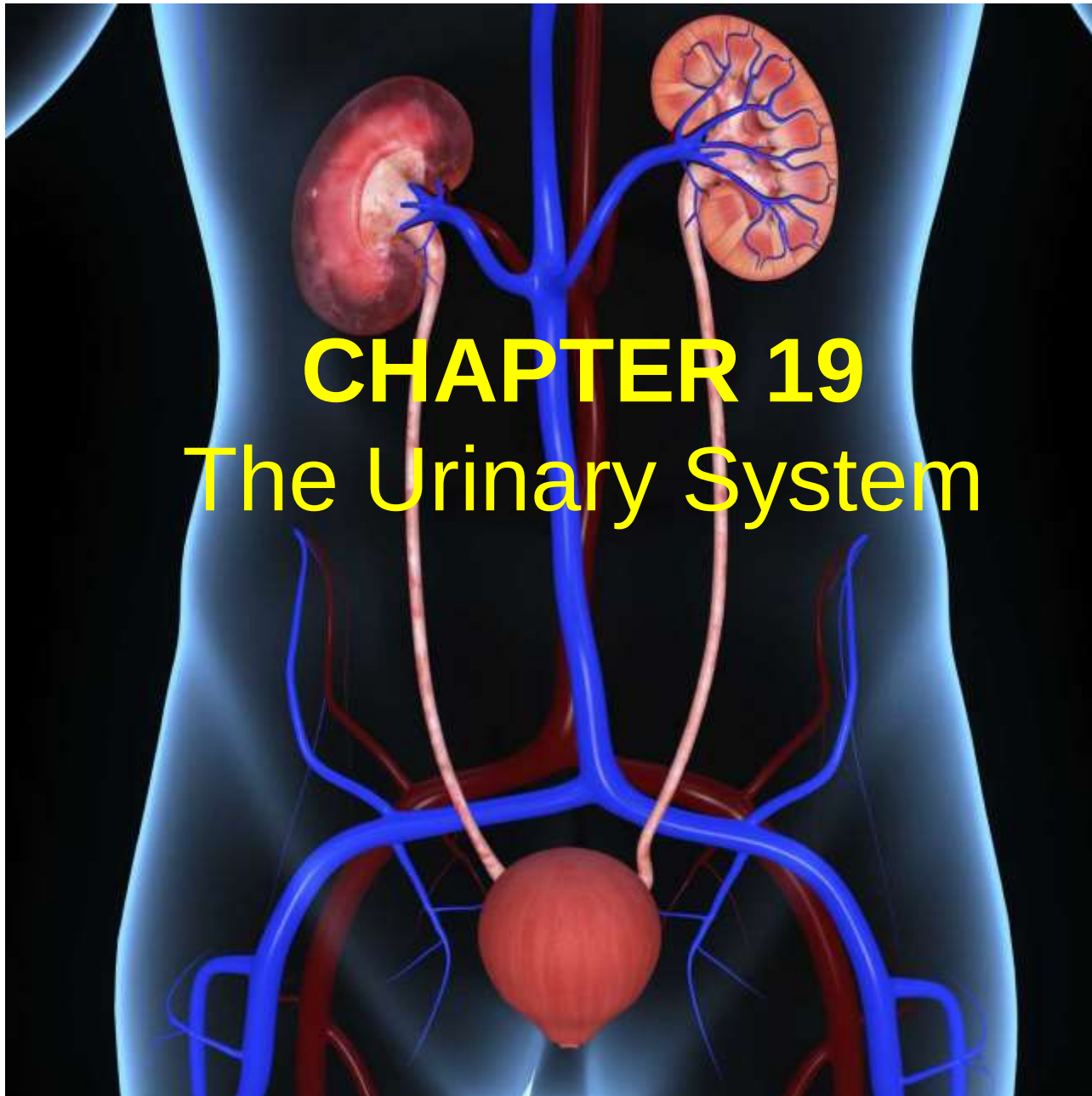




CHAPTER 19

The Urinary System



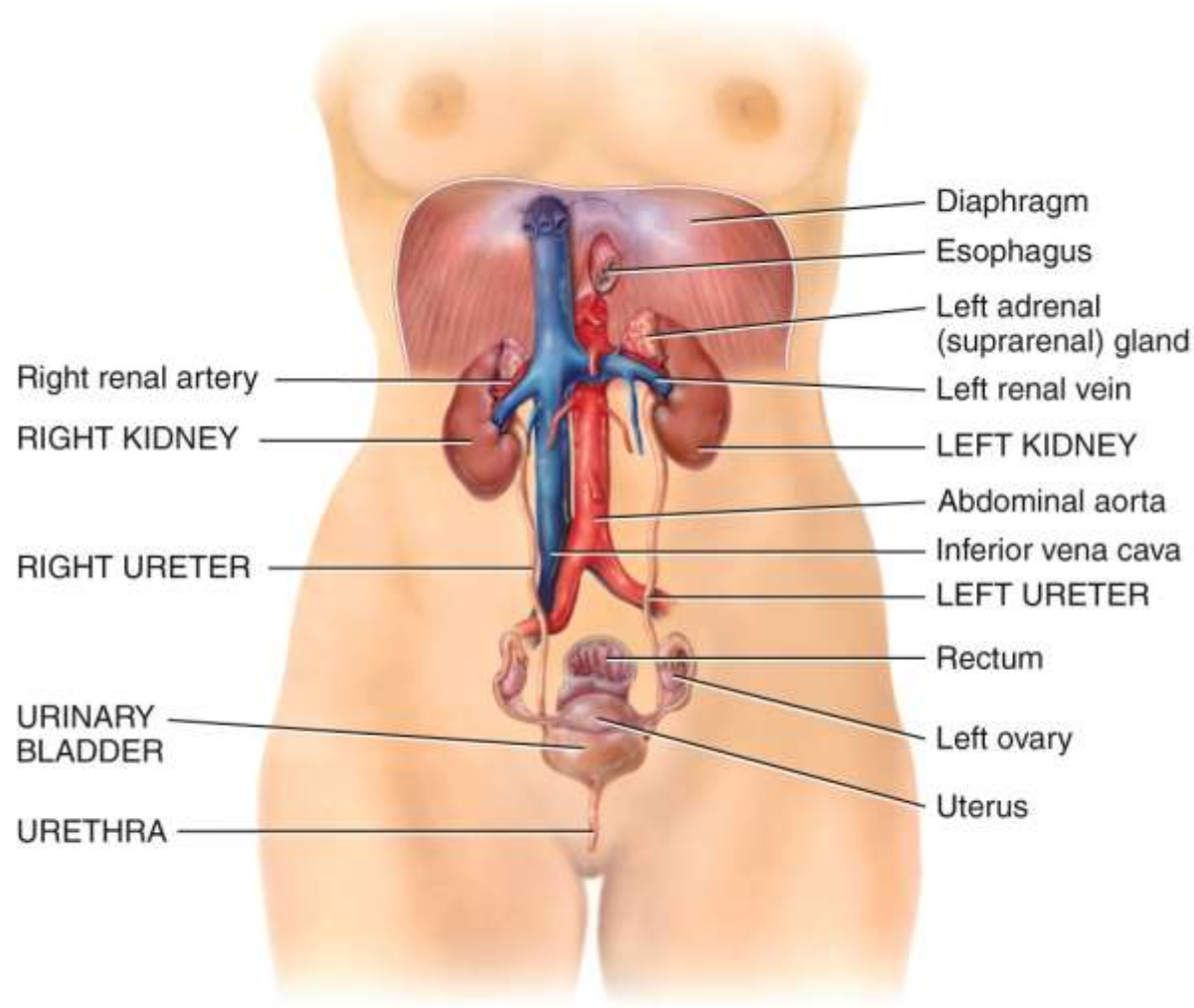


Overview of the Urinary System

- The urinary system consists of two kidneys, two ureters, one urinary bladder, and one urethra.
- After kidneys filter blood plasma, they return most of the water and solutes to the bloodstream.
- Remaining water and solutes constitute urine.

