EXCRETION IN MAMMALS

INTRODUCTION:
OBJECTIVES

- Excretion is the removal of toxic waste products of metabolism from the body
- The end products of metabolism have to be eliminated to the outside
- The process of excretion and osmoregulation are performed by the same set of organs and homeostatis.
- In this chapter you will study how animals get rid of toxic nitrogen
- You will also study the structure and function of the excretory organs and the mechanism that regulate kidney function

NITROGEN EXCRETION

- Nitrogen is a characteristic constituent of amino acids and proteins
- Animals receive amino acids in diet and use them to synthesize a variety of functional nitrogenous compounds such as nucleic acids, proteins both enzymic and non-enzymic, some hormones and neurotransmitters
- The amount of amino acids obtained in diet is usually in excess of the need for the synthesis of the functional nitrogenous compounds
- The excess of amino acids is either catabolised for the release of energy or is used for the synthesis of glycogen and fat
- When amino acids, proteins or nucleic acids are catabolised, nitrogen containing excretory end-products are formed, which are **ammonia,urea and uric acid**

CLASSIFICATION OF ANIMALS ACCORDING TO TYPE OF EXCRETORY PRODUCTS

- Animals are often grouped according to their main excretory products:

i. Those that excrete mainly ammonia as the end product of protein metabolism are called **ammonotelic**

ii. Those that excrete mostly urea are **ureotelic**

iii. Those that form mainly uric acid are **uricotelic**

iv. Those that secrete guanine are **guanotelic**

Table 4.1 : Major Nitrogen Excretory Products in Various Animal Groups

Animal	Major end-product of protein metabolism	Habitat
Aquatic invertebrates	Ammonia	Aquatic
Teleost fish	Ammonia, some urea	Aquatic
Elasmobranchs	Urea	Aquatic
Crocodiles	Ammonia, some uric acid	Semiaquatic
Amphibians, larval	Ammonia	Aquatic
Amphibians, adult	Urea	Semiaquatic
Mammals	Urea	Terrestrial
Turtles	Urea and uric acid	Terrestrial
Insects	Uric acid	Terrestrial
Land gastropods	Uric acid	Terrestrial
Lizards	Uric acid	Terrestrial
Snakes	Uric acid	Terrestrial
Birds	Uric acid	Terrestrial

VERTEBRATE KIDNEY

- Typically, al vertebrates have a pair of kidneys, which function on the filtration-reabsorption-secretion principle
- The kidneys are the primary means for eliminating waste products of metabolism that are no longer needed by the body
- These products include urea (from the metabolism of amino acids),creatinine (from muscle creatine), uric acids (from nucleic acids), end products of haemoglobin breakdown (such as bilirubin) and metabolites of various hormones
- These waste products must be eliminated from the body as rapidly as they are produced
- The kidneys also eliminate most toxins and other foreign substances that are either produced by the body or ingested, such as pesticides, drugs and food additives.

EXCRETORY SYSTEM IN VERTEBRATES

- The urinary system is almost similar in all vertebrates
- It consists of two kidneys located postero-dorsally
- From each kidney a ureter, or excretory duct, carries the urine posteriorly
- In most mammals, the ureters empty into the bladder which opens to the outside through the urethra

