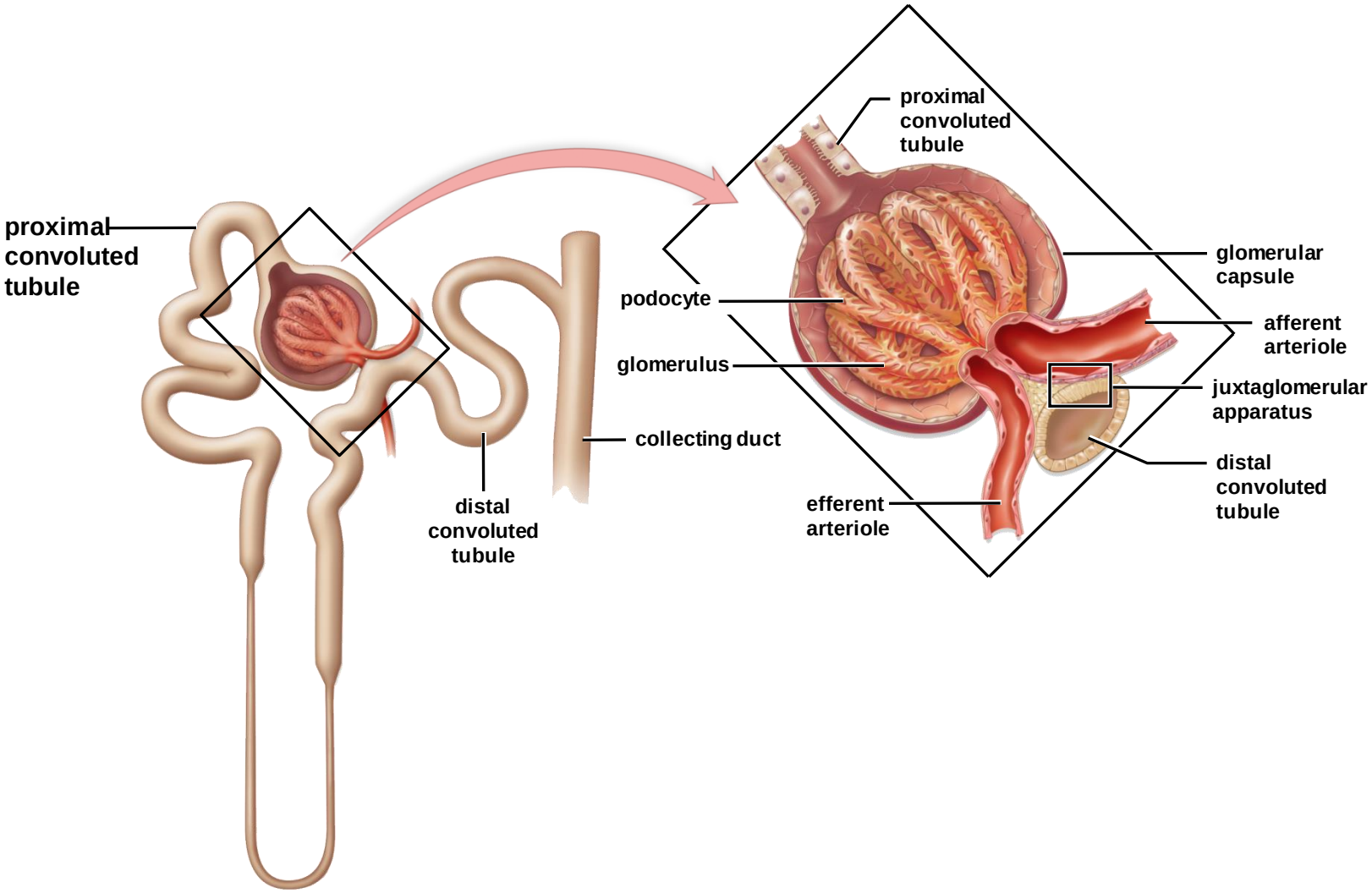

Figure 11.8 The juxtaglomerular apparatus of the nephron.

How is blood volume and pressure maintained by the kidneys?

- Reabsorption of salt – increases the blood volume
  - Aldosterone promotes the excretion of K^+ and the reabsorption of Na^+.
  - Atrial natriuretic hormone (ANH) is secreted by the heart when blood volume increases and inhibits the secretion of aldosterone which promotes the excretion of Na^+.

How is blood volume and pressure maintained by the kidneys?

