FOR SECOND YEAR STUDENTS

Lectures Notes

Unit – V

The body Fluids and Kidney

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LECTURE –1

MULTIPLE FUNCTIONS OF THE KIDNEYS IN HOMEOSTASIS

Excretion of metabolic waste products and foreign chemicals

- Kidneys are not only the **excretory organs** but are also the **regulatory organ** because their major role is in homeostasis.
  - Urea end product of amino acid metabolism.
  - Creatinine end product of metabolism of muscle.
  - Uric acid end product of nucleic acid metabolism.
  - Bilrubin end product of haemoglobin degradation.
  - Kidneys excrete harmful chemical substances. Toxins, Drugs, Heavy metals

Regulation of water and electrolyte balances

- Kidney maintain water balance in the body.

MULTIPLE FUNCTIONS OF THE KIDNEYS IN HOMEOSTASIS (CONTINUED)

Regulation of body fluid osmolality and electrolyte concentration

- Kidney response to sudden 10 fold increase in sodium intake from a low level of 30m Eq/day to high level of 300 m Eq/day within 2-3 days after rising the sodium intake, renal excretion also increases to about 300 m Eq/day.

Regulation of acid-base balance

- Body is under constant threat to develop acidosis. Kidneys play major role in preventing acidosis.

Regulation of arterial pressure

- Kidney play an important role in the regulation of arterial blood pressure kidney regulate arterial blood pressure by two ways.
- By regulating the volume of ECF.
- By renin angiotensin mechanism.

MULTIPLE FUNCTIONS OF THE KIDNEYS IN HOMEOSTASIS (CONTINUED)

Secretion, metabolism, and excretion of hormones

- Kidneys secrete money hormonal substances the harmones secreted by kidneys are:

1. Erythropoietin
2. Thrombopoitin
3. Renin
4. 1,25-Dihydroxy chole calciferol.
5. Prostaglandins

Gluconeogenesis

- Kidney synthesis glucose from amino acids and other precursors during prolong fasting a process referred as gluconeogensis.

Regulation of calcium bone metabolism

- Regulation of blood calcium level by activating 1,25 Dihydroxy chole calciferol into vitamin D. Vitamin D is necessary for the absorption of calcium intentine.

GENERAL ORGANIZATION OF THE KIDNEYS

- The two kidneys lie on the posterior wall of the abdomen outside the peritoneal cavity.
- Each kidney lies on one side of the vertebral column at the level of 12 thoracic to 3rd lumber vertebrae.
- Right kidney normally is situated lower than the left presumably because of the position of liver.
- Each kidney is about 10 to 12cm long, 5 to 6cm wide and 2.5 cm deep.
- Each kidney of the adult human weight about 150 grams and is about the size of the clenched fist.
- The medial side of each kidney contain an indented region called the hilum through which pass the renal artery and vein, lymphatics, nerve supply, and ureter that carries the final urine from the kidney to the bladder where it is stored until emptied.

