The urinary system helps regulate the body’s bloodstream by filtering and eliminating unwanted substances through urination. The urinary system’s primary structures include the kidneys, ureters, bladder, and urethra. In this eBook, we will look at these primary structures as well as some urinary pathologies.
The kidneys are bean-shaped organs situated in the back of the abdominal wall—there is one on each side of the spinal column (between the T12-L3 vertebrae). The right kidney sits slightly lower than the left to accommodate the liver. The kidneys filter blood and turn waste into urine.

Did you know?

The average kidney weighs around an average cell phone, around 4-6 ounces. (Source)
Each kidney consists of an outer **renal cortex**, an inner **renal medulla**, and a **renal pelvis**. **Nephrons**—complex structures whose purpose is to filter blood, reabsorb what the body needs, and excrete the rest as urine—are located in the cortex and medulla. Blood filtration and urine formation occur within the nephrons. Urine passes from the renal pyramids into the renal pelvis. This funnel-shaped structure occupies the central cavity of each kidney. Urine drains from the renal pelvis into the ureter.
Blood enters the kidneys through the **renal arteries**. These arteries branch into tiny capillaries in the nephrons. The filtered blood leaves through the **renal veins**. All the blood in the body moves in and out of the kidneys hundreds of times each day, filtering about 189.2 liters of liquid in total!
There are three main steps of urine formation: glomerular filtration, reabsorption, and secretion. These processes ensure that only waste and excess water are removed from the body.

**Glomerular Filtration:**

Each kidney contains over 1 million nephrons. Each nephron has a glomerulus—a network of capillaries surrounded by a cuplike structure called the glomerular capsule (also referred to as Bowman’s capsule). Inside the glomerulus, blood pressure pushes fluid from capillaries into the glomerular capsule through a specialized layer of cells. This layer allows water and small solutes to pass but blocks blood cells and large proteins from leaving the bloodstream. The filtrate (the fluid that has passed through the membrane and is in the glomerular capsule) flows from the capsule further into the nephron.
Reabsorption:

When the filtrate exits the glomerular capsule, it flows into a duct called the renal tubule. As the filtrate moves through the renal tubule, vital nutrients (essential ions, glucose, amino acids, and smaller proteins) and some water are reabsorbed through the tube wall into the adjacent capillaries.

Secretion:

At the same time, waste ions and hydrogen ions pass from the capillaries into the renal tubule. This process is called secretion. The secreted ions combine with the remaining filtrate to become urine. The urine flows out of the nephron tubule into a collecting duct, then moves through the renal pelvis and out of the kidney.
The ureters are long, thin tubes made of smooth muscle. Contractions of the smooth muscle push urine from the kidneys down to the bladder. In adults, the ureters are 25–30 cm long (about the length of a 12-inch ruler).

**Urine Composition:**

Urine is about 95% water and 5% waste products (0.2% creatinine, ammonia, and uric acid; 2.8% dissolved salts and other ions; 0.2% urea).
The bladder is shaped like a pyramid when it is empty. The detrusor muscle and the folds inside the bladder, called rugae, give the bladder elasticity and allow it to expand from this pyramid shape into an oval shape as it fills with urine. Urine enters the bladder from the ureters through the ureter orifices. The overall size of the bladder varies depending on how much urine it contains at the time.
The bladder has two different sphincters that can control the flow of urine out of the body. The **internal sphincter** surrounds the opening of the bladder to the urethra and relaxes to allow urine to pass. Control of the internal urethral sphincter is involuntary, which means that we don’t consciously decide when it opens and closes. The **external sphincter** surrounds the urethra outside the bladder and must relax for urination to occur. Control of the external urethral sphincter is voluntary, which means we can consciously allow it to relax or force it not to do so.

When your bladder is about 200 ml full of urine, stretch receptors in the bladder wall activate. The detrusor muscle contracts and the internal sphincter starts to relax, which sends a signal to the nervous system creating the urge to “go.” This is called the micturition reflex. At 500 ml, the muscle contractions begin to force open the internal sphincter and if the external sphincter is not powerful enough to prevent it, involuntary urination will occur. We gain control of urination between the ages of 2 and 3 as our brain develops.
When the process of urination begins, urine exits the bladder and enters the urethra, where urine will be excreted from the body. The urethra is different depending on the sex of the body:

**FEMALE**

The urethra is narrow and about 4 cm long. It extends from the bladder neck to the external urethral orifice in the vestibule of the vagina.

**MALE**

The urethra is about 17.5–20 cm, four or five times as long as in females. The male urethra is divided into three sections: the prostatic urethra (the widest portion), the membranous urethra (the narrowest portion), and the spongy urethra (the longest portion). It extends from the bladder neck through the prostate and the penis to the external urethral orifice.
Chronic renal failure is the gradual breakdown of renal function—for example, the vessels leading to the kidney don’t provide adequate blood supply or the nephrons are not functioning properly. As chronic kidney failure worsens, damaged glomeruli and tubules fail to properly remove sodium and other ions, leading to toxin buildup in the blood. In addition, the kidneys’ production of erythropoietin (a hormone from the kidney that helps increase the rate of red blood cell production) decreases.
Kidney stones are undissolved mineral or acid salts in urine that have crystallized. Kidney stones typically originate in the renal calyces or pelvis. Small stones (<5mm) often move into the ureter and pass down the urinary tract with minimal symptoms. Larger stones are more likely to obstruct the renal tubules and damage kidney tissue. The stones also may get stuck in the urinary tract, leading to significant obstructions of urine flow, causing an infection or a buildup of fluid pressure. Kidney stones cause waves of excruciating back and side pain. If they are not broken up or surgically removed, infection or pressure can progress upward into the kidney and cause hydronephrosis (swelling) damage to functional tissue, and potentially, postrenal failure.
Polycystic kidney disease (PKD) is an inherited condition in which fluid-filled cysts damage and replace normal kidney tissue, leading to a breakdown in kidney function. The renal calyces and renal pelvis are flattened and distorted, and the whole kidney becomes bumpy and enlarged. As functional tissue is lost, the cardiovascular and renal systems may compensate by increasing blood pressure to raise the filtration rate of surviving nephrons. When more kidney structures are damaged, this can lead to chronic renal failure. Back and flank pain, abdominal fullness, hematuria (blood in the urine), and hypertension (high blood pressure) are all common initial symptoms of PKD.
Acute tubular necrosis is damage to the epithelial cells that line tubules within the nephrons. This affects the kidneys’ ability to filter blood and excrete wastes and water—the damaged nephrons are unable to filter urea and other wastes out of the blood. Decreased urine output is a frequent sign of significant necrosis and may lead to kidney infection. If acute tubular necrosis is left untreated, fluid and waste will build up inside the body, leading to uremia, edema, fluid and electrolyte imbalances, and other complications of acute renal failure.
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