FUNCTIONS OF THE URINARY SYSTEM
The urinary system consists of two kidneys, two ureters, the urinary bladder, and the urethra.

1. Two kidneys.
   A. The kidneys eliminate waste products (e.g., urea, uric acid, creatinine). Other systems, such as the respiratory, digestive, and integumentary systems also eliminate waste products (e.g., carbon dioxide, water).
   B. The kidneys maintain water and electrolyte balance.
      1) Sodium and potassium levels affect membrane potentials. Sodium affects water balance.
      2) Water affects blood volume and thus blood pressure.
      3) Regulation of blood pH.
   C. Erythropoietin increases red blood cell production.
   D. Renin increases blood pressure by increasing the formation of angiotensin I, which is converted into angiotensin II.
      1) Angiotensin II causes vasoconstriction of blood vessels.
      2) Angiotensin II stimulates aldosterone production, which increases blood volume.
   E. Conversion of vitamin D to an active form.

2. The urinary bladder stores urine.

3. Conducting tubes.
   A. The ureters conduct urine from the kidneys to the urinary bladder.
   B. The urethra conducts urine from the urinary bladder to the exterior of the body.
KIDNEY ANATOMY AND HISTOLOGY
Location and External Anatomy of the Kidneys

1. The **renal capsule** covers and contains the kidney. The **perirenal fat** provides protection against mechanical shock.

2. The **renal fascia** anchors the kidney to the posterior abdominal wall. **Ptosis** (drooping) of the kidney occurs when the kidney is not held in place by the renal fascia. It can cause bending and blockage of the ureter, reflux of urine, and retrograde pressure within the kidney.

3. The kidneys are retroperitoneal.

4. The kidney is bean shaped. Near the center is the **hilum** through which the ureter and lymphatic vessels exit, and through which blood vessels enter and exit the kidney.

5. The hilum opens into a space called the **renal sinus**, which is filled with fat, connective tissue, blood vessels, and the renal pelvis (see below)

Internal Anatomy of the Kidneys

1. The **cortex** is the outer layer and the **medulla** is the inner layer of the kidney.

2. Extensions of the cortex, the **renal columns** project into the medulla.

3. The medulla consists of the **renal pyramids**, which are separated by the renal columns. Extensions of the renal pyramids, the **medullary rays**, project into the cortex. The medullary rays collect urine and conduct the urine to the **renal papillae**, which are the tips of the renal pyramids.

4. The renal papillae project into a funnel-shaped chamber called a **minor calyx**. There are eight to 20 minor calyces per kidney.

5. The minor calyces join to form larger chambers called a **major calyx**. There are two or three major calyces per kidney.

6. The major calyces join to form an enlarged chamber, the **renal pelvis**, which is found inside the renal sinus.

7. The renal pelvis forms the superior part of the ureter.

8. Urine travels from the renal papillae to the minor calyces, then to the major calyces, the renal pelvis, the ureter, the urinary bladder, and lastly through the urethra
**Histology of the Kidneys**

1. The **nephron** is the functional unit of the kidney. There are approximately 1.3 million nephrons in each kidney. One third of the nephrons must be functional to ensure survival.

![FIGURE 26.4](image)

A. Parts of the nephron:
   1) **Renal corpuscle**, which consists of the **glomerulus** and **Bowman's capsule**.
   2) **Proximal tubule**.
   3) **Loop of Henle**, which consists of a descending and ascending limb.
   4) **Distal tubule**.

B. Location of the nephrons:
   1) The renal corpuscle and convoluted tubules are located in the cortex.
   2) The loop of Henle extends into the medulla.
   3) **Juxtamedullary nephrons** are located near the division between the cortex and the medulla. They have long loops of Henle that extend further into the medulla than the loops of Henle of the **cortical nephrons**.

2. The distal tubule of several nephrons empty into a **collecting duct**. Note that the collecting duct is not part of a nephron. The collecting ducts (plus loops of Henle that run parallel to the collecting ducts) form the medullary rays that extend into the cortex.

3. The collecting ducts join to form **papillary ducts**, which extend to the tips of the renal pyramids (renal papillae).

