URINARY SYSTEM ANATOMY

Adapted from Human Anatomy & Physiology – Marieb and Hoehn (9th ed.)

OVERVIEW

Metabolism of nutrients by the body produces wastes that must be removed from the body. Although excretory processes involve several organ systems (e.g., lungs excrete carbon dioxide), it is mainly the urinary system that removes nitrogenous wastes from the body. The urinary system is also responsible for maintaining the electrolyte, acid-base, and fluid balances of the blood and is thus a major, if not *the* major, homeostatic organ system of the body.

The primary organs in the urinary system are the paired **kidneys** (Figure 1). To properly do their job, the kidneys act first as blood "filters", and then as blood "processors". They allow toxins, metabolic wastes, and excess ions to leave the body in the urine, while retaining needed substances and returning them to the blood. In addition to the kidneys, the urinary system also includes the **ureters**, which transport the urine from the paired kidneys to the **urinary bladder** where it is collected and stored. Once the bladder is full, the urine exits the body via the **urethra**.

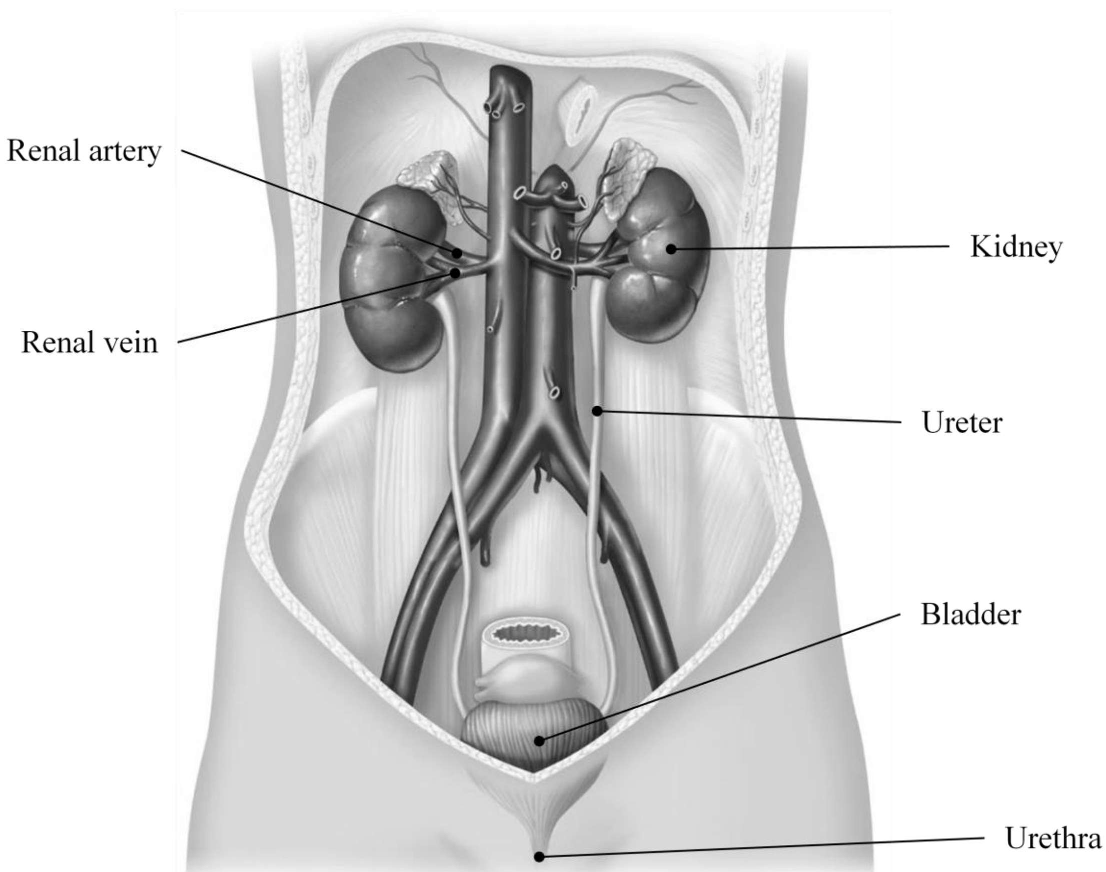

Figure 1: Major organs of the urinary system.