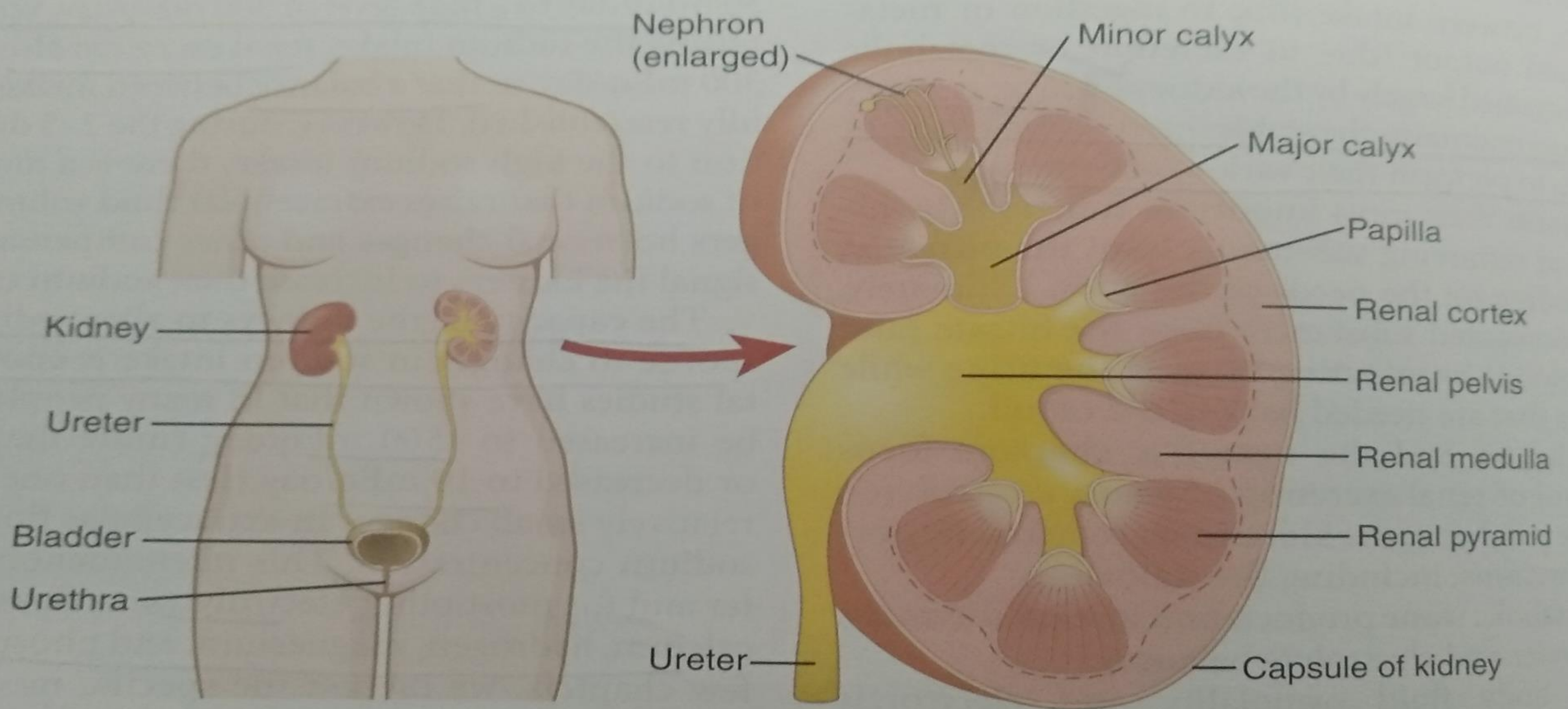
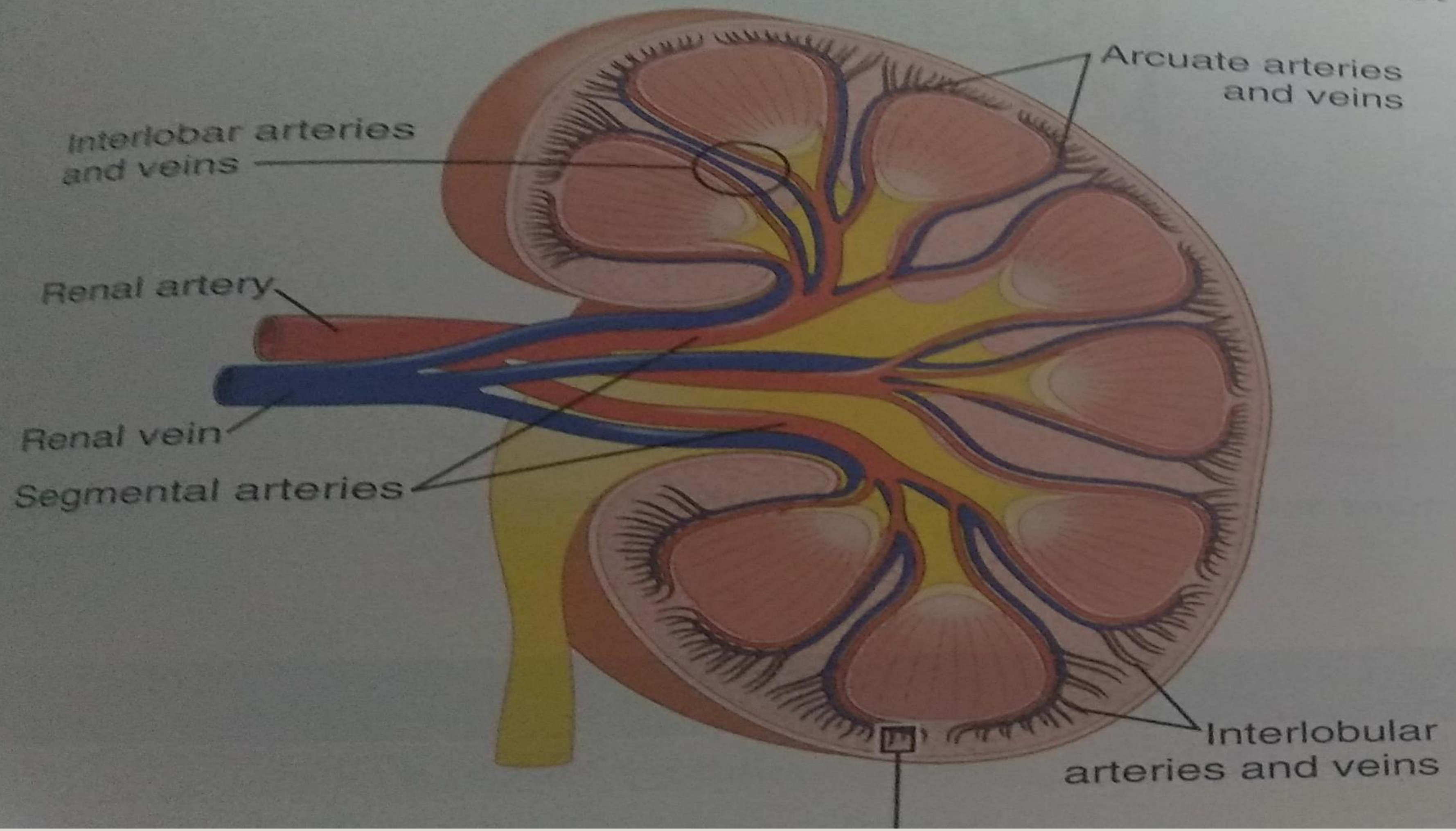


