

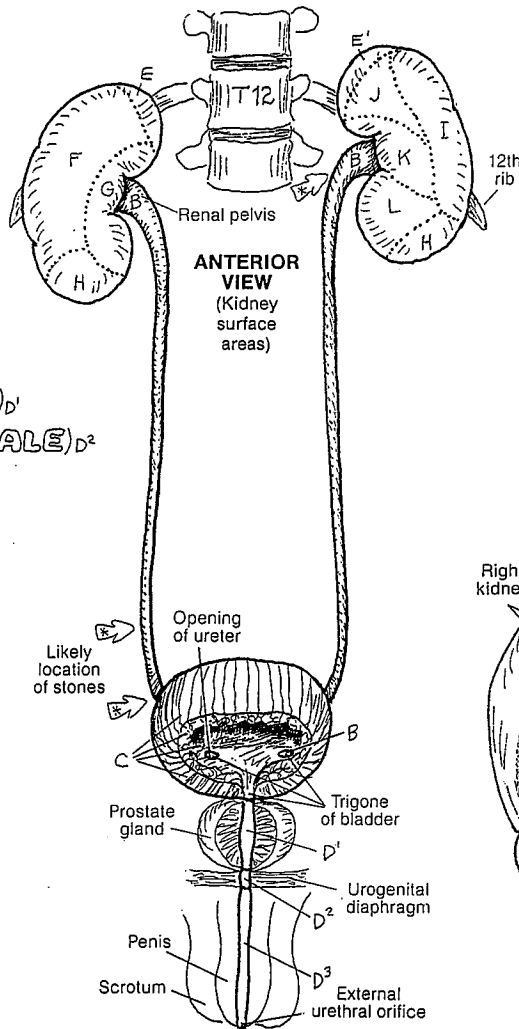
URINARY TRACT

URINARY TRACT

- KIDNEY ^A
- URETER ^B
- URINARY BLADDER ^C
- URETHRA ^D
- PROSTATIC U. (MALE) ^{D¹}
- MEMBRANOUS U. (MALE) ^{D²}
- SPONGY U. (MALE) ^{D³}

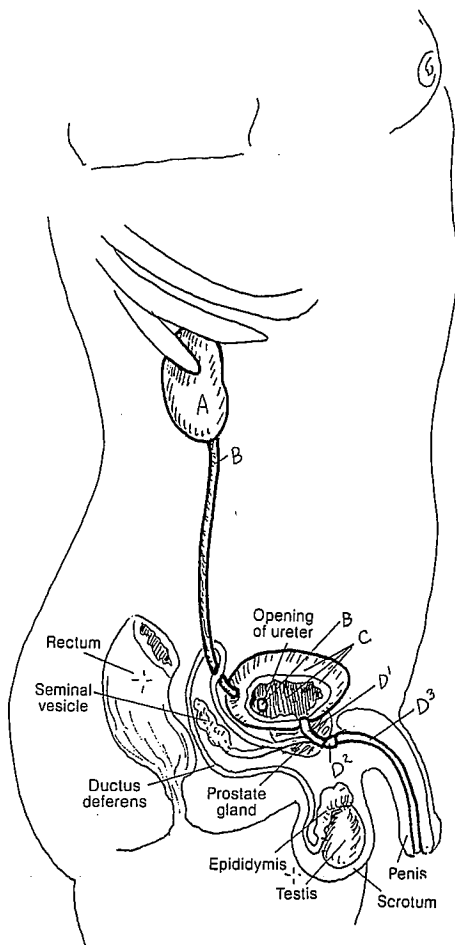
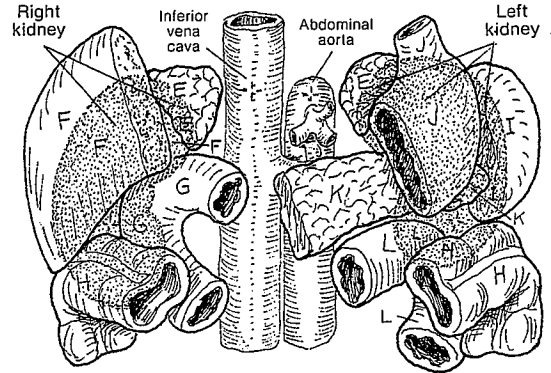
KIDNEY RELATIONS

- SUPRARENAL (ADRENAL) GLAND ^E
- LIVER ^F
- DUODENUM ^G
- TRANSVERSE COLON ^H
- SPLEEN ^I
- STOMACH ^J
- PANCREAS ^K
- JEJUNUM ^L



CN: Use very light colors for C and E-L.
 (1) Color the three views of the urinary tract simultaneously. Note that the kidneys at the top of the plate are to be colored according to areas that are in contact with other organs. Also note that the ureters penetrate the posterior wall of the urinary bladder, and that these openings receive a color. (2) Color the anterior relations of the kidneys. The kidneys are shown as underlying, shaded silhouettes and receive no color of their own. (3) Color gray the arrows marking sites of potential obstruction by "stones."