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 25.1

Functional Anatomy

Kidney

The paired **kidneys** lie in a retroperitoneal position (between the dorsal body wall and the parietal peritoneum) in the superior lumbar region. Extending approximately from T_{12} to L_3, the kidneys receive some protection from the lower part of the rib cage. The right kidney is slightly lower than the left kidney because it is "crowded" by the liver. In a living person, fat deposits (call the adipose capsule) hold the kidneys in place against the muscles of the posterior trunk wall (Figure 1).

Each kidney is fed by a **renal artery** which branches off the descending aorta. A **renal vein** drains blood from each kidney, entering into the inferior vena cava. These vessels enter / exit the kidney in the indented medial region of the kidney called the **renal hilum**.

Externally, each kidney is surrounded by a smooth transparent membrane called the **fibrous capsule** (Figure 2). Internally, the kidney is divided into several regions. The **renal cortex** is the most superficial region. It appears lighter in color and is the site of glomerular filtration and a majority of tubular reabsorption / secretion. Deep to the cortex is located the **renal medulla**. The medulla, appearing much darker in color, is segregated into triangular areas called the **medullary (renal) pyramids**. The base of each pyramid faces toward the cortex with the pointed apex, termed the **renal papilla**, directed toward the innermost region of the kidney. The renal pyramids are separated by the **renal columns**, which are composed of tissue similar in appearance to the renal cortex.

The innermost region of the kidney, medial to the renal hilus, consists of a relatively flat, basin-like cavity called the **renal pelvis**. Finger-like extensions of the pelvis form cup-like areas called calyces that enclose the renal papilla of the medullary pyramids. **Minor calyces** immediately surround each renal papilla with the minor calyces then joining to form **major calyces** which drain into the renal pelvis.

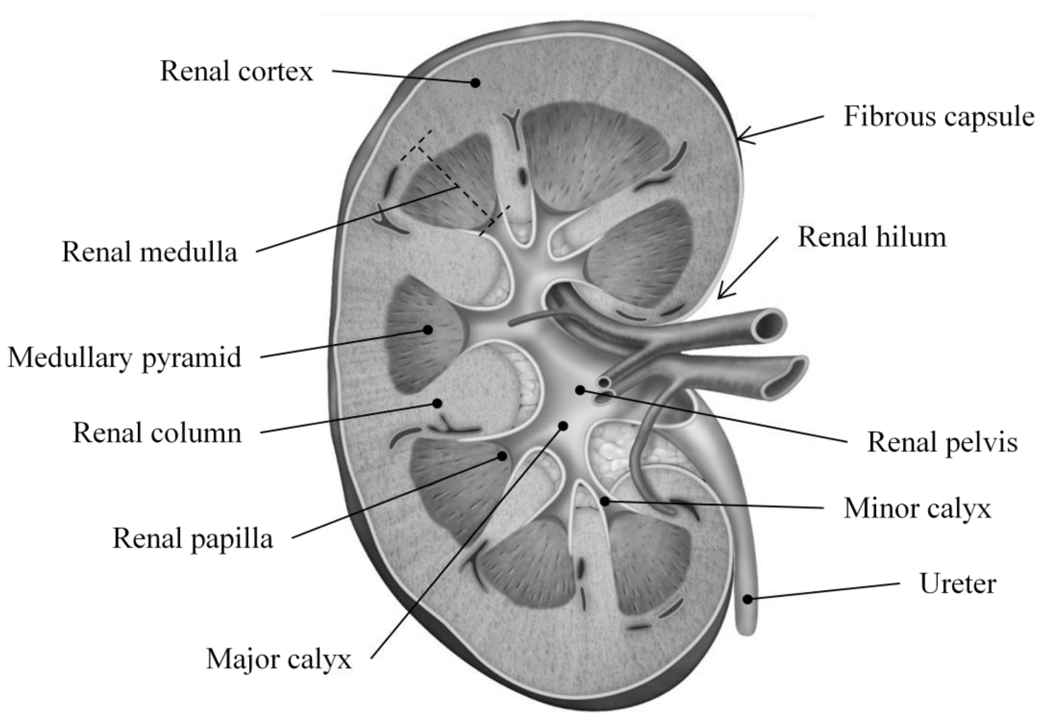

Figure 2: Internal anatomy of the kidney.