Figure 76-2 General organization of the kidneys and the urinary system.

FUNCTIONAL ANATOMY OF THE KIDNEYS

- In humans, the paired kidneys are bean shaped, each weighing about150grams, and are located just below the stomach, one on each side of the mid dorsal line
- Histologically, each kidney is made up of an outer zone, the cortex, and an inner zone, the medulla, including its connective tissue and rich vascular supply
- The medulla is divided into 8-10 cone-shaped masses of tissues called renal pyramids
- The base of each pyramid originates at the border between the cortex and medulla and terminates in the papilla, which projects into the space of the renal pelvis, a funnel shaped continuation of the upper end of the ureter
- The outer border of the pelvis is divided into open-ended pouches called major calyces that extend downward and divide into minor calyces, which collect urine from the tubules of each papilla
- The walls of the calyces, pelvis and ureter contain contractile elements that propel the urine toward the bladder, where urine is stored until it is emptied by micturition.
- Each kidney contains about one million single units called nephrons or renal tubules

1,000,000
nephrons, each capable of forming urine. The kidney cannot



NEPHRON OR KIDNEY TUBULE

- Each nephron which is about 45 to 65mm long consists of a round malpighian body,which is filled with capillary network called the glomerulus, and a tube which is divided into three parts-the proximal convoluted tubule (15mm long and55μm in diameter) located in the cortex, a thin segment (2 to 14mm long), and the distal convulted tubule (about 5 mm long), which joins with other tubules to form the collecting ducts that open into the pelvis of the kidney
- Part of the tubule, including the thin segment, makes a hairpin loop, which is called the loop of Henle which is greatly elongated and narrow loop is adapted specifically for water recovery by means of a countercurrent osmotic multiplier system
- Only animals (birds and mammals) that have the loop of Henle can excrete concentrated urine

