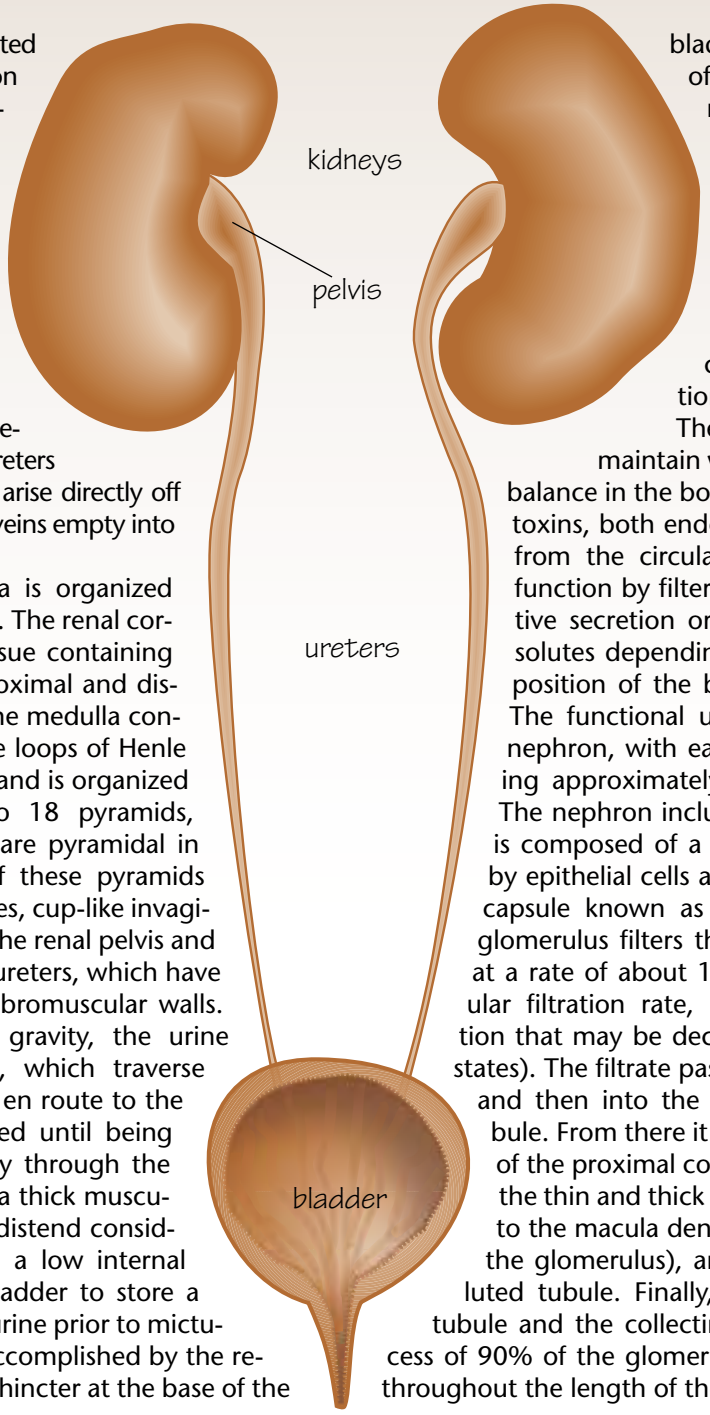
Basic Urinary Tract Anatomy and Histology