ANTERIOR RELATIONS OF THE KIDNEYS



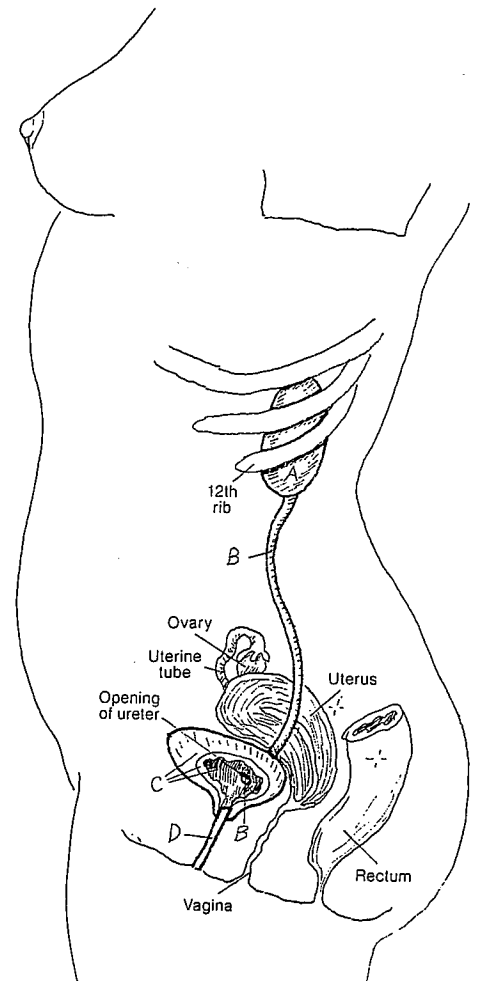
The urinary tract consists of paired *kidneys* and *ureters* in the retroperitoneum, a single *urinary bladder*, and a *urethra*. The urinary tract represents a pathway for the elimination of metabolic by-products and toxic and other nonessential molecules, all dissolved in a small volume of water (urine). The *kidneys* are not simply instruments of excretion; they function in the conservation of water and maintenance of acid-base balance in the blood. The process is a dynamic one, and what is excreted as waste in one second may be retained as precious in the next.

The ureters are fibromuscular tubes, lined by transitional epithelium. Three areas of the ureters are relatively narrow and are prone to being obstructed by mineralized concretions ("stones") from the kidney (see arrows).

The fibromuscular urinary bladder lies in the true pelvis, its superior surface covered with peritoneum. The mucosa is lined with transitional epithelium. The bladder can contain as little as 50 ml of urine and can hold as much as 700-1000 ml without injury; as it distends, it rises into the abdominal cavity and bulges posteriorly. The mucosal area between the two ureteral orifices and the urethral orifice is called the trigone.

The fibromuscular, glandular urethra, lined with transitional epithelium except near the skin, is larger in males (20 cm) than females (4 cm). Hence, urethritis is more common in men, cystitis is more common in women.

The urethra is described in three parts in the male (*prostatic*, *membranous*, and *spongy*). The membranous urethra is vulnerable to rupture in the urogenital diaphragm with trauma to the low anterior pelvis.



KIDNEYS & RELATED RETROPERITONEAL STRUCTURES

CN: Use red for B, blue for L, and a very light color for X (use a color, not gray). (1) Color the various structures in the abdominal cavity. Part of the peritoneum (X), whose title is among the upper diagrams, is shown covering much of the right side. (2) At the upper right, note the relationship of the retroperitoneum to the parietal peritoneum.