Renal Fraction

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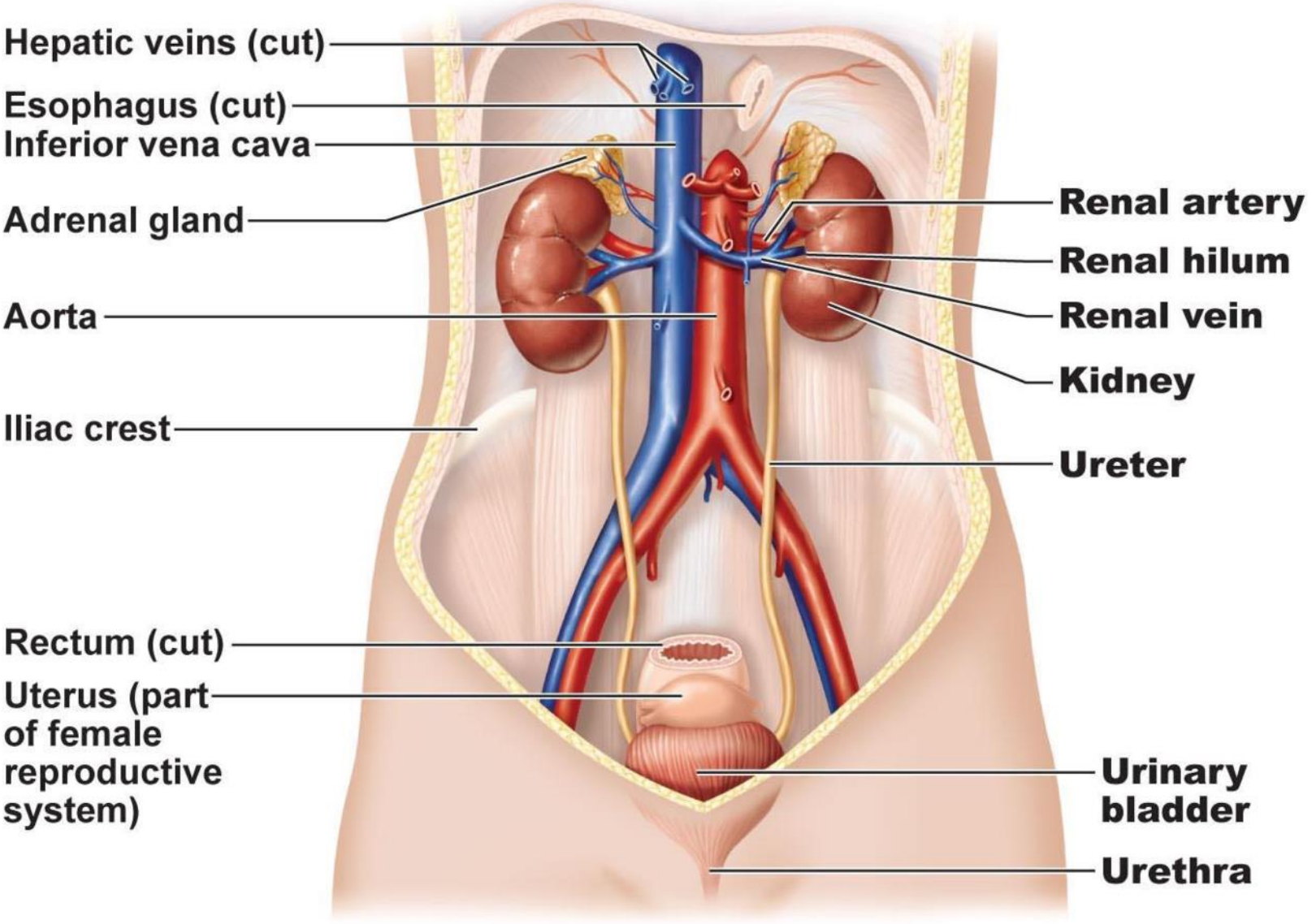