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 25.3

Exercise 1

Utilizing the kidney model, locate the following structures: *fibrous capsule, renal hilum, renal cortex, renal medulla, medullary pyramid, renal column, renal papilla, renal pelvis major calyx,* and *minor calyx.*

Kidney Blood Supply

The kidneys continuously cleanse the blood and adjust its composition, so it is not surprising that they have a rich blood supply. Under normal resting conditions, the large renal arteries deliver one-fourth of the total cardiac output (~ 1200 ml) to the kidneys each minute.

The **renal arteries** exit at right angles from the abdominal aorta. As each renal artery approaches a kidney, it divides into five **segmental arteries** (Figure 3). Within the renal sinus, each segmental artery branches further to form several **interlobar arteries**. At the cortex-medulla junction, the **interlobar arteries** branch into the **arcuate arteries** that arch over the bases of the medullary pyramids. Small **cortical radiate arteries** radiate outward from the arcuate arteries to supply the cortical tissue.

Afferent arterioles branching from the cortical radiate arteries begin a complex arrangement of microscopic blood vessels. These vessels are key elements of kidney function which will be examined shortly during the description of the nephron.

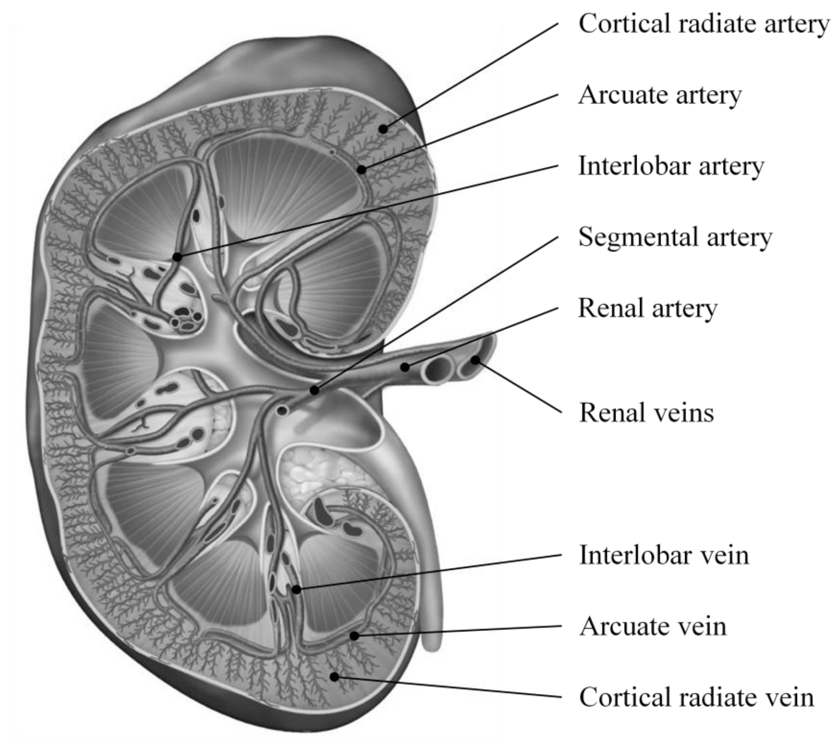

Figure 3: Blood vessels of the kidney.

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 25.4

Veins trace the pathway of the arterial supply in reverse (Figure 3). Blood leaving the renal cortex drains sequentially into the **cortical radiate veins**, **arcuate veins**, **interlobar veins**, and finally the **renal veins**.

Exercise 2

Utilizing the kidney and nephron models, locate the following vessels: *renal artery, segmental artery, interlobar artery, arcuate artery, cortical radiate artery, cortical radiate vein, arcuate vein, interlobar vein,* and *renal vein.*

Microanatomy of Kidney

At the microscopic level, each kidney is composed of upwards of a million **nephrons**, the anatomical unit responsible for forming urine (Figure 4). Each nephron consists of a **glomerulus** (a capillary cluster) and a **renal tubule**. Each renal tubule begins as a blind-ended sac that gradually surrounds and encloses an adjacent glomerulus. The enlarged end of the tubule encasing the glomerulus is the **glomerular (Bowman's) capsule**, and its inner wall consists of specialized cells with long branching processes called **podocytes**. Podocytes cling to each other and to the endothelial wall of the glomerular capillaries, forming a very porous membrane around the glomerulus.