- Establishment of solute gradient – a greater concentration is towards the inner medulla

- Reabsorption of water – due to the solute gradient, water leaves the descending limb of the loop of the nephron; then antidiuretic hormone (ADH) from the pituitary plays a role in water reabsorption at the collecting duct

Water reabsorption in nephrons

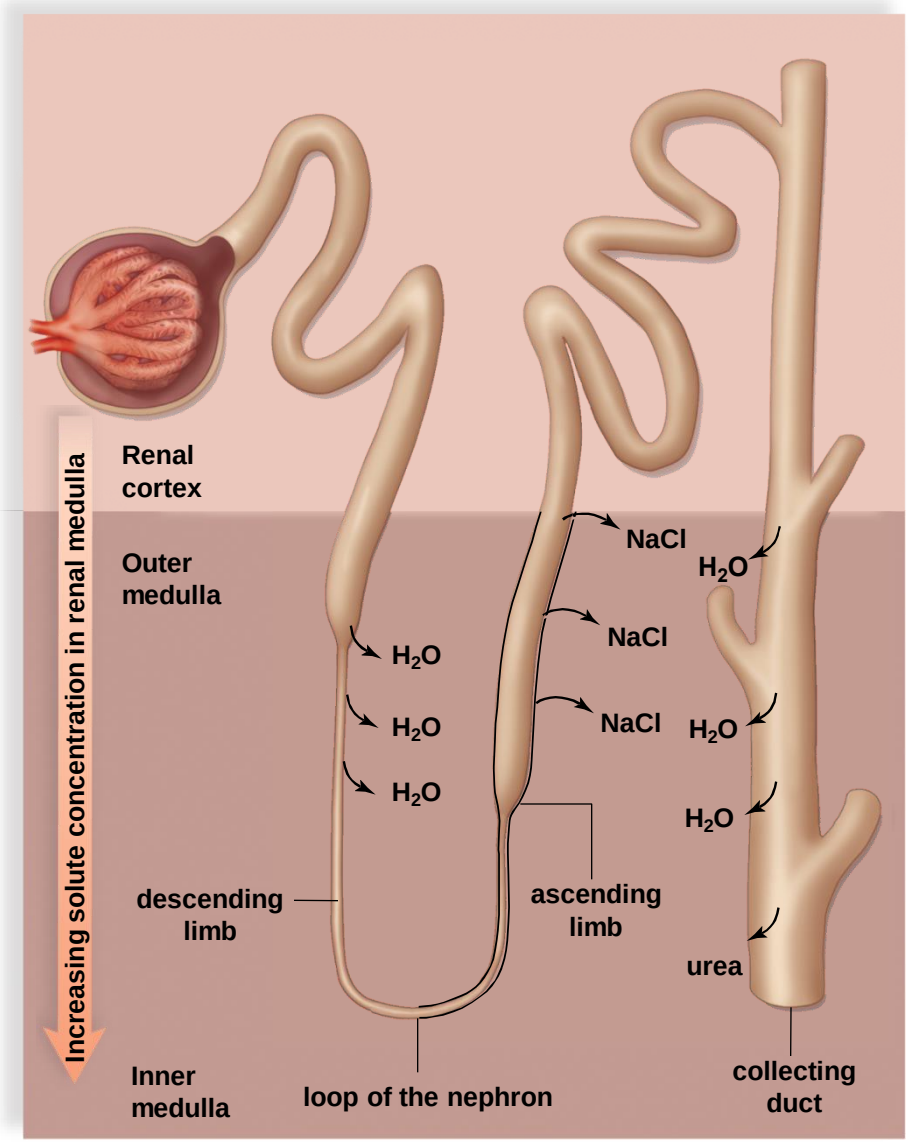

Figure 11.9 Movement of salt and water within a nephron.

What role does alcohol play in this process?

- Alcohol inhibits ADH secretion and thus increases the amount of urine and dehydration.

How is the acid-base balance maintained?

- Buffers are a chemical or a combination of chemicals that can take up excess H^+ or excess OH^-.

When H^+ are added to blood:

$$H^+ + HCO_3^- \longrightarrow H_2CO_3$$

When OH- are added to blood:

$$OH^- + H_2CO_3 \longrightarrow HCO_3^- + H_2O$$

How is the acid-base balance maintained?

- The respiratory center in the brain can increase breathing rate if the buffers cannot maintain the pH.

- Ultimately, the kidneys are responsible for maintaining blood pH.