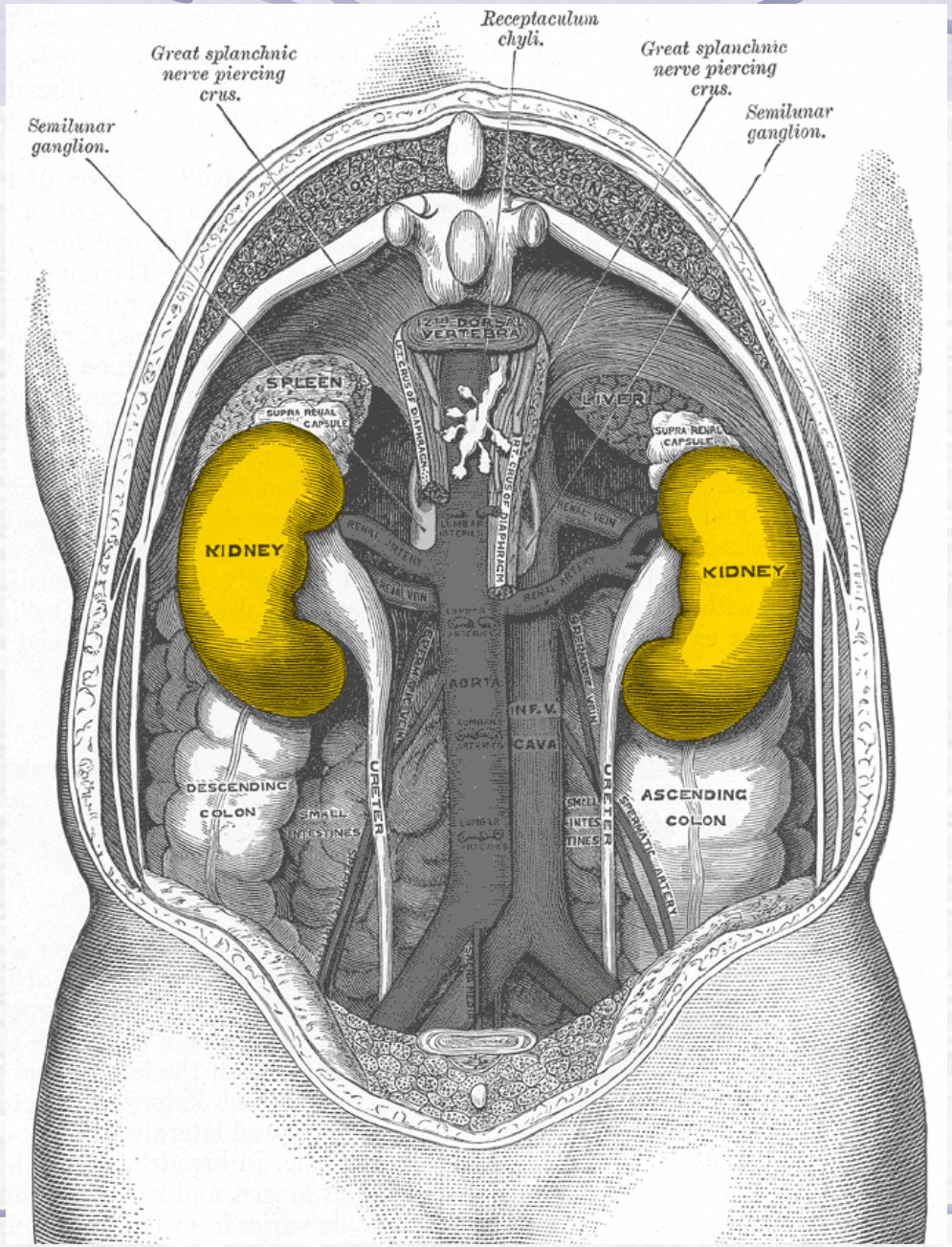
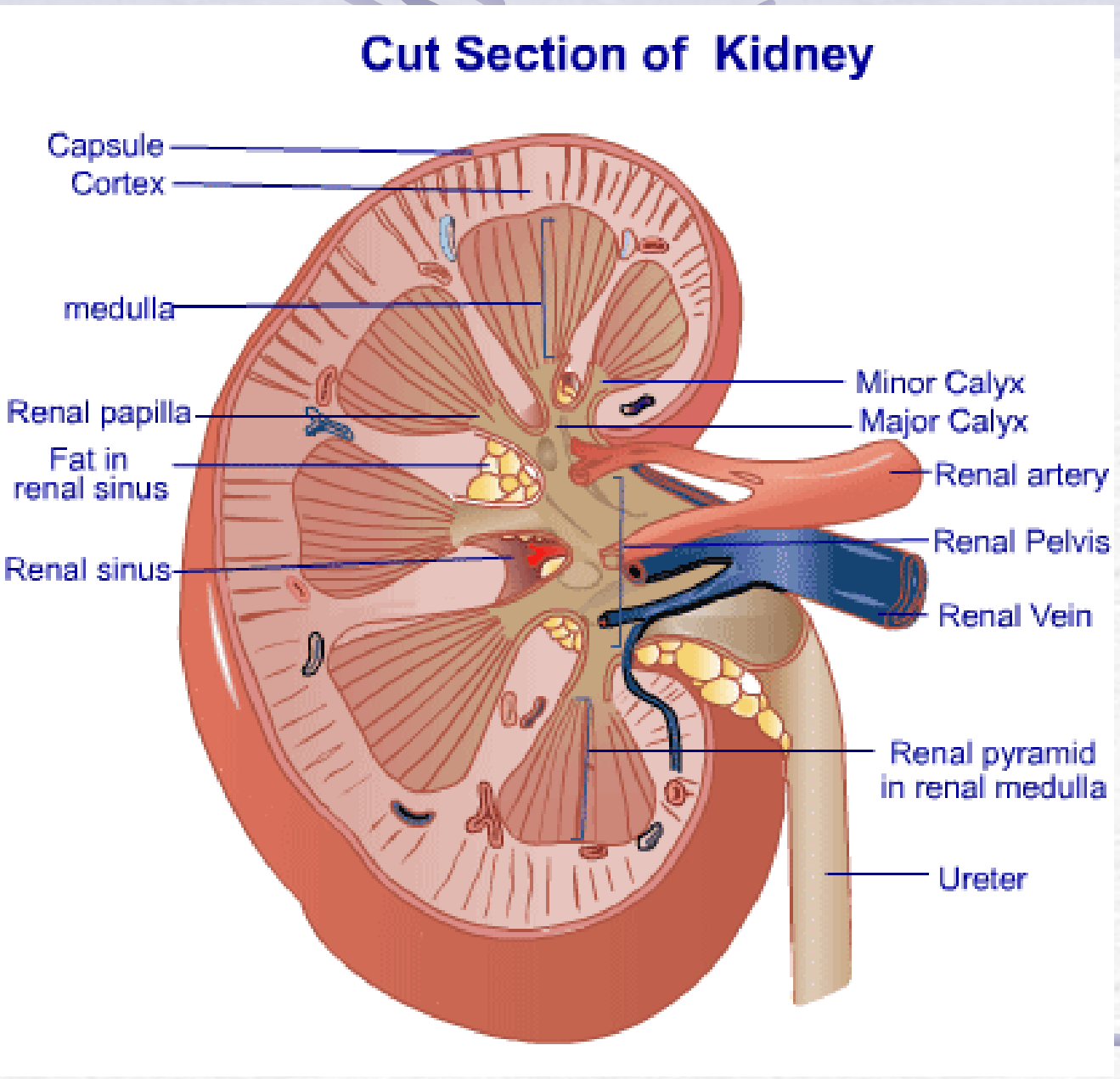