KIDNEY

URETER ^{A'}

URINARY BLADDER ^{A''}

AORTA & BRANCHES ⁺

GELIAC A. & BRANCHES ^c

SUPRARENAL A. ^d

SUP. MESENTERIC A. ^e

RENAL A. ^f

TESTICULAR A. ^g

INF. MESENTERIC A. ^h

COMMON ILIAC A. ⁱ

INTERNAL ILIAC A. ^j

EXTERNAL ILIAC A. ^k

INFERIOR VENA CAVA & TRIBUTARIES ⁺

INTERNAL ILIAC V. ^m

EXTERNAL ILIAC V. ⁿ

COMMON ILIAC V. ^o

TESTICULAR V. ^p

RENAL V. ^q

SUPRARENAL V. ^r

HEPATIC V. ^s

ORGANS & DUCTS ⁺

ESOPHAGUS ^t

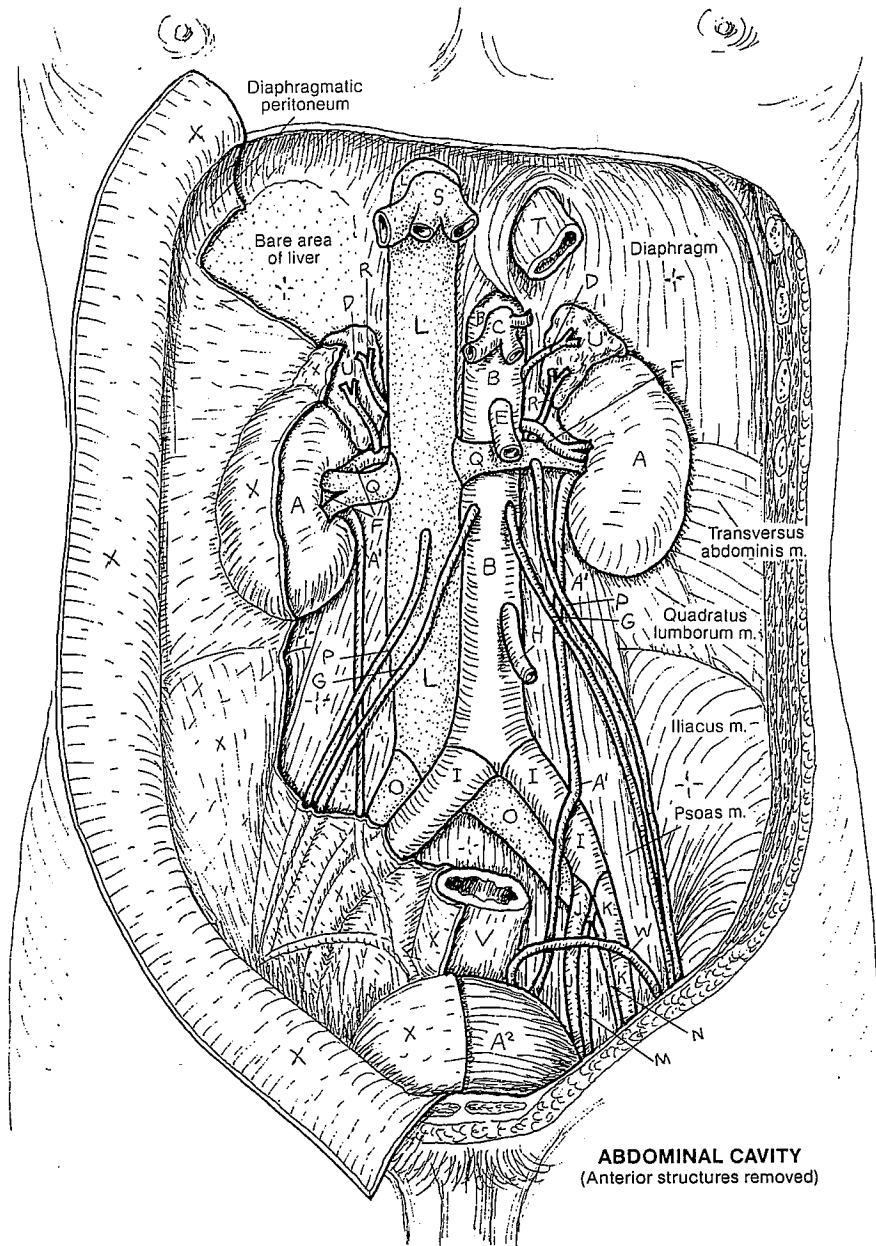
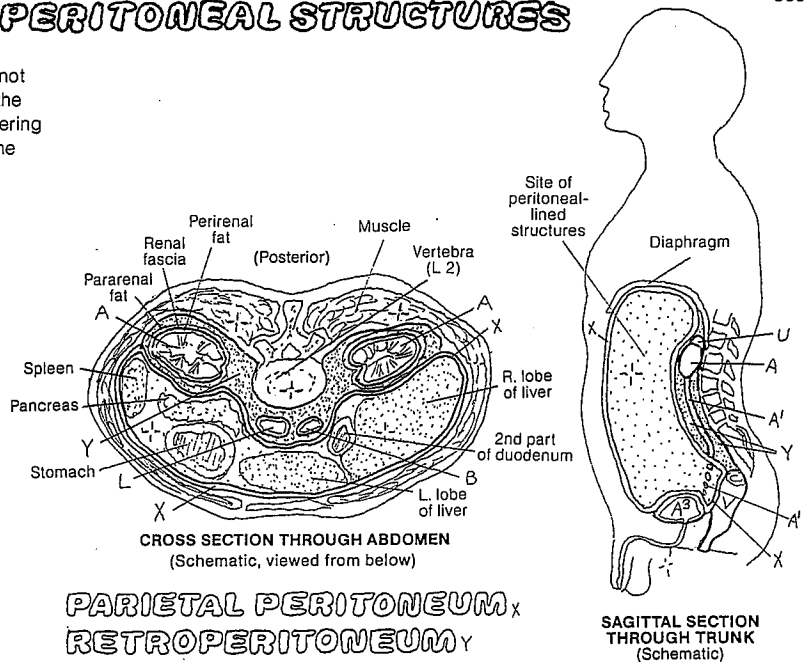
SUPRARENAL GLAND ^u