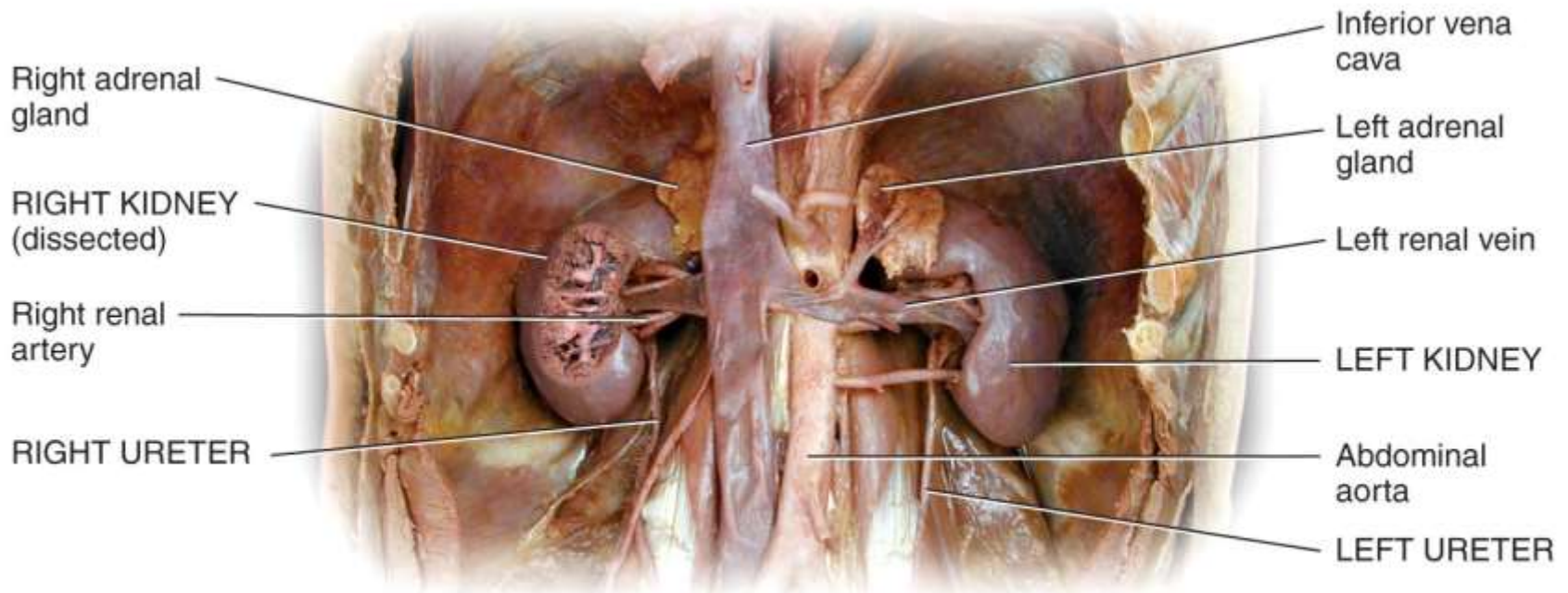


Organs of the Urinary System



(a) Anterior view of urinary system

Organs of the Urinary System

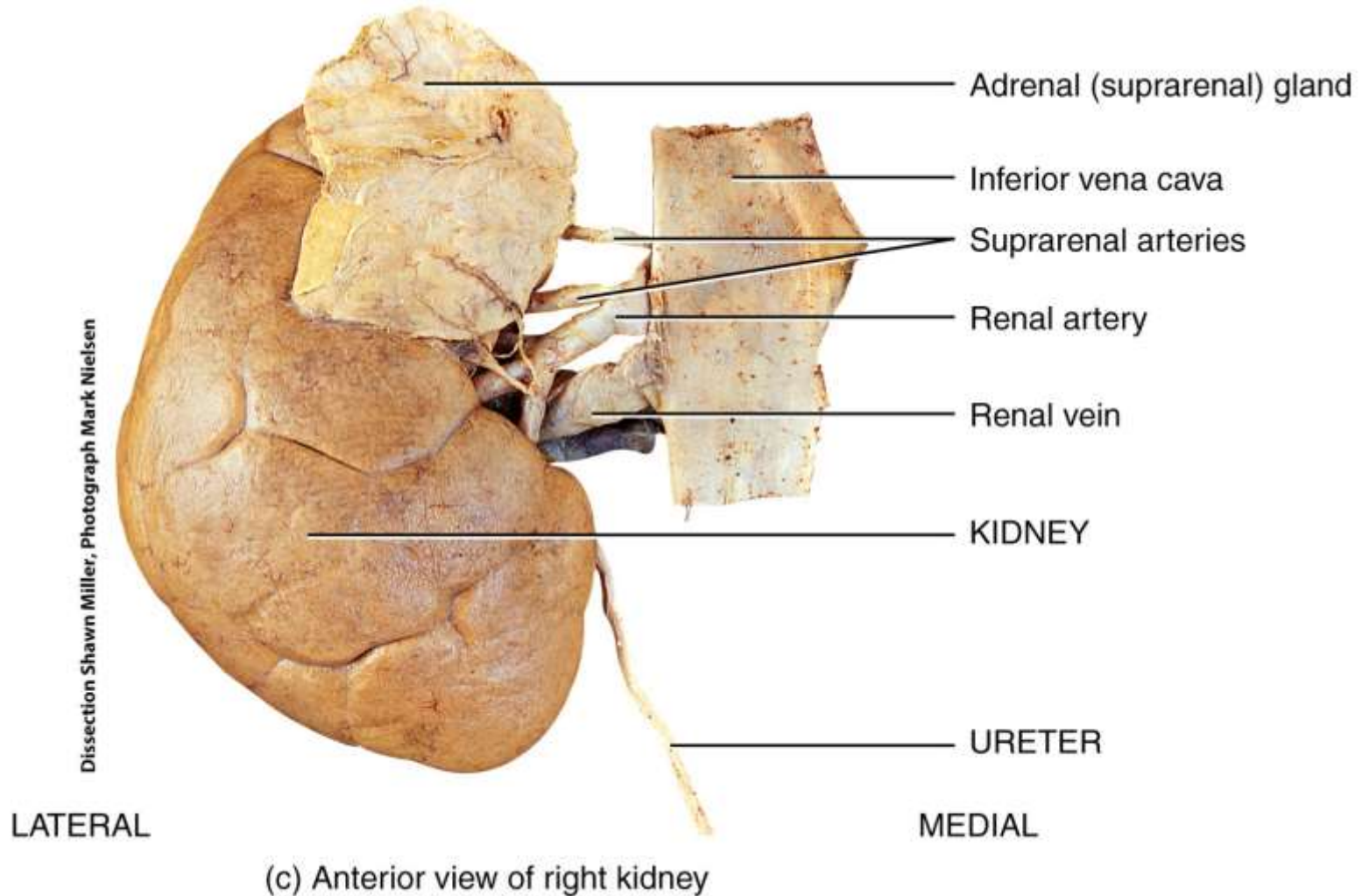


Dissection Shawn Miller, Photograph Mark Nielsen

(b) Anterior view of urinary system



Organs of the Urinary System





Overview of the Urinary System

- **Functions of the kidneys:**
 - Regulation of blood ionic composition
 - Regulation of blood pH
 - Regulation of blood volume
 - Enzymatic regulation of blood pressure
 - Maintenance of blood osmolarity
 - Production of hormones
 - Regulation of blood glucose level
 - Excretion of wastes and foreign substances

The Urinary System: Water and Fluid Flow



Interactions Animation

- [Water and Fluid Flow](#)

R. Bishay

You must be connected to the internet to run this animation.

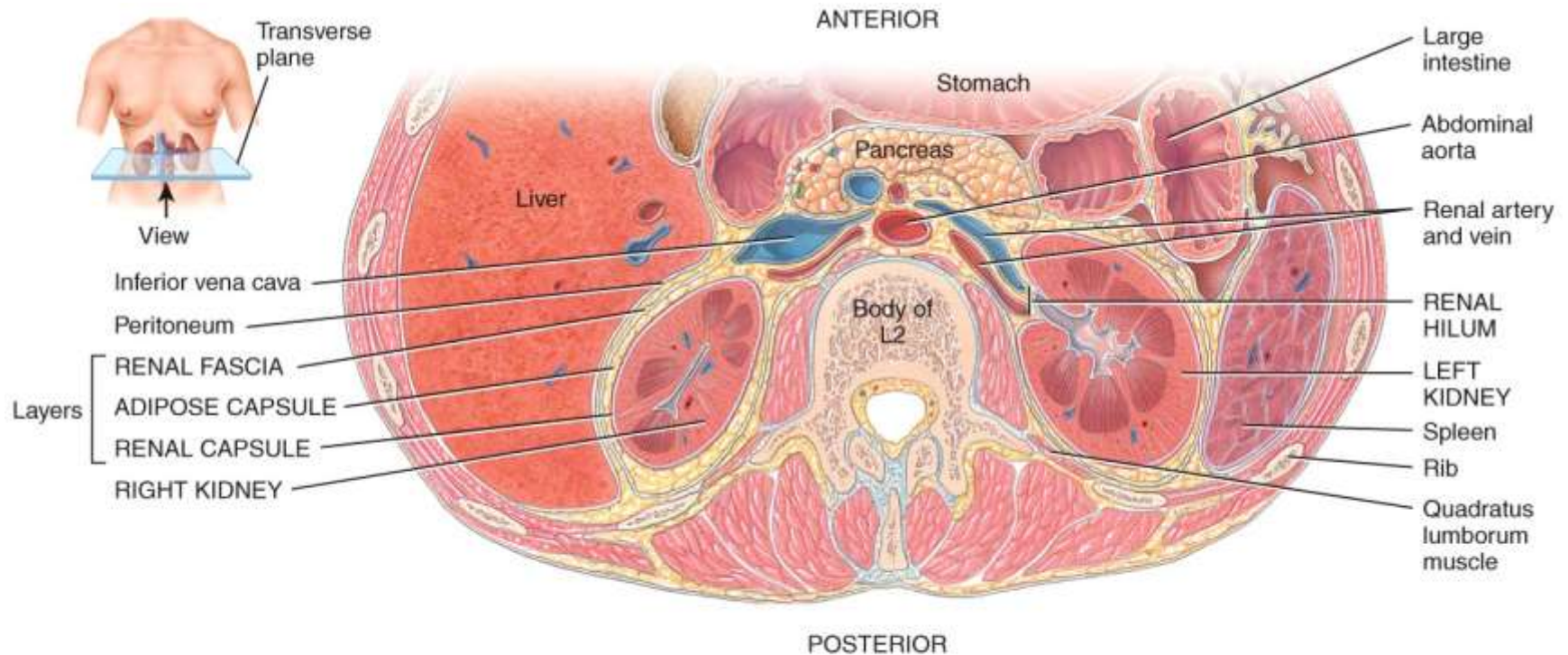


External Anatomy of Kidneys

- **Renal hilum:** or renal pedicle is the hilum of the kidney, that is, its recessed central fissure where its vessels, nerves and ureter pass. The medial border of the kidney is concave in the center and convex toward either extremity; it is directed forward and a little downward.
- Three layers of tissue surround each kidney:
 - **Renal capsule (deep layer):** The renal capsule is a tough fibrous layer surrounding the kidney and covered in a layer of perirenal fat known as the adipose capsule of kidney.
 - **Adipose capsule (middle layer):** is a mass of fatty tissue surrounding the renal capsule. It protect the kidney from trauma & holds it firmly in place within the abdominal cavity.
 - **Renal fascia (superficial layer):** is a layer of connective tissue encapsulating the kidneys and the adrenal glands



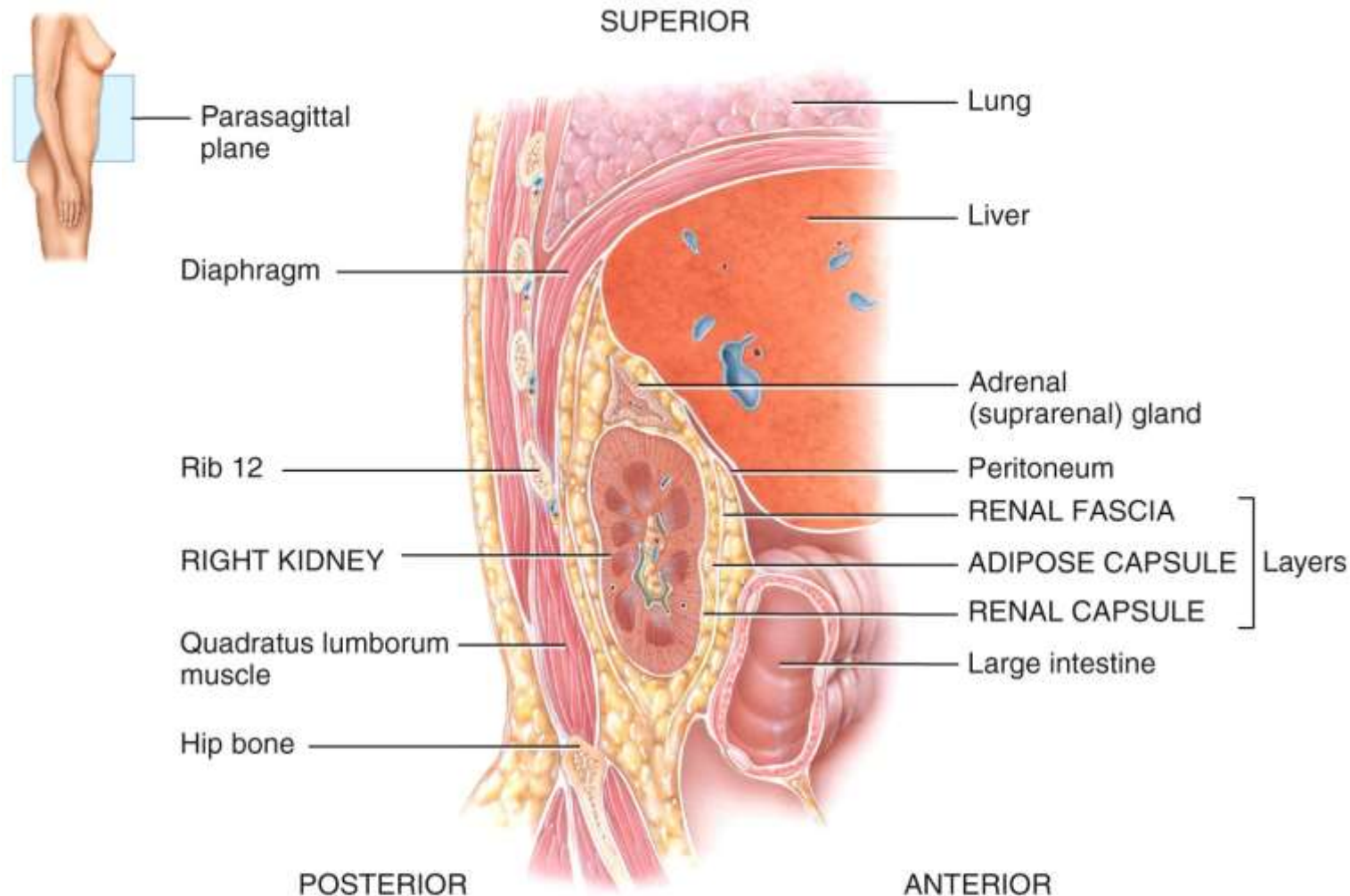
Position and Coverings of the Kidneys



(a) Inferior view of transverse section of abdomen (L2)



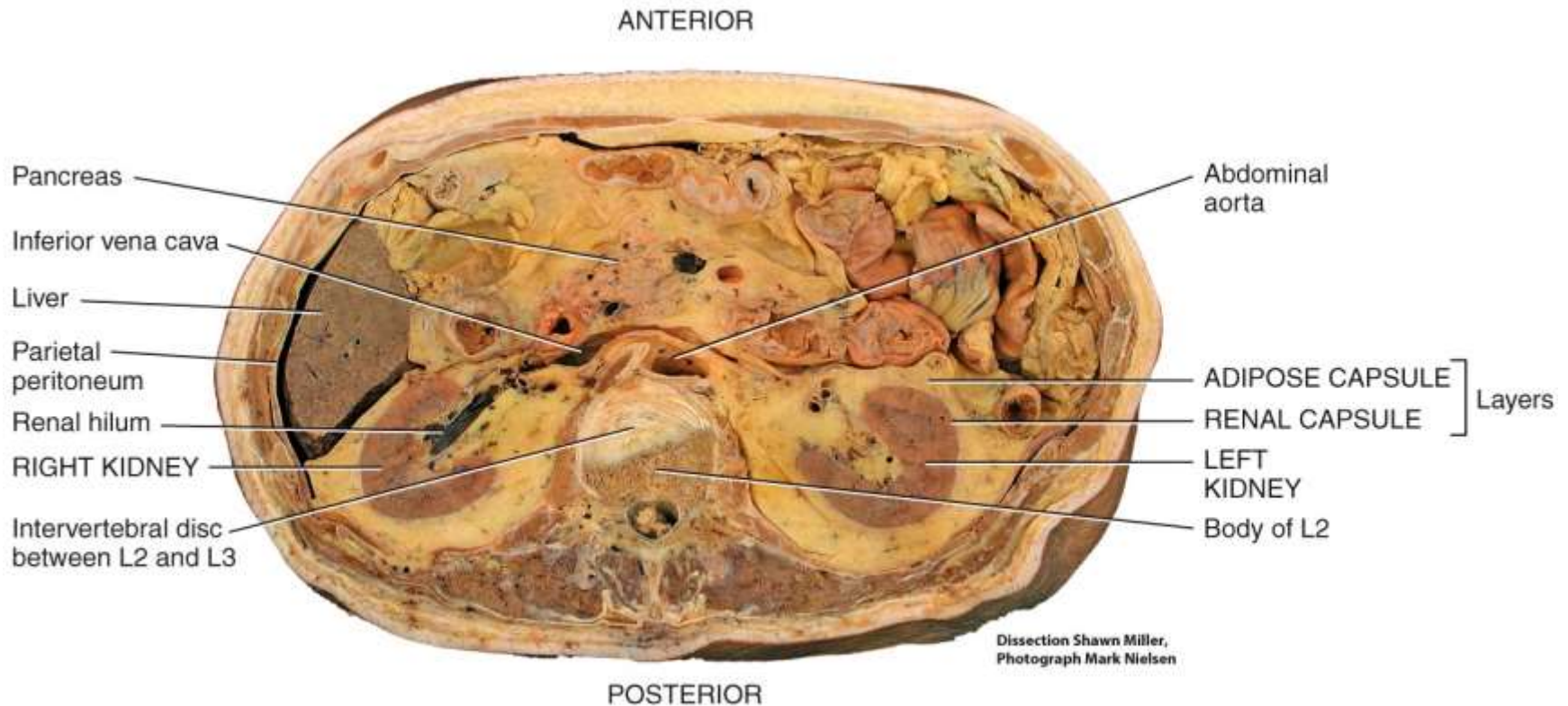
Position and Coverings of the Kidneys



(b) Sagittal section through the right kidney



Position and Coverings of the Kidneys



(c) Inferior view of transverse section of abdomen between L2 and L3



Clinical Connection

- **Nephroptosis:** also known as a floating kidney and renal ptosis, is a condition in which the kidney descends more than 2 vertebral bodies (or >5 cm) during a position change from supine to upright.
- In some cases, **nephroptosis** can cause severe symptoms, including flank pain and blood in the urine.