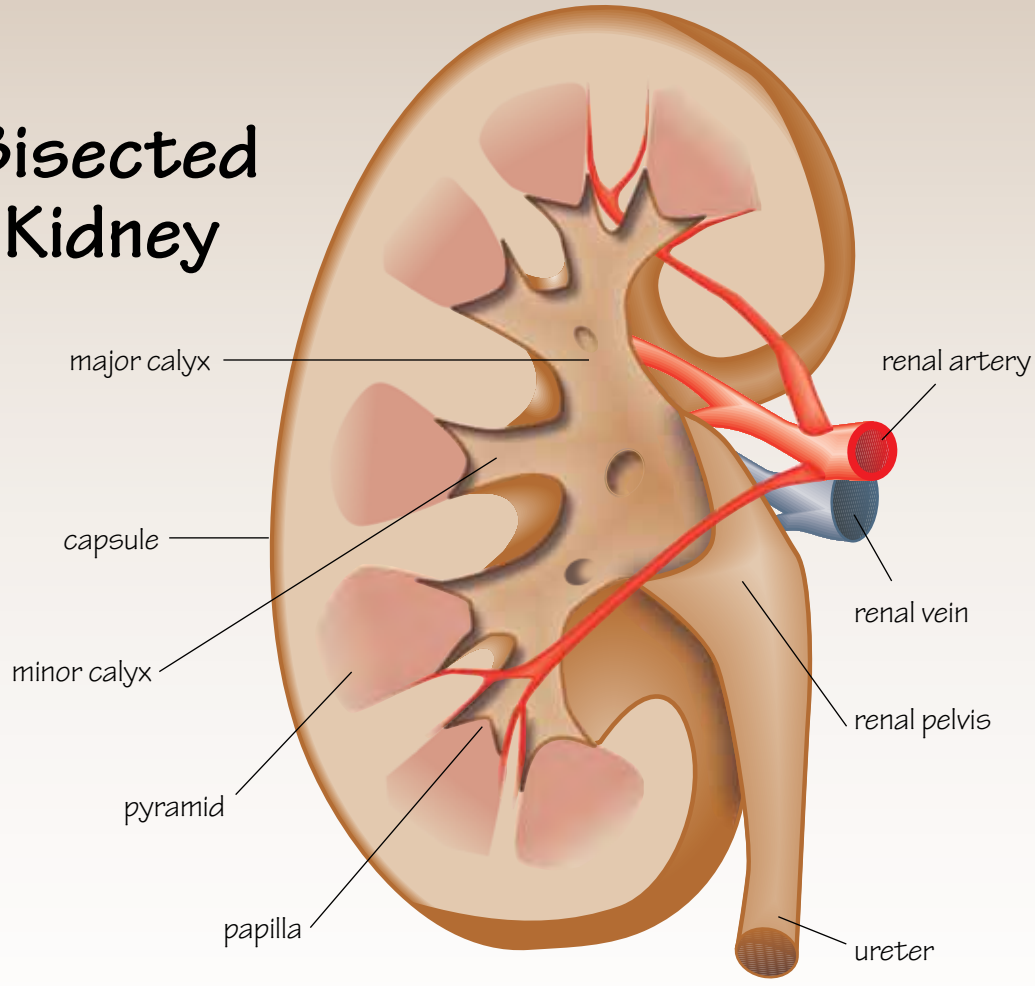


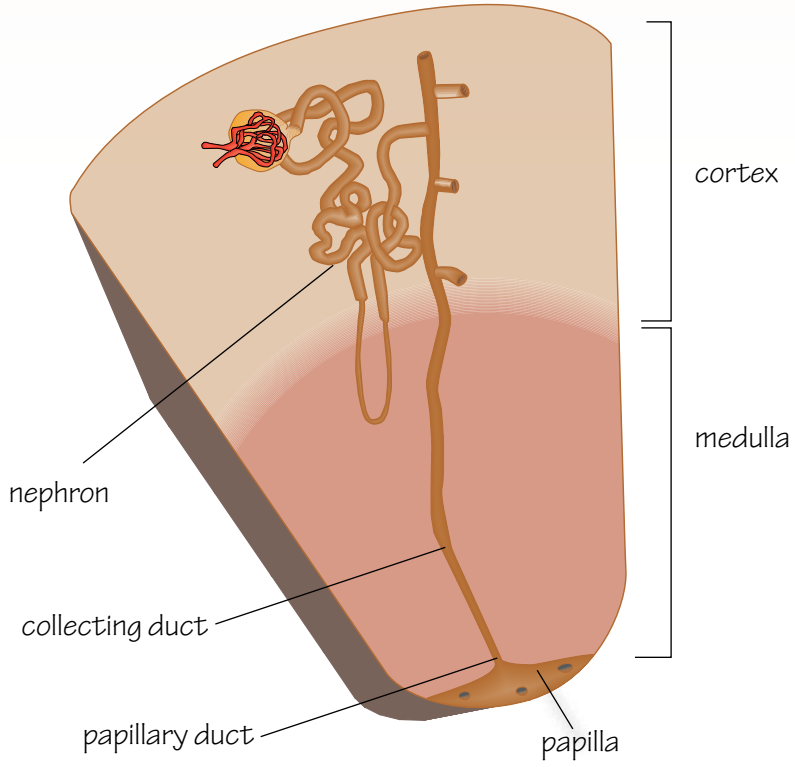
The two kidneys are located in the retroperitoneum on either side of the vertebral column. They have a dense fibrous capsule and are surrounded by adipose tissue (Gerota's fascia), which cushions the kidneys from damage. They are bean-shaped organs, approximately 11 cm in length, each with a hilum from which the renal arteries, veins, and ureters emerge. The renal arteries arise directly off of the aorta, and the renal veins empty into the inferior vena cava.

The renal parenchyma is organized into a cortex and medulla. The renal cortex is a thick band of tissue containing the glomeruli and the proximal and distal convoluted tubules. The medulla contains the thin limbs of the loops of Henle and the collecting ducts, and is organized into approximately 8 to 18 pyramids, so named because they are pyramidal in shape [1]. The apices of these pyramids point into the renal calyces, cup-like invaginations that converge in the renal pelvis and funnel the urine into the ureters, which have small lumina and thick fibromuscular walls. Through peristalsis and gravity, the urine flows down the ureters, which traverse the retroperitoneal space en route to the bladder, where it is stored until being eliminated from the body through the urethra. The bladder has a thick muscular wall, which is able to distend considerably while maintaining a low internal pressure, allowing the bladder to store a considerable quantity of urine prior to micturition [1]. Micturition is accomplished by the relaxation of the urethral sphincter at the