Chapter 9 – Renal Filtration and Urine Formation

Objectives

Given the synopsis in this chapter, competence in each objective will be demonstrated by responding to multiple choices or matching questions, completing fill-in questions, or writing short answers, at the level of 75% or greater proficiency for each student..

A. To describe the general organization and function of the urinary system, especially the kidney and the nephron.
B. To explain the process of blood filtration by the glomerular capillaries, including glomerular filtration rate.
C. To explain reabsorption of filtrate from the renal tubules.

The urinary system includes the kidneys, ureters, bladder, and urethra. The primary purpose of the urinary system is to filter the blood plasma, to reabsorb needed fluids and electrolytes, and to excrete unneeded (or excess) substances. The urinary system plays a critical role in maintaining fluid and electrolyte balance and in the long-term regulation of acid-base balance, blood volume and blood pressure.

Organization of the Urinary System

The kidneys are located in the retroperitoneal cavity of the abdomen, as shown in Figure 9.1. The ureters extend from each kidney to the urinary bladder. The urinary bladder rests on the anterior floor of the pelvic cavity.

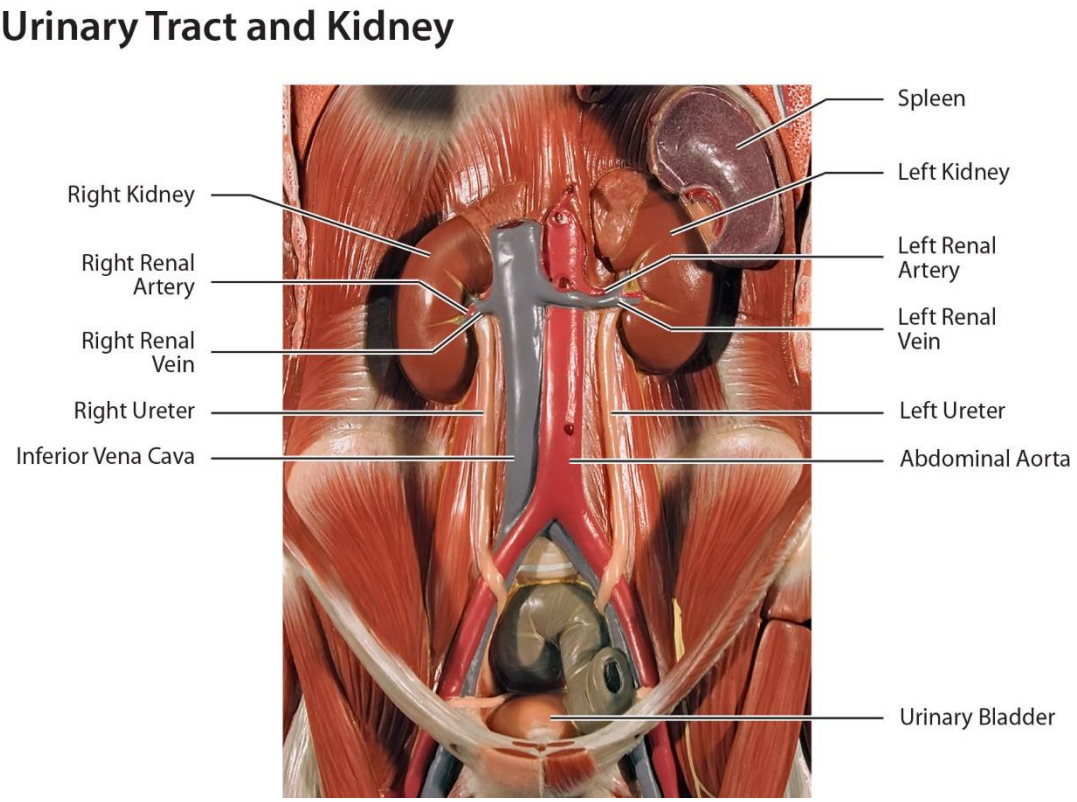

Figure 9.1 © 2014 David G. Ward, Ph.D., Atlas of Anatomy for Allied Health

The internal structure of the kidney is shown in Figure 9.2. Each kidney is surrounded by the renal capsule. Internally, the outer region is the cortex and the inner region is the medulla. Blood enters the kidney by way of the renal artery which branches into several branches (not labeled). Ultimately blood reaches the cortex. In the cortex, water, ions and small molecules are pushed out of the blood, using a process called filtration. Beginning in the cortex and continuing into the pyramids of the medulla, most of the water, electrolytes and small molecules are returned to the blood, using a process called reabsorption. The water, ions, and molecules not reabsorbed are collected from each pyramid and transported to the renal pelvis and ureter, to become the urine.

