XI. URINARY SYSTEM
URINARY TRACT

URINARY TRACT: *
KIDNEY:
URETER:
URINARY BLADDER:
URETHRA:
PROSTATIC U. (MALE):
MEMBRANOUS U. (MALE):
SPONGY U. (MALE):

KIDNEY RELATIONS: *
SUPRARENAL GLAND:
LIVER:
DUODENUM:
TRANSVERSE COLON:
SPLEEN:
STOMACH:
PANCREAS:
JEJUNUM:

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 non-essential 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.
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 are all retroperitoneal. Arteries and veins travel between layers of peritoneum to reach the organs they supply/drain. Lymph nodes, lumbar trunks, and the cysternal chyl (not shown) are all 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 perilrenal 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.
XI. URINARY SYSTEM
KIDNEY STRUCTURE

Draw: Use red for H, blue for I, yellow for K, and very light colors for B, E, F, G, and J. (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) Complete the overview diagram at the top of the plate.

PERIPHERAL PART: *
RENA L CAPSULE A
CORTEX B
MEDULLA (PYRAMID) C
PAPILLA D

INNER CENTRAL PART: *
MINOR CALYX E
MAJOR CALYX F

HILUS: *
RENAL PELVIS G
RENAL ARTERY H
OXYGENATED BLOOD H'
RENAL VEIN I
DEOXYGENATED BLOOD I'
RENAL SINUS J
URETER K
URINE H''

1200 mL/min H''
(Into both kidneys)

1239 mL/min I
(Out of both kidneys)

Minor and Major calyces are cut open

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 which 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 hilus), 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!
XI. URINARY SYSTEM
URINIFEROUS TUBULE

CN: Use red for E, yellow for K, and the same colors used on the preceding plate A-D.
(1) Complete the drawing above. (2) In the enlarged wedge-shaped section, one unifor-
mous tubule is shown; actually, thousands are packed in each such section. Color all
directional arrows the color of the adjacent vessel. (3) In the diagram below, color the
capsule space gray but not the arrows representing filtrate.

KIDNEY SECTION:

CAPSULE
CORTEX
MEDULLA
PAPILLA

NEPHRON:

RENAL CORPUSCLE:

GLomerulus
GLomerular (Bowman's)
CAPSULE
Parietal layer
Visceral layer (Podocytes)
Capsular space

PROXIMAL TUBULE:

CONVOLUTED PART
STRAIGHT PART
LOOP OF HENLE
DISTAL TUBULE:

STRAIGHT PART
CONVOLUTED PART
COLLECTING TUBULE

Urine

BLOOD VESSELS:

INTERLOBULAR ARTERY
AFFERENT ARTERIOLE
EFFERENT ARTERIOLE

The functional unit of the kidney is the nephron (one million per kidney). Each
nephron and a collecting tubule constitute a unifororous (renal) tubule; each
nephron consists of a renal corpuscle and tubules leading to a collecting
tubule. The renal corpuscles are in the cortex; the tubules are in both
the cortex and the medulla. Each corpuscle consists of a glomerular capsule
invaginated by a cluster of specialized capillary-like vessels (glomerulus). The
vessel leading into each glomerulus is an afferent arteriole, a downstream,
5th-order branch of the renal artery. Its entrance into the capsule is the vascular
pole. The efferent arteriole departs the vascular pole, its blood destined for the
tubular capillary plexus (next plate).
The capsule is shaped like a soft, rubbery, partly flat hollow ball pushed in on
one side so that it has an outer and an inner layer to it. The inner layer (of cells)
is called the visceral layer; the outer layer the parietal layer; the interior is the
capsular space which opens into the proximal tubule (urinary pole). The vis-
ceral layer is intimately and complexly interwoven with the glomerular vessels.
Each cell in the layer has the shape of a centipede, with a "body" containing
the nucleus, and multiple "legs" (cell membrane-lined cytoplasmic exten-
sions called primary processes). These processes incompletely encircle the
glomerular vessels, leaving slits (interdigitations) among the processes. The
"legs" have "feet" (called foot or secondary processes) which attach to the
porous vessel wall in such a way as to leave filtration spaces among them.
These highly modified, simple squamous epithelial cells of the visceral layer
are called podocytes. Plasma escapes the glomerular vessel through the
pores, then rushes through the filtration slits to enter the capsular space.
This non-cellular plasma filtrate enters the proximal tubule.

We continue with the structure and function of the parts of the unifororous
tubule, in conjunction with the vascular system, in the next plate.
XI. URINARY SYSTEM
RENAL CIRCULATION

CN: Use red for A and blue for I, and a very light color for F. (1) Color the major blood vessels (A-D), noting that the corresponding veins receive only one color (blue). (2) Color the nephrons in the larger illustration gray. Note that the glomerular capsules have been opened to reveal the glomeruli (F). All arrows receive the color of the adjacent vessels.

The nephron consists of the renal corpuscle and tubules less collecting tubules. The renal corpuscle was considered in Plate 111. Refer to that plate as necessary for the following paragraph. The proximal tubule close to the capsule of origin is highly convoluted. The pyramid-shaped cuboidal cells of this tubule absorb 85% of the vitamins, amino acids, small proteins, glucose, sodium chloride, and water that came in with the plasma filtrate. The straight part of the tubule descends to become the loop of Henle, the cells of which absorb large amounts of water. The cells of the distal tubule are relatively impermeable to water but not to minerals. Here the filtrate tends to become diluted. The reabsorption of sodium (Na+) is facilitated by aldosterone from the adrenal cortex and by dietary restriction of salt. The cells of the collecting tubule are permeable to water (taking it out of the tubule) in the presence of antidiuretic hormone (ADH, vasopressin). It is significantly less permeable in the absence of ADH, and even less so in the presence of diuretic medication.

The renal vascular pattern explains how the tubular cells can recover large amounts of fluid/solute from the filtrate and secrete it into the peritubular capillary plexus, to the extent that only 1% of the plasma filtered by the glomerular capsule reaches the calyces at any one moment. Follow the route of blood from the renal artery to and through the glomeruli to the efferent arterioles. The efferent arteriole in the upper and middle cortex branches into a peritubular capillary plexus that is intertwined around the convoluted tubules. The plexus is drained by interlobular veins which conduct the blood toward the renal vein.

In nephrons close to the medulla (juxtamedullary nephrons), the efferent arteriole (shown without itsglomerulus of origin) may give off straight vessels (vasa recta) that “descend” into the medulla adjacent to the straight tubules. These vessels contribute to a separate peritubular capillary plexus in the medulla. Medullary vessels leaving the peritubular capillary plexuses form or contribute to “ascending” vasa recta which generally terminate by joining the arcuate veins. The relationship of the vasa recta to the loops of Henle is a critical factor in the success of water reabsorption. The circulatory pattern among the uniferous tubules is a vital feature in the preservation of body water and the maintenance of chemical neutrality throughout the body.