base of the bladder and the contraction of the detrusor muscle. Any mechanical barrier, such as an enlarged prostate gland, or a variety of neuromuscular and inflammatory disorders, can interfere with this normal function and cause symptoms, including dysuria, hesitation, frequency, etc.

The kidneys function to maintain water, pH, and electrolyte balance in the body, as well as to eliminate toxins, both endogenous and exogenous, from the circulation. They perform this function by filtering the blood with selective secretion or reabsorption of specific solutes depending on the chemical composition of the blood at any given time. The functional unit of the kidney is the nephron, with each adult kidney containing approximately 0.4 to 1.2 million [2]. The nephron includes a glomerulus, which is composed of a capillary tuft surrounded by epithelial cells and a thin fibrous globoid capsule known as Bowman's capsule. The glomerulus filters the blood indiscriminately at a rate of about 125 mL/min (the glomerular filtration rate, an index of renal function that may be decreased in various disease states). The filtrate passes into Bowman's space and then into the proximal convoluted tubule. From there it passes into the pars recta of the proximal convoluted tubule, through the thin and thick limb of the loop of Henle, to the macula densa (which lies adjacent to the glomerulus), and into the distal convoluted tubule. Finally, it enters the collecting tubule and the collecting duct of Bellini. In excess of 90% of the glomerular filtrate is reabsorbed throughout the length of the nephron [1]. The modi-