Receptaculum chyli.
Great splanchnic nerve piercing crus.
Great splanchnic nerve piercing crus.
Semilunar ganglion.
Semilunar ganglion.
12TH DORSAL VERTEBRA
SPLEEN
SUPRA RENAL CAPSULE
LIVER
SUPRA RENAL CAPSULE
KIDNEY
KIDNEY
RENAL ARTERY
RENAL VEIN
RENAL VEIN
RENAL ARTERY
AORTA
INF. V. CAVA
URETER
URETER
DESCENDING COLON
SMALL INTESTINES
SMALL INTESTINES
ASCENDING COLON
SPERMATIC ARTERY

PHYSIOLOGY ANATOMY OF THE KIDNEYS

- If the kidneys is bisected from top to bottom, the two major regions that can be visualized are
  - Outer cortex (granular in appearance)
  - Inner region medulla (striated triangles- renal pyramids)
- The medulla is divided into multiple **Cone shaped** masses of tissue called renal pyramids.
- The base of each pyramids originates at the border between the cortex and medulla and terminates in the **Papilla,** (8 to 18 per kidney) 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 calices** that extend downward and divide into **minor calices,** which collect urine from the tubules into minor calices, which collect urine from the tubules of each papillae.

Cut Section of Kidney



NEPRON

- Structural and functional unit of kidney.
- Each kidney consist of 1 to 1.3 million of nephrons.
- Nephron consist of a vascular component and tubular component both of which are intimately related structurally and functionally.