Internal Anatomy of the Kidneys

- **Two distinct regions:**

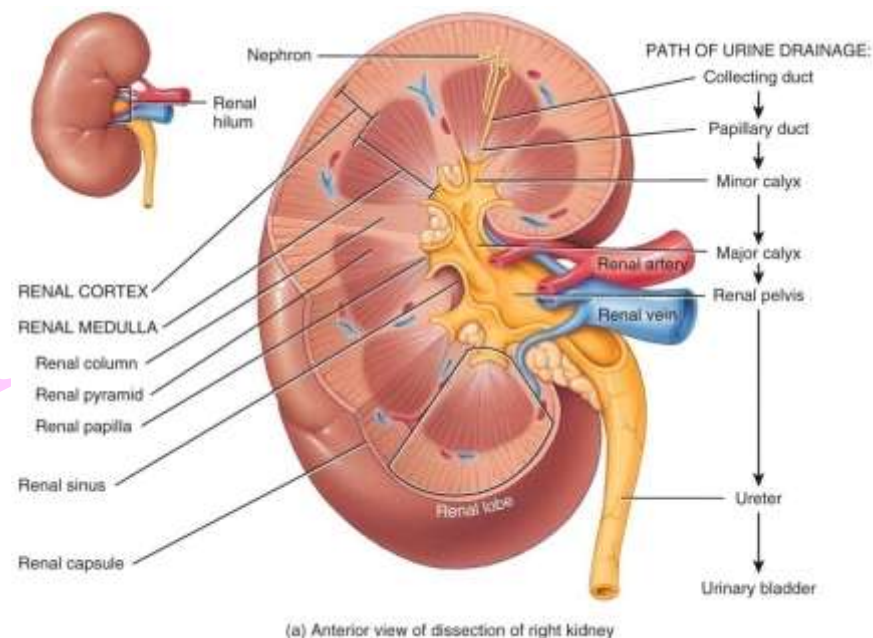
- **Renal cortex:** is the outer portion of the kidney between the renal capsule and the renal medulla, The renal cortex is the part of the kidney where ultrafiltration occurs.
- **Renal medulla:** is the innermost part of the kidney, blood enters into the kidney via the renal artery, which then splits up to form the interlobar arteries.

N.B.: Renal medulla consists of several renal pyramids.



Internal Anatomy of the Kidneys

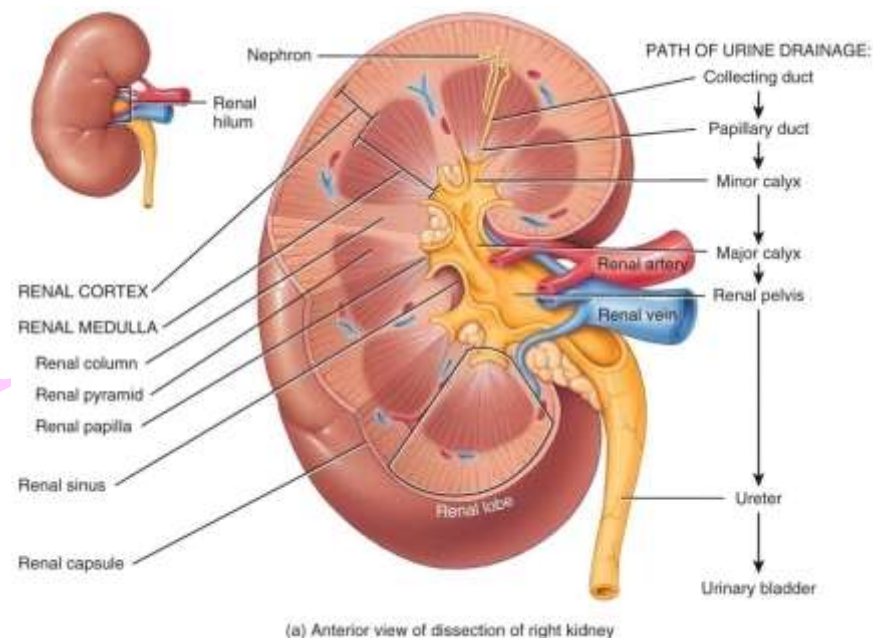
- **Nephrons:** is the microscopic structural and functional unit of the kidney. It is composed of a renal corpuscle and a renal tubule. The renal corpuscle consists of a tuft of capillaries called a glomerulus and an encompassing Bowman's capsule. The renal tubule extends from the capsule.
- **Papillary ducts:** Papillary (collecting) ducts are anatomical structures of the kidneys, previously known as the ducts of Bellini. Papillary ducts represent the most distal portion of the collecting duct. They receive renal filtrate (precursor to urine) from several medullary collecting ducts and empty into a minor calyx.
- **Renal papilla:** is the location where the renal pyramids in the medulla empty urine into the minor calyx in the kidney.





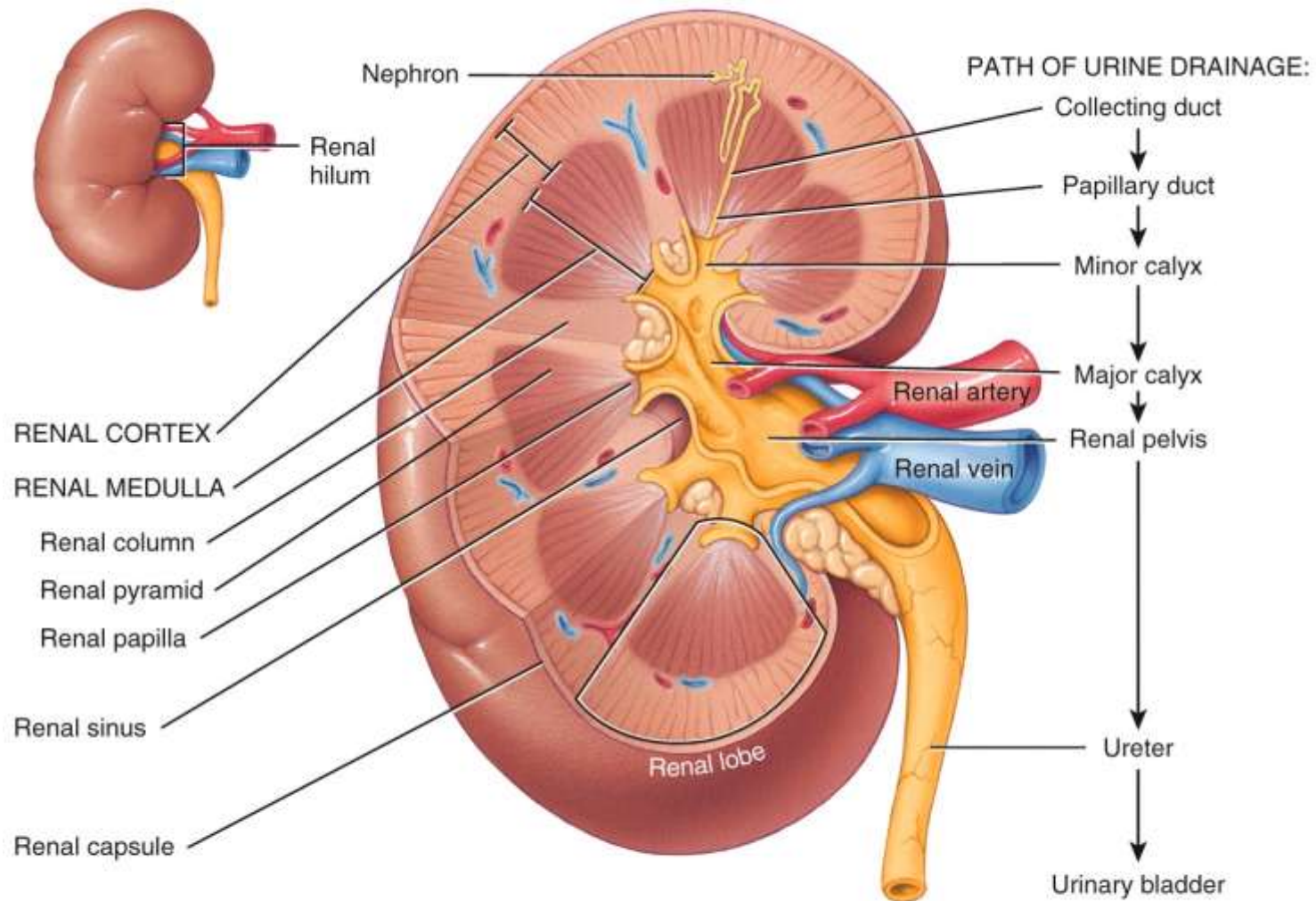
Internal Anatomy of the Kidneys

- **Minor and major calyces:**
The renal calyces are chambers of the kidney through which urine passes. The minor calyces surround the apex of the renal pyramids. Urine formed in the kidney passes through a renal papilla at the apex into the minor calyx; two or three minor calyces converge to form a major calyx, through which urine passes before continuing through the renal pelvis into the ureter.
- **Renal pelvis:** is the point where the two or three major calyces join together, The renal pelvis functions as a funnel for urine flowing to the ureter.
- **Renal sinus:** is a cavity within the kidney which is occupied by the renal pelvis, renal calyces, blood vessels, nerves and fat.