Bisected Kidney

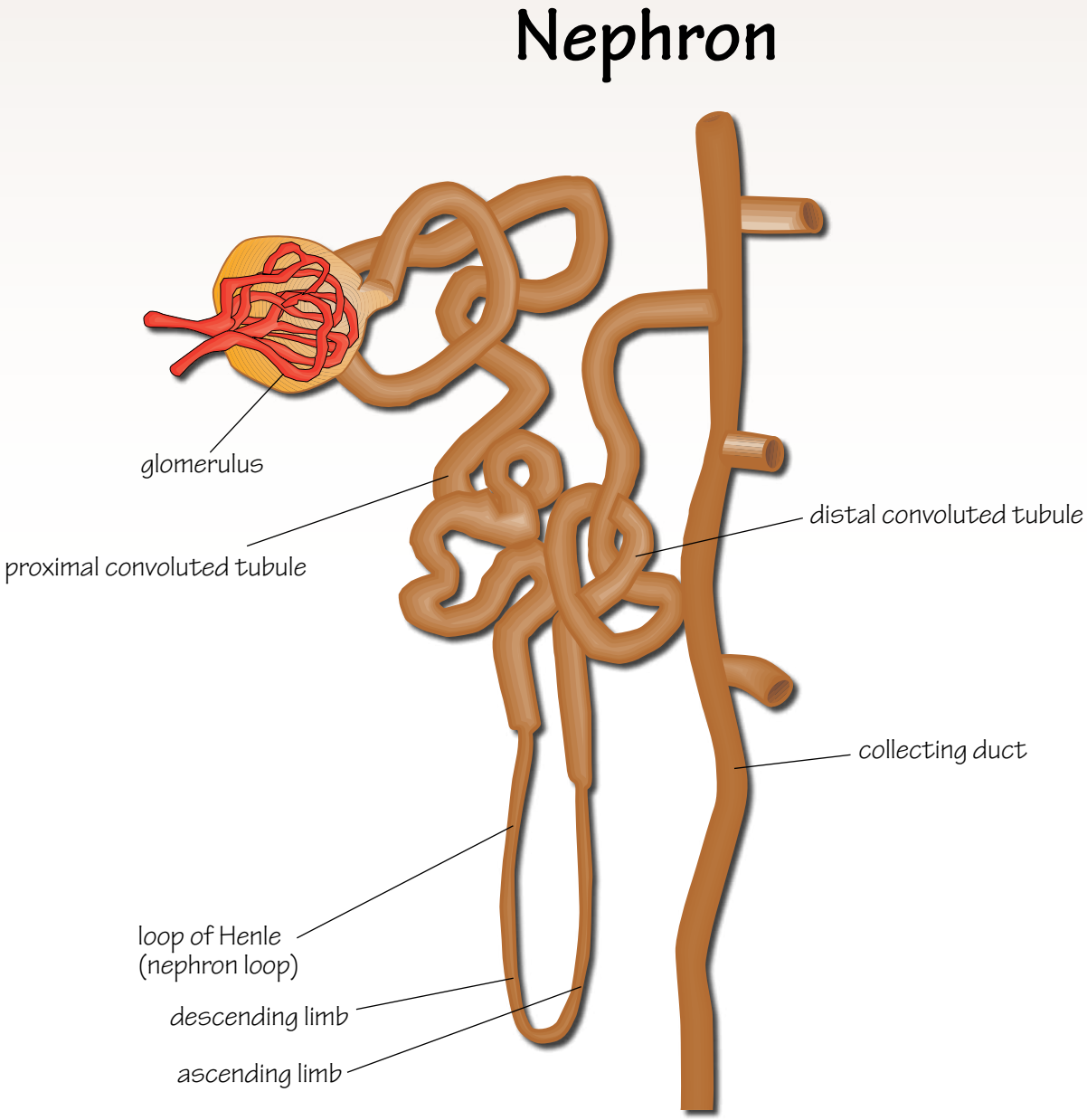




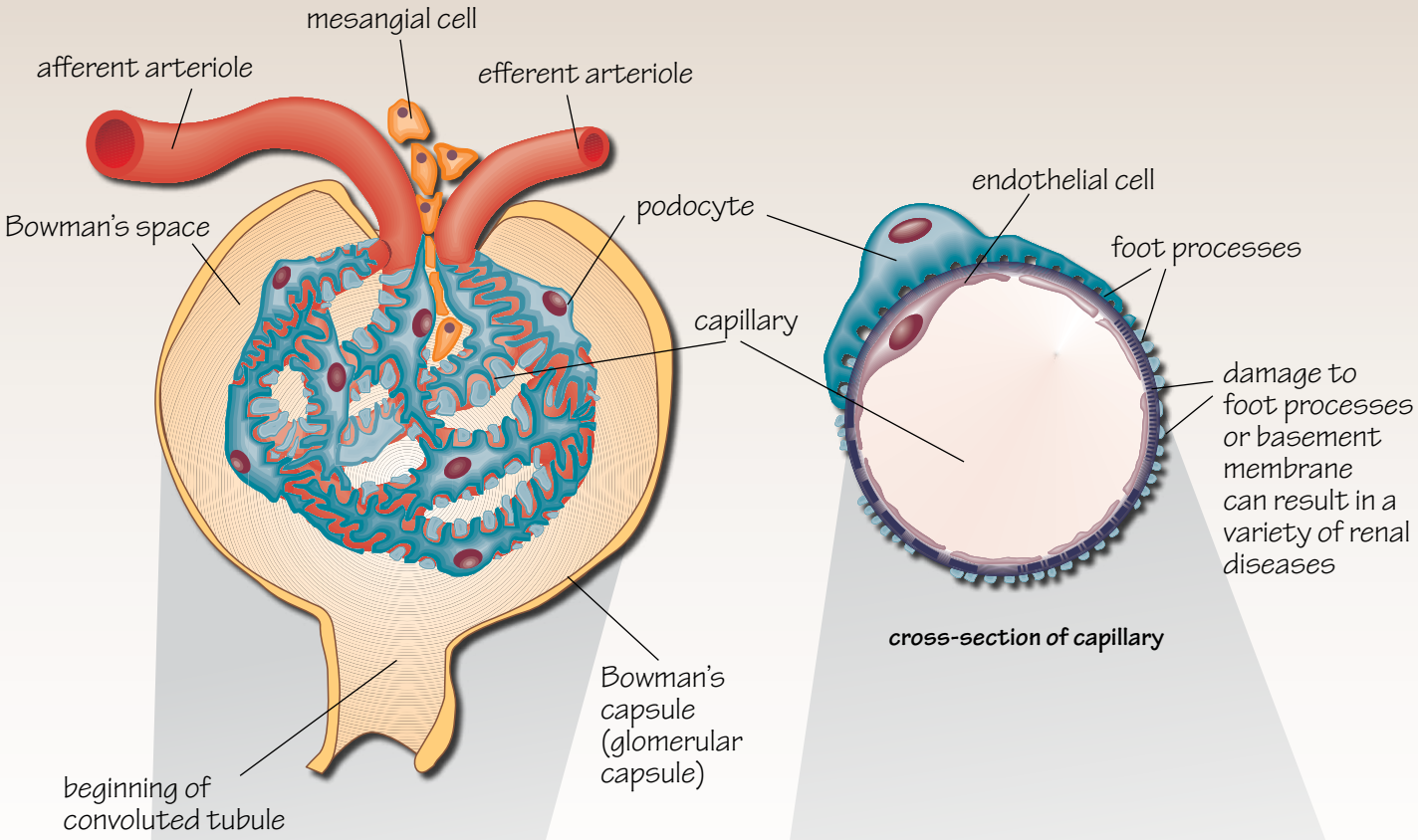
fied filtrate, now known as urine, drips from the collecting ducts as they empty their contents at the tips of the pyramids into the calyces, and from there to the renal pelvis, ureter, bladder, urethra, and finally excretion.

