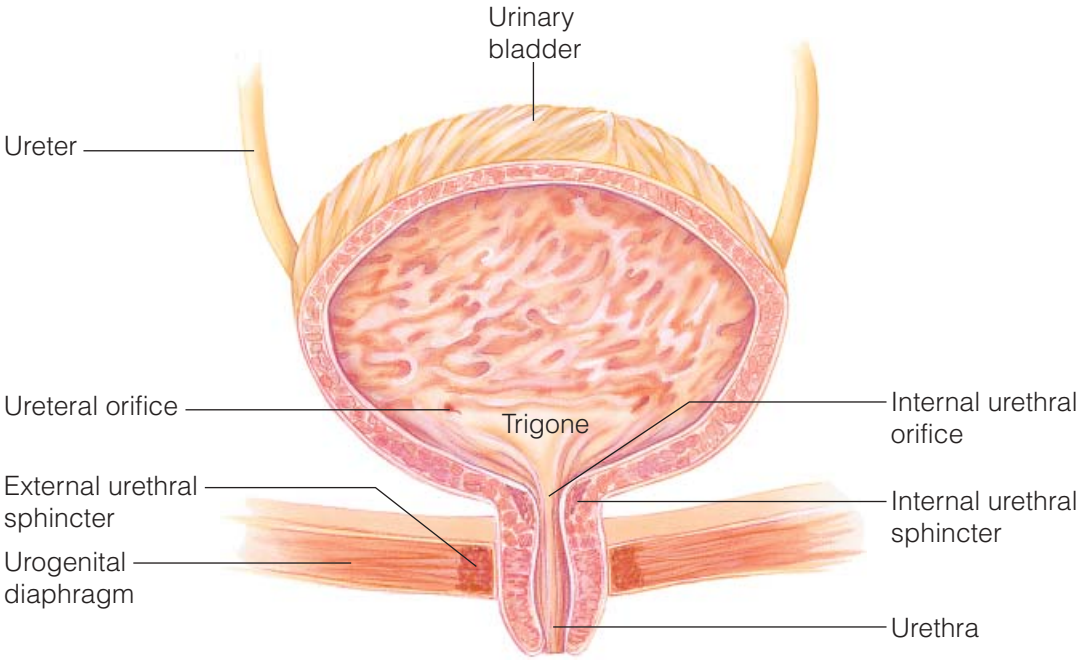

FIGURE 15.6 Basic structure of the urinary bladder and urethra of the female. The urethra of the male, which runs through the length of the penis, is substantially longer than that of the female.

Ureters, Urinary Bladder, and Urethra

Ureters

The **ureters** (u-re′terz) are slender tubes each 25 to 30 cm (10 to 12 inches) long and 6 mm (¼ inch) in diameter. Each ureter runs behind the peritoneum from the renal hilus to the posterior aspect of the bladder, which it enters at a slight angle (see Figures 15.1 and 15.6). The superior end of each ureter is continuous with the pelvis of the kidney, and its mucosal lining is continuous with that lining the renal pelvis and the bladder below.

Essentially, the ureters are passageways that carry urine from the kidneys to the bladder. Although it might appear that urine could simply drain to the bladder below by gravity, the ureters *do* play an active role in urine transport. Smooth muscle layers in their walls contract to propel urine into the bladder by peristalsis. Once urine has entered the bladder, it is prevented from flowing back into the ureters by small valvelike folds of bladder mucosa that flap over the ureter openings.

Homeostatic Imbalance

When urine becomes extremely concentrated, solutes such as uric acid salts form crystals that precipitate in the renal pelvis. These crystals are called **renal calculi** (kal′kyoo-li; *calculus* = little stone), or kidney stones. Excruciating pain that radiates to the flank occurs when the ureter walls close in on the sharp calculi as they are being eased through the ureter by peristalsis or when the calculi become wedged in a ureter. Frequent bacterial infections of the urinary tract, urinary retention, and alkaline urine all favor calculi formation. Surgery has been the treatment of choice, but a newer noninvasive procedure *(lithotripsy)* that uses ultrasound waves to shatter the calculi is becoming more popular. The pulverized, sandlike remnants of the calculi are painlessly eliminated in the urine.