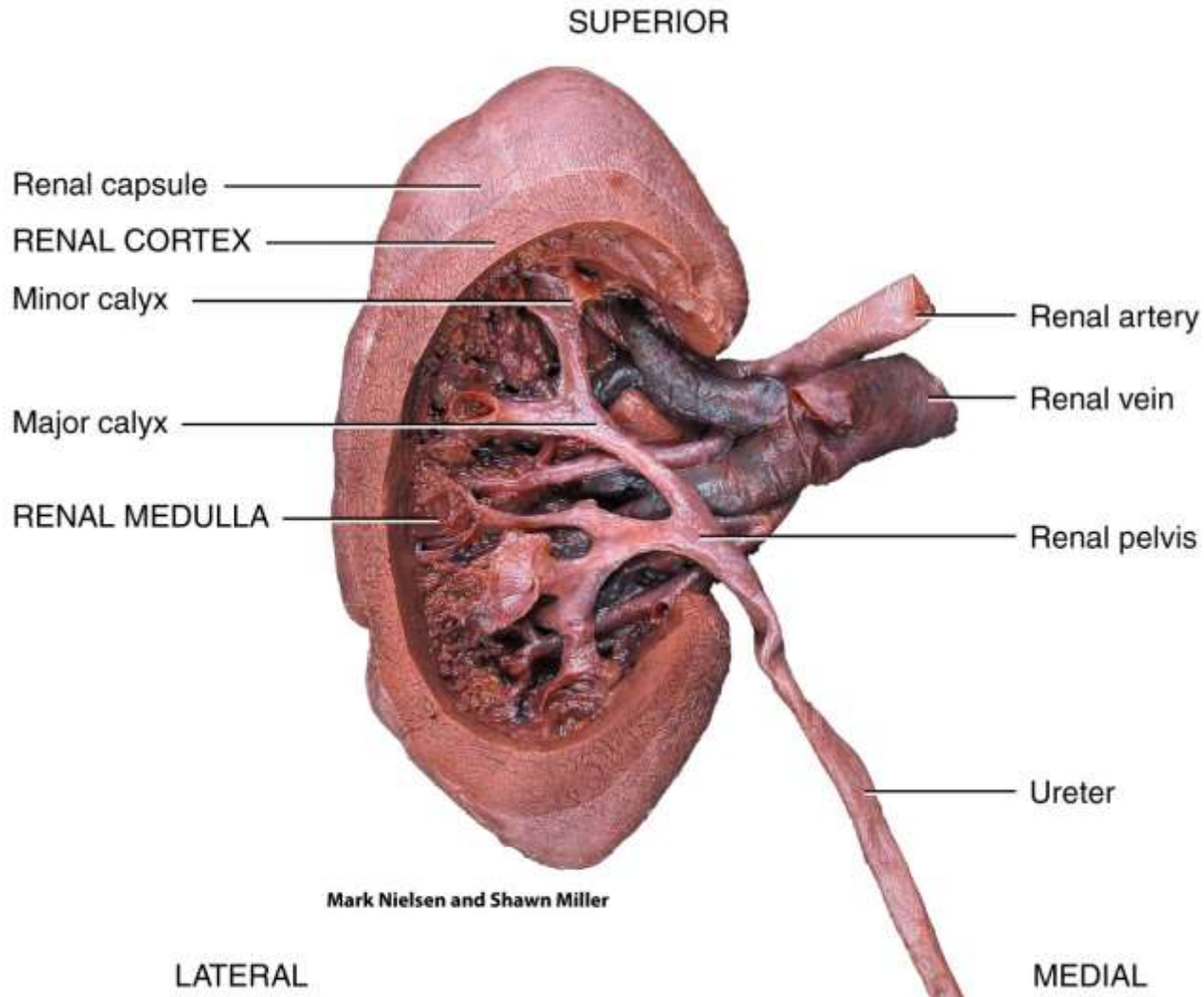
Internal Anatomy of the Kidneys



(a) Anterior view of dissection of right kidney



Internal Anatomy of the Kidneys



(b) Posterior view of dissection of left kidney



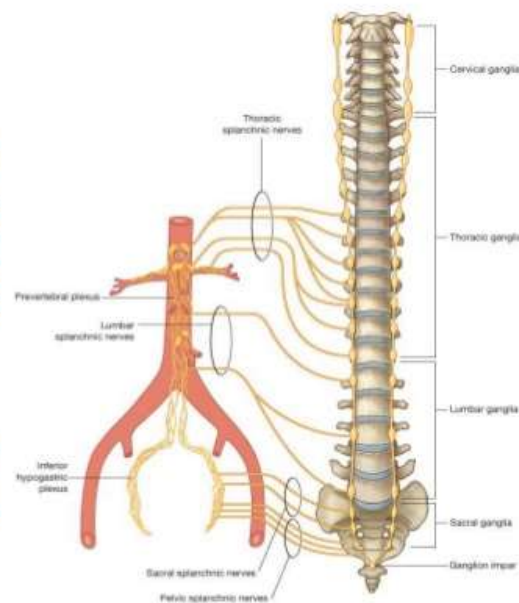
Blood and Nerve Supply of the Kidney

- Renal arteries
- Segmental arteries
- Interlobar arteries
- Renal lobe
- Arcuate arteries
- Afferent arterioles
- Glomerulus
- Efferent arteriole
- Peritubular capillaries
- Vasa recta

NERVE SUPPLY

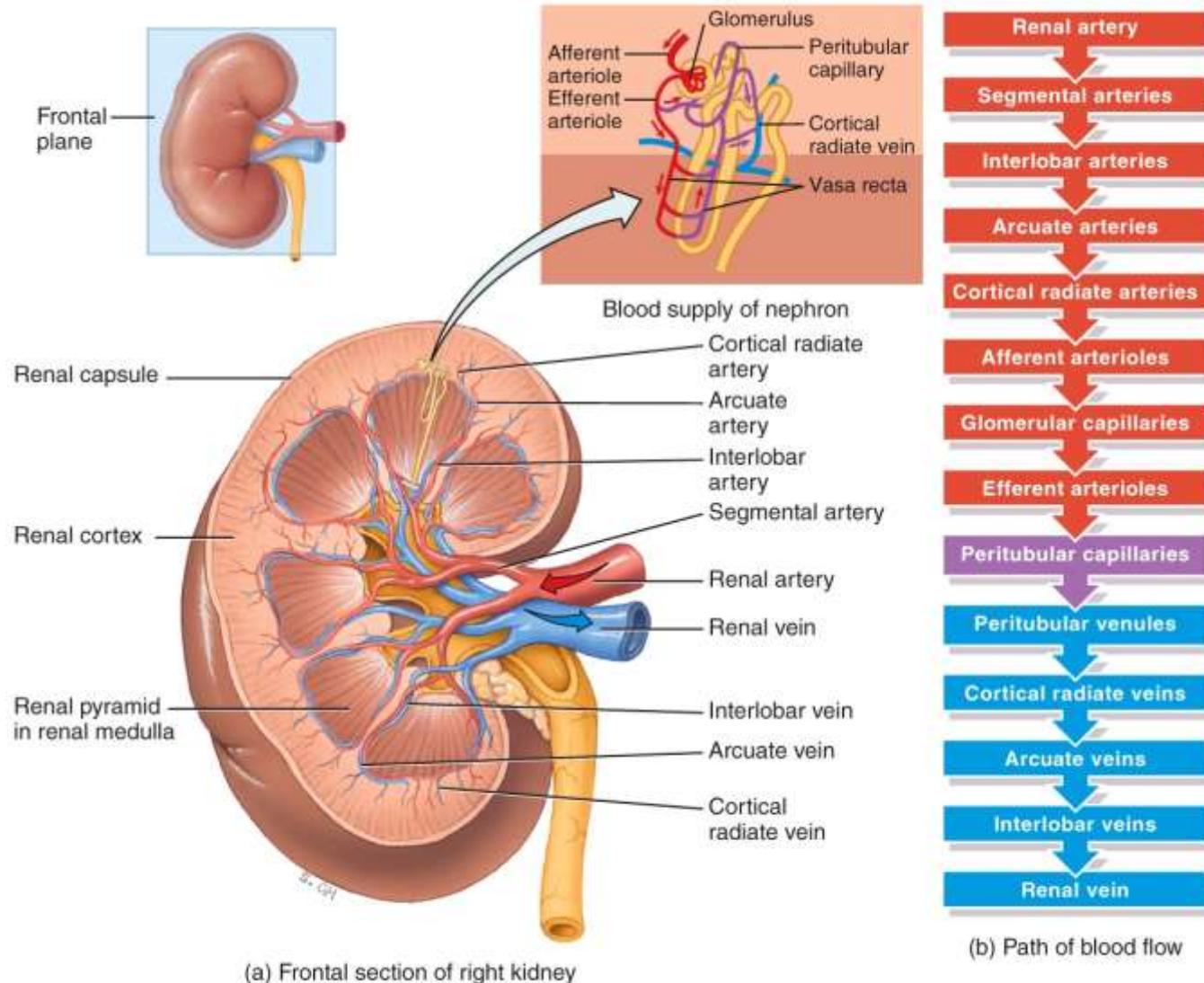
Sympathetic supply from renal, testicular, ovarian, hyogastric & pelvic plexus.

Para sympathetic supply from sacral plexus.





Blood Supply of the Kidneys





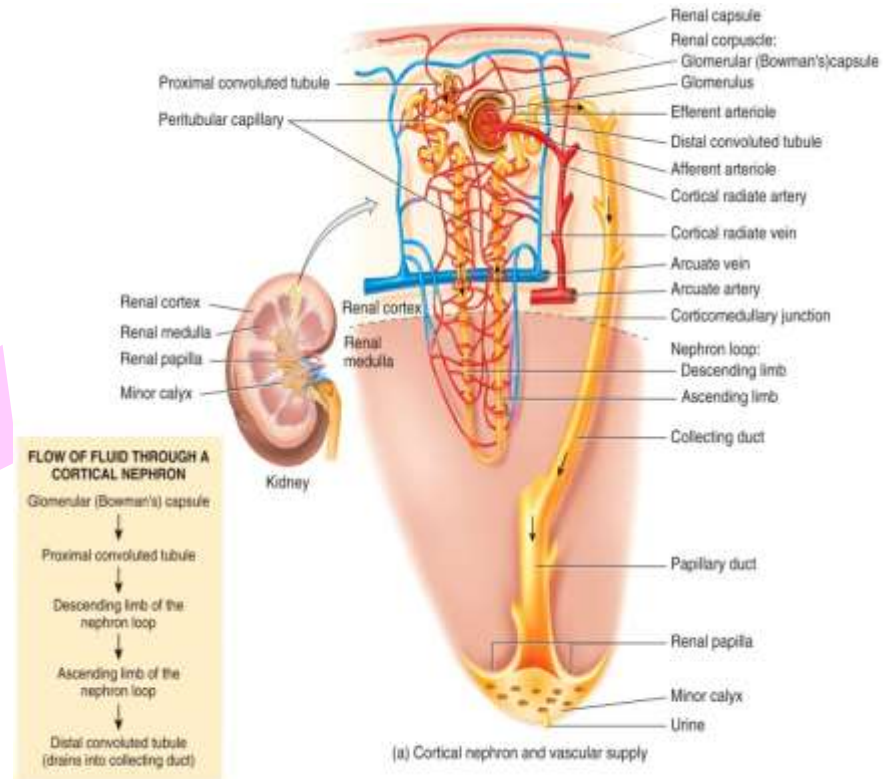
The Nephron

- A **nephron** consists of two parts:
 - Renal corpuscle
 - Renal tubule
- The two components of a renal corpuscle:
 - Glomerulus (capillary network)
 - Glomerular (Bowman's) capsule
- The fluid (filtrate) passes through the renal tubule, which consists of:
 1. Proximal convoluted tubule (PCT)
 2. Nephron loop (loop of Henle)
 3. Distal convoluted tubule (DCT)



The Nephron

- A nephron consists of two parts:
 - Renal corpuscle: is the blood-filtering component of the nephron of the kidney.
 - Renal tubule: is the portion of the nephron containing the tubular fluid filtered through the glomerulus.
- The two components of a renal corpuscle:
 - Glomerulus (capillary network): is a network of small blood vessels (capillaries) known as a tuft, located at the beginning of a nephron in the kidney. The tuft is structurally supported by the mesangium - the space between the blood vessels - made up of intraglomerular mesangial cells.
 - Glomerular (Bowman's) capsule: is a cup-like sack at the beginning of the tubular component of a nephron in the mammalian kidney that performs the first step in the filtration of blood to form urine. A **glomerulus** is enclosed in the sac.