Vascular Component

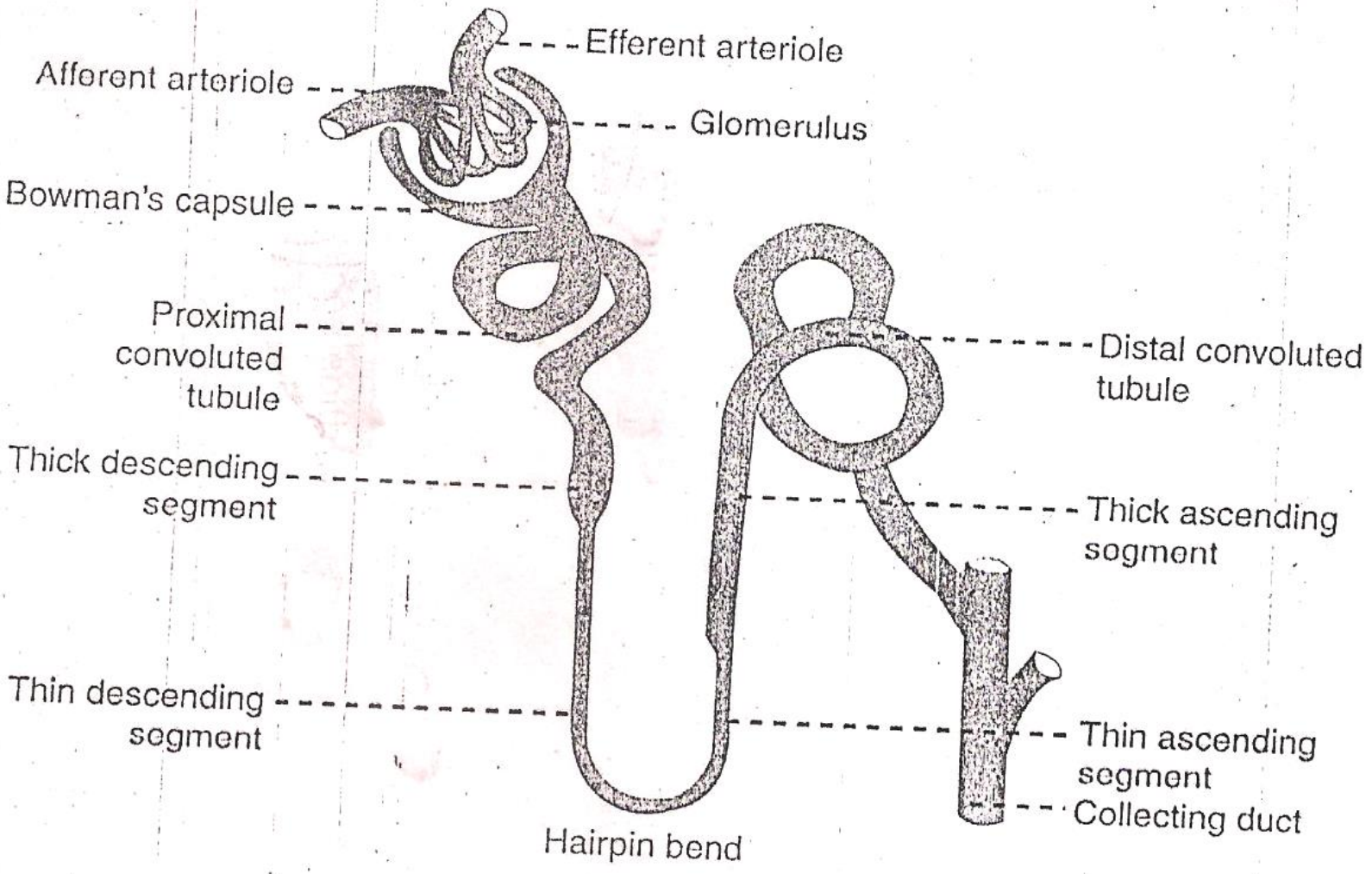
- Glomerulus
- Afferent arteriole
- Efferent arteriole