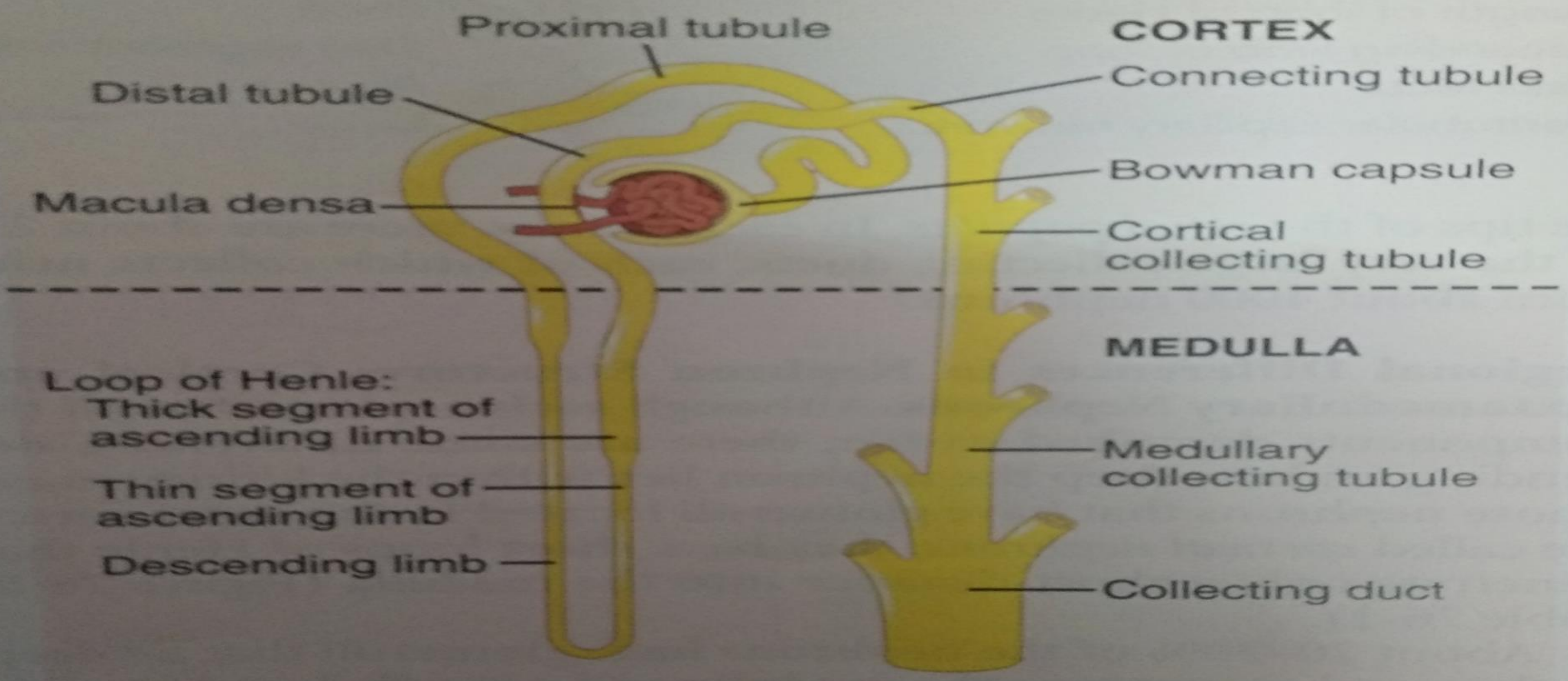


Figure 76-4 Basic tubular segments of the nephron. The relative lengths of the different tubular segments are not drawn to scale.

FUNCTIONS OF KIDNEYS: WHY KIDNEYS ARE NECESSARY?

1. Regulation of water electrolyte balance
2. Regulation of Arterial Pressure
3. Regulation of Acid-Base Balance
4. Regulation of Erythrocyte Production
5. Regulation of 1,25- Dihydroxyvitamin D3 Production
6. Glucose synthesis

Question ???

MECHANISM OF URINE FORMATION

- Urine Formation results from Glomerular Filteration, Tubular Reaborption and Tubular secretion
- Expressed mathematically,

Urinary excretion rate = Filteration rate – Reabsorption rate + Secretion rate

- Urine formation begins when a large amount of fluid that is virtually free of protein is filtered from the glomerular capillaries into Bowman's capsule
- As filtered fluid leaves Bowman's capsule and passes through the tubules, it is modified by reabsorption of water and specific solutes back into the blood or by secretion of other substances from the peritubular capillaries into the tubules.