The glomerular capillary is in close contact with specialized epithelial cells called podocytes. The blood is separated from Bowman's space by three structures: a single layer of endothelial cells, a thin glomerular basement membrane (GBM), and a podocyte on the other side of the GBM. The podocytes form foot processes that fuse into the lamina rare externa of the GBM. Between the foot processes are thin filtration slit diaphragms, which keep large proteins from passing. Damage to the glomerulus can result in fusion of the podocyte foot processes and loss of the filtration slit diaphragm, with resultant proteinuria. Mesangial cells within the glomerulus are modified myofibroblasts that support the tuft, help regulate blood flow, and have phagocytic properties [3].

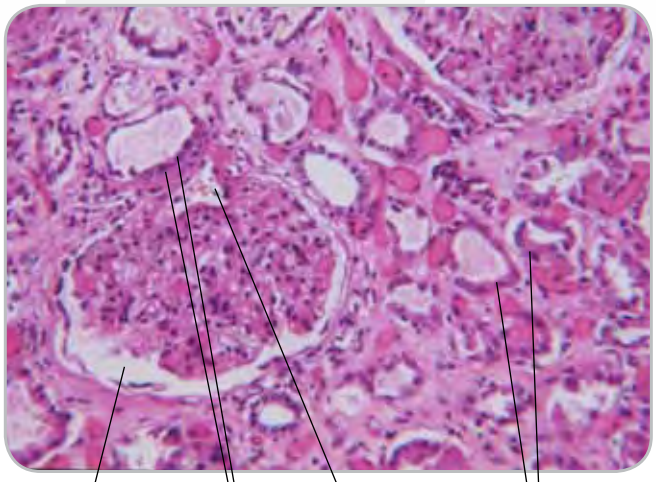
The renal tubules, from the proximal convoluted tubule to the distal convoluted tubule and including