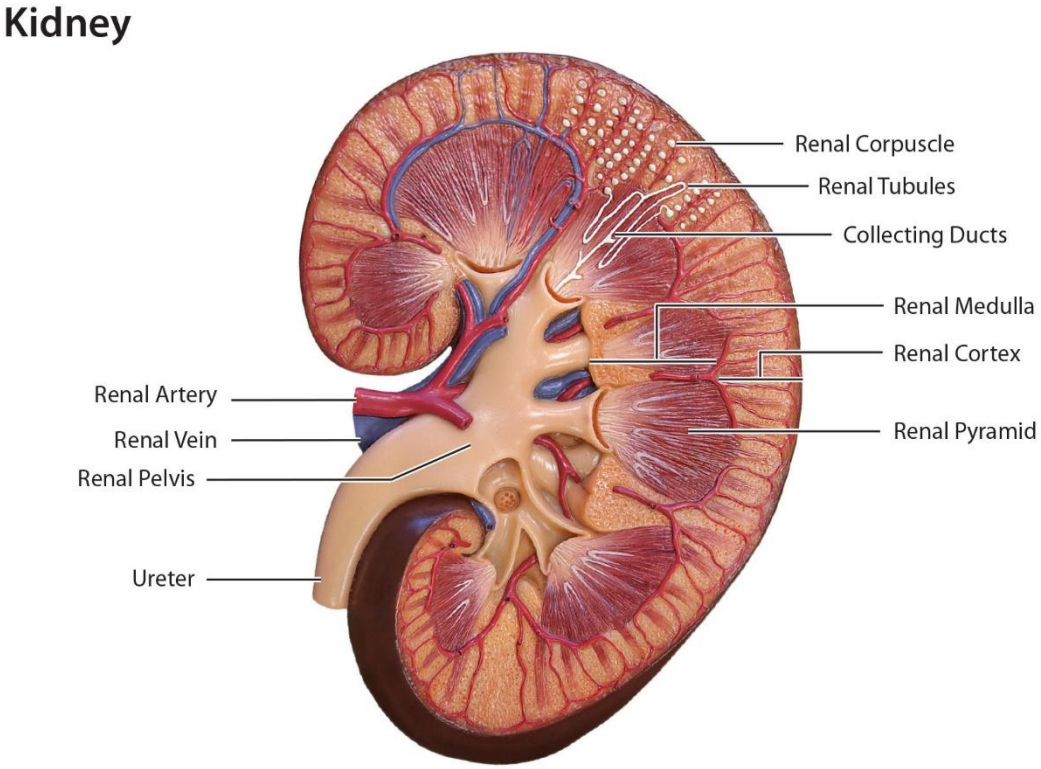

Figure 9.2 © 2014 David G. Ward, Ph.D., Atlas of Anatomy for Allied Health

The processes of filtration and reabsorption occur in the nephrons which are shown in more detail in Figures 9.3. Blood travels to afferent arterioles that enter renal corpuscles where filtration occurs. Filtrate from the blood passes into the proximal convoluted tubules and the blood continues into the efferent arterioles and to the peritubular capillaries. Blood is collected from the peritubular capillaries by veins. The filtrate continues through the proximal convoluted tubules, the descending and ascending nephron loops, the distal convoluted tubules, the collecting tubules and ducts, where reabsorption occurs. The collecting ducts merge to form ducts which empty into the renal pelvis, as shown in Figure 9.2.