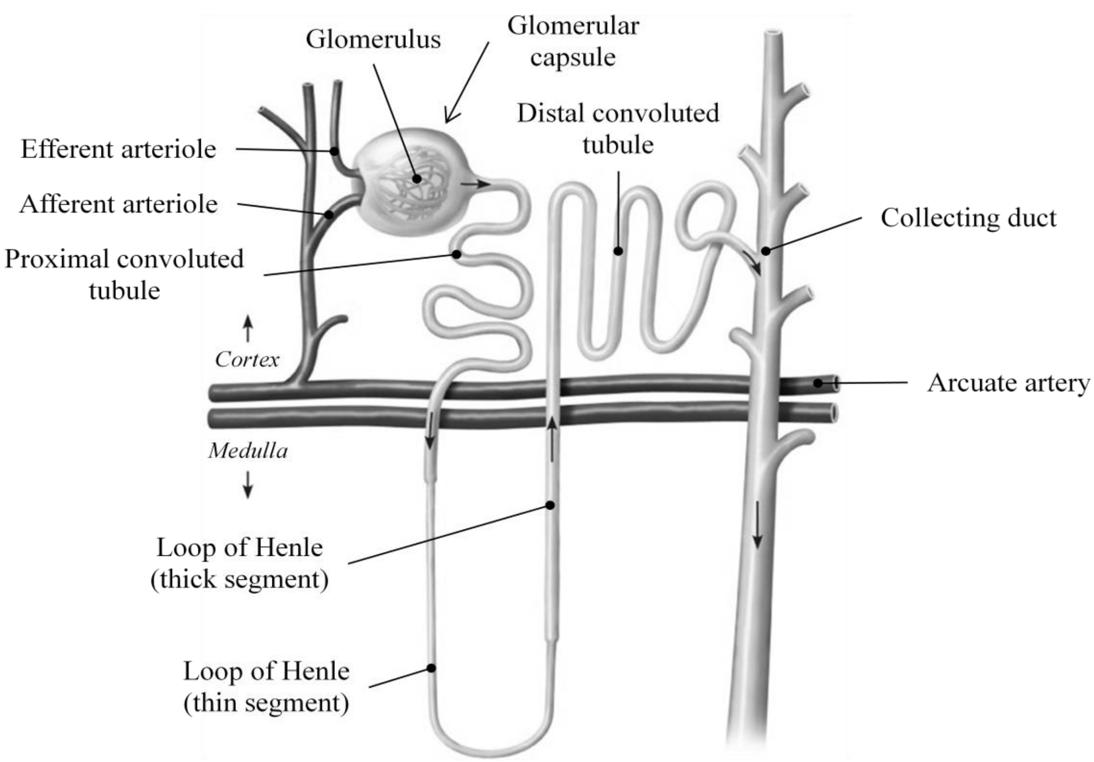

Figure 4: Location and structures of the nephron.

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 25.5

The anatomical areas of the rest of the renal tubule, in order from the glomerular capsule, are the **proximal convoluted tubule**, **loop of Henle**, and the **distal convoluted tubule**. The proximal convoluted tubules are formed by cuboidal epithelial cells with their luminal (exposed) surfaces bearing dense microvilli – this is where a large part of the filtrate reabsorption occurs. The distal convoluted tubules are similar in structure to the proximal convoluted tubules except the cells appear smaller and lack microvilli. The U-shaped loops of Henle are either composed of simple squamous epithelium (**thin segment**) or simple cuboidal / columnar (**thick segment**), depending on whether the region is involved in the passive diffusion of water or the active transport of salts.

Most nephrons, called **cortical nephrons**, are located entirely within the cortex. However, parts of the loops of Henle of the **juxtamedullary nephrons** penetrate well into the medulla. The **collecting ducts**, each of which receives urine from many nephrons, run downward through the medullary pyramids to empty the urine product into the calyces and ultimately the pelvis of the kidney.