RECTUM ^v

DUCTUS (VAS) DEFERENS ^w

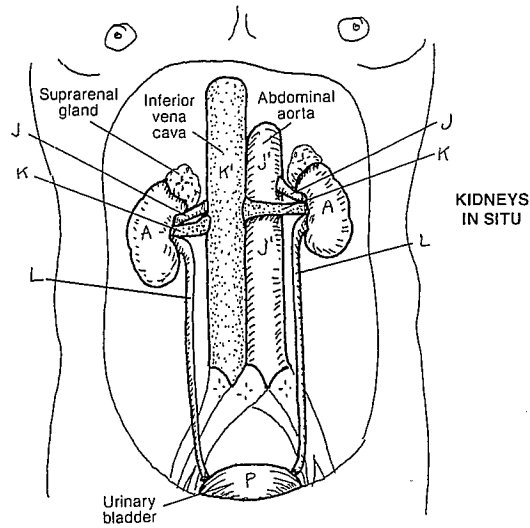
The paired kidneys and ureters lie posterior to the *parietal peritoneum* of the abdominal cavity; they are, therefore, in the *retroperitoneum*. During fetal development, some abdominal structures arise in the retroperitoneum (e.g., kidneys), and some become retroperitoneal as a result of movement of visceral organs (e.g., ascending/descending colon, pancreas). The abdominal *aorta* and its immediate branches and the *inferior vena cava* and its immediate tributaries all are retroperitoneal. Arteries and veins travel between layers of peritoneum to reach the organs they supply/drain. Lymph nodes, lumbar trunks, and the cysternal chyli (not shown) all are retroperitoneal. The ureters descend in the retroperitoneum and under the parietal peritoneum to reach the posterior and inferior aspect of the bladder. Pelvic viscera and vessels lie deep to the parietal peritoneum.

The kidneys are encapsulated in perirenal fat, secured by an outer, stronger layer (renal fascia). Each kidney and its fascia are packed in pararenal fat. These compartments do not communicate between left and right. Such a support system permits kidney movement during respiration but secures them against impact forces.



KIDNEY & URETER

CN: Use red for J, blue for K, yellow for P, and very light colors for B, F, G, H, and I. (1) Begin with the large illustration and note that the thickness of the renal capsule (A) has been greatly exaggerated for coloring purposes. Color the cut edges of blood vessels in the cortex (B). Also color the titles and arrows reflecting blood and urine flow. (2) Color the large arrow (E) pointing to the concavity of the bean-shaped kidney, the renal hilum.



KIDNEY:

- RENAL CAPSULE_A
- RENAL CORTEX_B
- RENAL MEDULLA (PYRAMID)_C
- RENAL PAPILLA_D
- RENAL HILUM_E
- MINOR CALYX_F
- MAJOR CALYX_G
- RENAL PELVIS_H
- RENAL SINUS_I

RENAL ARTERY:

OXYGEN-RICH BLOOD_J

RENAL VEIN_K

OXYGEN-POOR BLOOD_{K'}

URETER_L

MUCOSA: TRANSITIONAL EPITHELIUM

MUCOSA: LAMINA PROPIA_N

MUSCULARIS: CIRC._O/LONG._P

ADVENTITIA_{L'}

URINE_P

1300 mL/min_J
(Into both kidneys)