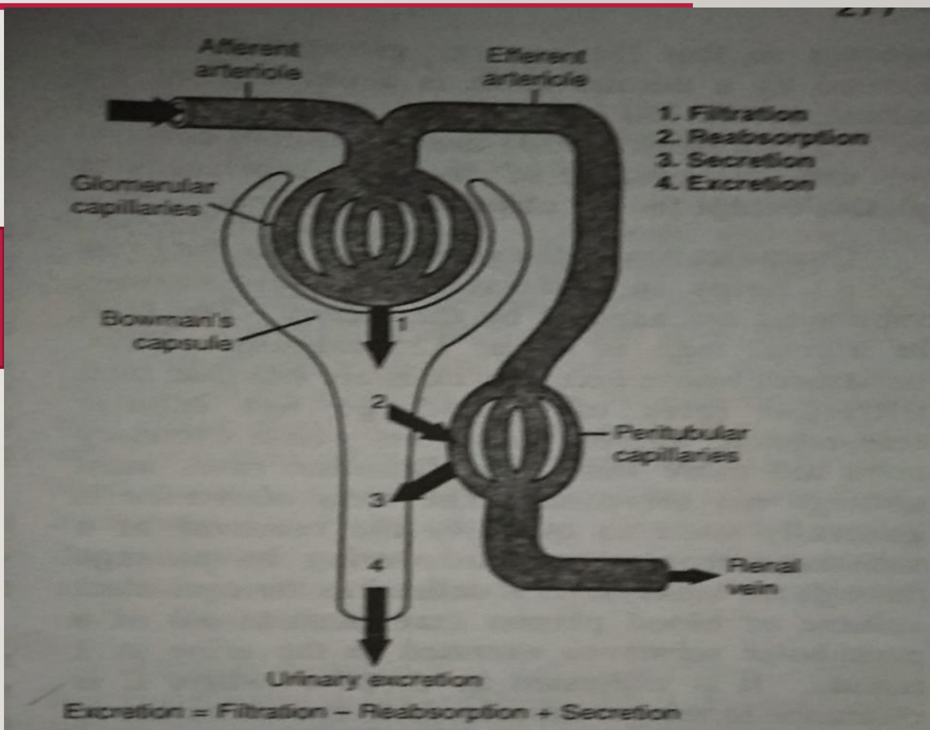


Fig. 20.4. Processes that determine the composition of the urine. Urinary excretion rate of a substance is equal to the rate at which the substance is filtered minus its reabsorption rate plus the rate at which it is secreted from the peritubular capillary blood into the tubules.

QUESTION TIME

Why the GFR
is so high?

1. GLOMERULAR FILTERATION

- This is the first step in making urine
- It is the process that kidneys use to filter excess fluid and waste product out of blood into the urine collecting tubules of the kidney so that they maybe eliminated from the body.
- Urine formation begins with filtration of large amounts of fluid through the glomerular capillaries into Bowman's capsule
- Like most capillaries, the glomerular capillaries are relatively impermeable to proteins, so the filtered fluid (called the glomerular filterate) is essentially protein free and devoid of cellular elements including red blood cells

- Blood entering the glomerulus through the afferent arteriole is filtered into the lumen of the Bowman's capsule to give rise to ultrafilterate.
- The glomerular filterate is nearly isosmotic to plasma and contains ions and other solutes of small size essentially at the same concentrations as in plasma
- The blood pressure in the glomerular capillaries provides the driving force for filteration
- High hydrostatic pressure in the glomerular capillaries (about 60mm Hg) causes rapid fluid filteration, whereas a much lower hydrostatic pressure in the peritubular capillaries (about 13mmHg) permits fluid reabsorption.

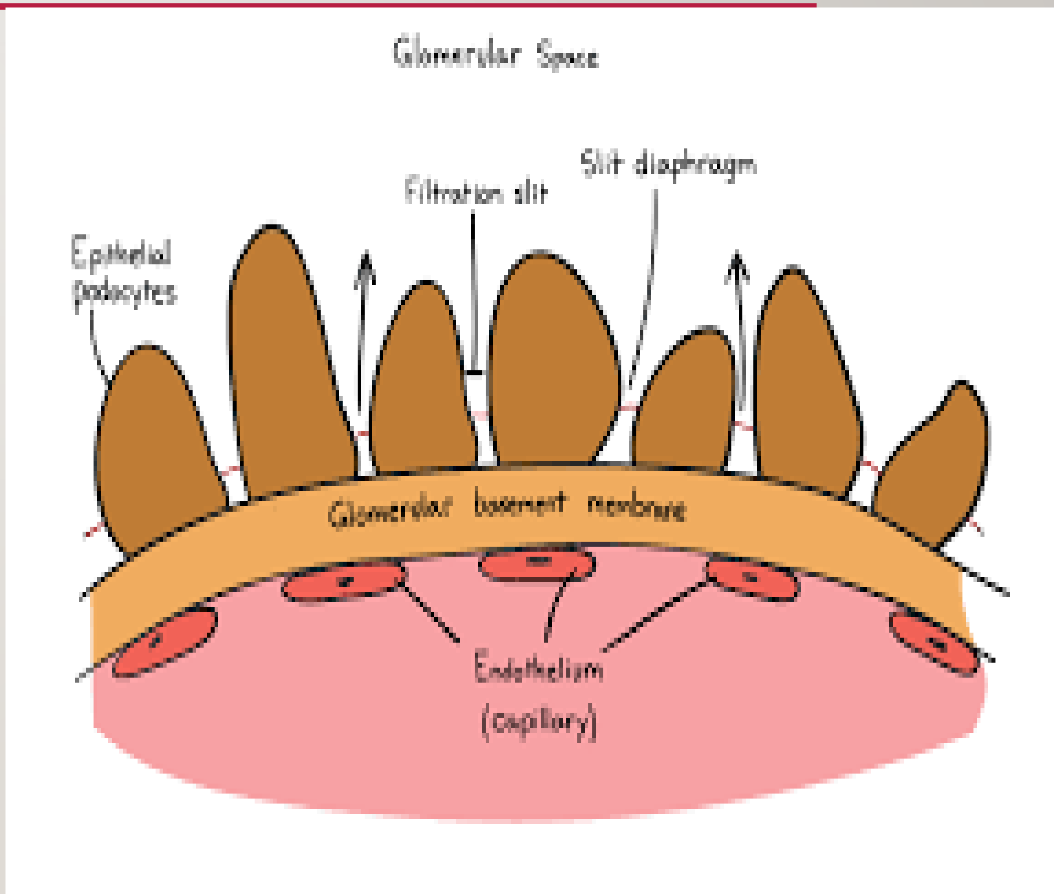
- In an average 70-kg man, the combined blood flow through both kidneys is about 1100mL/min or about 22% of the cardiac output