Nephron function depends on some unique features of the renal circulation. There are two distinct capillary beds, the glomeruli (described earlier) and the **peritubular capillaries**. The glomerulus, fed by the **afferent arteriole** and drained by the **efferent arteriole**, is responsible for forming the filtrate which is processed by the renal tubule. Peritubular capillary beds arise from the efferent arterioles and cling to the renal tubules. This capillary bed is responsible for absorbing solutes and water that are reclaimed from the filtrate by the tubule cells. Specialized peritubular capillaries, called **vasa recta**, are found around the deep loops of Henle associated with the juxtamedullary nephrons. These vessels play an important role in forming concentrated urine.

Exercise 3

Utilizing the model showing a kidney nephron, located the following structures: *glomerulus*, *glomerular capsule*, *proximal convoluted tubule*, *loop of Henle* (*thin* / *thick segments*), *distal convoluted tubule*, *collecting duct*, *afferent arteriole*, *efferent arteriole*, *peritubular capillaries*, *vasa recta, cortical nephron,* and *juxtamedullary nephron*.

Exercise 4

On the class webpage (www.wou.edu/~lemastm/Teaching/BI336) there is a PowerPoint file containing histological images taken from the urinary system. Find the image labeled 'Kidney' and properly label *renal cortex, renal medulla, glomerulus, glomerular capsule, podocyte, proximal convoluted tubule, distal convoluted tubule, thin segment of loop of Henle,* and *thick segment of loop of Henle.* Next, examine an actual histological slide (see slide box at your bench) taken from a kidney and visually identify the structures listed above.

Ureter

The ureters are slender tubes that convey urine from the kidneys to the bladder. Each ureter begins at the level of L_2 as a continuation of the renal pelvis (Figure 1). From there, it descends behind the peritoneum and runs obliquely through the posterior bladder wall. This arrangement prevents backflow of urine because any increase in bladder pressure compresses and closes the distal ends of the ureters.

Exercise 5

Utilizing the model showing the complete urinary system, locate the *ureters*.

Histologically, the ureter wall has three layers. The **mucosa** contains a **transitional epithelium** that is continuous with the mucosae of the kidney pelvis superiorly and the bladder medially. The **muscularis** is composed chiefly of two smooth muscle sheets – the internal longitudinal layer and the external circular layer. The **adventitia** covering the ureter's external surface is typical fibrous connective tissue.

Exercise 6

Find the image from the PowerPoint file containing histological images labeled 'Ureter' and properly label *mucosa, transitional epithelium, muscularis,* and *adventitia.* Next, examine an actual histological slide (see slide box at your bench) taken from a ureter and visually identify the structures listed above.

Urinary Bladder:

The **urinary bladder** is a smooth, collapsible, muscular sac that stores urine temporarily (Figure 5). The bladder is located retroperitoneally on the pelvic floor just posterior to the pubic symphysis. The interior of the bladder has openings for both ureters (**ureteric orifices**) and the urethra. The smooth, triangular region of the bladder based outlined by these three openings is the **trigone**, important clinically because infections tend to persist in this region.

Exercise 7

Utilizing the model showing the complete urinary system, located the *bladder, trigone,* and *ureteric orifices*.

The wall of the bladder is composed of three layers: a **mucosa** containing a **transitional epithelium**, a thick muscular layer called the **detrusor muscle**, and a fibrous **adventitia**. When empty, the bladder collapses into its basic pyramidal shape and its walls are thick and thrown into folds. When full, the bladder expands, becomes pear-shaped, and rises superiorly in the abdominal cavity.