Tubular component

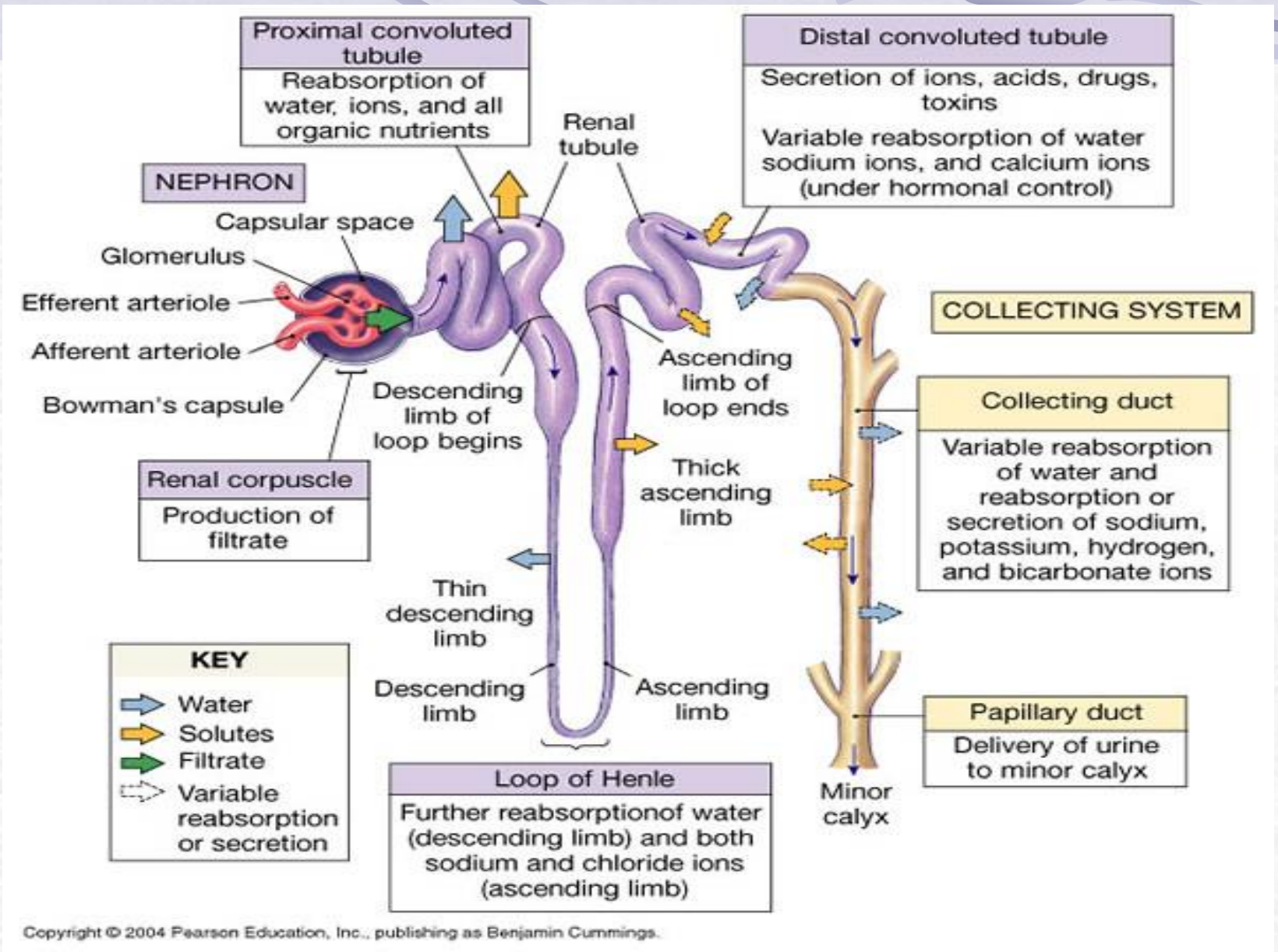
- Bowman’s Capsule
- Proximal tubule
- Loop of Henle
- Descending and ascending limb of Henle’s loop

Combined Vascular and tubular component

Juxtraglomerular apparatus



: Parts of nephron



GLOMERULUS(Ball like tuft of capillaries)

- Glomerular capillaries connect an afferent to an efferent arteriole.
- Afferent arteriole after entering the glomerulus divide into 4 or 5 large capillaries, each large capillary subdivides into small capillaries, which reunite to form efferent arteriole.
- The diameter of the efferent arteriole is less than that of afferent arteriole.
- Capillaries(which forms outer layer of glomerular membrane) are made of single layer of endothelial cells attached to a basement membrane.