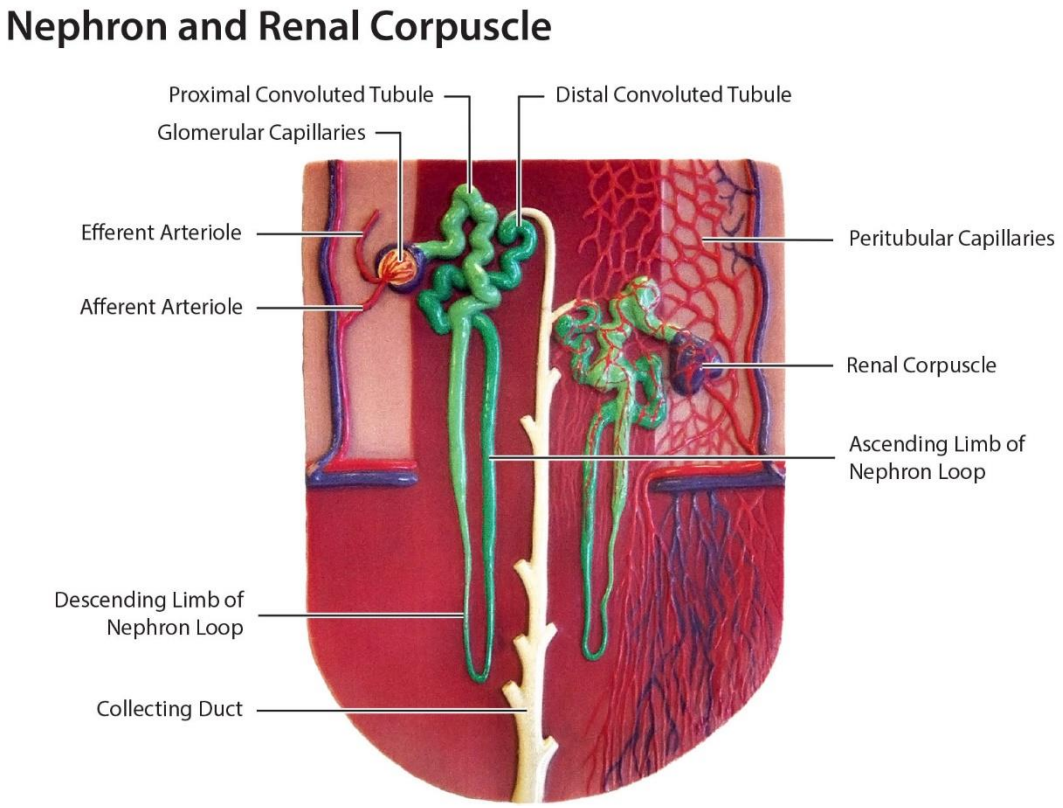

Figure 9.3 © 2014 David G. Ward, Ph.D., Atlas of Anatomy for Allied Health

Filtrate Formation

The kidney acts on the blood to filter plasma, to reabsorb needed fluids and electrolytes, and to excrete unneeded substances. Plasma is filtered out of the blood by glomerular filtration. Substances are reabsorbed from the renal tubules back into the blood in the peritubular capillaries.

Glomerular filtration

Filtration of the blood occurs in the renal corpuscles. The internal structure of a renal corpuscle is shown in the upper corner of Figure 9.3. Blood enters the corpuscle under pressure by way of an afferent arteriole that connects to a capillary network called the glomerular capillaries (glomerulus). Water, electrolytes and small molecules are pushed through the capillaries and into the space of the renal corpuscle. The proximal convoluted tubule extends from the renal corpuscle like a drain pipe.

The blood pressure is sufficient to produce a substantial quantity of filtrate. The amount of filtrate formed each minute is called the glomerular filtration rate (GFR).

- Glomerular Filtration Rate (GFR) is about 125 mL/min total for both kidneys.

A normal GFR of 125 mL/min is equal to 7.5 L/hr and 180 L/day. The total plasma volume of blood is only about 3 L. Therefore the total plasma volume is filtered 2.5 times each hour and 60 times each day. A normal 24 hour urine volume is about 1.8 L which is only 1% of the 24 hour glomerular filtration. Therefore about 99% of the glomerular filtration is reabsorbed.

- About 1% of filtrate is excreted as urine; about 99% of filtrate is reabsorbed.

Reabsorption and Secretion – Renal Tubules and Ducts

Proximal convoluted tubule

The proximal convoluted tubule acts as a mass absorber. About two-thirds (67%) of filtered water and solutes are reabsorbed in this region, as shown in Figure 9.4.

- Water is a major substance reabsorbed
- Major solutes reabsorbed include sodium, chloride, potassium, calcium, bicarbonate, glucose, amino acids, fatty acids, and urea.
- In addition, some solutes are secreted into the tubular fluid and include hydrogen ions and various anions such as sulfate and oxalate.

Nephron loop

The nephron loop acts in part as a mass absorber and in part to create an osmotic gradient for reabsorption of water. About 15% of filtered water and 25% of filtered Na^+, Cl^-, and K^+ are reabsorbed in this region, as shown in Figure 9.4.

- Water is a major substance reabsorbed
- The major solutes reabsorbed include sodium, chloride, potassium, calcium, and bicarbonate. In addition, hydrogen ions are secreted into the tubular fluid.

Distal convoluted tubule (early segment)

The early distal tubule (DCT1) acts mainly to fine tune the reabsorption of sodium and chloride ions. About 4% of filtered Na^+ and Cl^- is reabsorbed, as shown in Figure 9.4.

- The major solutes reabsorbed include sodium and chloride.
- Sodium reabsorption is under the control of the hormone Aldosterone.

Distal convoluted tubule (late segment) and collecting tubules/ducts

The late distal tubules (DCT2) and the collecting tubules/ducts act mainly to fine tune the reabsorption of water; and to a lesser extent sodium, chloride, potassium, and calcium ions. About 8-17% of filtered water and 3% of filtered Na^+ are reabsorbed, as shown in Figure 9.4.