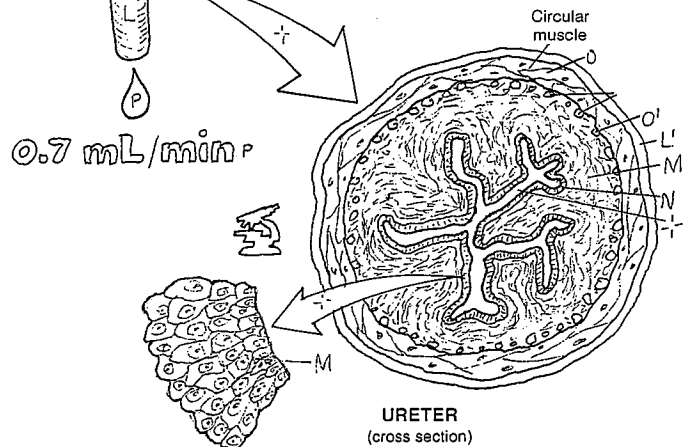
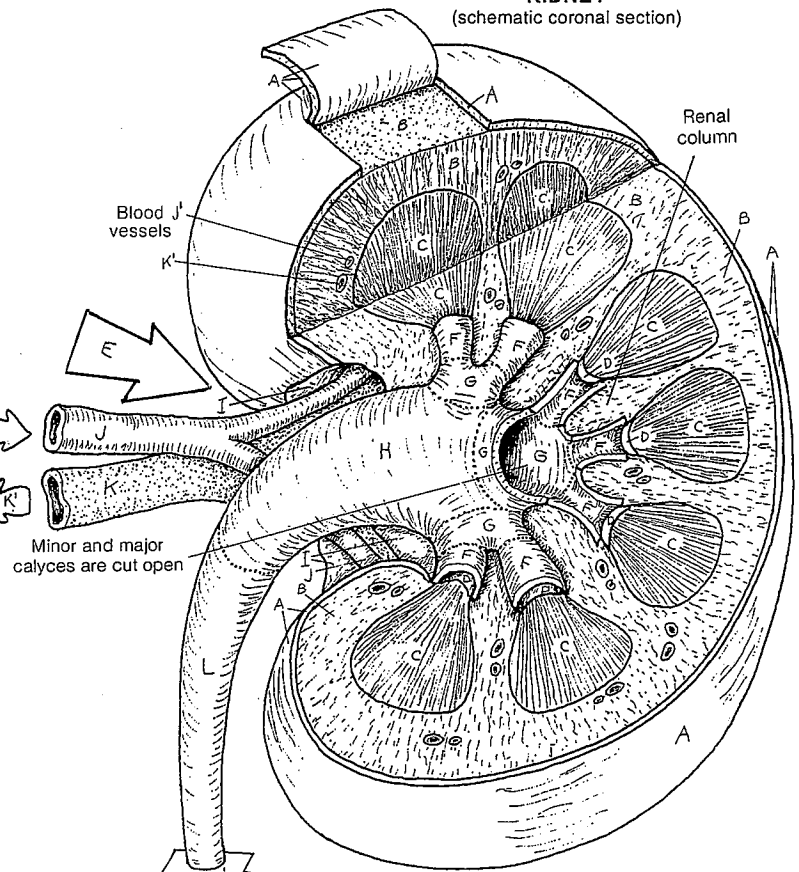
1299 mL/min_{K'}
(Out of both kidneys)

The kidney consists of filtering capsules, tubules, and blood vessels tightly pressed together into what is called the parenchyma. The parenchyma of the kidney consists of an outer *cortex* covered on its surface by a thin fibrous *capsule*, and an inner *medulla* consisting of pyramids of straight tubules. The cortex reaches down between the pyramids (renal columns). The cortex consists of convoluted tubules and filtering capsules. The apex of each medullary pyramid forms a *papilla* that fits into the small cup-shaped funnel called the *minor calyx*. These funnels, numbering 8-18, open into three much larger *major calyces*, all of which open into the cavity called the *renal pelvis*. In the concavity of the kidney (the hilum), in an area called the *renal sinus*, the renal pelvis narrows to form the proximal *ureter*, sharing the area with the renal artery and vein.

Renal blood flow (the amount of blood flowing through the kidneys) is about 1300 mL per minute (both kidneys). About 125-130 mL of plasma is filtered into the renal tubular systems each minute. Less than 1% of that filtered plasma (about 0.7 mL) is actually excreted as *urine*. Clearly, the kidney is in the water conservation business!

The structure of the ureter is a continuation of the renal pelvis. The epithelial layer is *transitional*, a variably stratified layer dependent upon the volume of urine in the ureter. The fibrous *lamina propria* supports the epithelia and blood vessels as well as nerves. The *muscular coat* consists of both longitudinal (inner) and circular layers. The outer layer of the urethra (*adventitia*) is fibrous.

KIDNEY (schematic coronal section)

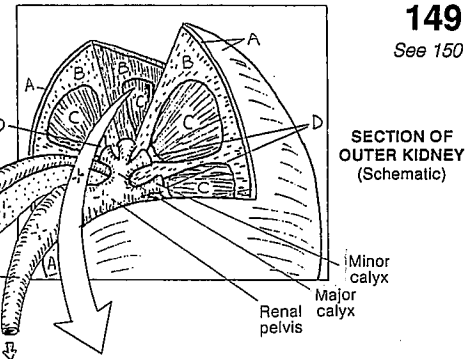


RENAL TUBULE

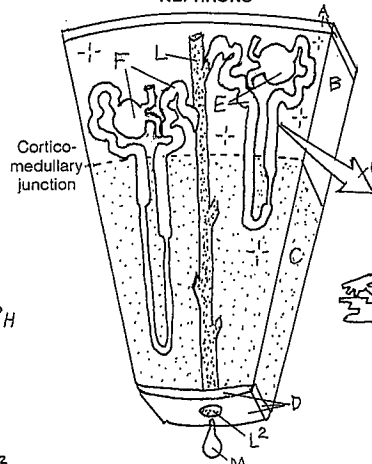
CN: Use red for G, yellow for M, and a very light color for H. Some colors will be used for the same structures on Plate 150. (1) Begin with kidney regions. (2) Color the two types of nephrons. (3) Color the detailed view of the cortical nephron. (4) At the bottom of the page, the capillary-like vessels of the glomerulus (G¹) are largely covered by podocytes (visceral layer, H²); but not entirely. Color both; see smaller drawing where podocytes have been removed to reveal a porous capillary. The capsular space (H³) is left uncolored.