- Considering that the two kidneys constitute only about 0.4% of the total body weight, one can readily see that they receive an extremely high blood flow compared with other organs

GLOMERULAR CAPILLARY MEMBRANE

- The glomerular capillary membrane has three (instead of the usual two)major layers:

1. Endothelium
2. A basement membrane
3. A layer of epithelial cells (podocytes) surrounding the outer surface of the capillary membrane



- Filterability of solutes is inversely related to their size
- Negatively Charged large molecules are filtered less easily than positively charged molecules of equal molecular size
- Minimal change nephropathy

QUANTIFICATION OF GFR

- Quantification of the GFR helps in understanding how various substances are handled by the kidneys
- The GFR in normal man is about 125ml/min
- Thus substances whose excretory rates are less than their filtration rates must undergo net tubular reabsorption,whereas substances whose excretory rates are are more than their filtration rates must undergo secretion

CLEARANCE

- The term clearance is generally used to quantify the removal of a substance from the blood during its passage through the kidneys
- It is defined as the equivalent volume of blood plasma that contains all of a peritubular substance excreted in the urine in 1 minute
- It is expressed as $C = UV/P$, where C is the clearance in ml per minute, U is concentration in urine, V is the urine volume in ml per minute, and P is the plasma concentration

2. TUBULAR REABSORPTION

- The four segments of renal tubule- the proximal convoluted tubule (PCT), Loop of Henle (LH), distal convulted tubule (DCT) and collecting ducts (CD) –determine the composition and volume of urine by – (a) selective reabsorption of water and solutes and (b) by secretion of solutes
- Tubular Reabsorption – allows the kidneys to retain essential substances and regulate their levels by altering their reabsorption
- Glucose is completely reabsorbed
- Hormones , sympathetic nerves and Starling forces regulate NaCl reabsorption.
- ADH is the major hormone involved in the regulation of water reabsorption

ROUTES OF FILTERATION, REABSORPTION AND SECRETION

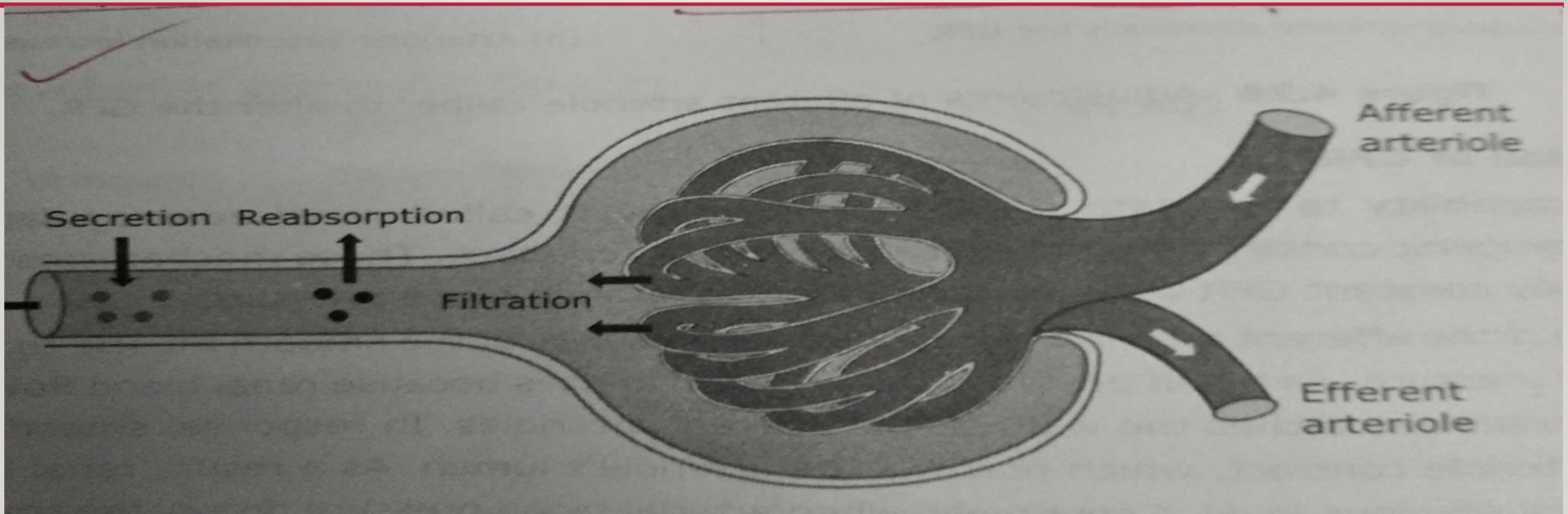


Figure 4.77 Filtration, reabsorption and secretion.