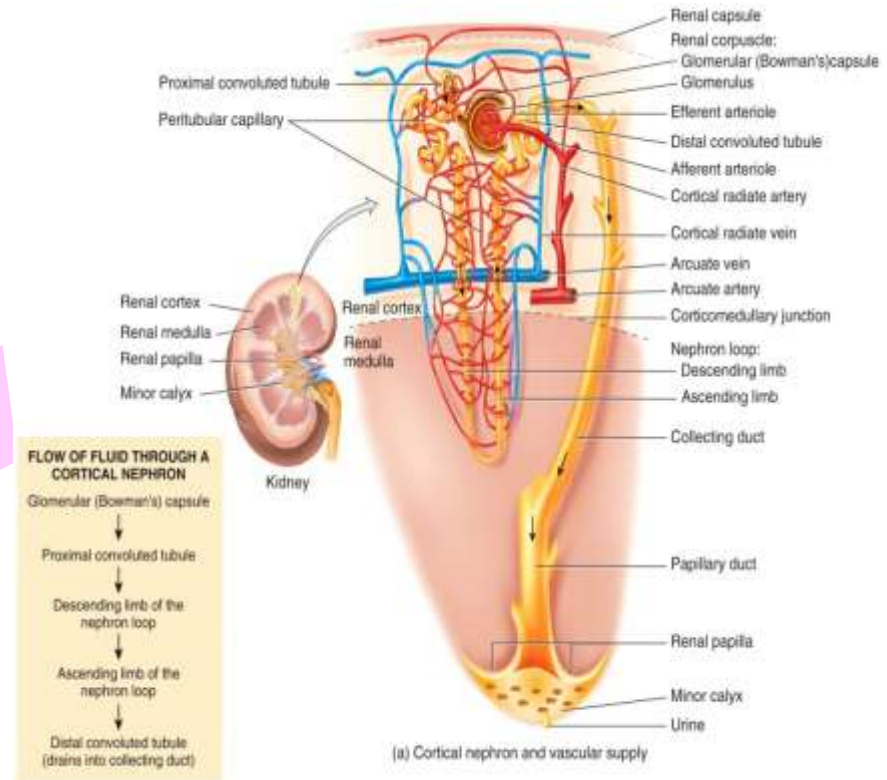




The Nephron

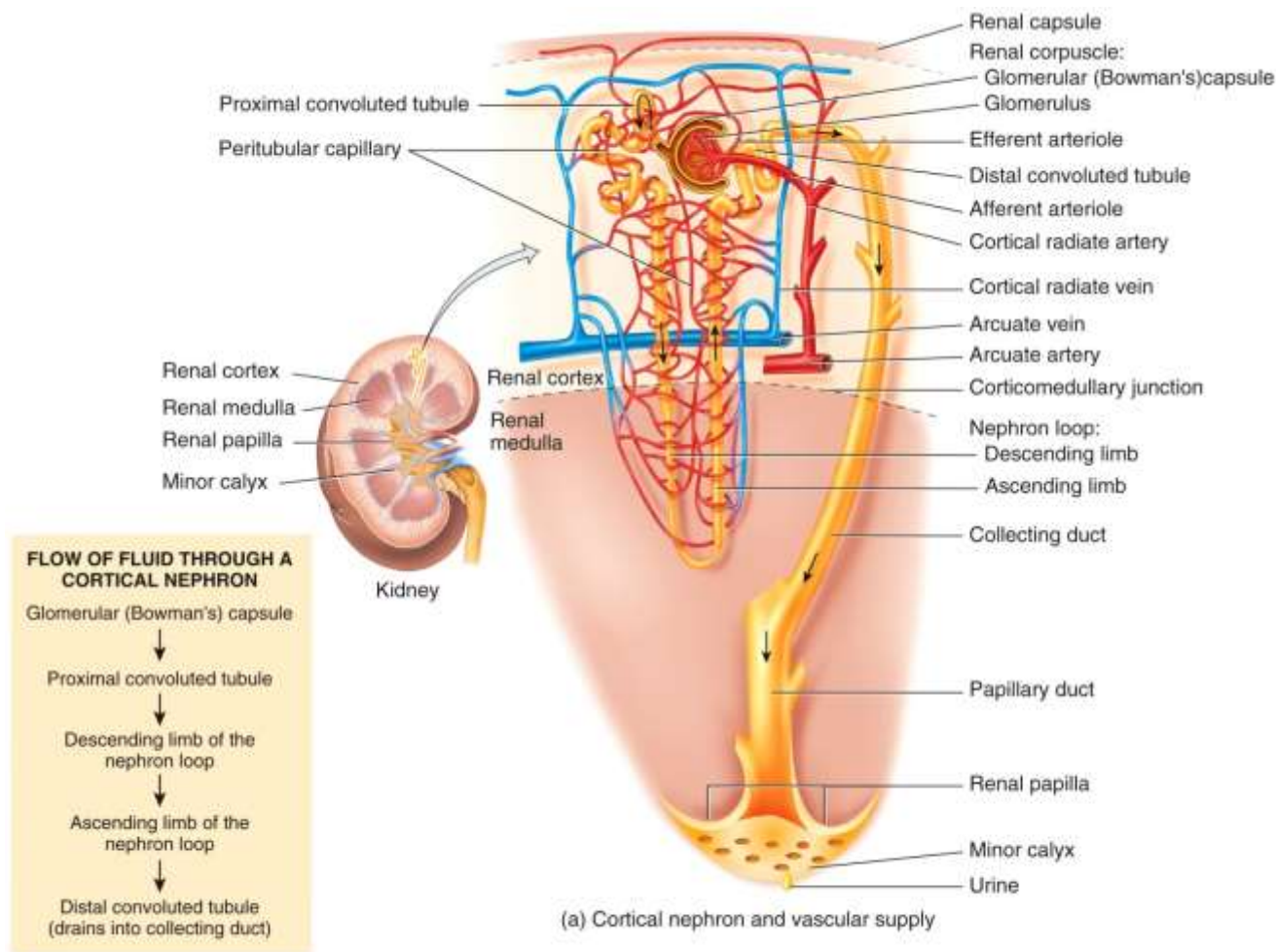
- **The fluid (filtrate) passes through the renal tubule, which consists of:**

1. Proximal convoluted tubule (PCT): is the segment of the nephron in kidneys which begins from the renal pole of the Bowman's capsule to the beginning of loop of Henle.
2. Nephron loop (loop of Henle): is the portion of a nephron that leads from the proximal convoluted tubule to the distal convoluted tubule, the loop of Henle's main function is to create a concentration gradient in the medulla of the kidney.
3. Distal convoluted tubule (DCT): is a portion of kidney nephron between the loop of Henle and the collecting tubule.



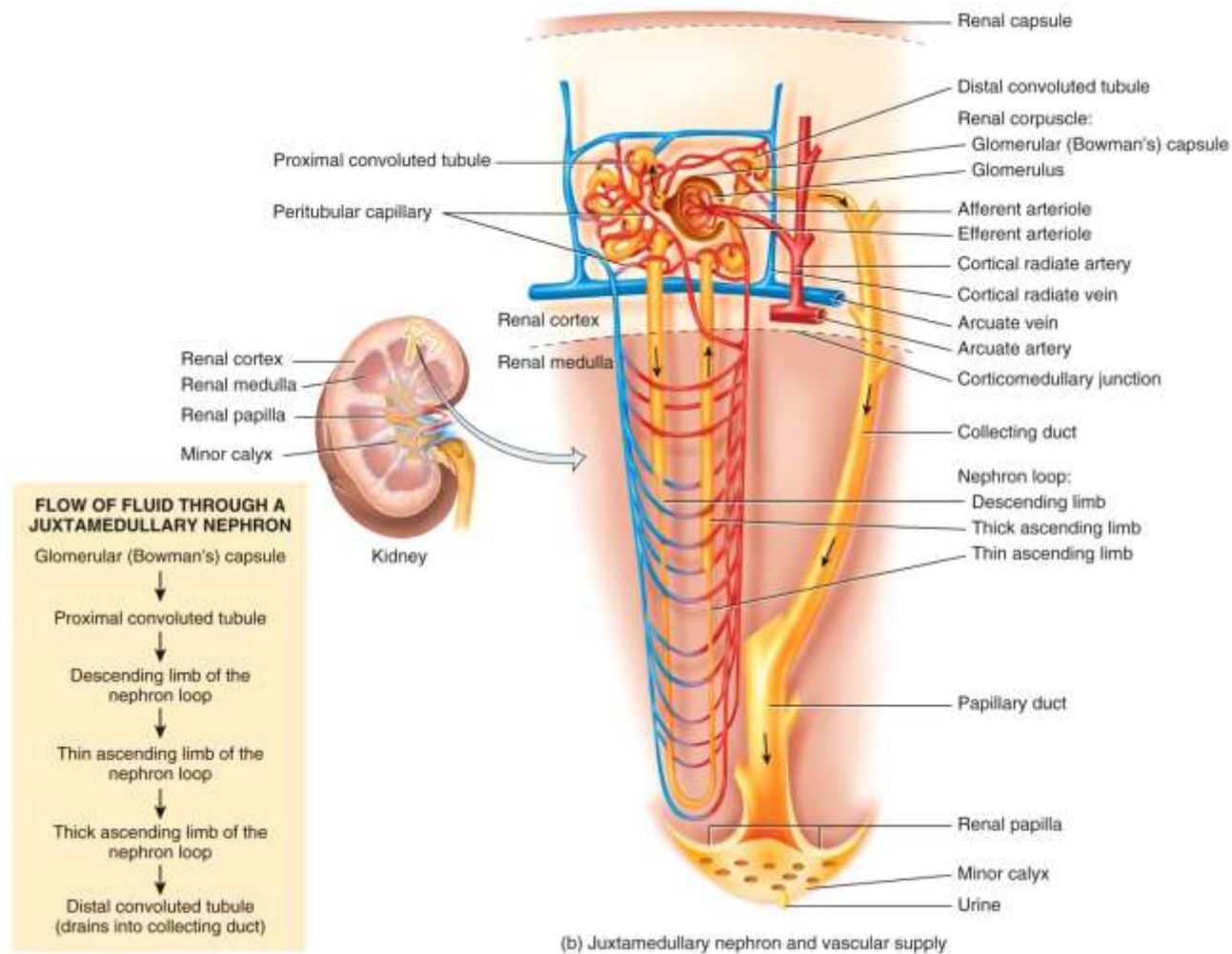


The Structure of Nephrons and Associated Blood Vessels





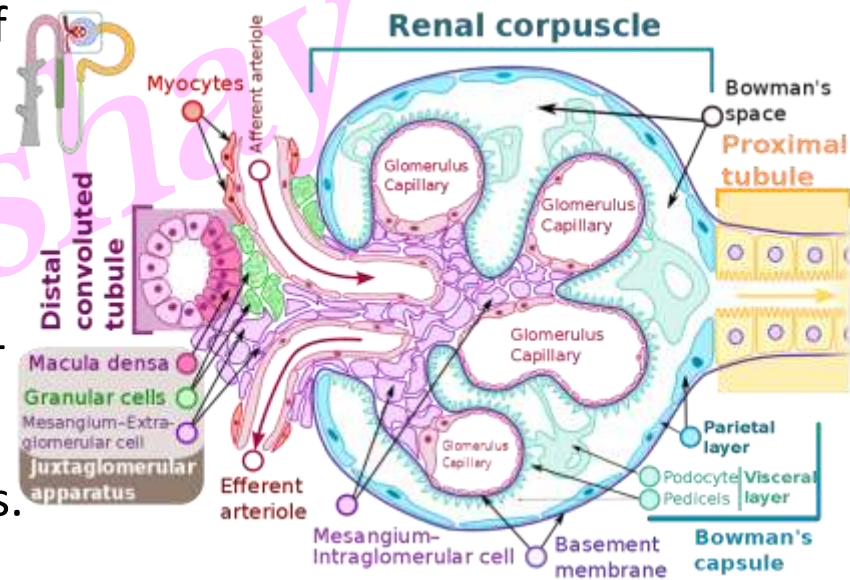
The Structure of Nephrons and Associated Blood Vessels



Histology of the Nephron and Collecting Duct



- **Glomerular (Bowman's) capsule**
 - Podocytes: (within visceral layer) are cells in the Bowman's capsule in the kidneys that wrap around capillaries of the glomerulus. Podocyte cells make up the epithelial lining of Bowman's capsule, the third layer through which filtration of blood takes place.
 - Capsular (Bowman's) space: (or "urinary space", or "capsular space")—Between the visceral and parietal layers, into which the filtrate enters after passing through the filtration slits. Visceral layer—Lies just above the thickened glomerular basement membrane and is made of podocytes.