KIDNEY REGION

CAPSULE
CORTEX
MEDULLA
PAPILLA



CORTICAL & JUXTAMEDULLARY NEPHRONS



RENAL TUBULE

NEPHRON

CORTICAL NEPHRON
JUXTAMEDULLARY NEPHRON

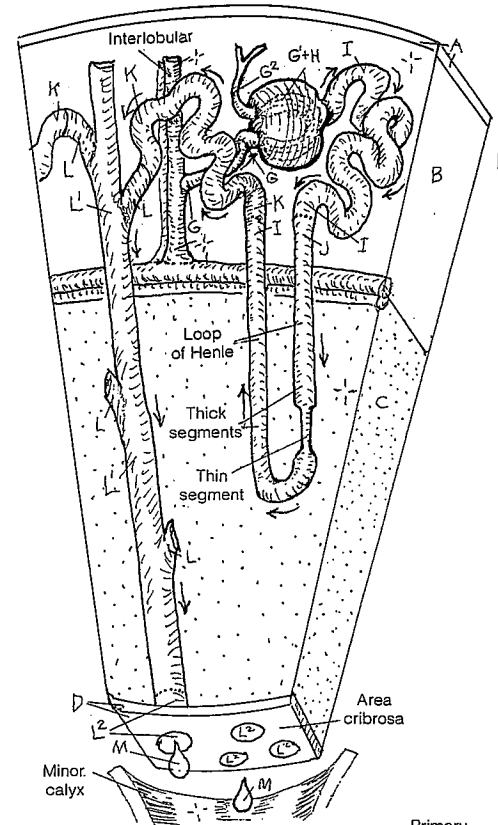
RENAL CORPUSCLE
AFFERENT ARTERIOLE
GLOMERULUS
GLOMERULAR CAPSULE
PARIENTAL LAYER
VISCERAL LAYER
CAPSULAR SPACE
EFFERENT ARTERIOLE

PROXIMAL CONVOLUTED TUBULE
LOOP OF HENLE
DISTAL CONVOLUTED TUBULE

COLLECTING TUBULE
COLLECTING DUCT
PAPILLARY DUCT

URINE

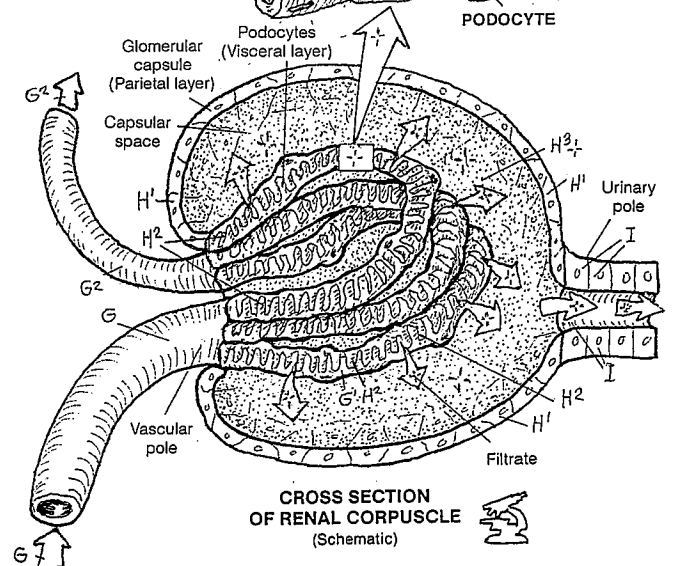
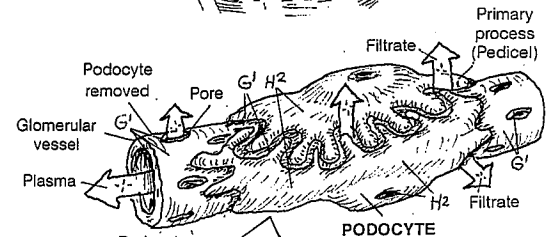
CORTICAL NEPHRON



The function of the renal (uriniferous) tubule is to (1) extract certain substances from the blood, (2) return certain substances to the blood, and (3) transport the leftovers to the urinary bladder for storage and expulsion from the body. The renal tubule consists of a *nephron* and a *collecting tubule*. The nephron consists of a renal corpuscle and a tubule that is both convoluted and straight throughout its course. At its termination, the nephron is continuous with the collecting tubule. Each collecting tubule joins with other collecting tubules to form a larger *collecting duct*. Passing through the papilla of the medulla (*papillary duct*), it empties into the minor calyx. Each papilla has multiple orifices of papillary ducts (*area cribrosa*).