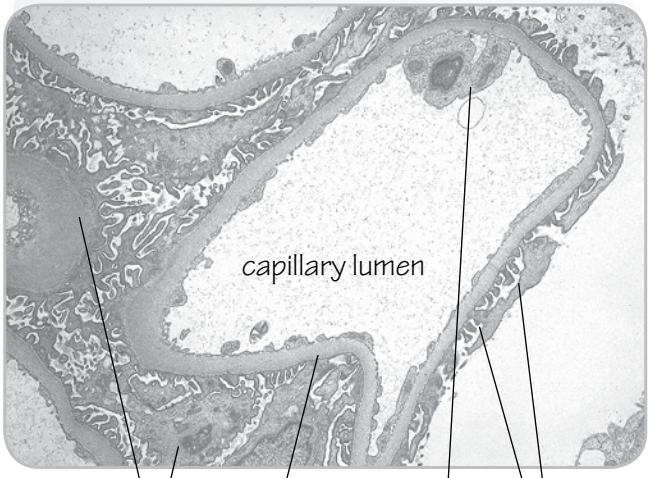
Glomerulus



H&E photomicrograph of a glomerulus



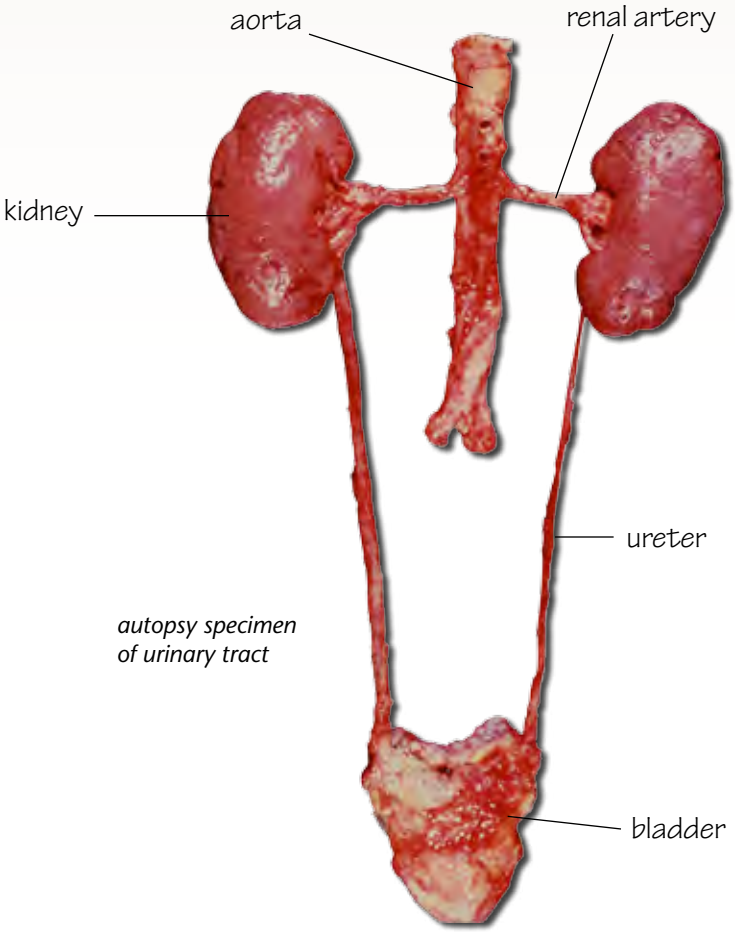
EM photograph of a glomerular capillary



the loop of Henle, are lined by a single layer of cuboidal epithelial cells, known as renal tubular epithelial cells (RTEs). These allow solutes and fluids to pass back and forth into the blood stream as part of the process of homeostasis. When the tubules are damaged, renal tubular epithelial cells can be seen in the urine and therefore are important to recognize (*see* "Renal Tubular Epithelial Cell," page 130). The cells lining the collecting ducts are cuboidal to columnar in shape but are less prone to damage. Some RTEs have a specialized function. The cells of the macula densa aggregate with the juxtaglomerular cells (which are modified smooth muscle cells) and the lacis cells to form the juxtaglomerular apparatus. This structure produces renin, which helps to regulate blood pressure by converting angiotensinogen to angiotensin I [3].