Urinary Bladder

The **urinary bladder** is a smooth, collapsible, muscular sac that stores urine temporarily. It is located retroperitoneally in the pelvis just posterior to the pubic symphysis. If the interior of the blad-

der is scanned, three openings are seen—the two ureter openings *(ureteral orifices)* and the single opening of the **urethra** (u-re′thrah) (the *internal urethral orifice*), which drains the bladder (Figure 15.6). The smooth triangular region of the bladder base outlined by these three openings is called the **trigone** (tri′gon). The trigone is important clinically because infections tend to persist in this region. In males, the *prostate gland* (part of the male reproductive system) surrounds the neck of the bladder where it empties into the urethra.

The bladder wall contains three layers of smooth muscle, collectively called the *detrusor muscle,* and its mucosa is a special type of epithelium, *transitional epithelium* (see p. 90). Both of these structural features make the bladder uniquely suited for its function of urine storage. When the bladder is empty, it is collapsed, 5 to 7.5 cm (2 to 3 inches) long at most, and its walls are thick and thrown into folds. As urine accumulates, the bladder expands and rises superiorly in the abdominal cavity (Figure 15.7). Its muscular wall stretches, and the transitional epithelial layer thins, allowing the bladder to store more urine without substantially increasing its internal pressure. A moderately full bladder is about 12.5 cm (5 inches) long and holds about 500 ml (1 pint) of urine, but it is capable of holding more than twice that amount. When the bladder is really distended, or stretched by urine, it becomes firm and pear-shaped and may be felt just above the pubic symphysis. Although urine is formed continuously by the kidneys, it is usually stored in the bladder until its release is convenient.

Urethra

The **urethra** is a thin-walled tube that carries urine by peristalsis from the bladder to the outside of the body. At the bladder-urethra junction, a thickening of the smooth muscle forms the **internal urethral sphincter** (see Figure 15.6), an involuntary sphincter that keeps the urethra closed when urine is not being passed. A second sphincter, the **external urethral sphincter,** is fashioned by skeletal muscle as the urethra passes through the pelvic floor. This sphincter is voluntarily controlled.

The length and relative function of the urethra differ in the two sexes. In females, it is about 3 to 4 cm (1½ inches) long, and its external orifice, or opening, lies anteriorly to the vaginal opening (see also Figure 16.8a, p. 537). Its function is to conduct urine to the body exterior.

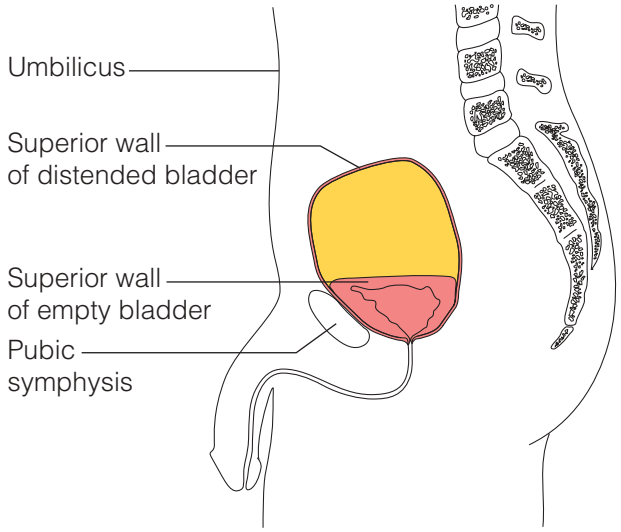

FIGURE 15.7 Position and shape of a distended and an empty urinary bladder in an adult male.

Homeostatic Imbalance

Since the female urinary orifice is so close to the anal opening, and feces contain a good deal of bacteria, improper toileting habits (that is, wiping from back to front rather than from front to back) can easily carry bacteria into the urethra. Moreover, since the mucosa of the urethra is continuous with that of the rest of the urinary tract organs, an inflammation of the urethra, or *urethritis* (u″re-thri′tis), can easily ascend the tract to cause bladder inflammation *(cystitis)* or even kidney inflammation (*pyelonephritis,* or *pyelitis*). Symptoms of urinary tract infection include *dysuria* (painful urination), urinary *urgency* and *frequency,* fever, and sometimes cloudy or blood-tinged urine. When the kidneys are involved, back pain and a severe headache are common.

In males, the urethra is approximately 20 cm (8 inches) long and has three named regions (see Figure 16.2, p. 530), the *prostatic, membranous,* and *spongy* (or *penile*) *urethrae.* It opens at the tip of the penis after traveling down its length. The urethra of the male has a double function. It carries urine out of the body, and it provides the passageway through which sperm is ejected from the body. Thus, in males, the urethra is part of both the urinary and reproductive systems.