The renal corpuscle consists of a *glomerular (Bowman's) capsule* intimately related to a tuft of capillaries (*glomerulus*). An *afferent arteriole* leads into the glomerulus and an *efferent arteriole* departs it, both at the vascular pole of the corpuscle (see next plate). The inner, indented wall of the epithelial capsule is its visceral layer; the outer wall is its parietal layer. The visceral layer is complexly interwoven with the glomerular vessels. The space between the visceral and parietal layers is the capsular space; it opens into the proximal convoluted tubule at the urinary pole of the renal corpuscle.

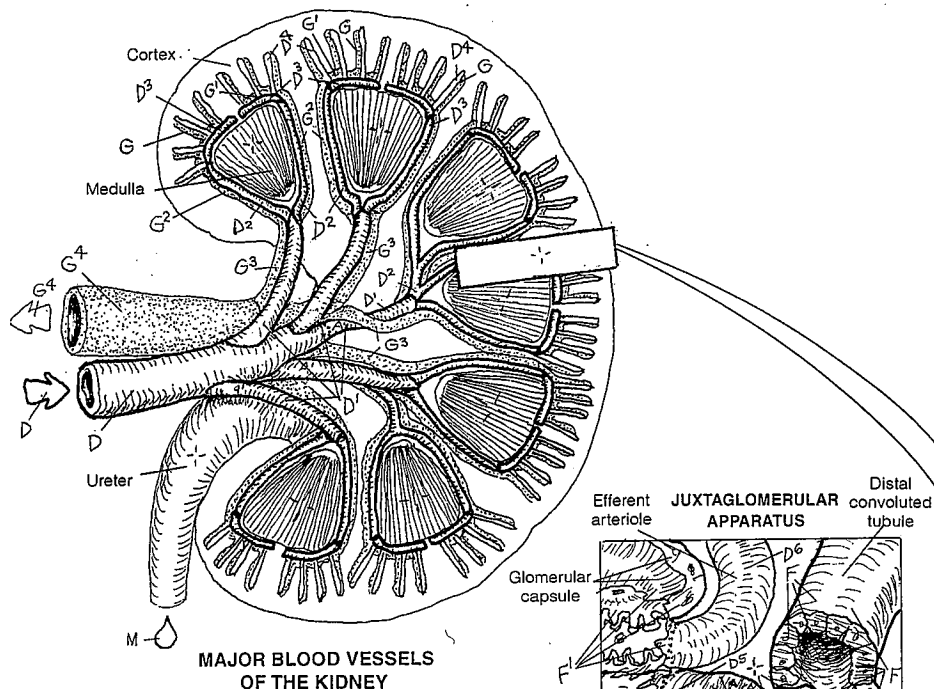
The cells of the visceral layer are highly modified simple squamous epithelia, called *podocytes*. Each has the shape of a centipede, with its "body" containing the nucleus and its multiple "legs" (primary processes or pedicels) being cell membrane-lined cytoplasmic extensions. These pedicels incompletely encircle a vessel, creating filtration slits. The "legs" have "feet" (secondary processes) that attach to the porous vascular wall and reduce further the filtration spaces "between the toes" (not shown). As the blood circulates through the glomerulus, plasma and its noncellular solutes (less proteins) are driven through the pores and slits to enter the capsular space. The filtrate's journey through the rest of the renal tubule is shown and described in the following plate.



CROSS SECTION OF RENAL CORPUSCLE (Schematic)

TUBULAR FUNCTION & RENAL CIRCULATION

CN: Use the same colors as were used on the preceding plate for A, B, C, M, and F. Use red for D, blue for G, and purple for E. (1) Begin with the major blood vessels of the kidney. (2) Color the entire enlarged nephron the color (F) from the preceding plate. Note that the afferent and efferent arterioles, although part of the dotted nephron, receive arterial colors (D⁵, D⁶). When coloring the inset of the juxtamedullary apparatus, leave the relevant cells blank, for easier identification.