The endothelial layer has pores with a diameter of 0.1.

The pores are called slit pores.

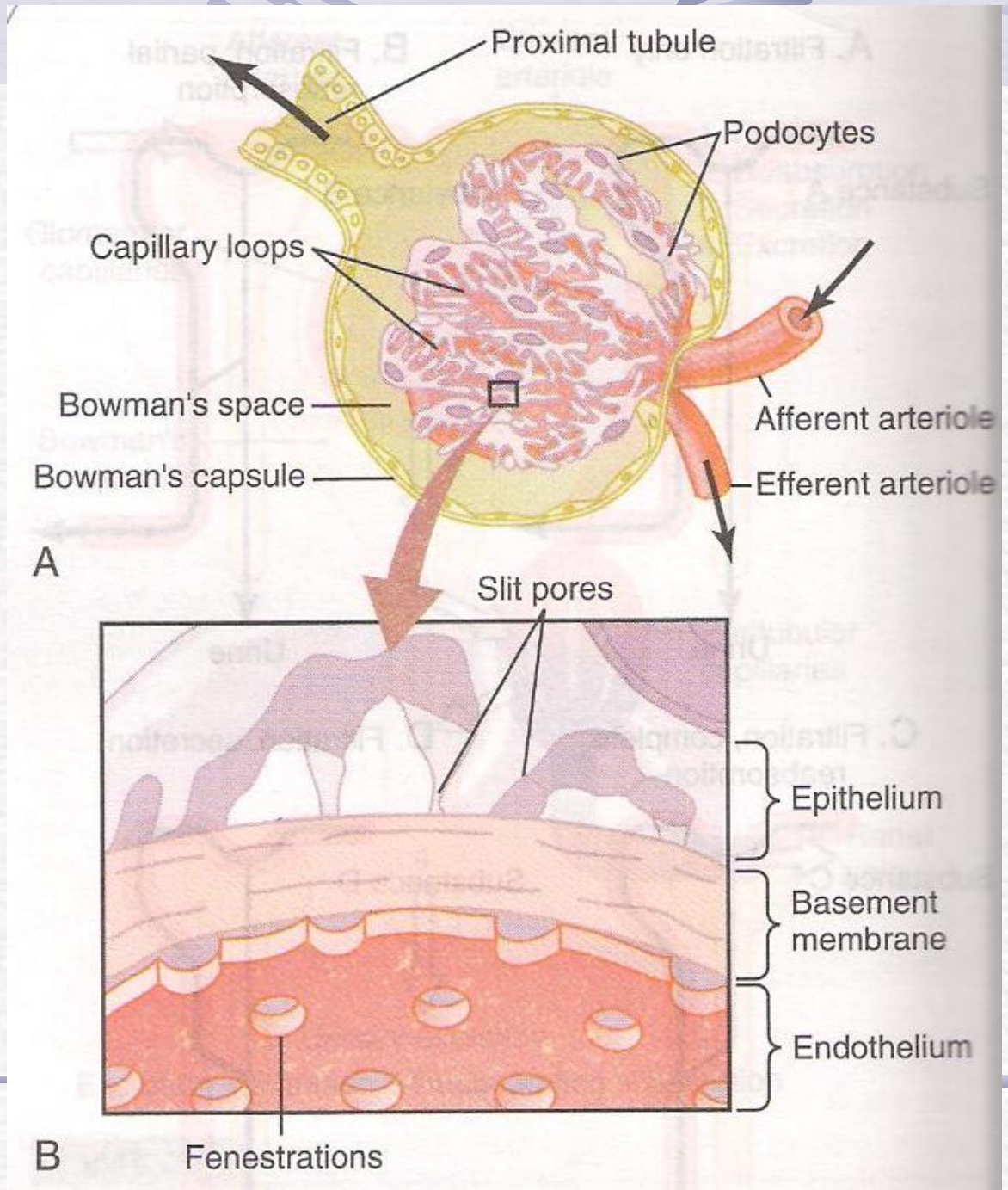
The pores are evidence of filtration function of the glomerulus. Pores that make over 100 times per permeable to water and solutes then capillaries elsewhere in the body.