The kidneys and blood pH

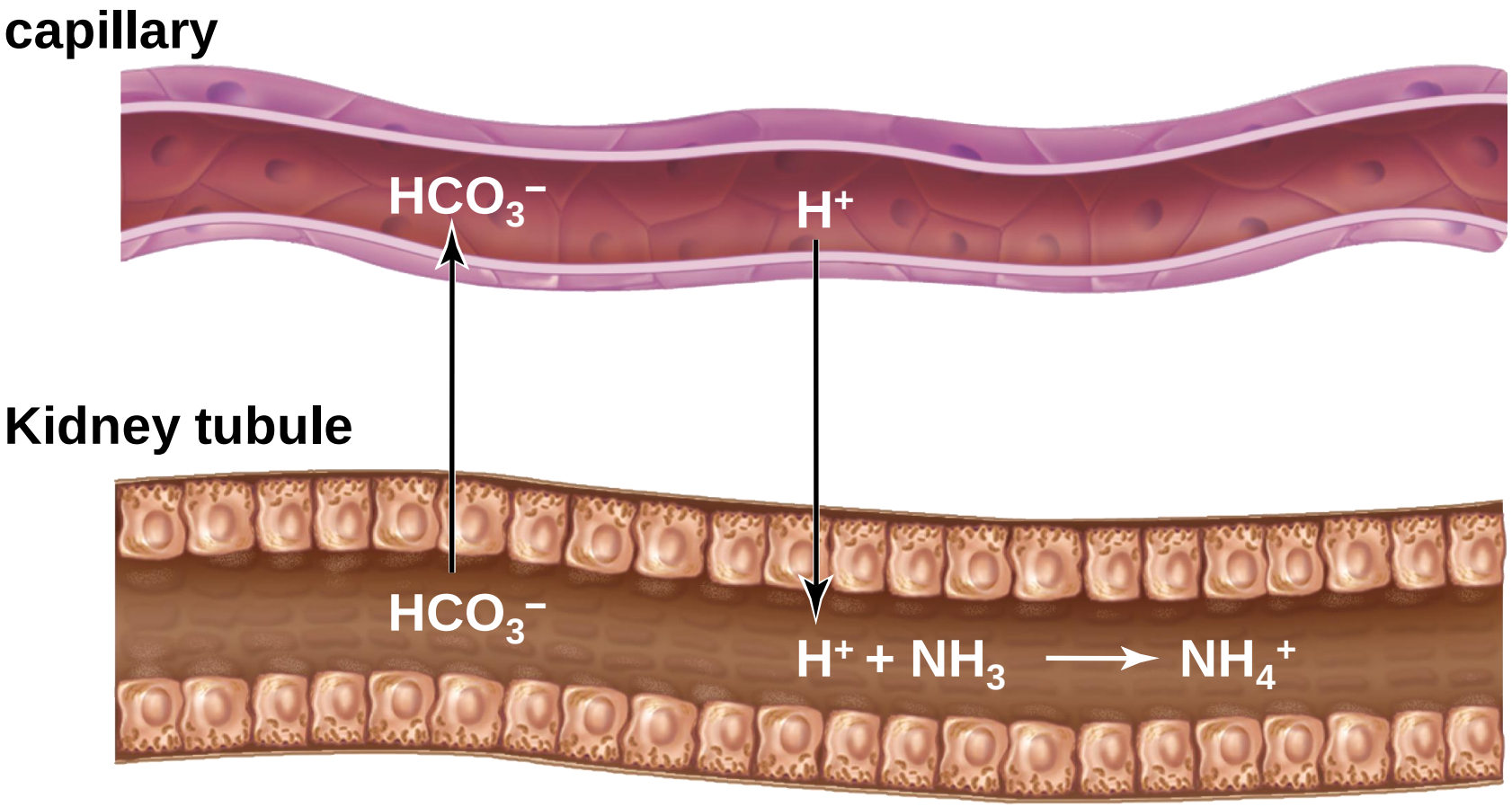

Figure 11.10 Blood pH is maintained by the kidneys.

Kidney function disorders

- Diabetes, hypertension, and inherited conditions are the most common cause of renal disease and failure such as:
  - Urethritis – localized infection of the urethra
  - Cystitis – infection in the bladder
  - Pyelonephritis – infection of the kidneys

Kidney function disorders

– Kidney stones – hard granules formed in the renal pelvis due to UTIs, enlarged prostate, pH imbalances, or intake of too much calcium

– Uremia – high levels of urea and other waste substances in the blood that cause a serious condition when water and salts are retained due to extensive nephron damage

How can kidney failure be treated?

- Hemodialysis – uses an artificial kidney machine to subtract and add substances to the blood as needed

- Continuous ambulatory peritoneal dialysis (CAPD) – uses the peritoneal membrane to filter the blood and allows a person to go about their normal life without interruption

- Kidney replacement – single kidney transplant with a high success rate

Hemodialysis using an artificial kidney machine

Figure 11.11
Hemodialysis using an artificial kidney machine.