ARTERIES:

- RENAL A. D
- SEGMENTAL A. D¹
- INTERLOBAR A. D²
- ARCUATE A. D³
- INTERLOBULAR A. D⁴

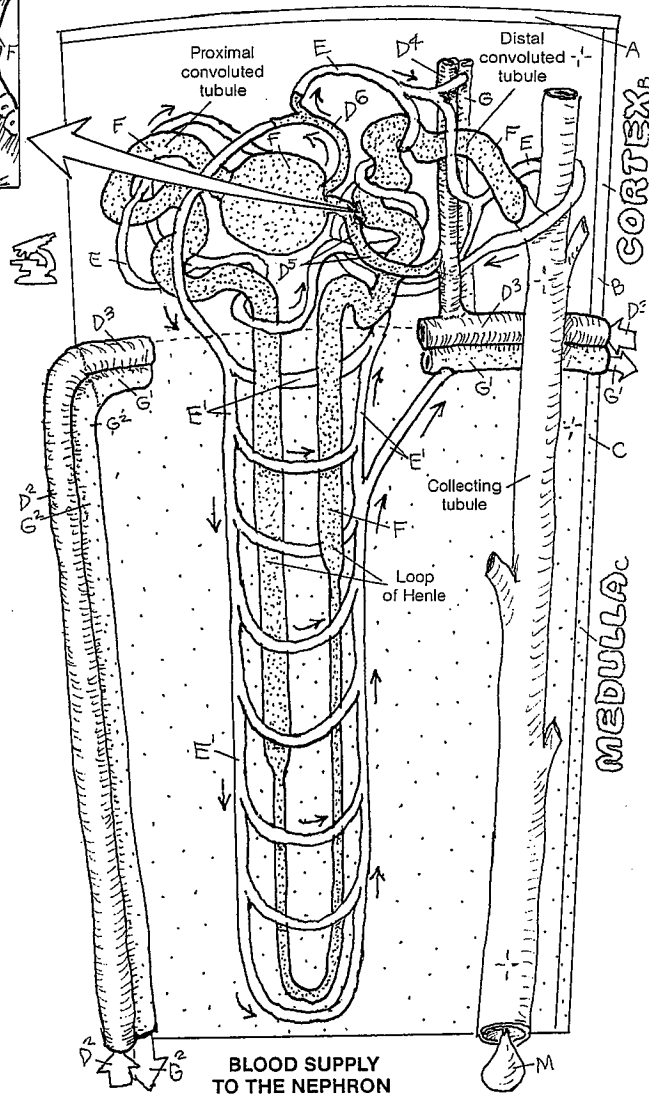
AFFERENT ARTERIOLE D⁵

- GLOMERULUS F¹
- EFFERENT ARTERIOLE D⁶
- PERITUBULAR CAPIL. PLEXUS E
- VASA RECTA E¹

VEINS:

- INTERLOBULAR V. G
- ARCUATE V. G¹
- INTERLOBAR V. G²
- SEGMENTAL V. G³
- RENAL V. G⁴

JUXTAMEDULLARY NEPHRON F



The juxtamedullary nephron shown here lies near the cortico-medullary border. Unlike nephrons of the deeper cortex, its descending tubules reach into the deep medulla, and its vascular relations are different. Of the 0.4–1 million or so nephrons in each kidney, about 30% are juxtamedullary in location.

In juxtamedullary nephrons, the efferent arteriole leads directly to the *vasa recta* (straight vessels) arranged close to the long tubules in the medulla. In the cortical nephrons, the efferent arteriole leads directly to the *peritubular capillary plexus*, which embraces the entire neuron. In some nephrons, both a peritubular capillary plexus and vasa recta may exist, as shown here. The venous side of the vasa recta flows into veins that may merge with the arcuate veins or continue up into the lower cortex to join the interlobular vein. The venous side of the peritubular capillary plexus joins the interlobular vein. It is the close relationship of tubule to blood vessel that makes possible the preservation of what is needed at any one moment and the rapid ejection of what is not needed, e.g., toxic substances.

The renal corpuscle filters the blood plasma. The resulting filtrate is discharged into the proximal tubule, where tubular reabsorption and tubular secretion begin. Water, sodium (Na⁺), glucose, and amino acids are rapidly reabsorbed by the tubular cells. The descending thin segment of the *loop of Henle*, composed of simple squamous epithelia, also reabsorbs water and electrolytes, principally by simple diffusion. The thin and thick segments of the ascending limb of the loop, however, are largely impermeable to water but actively reabsorb sodium, chloride, and other ions, leaving very dilute water going into the *distal tubule*.

The first part of the distal tube comes into contact with the afferent arteriole of the glomerulus of origin. Modified smooth muscle, renin-secreting, juxtamedullary (JG) cells in the arteriole are sensitive to arteriolar blood pressure. Modified epithelial cells in the adjacent distal tubule (macula densa) sense the solute content in the filtrate at that site. By their interaction, the glomerular filtration rate and blood pressure can be modulated. The distal tubule is impermeable to water while reabsorbing electrolytes. The dilute tubular fluid entering the collecting tubule is reabsorbed under the influence of anti-diuretic hormone (ADH). Fluid is continuously reabsorbed until the residual is discharged as urine at the papilla. For every 100 ml of filtrate formed, 1 ml of it will find the minor calyx.