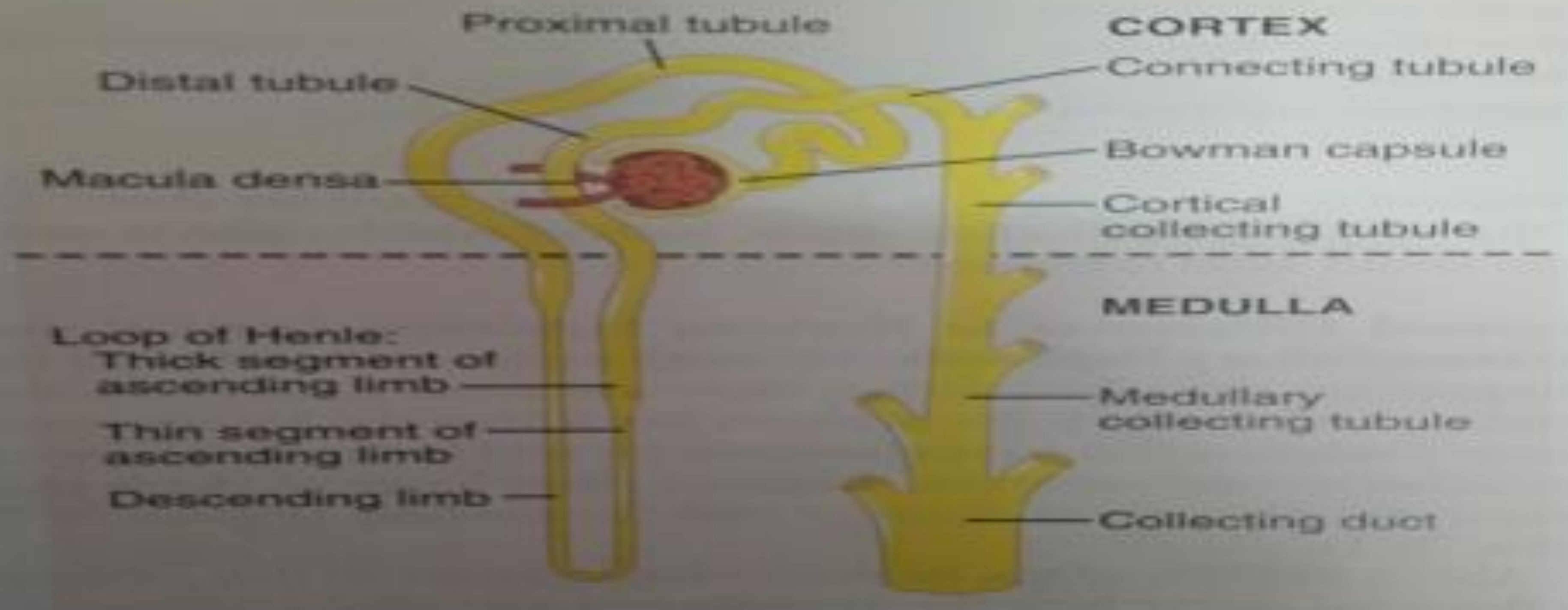
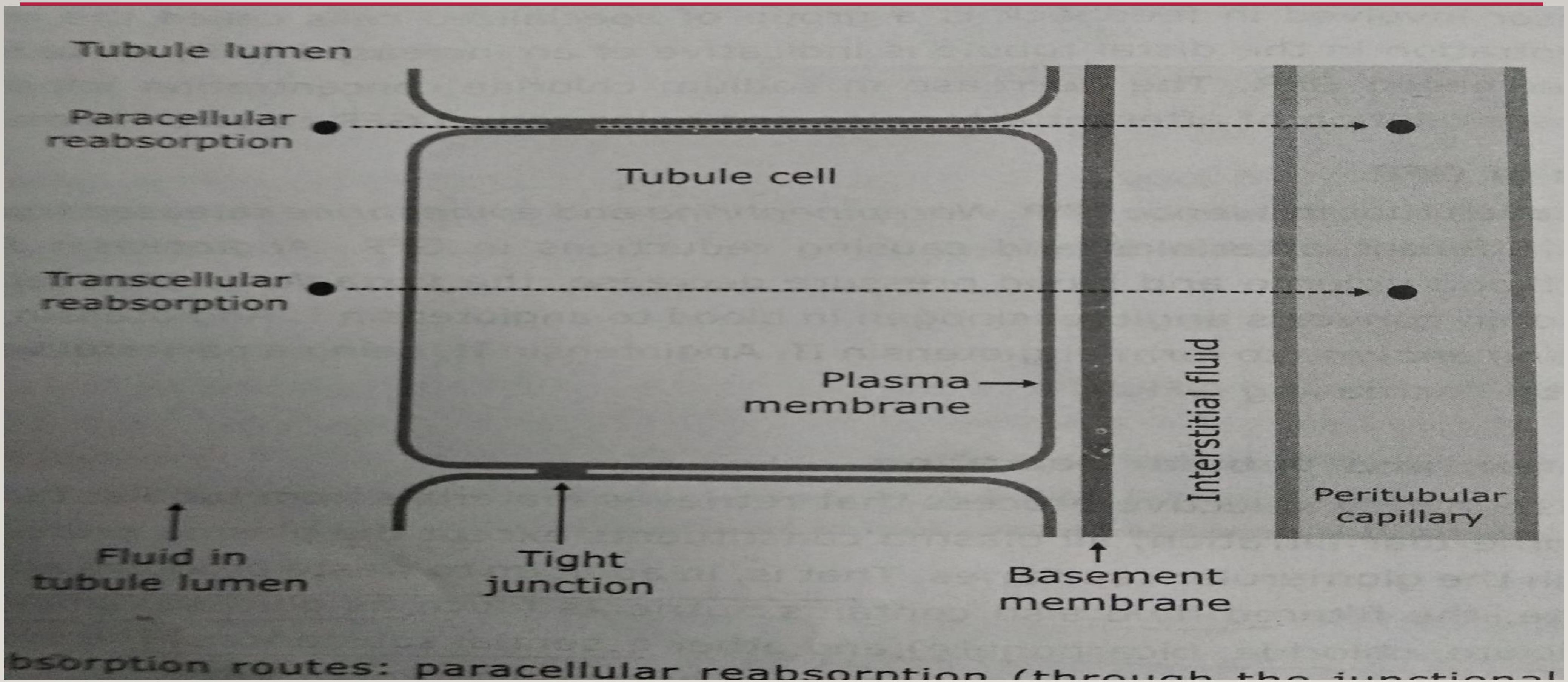