4. Details of the renal corpuscle.

![FIGURE 26.5](image)

A. The nephron begins as the renal corpuscle, which consists of the glomerulus and Bowman's capsule.

B. The glomerulus is a capillary network that is surrounded by Bowman's capsule. The capillaries of the glomerulus are unusual because they have open pores (fenestrae) which extend through the endothelium.

C. Bowman's capsule is a double-walled cup. [Do fist in balloon analogy. Compare to serous membranes]
   1) The **parietal layer** is the outer wall of the cup and consists of simple squamous epithelium.
2) The **visceral layer** is the inner wall of the cup and consists of specialized epithelial cells called **podocytes**.
   a. Podocytes wrap around the capillaries of the glomerulus.
   b. Podocytes have cellular processes with spaces between the process called **filtration slits**.

3) Between the parietal layer and the visceral layer is a space that is continuous with the lumen of the proximal tubule.

**D. The filtration** membrane consists of the capillary endothelium, a basement membrane, and the podocytes. Materials pass through the filtration membrane from the blood into the space of Bowman's capsule.

5. As the afferent arteriole approaches Bowman's capsule it joins with the distal tubule to form the **juxtaglomerular apparatus**.

![FIGURE 26.5b](image)

A. The **juxtaglomerular cells** are smooth muscle cells of the afferent arteriole that contribute to the juxtaglomerular apparatus.

B. The **macula densa** is epithelial cells of the distal tubule that contribute to the juxtaglomerular apparatus.

C. The juxtaglomerular apparatus produces **renin** which helps (eventually) to regulate blood pressure.
   1) The macula densa monitors the flow rate of filtrate through the nephron
   2) In ways that are not well understood, when flow rates decrease, the macula densa can stimulate the juxtaglomerular cells to secrete renin.

**Arteries and Veins of the Kidneys**

![FIGURE 26.7](image)

1. The **renal artery** branches from the abdominal aorta. The renal artery enters the renal sinus.

2. The renal artery divides to form the **segmental arteries**.

3. The segmental arteries divide to form the **interlobar arteries**. The interlobar arteries pass between the renal pyramids (within the renal columns).

4. The interlobar arteries form the **arcuate arteries**. The arcuate arteries pass between the cortex and medulla (along the base of the renal pyramids).
5. The **interlobular arteries** branch from the arcuate arteries. The interlobular arteries extend into the cortex.

6. **Afferent arterioles** branch from the interlobular arteries. The afferent arterioles go to the glomeruli which are surrounded by Bowman's capsules.

7. **Efferent arteries** leave the glomeruli.

8. The efferent arteries form the **peritubular capillaries**, which wrap around the proximal and distal tubules.

9. The **vasa recta** is the part of a peritubular capillary that runs alongside the loop of Henle.

10. The peritubular capillaries and vasa recta drain into **interlobular veins**. The venous return runs alongside the arteries and the veins have the same names, i.e., **interlobular veins**, **arcuate veins**, **interlobar veins**, and **renal veins**. The renal veins empty into the inferior vena cava.

**ANATOMY AND HISTOLOGY OF THE URETERS AND URINARY BLADDER**

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1. The **ureters** are tubes that extend from the renal sinuses of the kidneys to the urinary bladder. The ureters function to conduct urine from the kidneys to the urinary bladder.

2. The **urinary bladder** is a sac that functions to store urine. The urinary bladder connects to the urethra, which carries urine to the outside of the body.

   A. The ureters and urinary bladder are lined by transitional epithelium that allows them to stretch.
   B. The walls of the ureters and urinary bladder consist of smooth muscle that can stretch (permitting an increase in size) and contract (causing movement of urine)

4. Sphincters.
   A. In males, the **internal urinary sphincter** is smooth muscle found at the junction of the urinary bladder with the urethra. It prevents retrograde ejaculation of semen into the urinary bladder. Females do not have an internal urinary sphincter.
   B. In males and females, the **external urinary sphincter** is skeletal muscle that surrounds the urethra as it passes through the pelvic floor. The external urinary sphincter functions to regulate urine movement out of the urinary bladder.