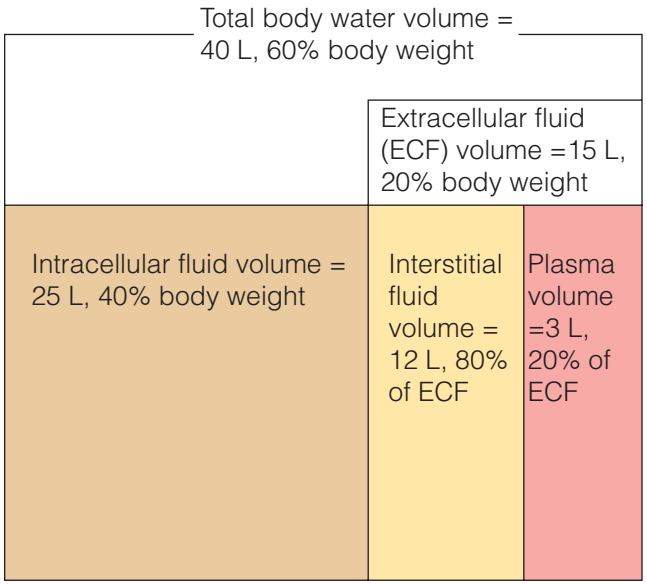

FIGURE 15.8 The major fluid compartments of the body. Approximate values are noted for a 70-kg (154-pound) male.

Micturition

Micturition (mik″tu-rish′un), or **voiding,** is the act of emptying the bladder. Two sphincters, or valves, the internal urethral sphincter (more superiorly located) and the external urethral sphincter (more inferiorly located) control the flow of urine from the bladder (see Figure 15.6). Ordinarily, the bladder continues to collect urine until about 200 ml have accumulated. At about this point, stretching of the bladder wall activates stretch receptors. Impulses transmitted to the sacral region of the spinal cord and then back to the bladder via the *pelvic splanchnic nerves* cause the bladder to go into reflex contractions. As the contractions become stronger, stored urine is forced past the internal urethral sphincter (the smooth muscle, involuntary sphincter) into the upper part of the urethra. It is then that a person feels the urge to void. Because the lower external sphincter is skeletal muscle and is voluntarily controlled, we can choose to keep it closed and postpone bladder emptying temporarily. On the other hand, if it is convenient, the external sphincter can be relaxed so that urine is flushed from the body. When one chooses not to void, the reflex contractions of the bladder will stop within a minute or so, and urine will continue to accumulate in the bladder. After 200 to 300 ml more have been collected, the micturition reflex occurs again. Eventually, micturition occurs whether one wills it or not.

Homeostatic Imbalance

Incontinence (in-kon′tĭ-nens) occurs when we are unable to voluntarily control the external sphincter. Incontinence is normal in children 2 years old or younger, because they have not yet gained control over their voluntary sphincter. It may also occur in older children who sleep so soundly that they are not awakened by the stimulus. However, after the toddler years, incontinence is usually a result of emotional problems, pressure (as in pregnancy), or nervous system problems (stroke or spinal cord injury).

Urinary retention is essentially the opposite of incontinence. It is a condition in which the bladder is unable to expel its contained urine. There are various causes for urinary retention. It often occurs after surgery in which general anesthesia has been given because it takes a little time for the smooth muscles to regain their activity. Another cause of urinary retention, occurring primarily in elderly men, is enlargement, or *hyperplasia,* of the prostate gland, which surrounds the neck of the bladder. As it enlarges, it narrows the urethra, making it very difficult to void. When urinary retention is prolonged, a slender flexible drainage tube called a *catheter* (kath′ĭ-ter) must be inserted through the urethra to drain the urine and prevent bladder trauma from excessive stretching.

Fluid, Electrolyte, and Acid-Base Balance

Blood composition depends on three major factors: diet, cellular metabolism, and urine output. In general, the kidneys have four major roles to play, which help keep the blood composition relatively constant. These are (1) excretion of nitrogen-containing wastes, maintaining (2) water and (3) electrolyte balance of the blood, and (4) ensuring proper blood pH. Excretion of nitrogenous wastes has already been considered; roles 2 through 4 are discussed briefly next.

Maintaining Water and Electrolyte Balance of Blood

Body Fluids and Fluid Compartments

If you are a healthy young adult, water probably accounts for half or more of your body weight—