Figure 76-4 Basic tubular segments of the nephron. The relative lengths of the different tubular segments are not drawn to scale.

- Transport Maximum: The maximum amount of a substance that can be reabsorbed per unit time is called the transport maximum.
- With exception of sodium, all actively reabsorbed substances have a Tm
- Solutes are reabsorbed by both active and passive process
- In Primary active transport: the energy derived from the hydrolysis of ATP is used to pump a substance across a membrane against the gradient
- In Secondary active transport: the energy stored in an ion's electrochemical gradient is used for gradient transport.

PARACELLULAR AND TRANSCELLULAR REABSORPTION ROUTES:



3.TUBULAR SECRETION:

TUBULAR SECRETION: As fluid flows along the renal tubule and through the collecting duct, the tubule and duct cells also secrete substances into tubular fluid. Secreted substances include hydrogen ions, potassium ions, creatinine, urea and certain drugs such as pencillin

Importance of tubular secretion:

1. The secretion of hydrogen ion helps control blood pH
2. The secretion of some substances (such as urea, creatinine and certain drugs) not needed by the body are removed from the blood

REABSORPTION AND SECRETION

- Proximal tubule :
- Reabsorption: Ions (sodium, chloride, bicarbonate, potassium), glucose and amino acids
- Secretion: Hydrogen ions, urea, creatinine
- Thin descending loop of Henle
- Reabsorption : water, urea and sodium
- Thick ascending loop of Henle:
- Reabsorption: sodium, chloridepottasium, calcium, bicarbonate and magnesium
- Secretion: Hydrogen ion

- <u>Medullary collecting duct:</u>
- Reabsorption: Urea, sodium
- Secretion: Hydrogen ions
- The reabsorption of water by the late distal tubule and cortical and medullary collecting duct is ADH dependent. The reabsorption of water is controlled by the level of ADH

- <u>Early distal convoluted tubule:</u>
- Reabsorption: Sodium, chloride, calcium, magnesium
- Late distal convoluted tubule and cortical collecting duct
- <u>Late distal convoluted tubule and cortical collecting duct:</u>
- Reabsorption: Principal cells (sodium) and intercalated cells (potassium and bicarbonate)
- Secretion: Principal cells (potassium) and intercalated cells (hydrogen ion)

IMPORTANT EVENTS IN THE RENAL TUBULES

- **PROXIMAL CONVULTED TUBULE:**
- The initial processing of the glomerular filterate occurs in the PCT
- The main events in the PCT are:

1. Reabsorption of nearly 75% to 80% of water from filterate
2. Reabsorption of two-thirds of filtered sodium and slightly more of pottassium

THANK YOU