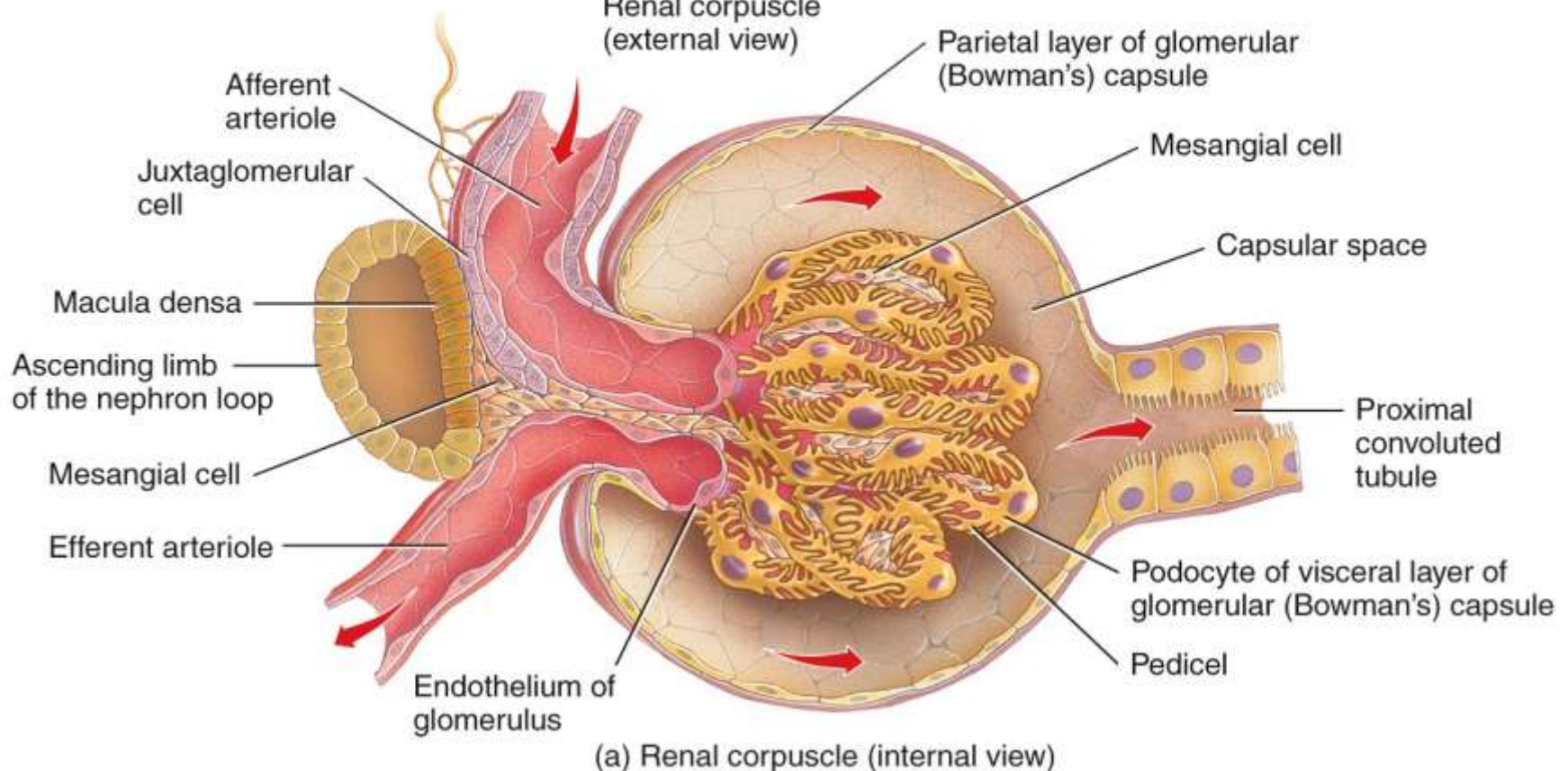
Clinical Connection

- Kidney transplant:
- A patient at Stage 4 has severe CKD, a GFR between 15-29 mL/min, and will likely need dialysis or a kidney transplant in the future
- *(According to the National Kidney Foundation, normal results range from 90 to 120 mL/min/1.73 m²)*
- Tissue typing
- Cross match
- Anti-rejection medications

Histology of a Renal Corpuscle

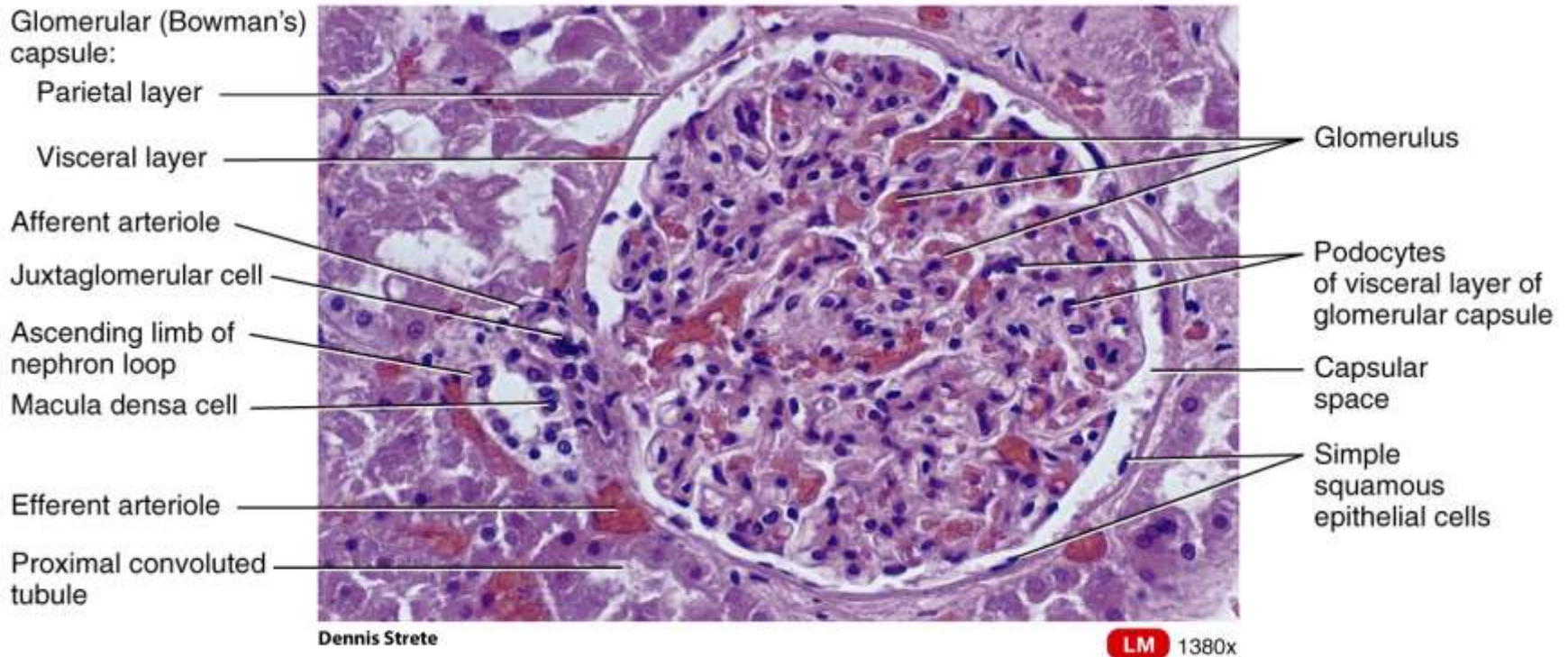


Renal corpuscle
(external view)





Histology of a Renal Corpuscle



(b) Renal corpuscle



Renal Tubule and Collecting Duct

- **Principal cells** are the main Na^+ reabsorbing cells and the site of action of aldosterone, K^+ -sparing diuretics, and spironolactone.
Principal cells secrete K^+ through an apical membrane potassium channel
 - Have receptors for two hormones that regulate function:
 - Antidiuretic hormone (ADH)
 - Aldosterone



Clinical Connection

- Glomerulonephritis:
- Based on integrative medicine: Nephritis in western medicine is **WIND WATER** in TCM:
- Fever, loin pain, sudden face edema

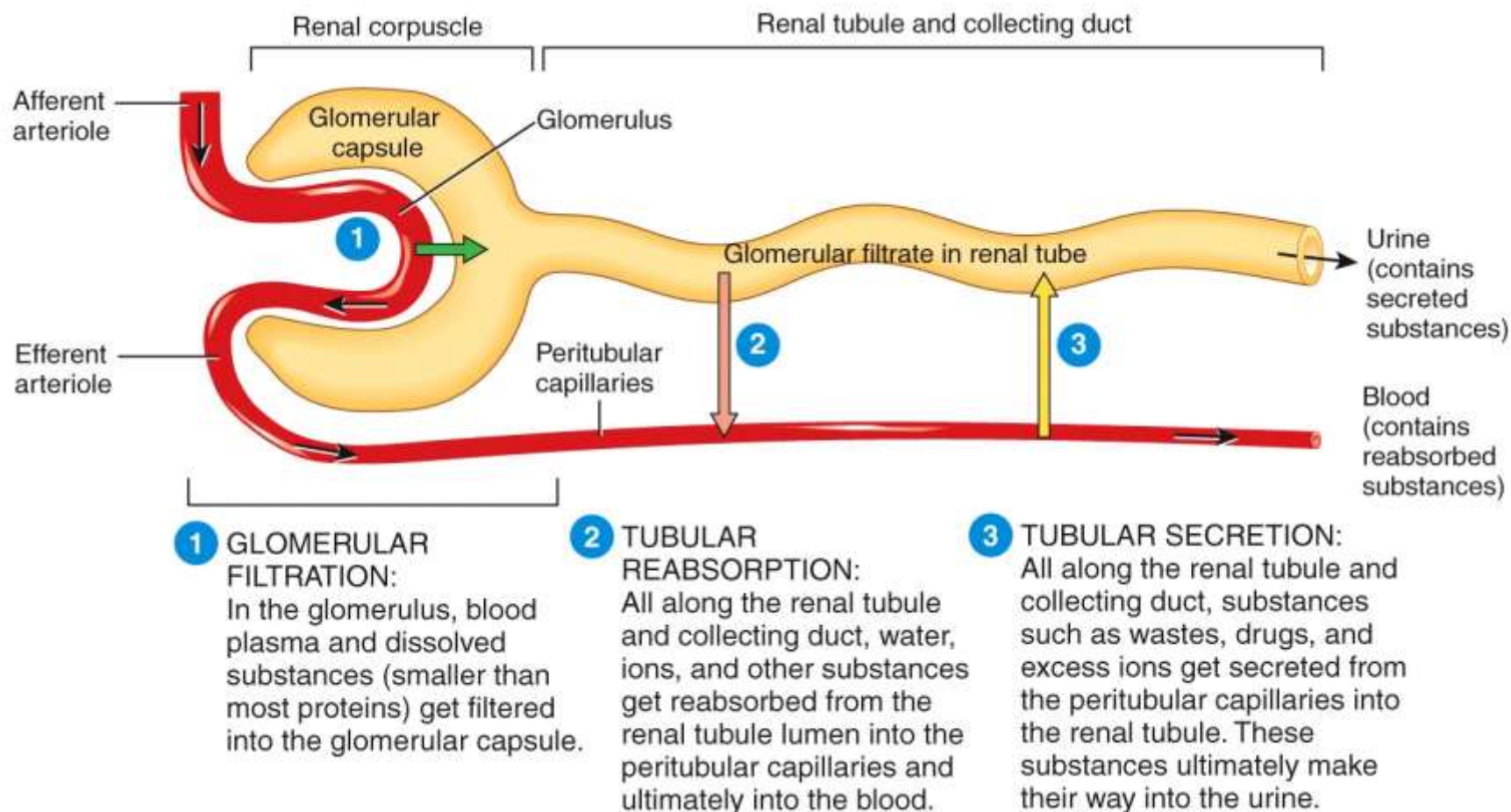


Functions of Nephrons

- *Nephron is the glomerulus (capillary network) & glomerular (Bowman 's) capsule:*
 - Glomerular filtration
 - Tubular re-absorption
 - Tubular secretion



Relationship of a Nephron's Structure to Its Three Basic Functions





Clinical Connection

- **Diuretics “water pills”**: is any substance that promotes diuresis, the increased production of urine. This includes forced diuresis. There are several categories of diuretics.
All diuretics increase the excretion of water from bodies, although each class does so in a distinct way.



Glomerular Filtration

- The fluid that enters the capsular space is called the glomerular filtrate.
- Average daily volume of glomerular filtrate is 150 liters in females and 180 liters in males.
- Filtration membrane or endothelia–capsular membrane



Glomerular Filtration

- Filtered substances move from the bloodstream through **three barriers**:
 - Fenestrations (pores)
 - Basal lamina
 - Pedicels: The **podocytes** have long processes, called foot processes, foot projections, or **pedicels**, for which the cells are named (podo- + -cyte). The foot projections wrap around the capillaries and leave slits between them. Blood is filtered through these slits, each known as a filtration slit or slit diaphragm



Glomerular Filtration

- Principle of filtration
- The volume of fluid filtered by the renal corpuscle is much larger than in other blood capillaries because:
 1. Glomerular capillaries present a large surface area for filtration.
 2. The filtration membrane is thin and porous.
 3. Glomerular capillary blood pressure is high.