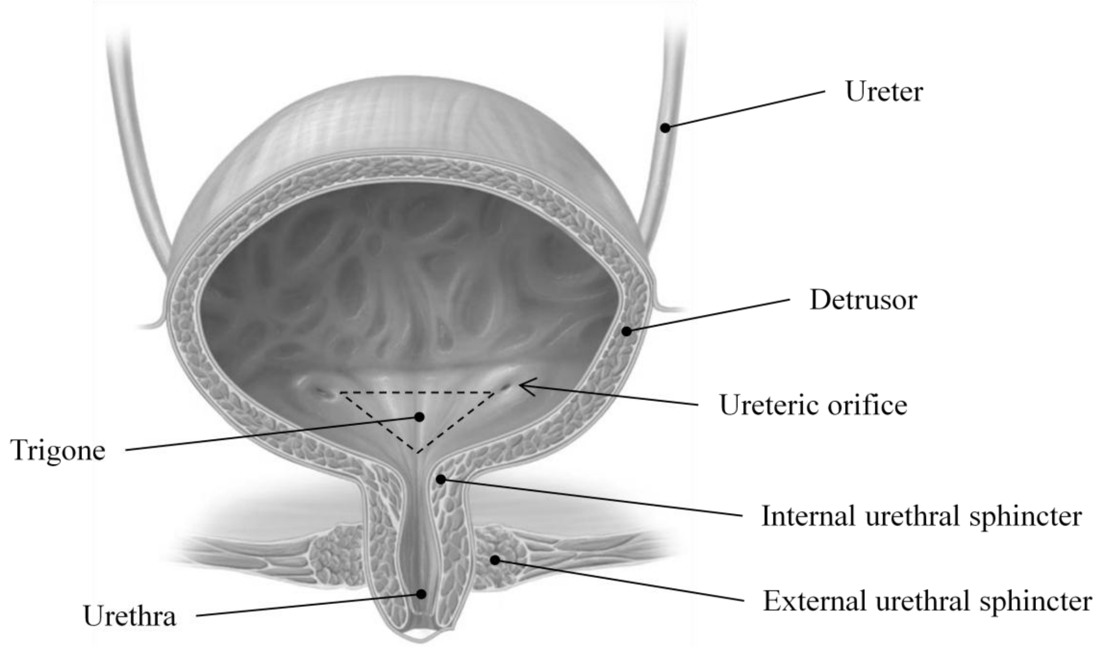

Figure 5: Structure of the urinary bladder and urethra (female).

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 25.20

Exercise 8

Find the image from the PowerPoint file containing histological images labeled 'Urinary Bladder' and properly label *mucosa, transitional epithelium, detrusor,* and *adventitia.* Next, examine an actual histological slide (see slide box at your bench) taken from a urinary bladder and visually identify the structures listed above.

Urethra:

The **urethra** is a thin-walled muscular tube that drains urine from the bladder and conveys it out of the body (Figure 5). At the bladder-urethra junction, the detrusor smooth muscle thickens to form the **internal urethral sphincter**. This involuntary sphincter, controlled by the autonomic nervous system, keeps the urethra closed when urine is not being passed and prevents leaking between voiding. The **external urethral sphincter** surrounds the urethra as it passes through the urogenital diaphragm. This sphincter is formed of skeletal muscle and is voluntarily controlled.

The length and functions of the urethra differ in the two sexes. In females, the urethra is only 3 – 4 cm long and fibrous connective tissue binds it tightly to the anterior vaginal wall. In males the urethra is approximately 20 cm long and has three distinct regions: the *prostatic urethra*, which runs through the prostate gland, the *membranous urethra*, which runs through the urogenital diaphragm, and the *spongy urethra*, which runs through the penis. The male urethra serves two functions – it carries semen as well as urine out of the body.

Exercise 9

Utilizing the model showing the complete urinary system, located the *urethra, internal urethral sphincter,* and *external urethral sphincter*.

The epithelium of the urethral **mucosa** is mostly **pseudostratified columnar epithelium** with short stretches of transitional epithelium near the urinary bladder and stratified squamous epithelium near the external opening. Otherwise, the **muscularis** is composed chiefly of two smooth muscle sheets – the internal longitudinal layer and the external circular layer – and the **adventitia** covering the urethral surface is typical fibrous connective tissue.

Exercise 10

Find the image from the PowerPoint file containing histological images labeled 'Urethra' and properly label *mucosa, pseudostratified columnar epithelium, muscularis,* and *adventitia.* Next, examine an actual histological slide (see slide box at your bench) taken from a urinary bladder and visually identify the structures listed above. (Note: The actual histological slide may contain different epithelial types depending on where along the urethra the section was taken)