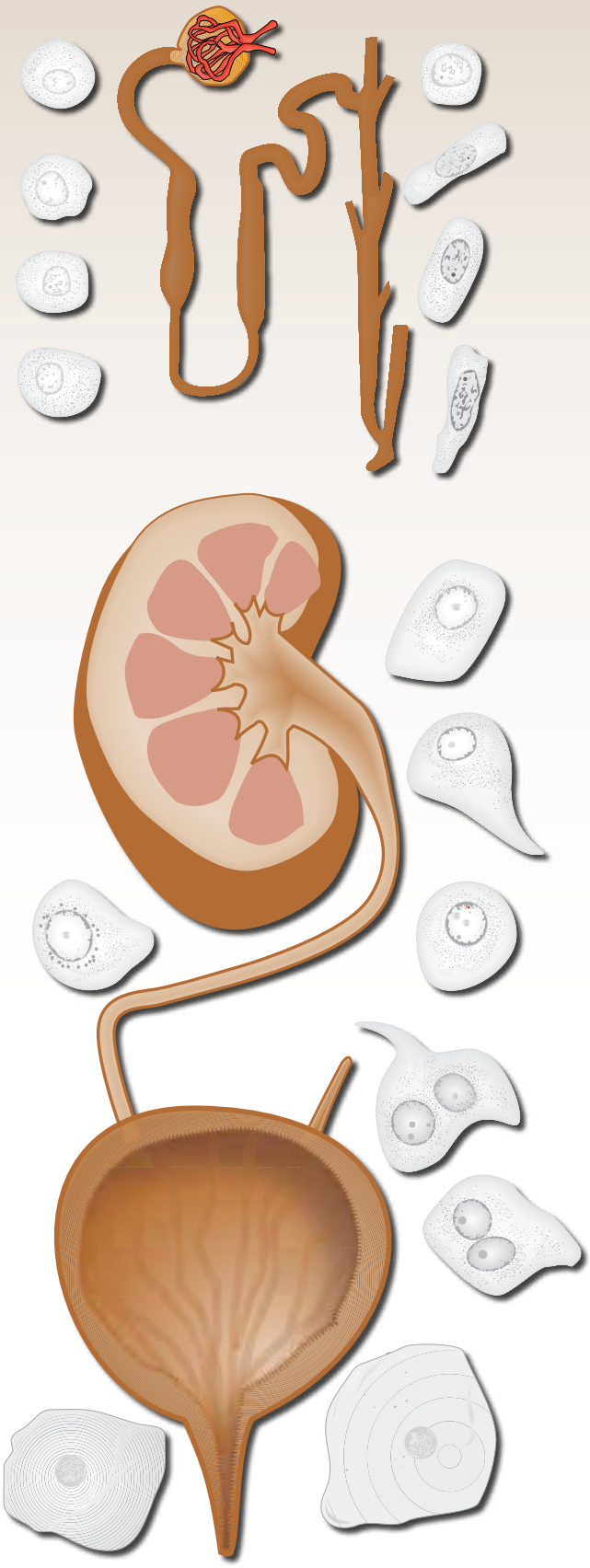
The calyces, pelves, ureters, bladder, and urethra are all lined by urothelium, also known as transitional epithelium. Transitional cells have a spherical or polyhedral shape and a central nucleus. They vary considerably in size, with those on the surface of the bladder mucosa being larger and often multinucleated (umbrella cells). This epithelium is uniquely suited to adapt to the shape of the bladder when distended or contracted. These cells can also be seen in the urinary sediment and are of importance only because they must be distinguished from RTEs, which are a marker of renal tubular damage. RTEs are smaller than transitional cells and often have the nucleus located to one side; occasionally a brush border can be seen (*see* "Transitional Epithelial Cell [Urothelial Cell]," page 116). If the transitional cells show any abnormal cytologic features, the possibility of transitional cell carcinoma should be considered.

Squamous epithelial cells can also be seen in the urinary sediment, since squamous metaplasia of the bladder trigone is common, especially in women. Vaginal contamination can also result in the appearance of squamous epithelial cells in the urine. These cells are typically flat, plate-like cells with small central nuclei and scattered cytoplasmic keratohyaline granules. Occasionally, they can be confused with transitional cells.



autopsy specimen of urinary tract

Cells Lining the Nephron and Urinary Tract



RTE Cells

Renal tubular epithelial cells line the tubular portions of the nephron (i.e., proximal and distal tubules and collecting ducts). They are usually elongated polyhedrons with granular cytoplasm, ranging in size from 15-35 µm. The cells tend to be larger and more elongate in the collecting ducts. Small numbers are not clinically significant, but greater than 15 RTEs per 10 high-power fields suggests intrinsic renal disease.

Transitional Epithelial Cells

Transitional cells (urothelial cells) line the urinary tract from the pelvis of the kidney to the trigone of the bladder, extending in males into the first part of the urethra. The cells measure 20-30 µm and are spherical or polyhedral. Occasional urothelial cells can be multinucleated. In small numbers, they have no clinical significance. Large clusters and sheets are common after instrumentation (e.g., catheterization). Atypical cells may be indicative of malignancy.

Squamous Epithelial Cells

Squamous cells line the female urethra, bladder trigone, and distal portion of the male urethra. They are large, thin, flat cells measuring 30-50 µm. They may be a contaminant from the vagina. Squamous cells have little or no clinical significance.