Renal Filtration

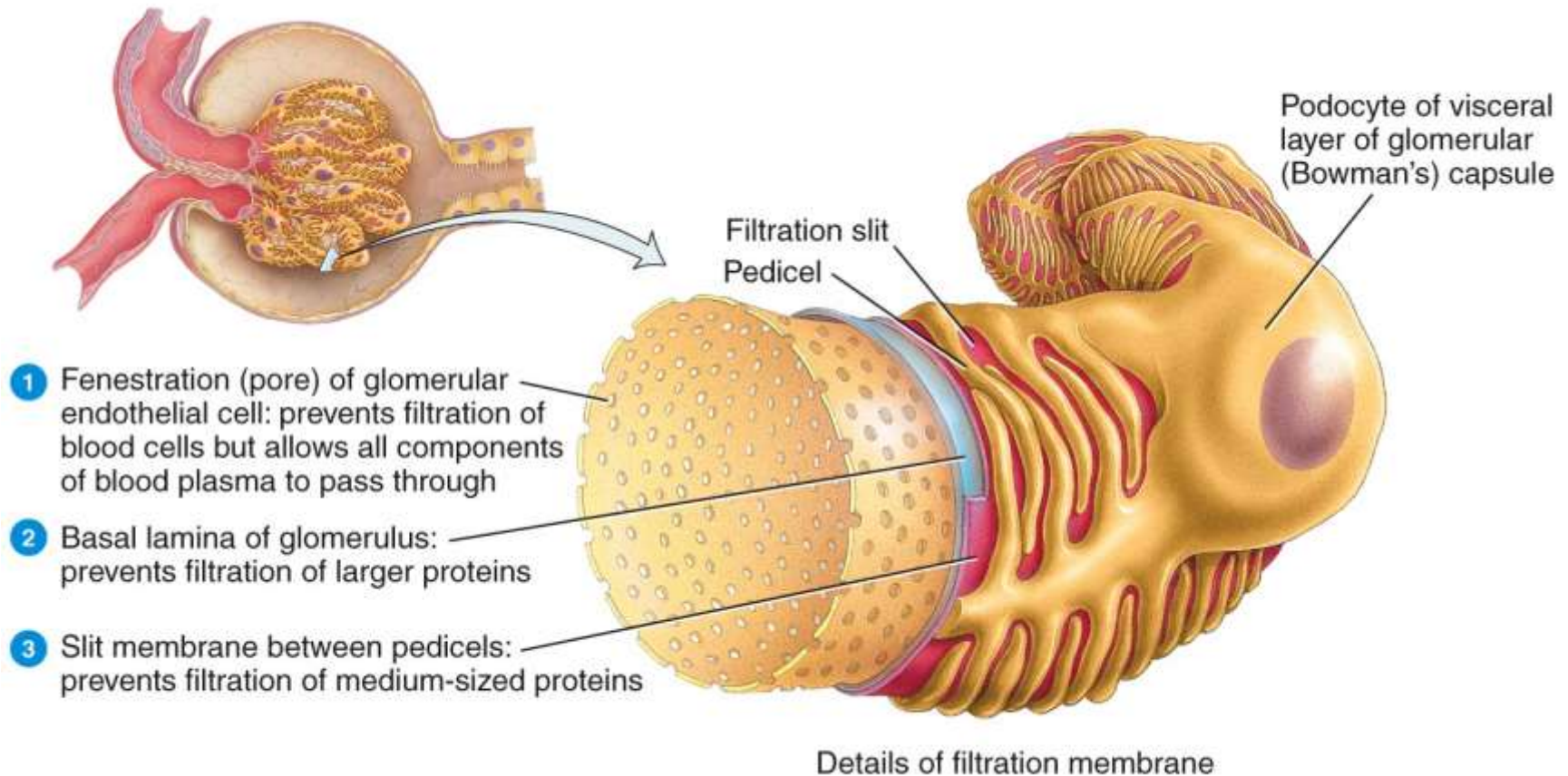
Interactions Animation

- [Renal Filtration](#)

R. Bishay

You must be connected to the internet to run this animation.

The Filtration (Endothelial–Capsular) Membrane





Tubular Reabsorption

- Epithelial cells all along the renal tubule and duct carry out reabsorption, but **proximal convoluted tubule** cells make the largest contribution.



Tubular Secretion

- Tubular secretion is the transfer of materials from the blood and tubule cells into glomerular filtrate.
- Secreted substances include H^+ , K^+ , ammonium ions (NH_4^+), creatinine, and certain drugs such as penicillin.

Renal Reabsorption and Secretion

Interactions Animation



- [Renal Reabsorption and Secretion](#)

R. Bishay

You must be connected to the internet to run this animation.



Water Homeostasis

Interactions Animation

- [Water Homeostasis](#)

R. Bishay

You must be connected to the internet to run this animation.



Clinical Connections

- Renal failure:**five stages of CKD and GFR for each stage:**
- **Stage 1** with normal or high GFR (GFR > 90 mL/min)
- **Stage 2** Mild **CKD** (GFR = 60-89 mL/min)
- **Stage 3A** Moderate **CKD** (GFR = 45-59 mL/min)
- **Stage 3B** Moderate **CKD** (GFR = 30-44 mL/min)
- **Stage 4** Severe **CKD** (GFR = 15-29 mL/min)
- **Stage 5** End **Stage CKD** (GFR <15 mL/min)
- *A patient at Stage 4 has severe CKD, a **GFR** between 15-29 mL/min, and will likely need dialysis or a kidney **transplant** in the future*
- Dialysis:There are **three** primary and two secondary **types of dialysis**: **hemodialysis** (primary), peritoneal **dialysis** (primary), hemo-filtration (primary), hemodiafiltration (secondary) and intestinal **dialysis** (secondary)



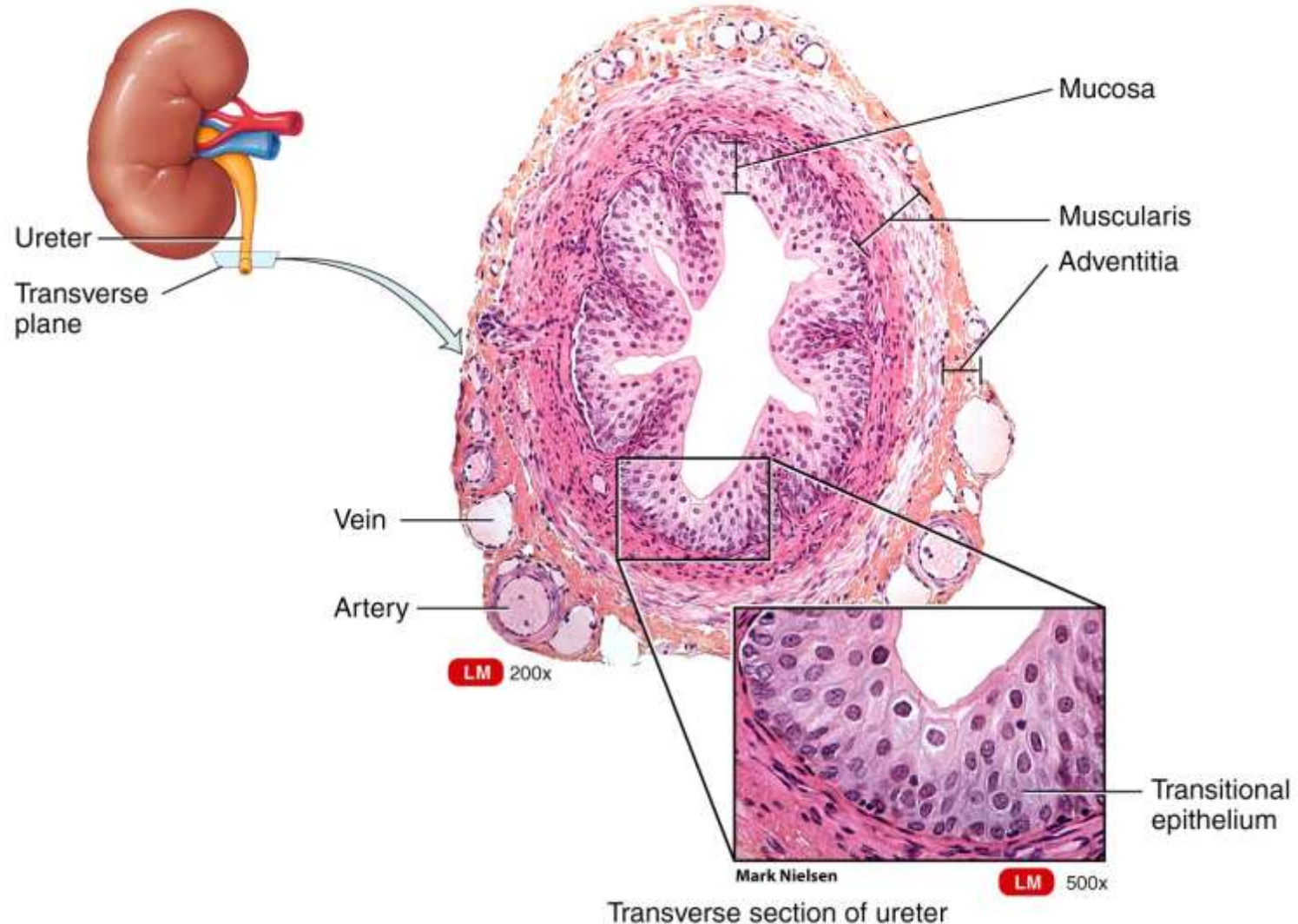
Ureters

- The ureters transport urine from the renal pelvis of one kidney to the urinary bladder.

R. Bishay



Histology of the Ureter





Clinical Connection

- **Cystoscopy:** is a procedure that allows your doctor to examine the lining of your bladder and the tube that carries urine out of your body (urethra). A hollow tube (**cystoscope**) equipped with a lens is inserted into your urethra and slowly advanced into your bladder



Urinary Bladder

- The urinary bladder is a hollow, distensible muscular organ.
- In males, it is directly anterior to the rectum.
- In females, it is anterior to the vagina and inferior to the uterus.



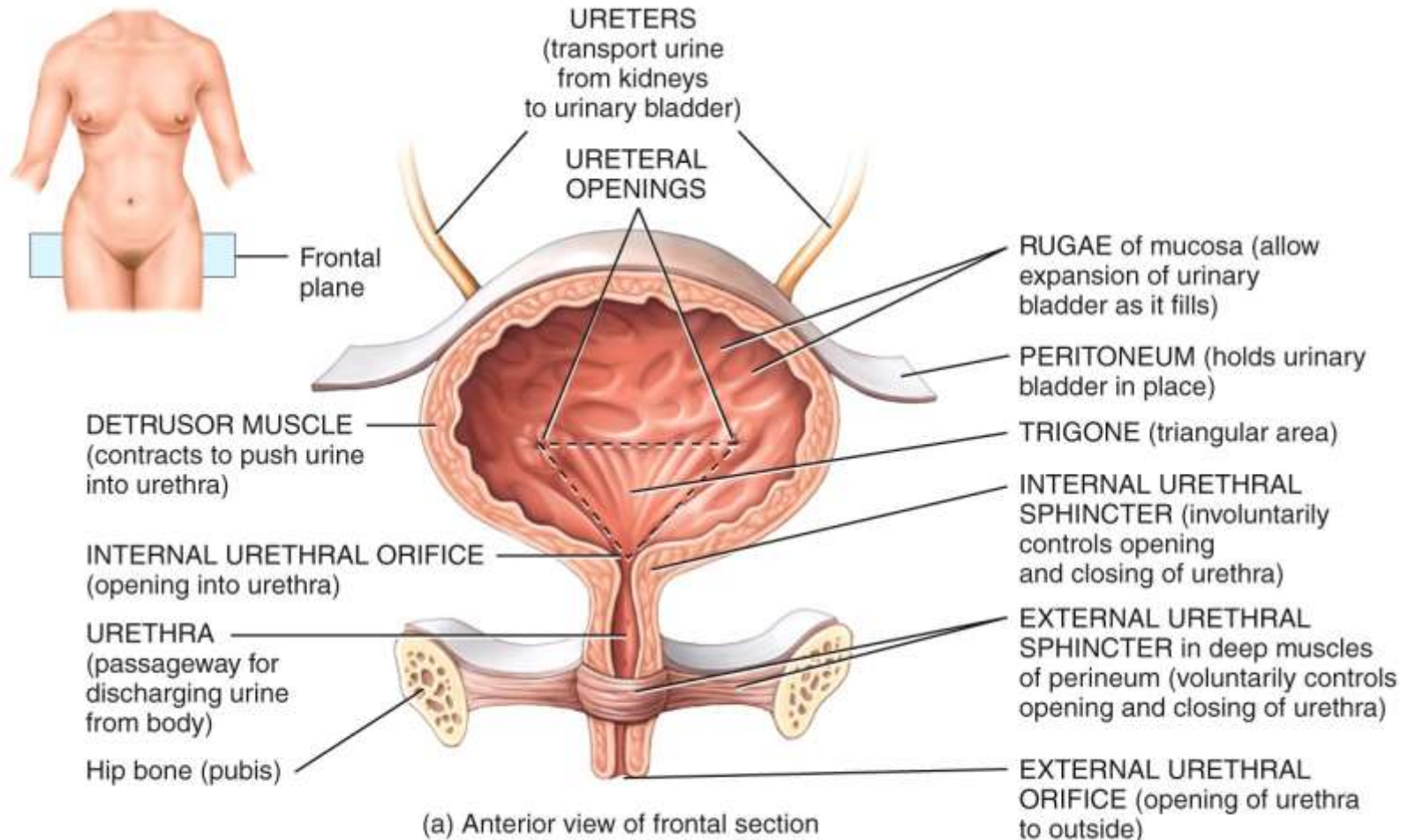
- Trigone
 - Two posterior corners contain the two ureteral openings.
 - Internal urethral orifice lies in the anterior corner.