- Water is the major substance reabsorbed
- Water reabsorption is under the control of the hormone Vasopressin.
- Solutes reabsorbed include sodium, chloride, potassium, calcium, and bicarbonate ions.

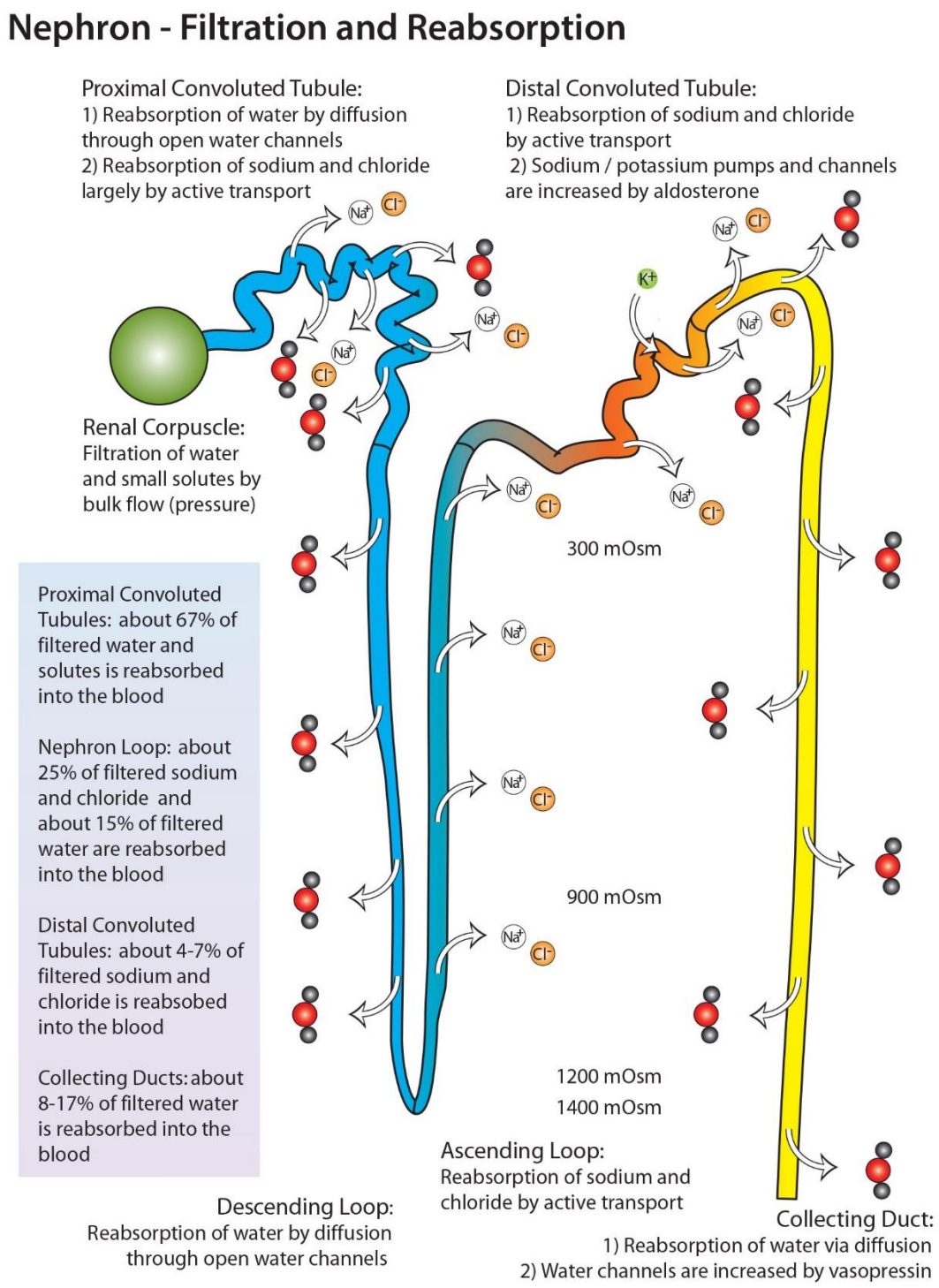

Figure 9.4 © 2014 David G. Ward, Ph.D., Atlas of Anatomy for Allied Health

Table 9.1 (next page) summarizes the amounts of common substances filtered from and reabsorbed back into the blood by the kidney.

Table 9.1. Summary of amounts filtered from and reabsorbed back into blood by the kidney each day.

Substance	Amount Filtered / day	Amount Reabsorbed / day	Percent Reabsorbed / day
Water	180,000 mL	178,200 mL*	99%
Na/Cl	1260 g	1247 g*	99%
Glucose	180,000 mg	180,000 mg	100%
Urea	50 g	25-40 g	50-80%

*based on normal salt and water balance