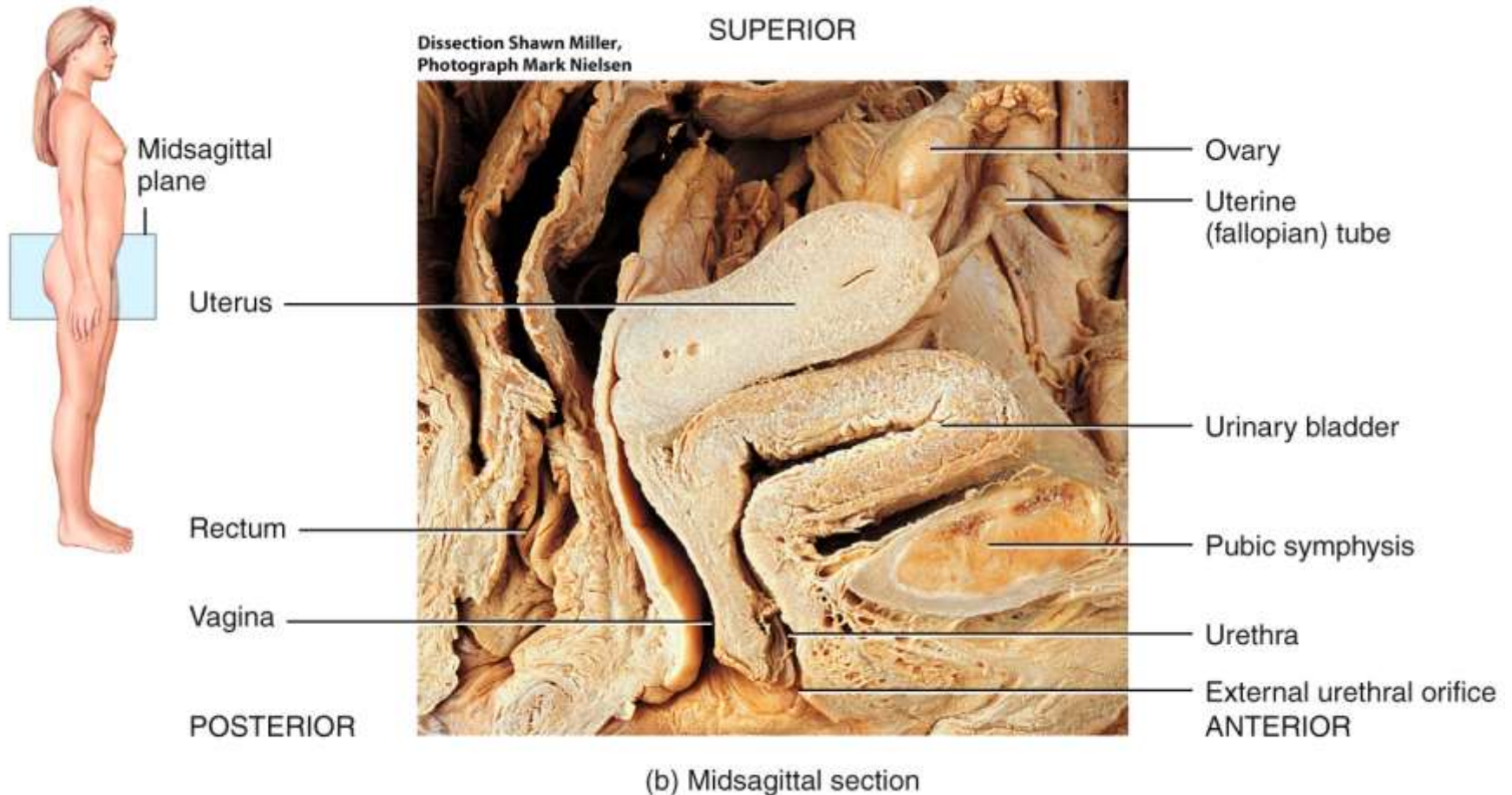
Urinary Bladder

- Three coats make up the wall of the urinary bladder:
 - Mucosa
 - Rugae
 - Muscularis (detrusor muscle)
 - Internal urethral sphincter
 - External urethral sphincter
 - Adventitia
 - Serosa

Ureters, Urinary Bladder, and Urethra in a Female

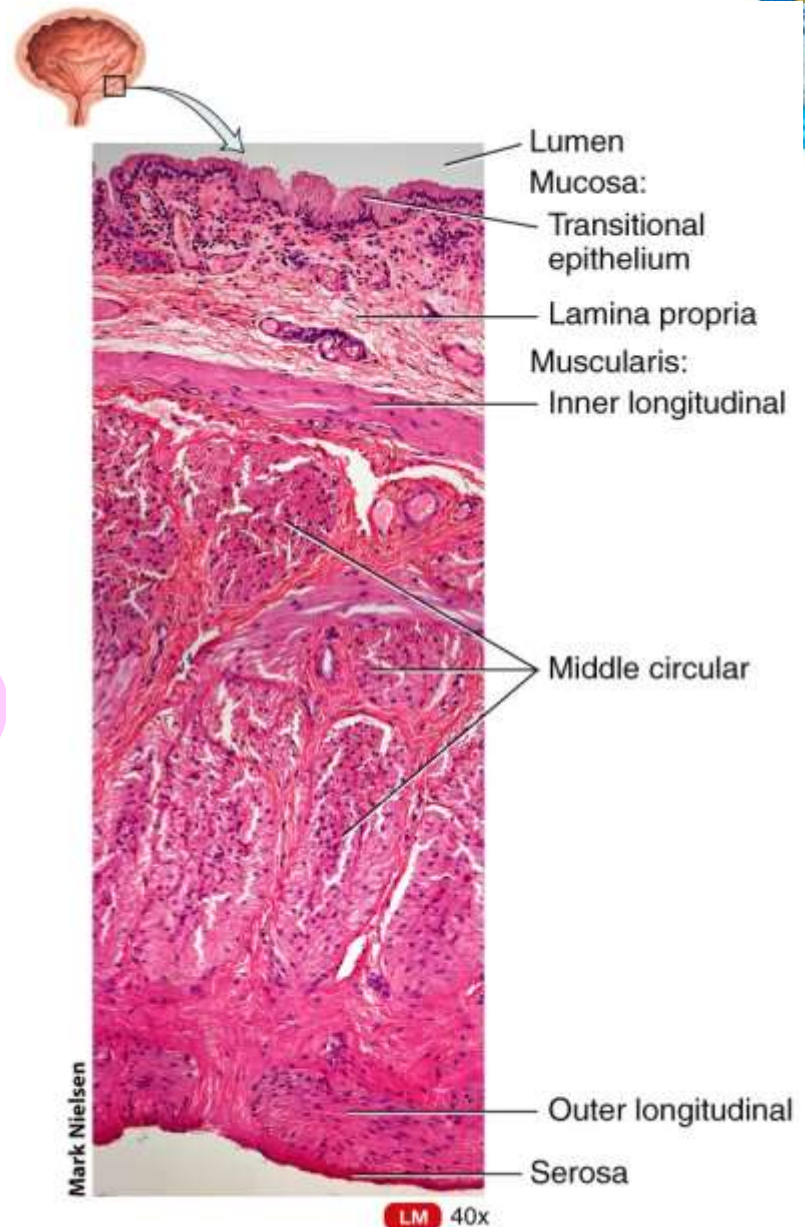


Ureters, Urinary Bladder, and Urethra in a Female



Histology of the Urinary Bladder

R. B



Transverse section of urinary bladder



Clinical Connection

- Incontinence
- **Urinary incontinence is more common than inability to control bowel movements and is further subdivided into the following types:**
- Stress incontinence. ...
- Overflow incontinence. ...
- Urge incontinence or overactive bladder. ...
- Functional incontinence. ...
- Mixed incontinence. ...
- Total incontinence. ...
- Bedwetting.



Urethra

- The urethra is a small tube leading from the internal urethral to the exterior of the body.
- Females
 - The opening of the urethra is the external urethral orifice.
 - The wall of the urethra consists of a deep mucosa and a superficial muscularis.
 - Female urethra is shorter than male one, more susceptible to UTI.s

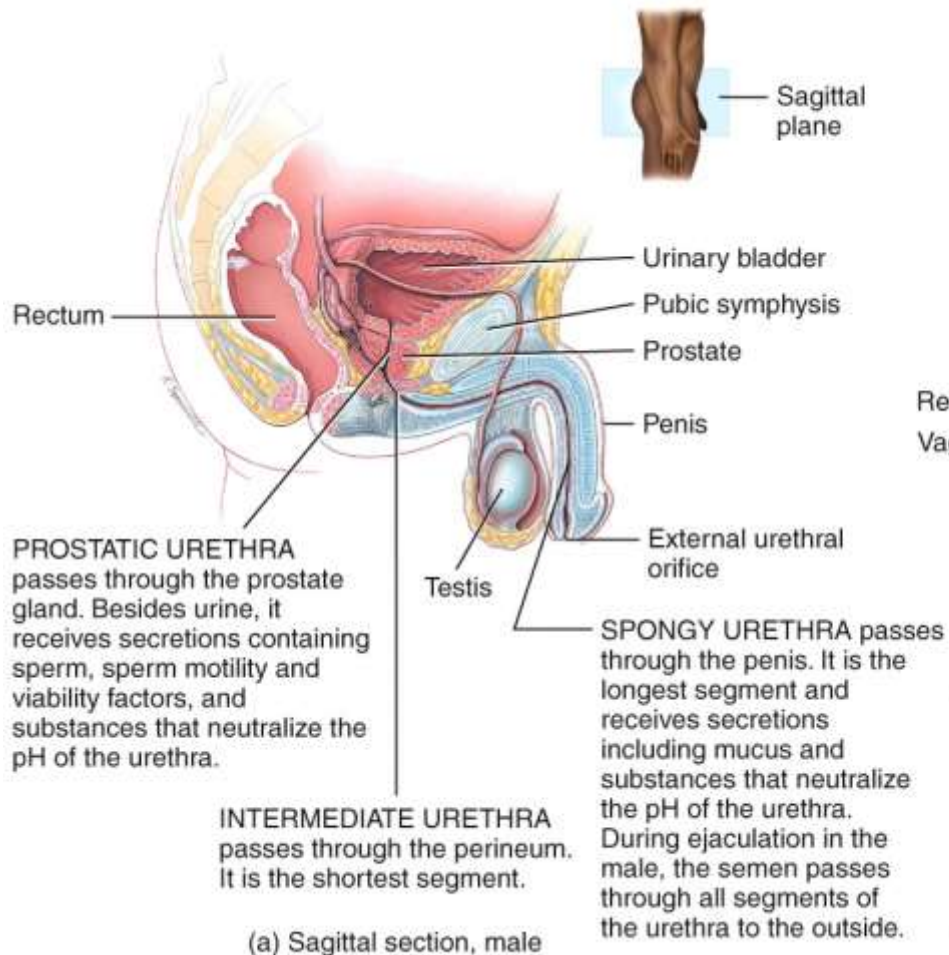
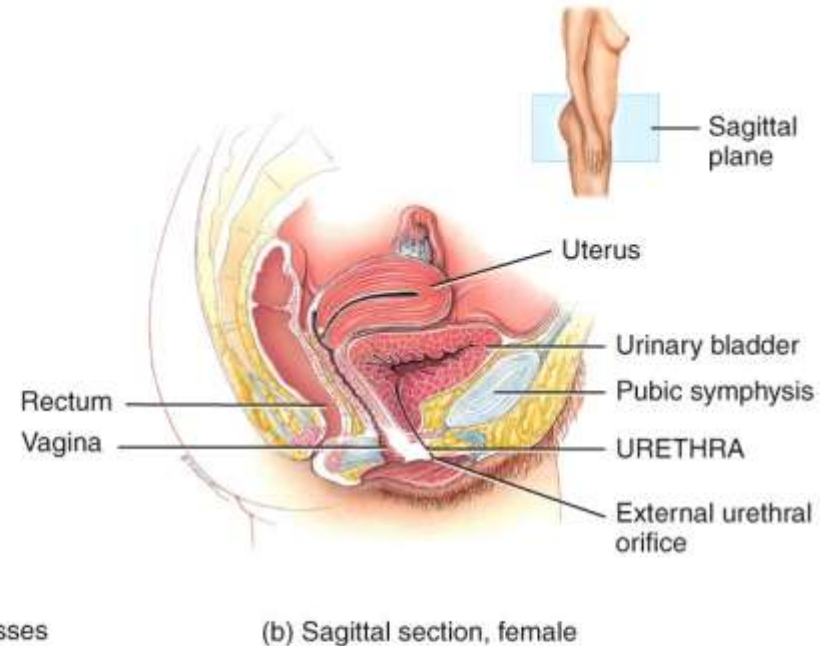


Urethra

- Males
 - The urethra first passes through the prostate, then through the deep perineal muscles, and finally through the penis.

R. Bishnoi

Comparison Between Female and Male Urethras



MALES VS. FEMALES

- The urethra is five times longer in males than in females.
- The urethra is divided into three segments in males but is only one short tube in females.
- The urethra is a common duct for the urinary and reproductive systems in males. These two systems are entirely separate in females.



Clinical Connection

- **Urinalysis:**
- A urinalysis is a test of your urine. A urinalysis is used to detect and manage a wide range of disorders, such as urinary tract infections, kidney disease and diabetes. A urinalysis involves checking the appearance, concentration and content of urine.