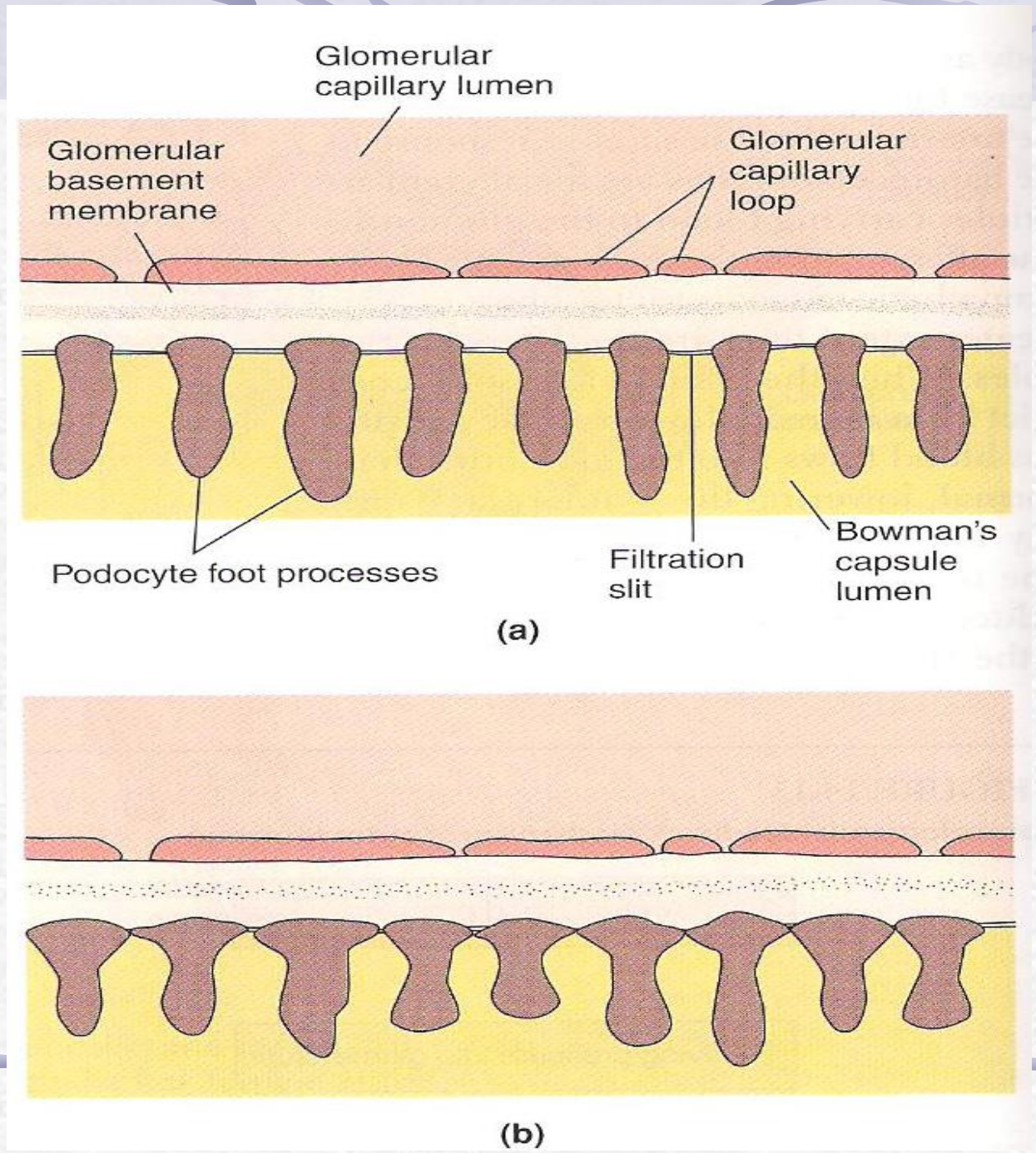
The Basement membrane form the middle layer of glomerular membrane. It is a cellular gelatinous layer composed of collagen(structural strength) and glycoprotein layer(discourage the filteration of small plasma protein due to its negative charge)

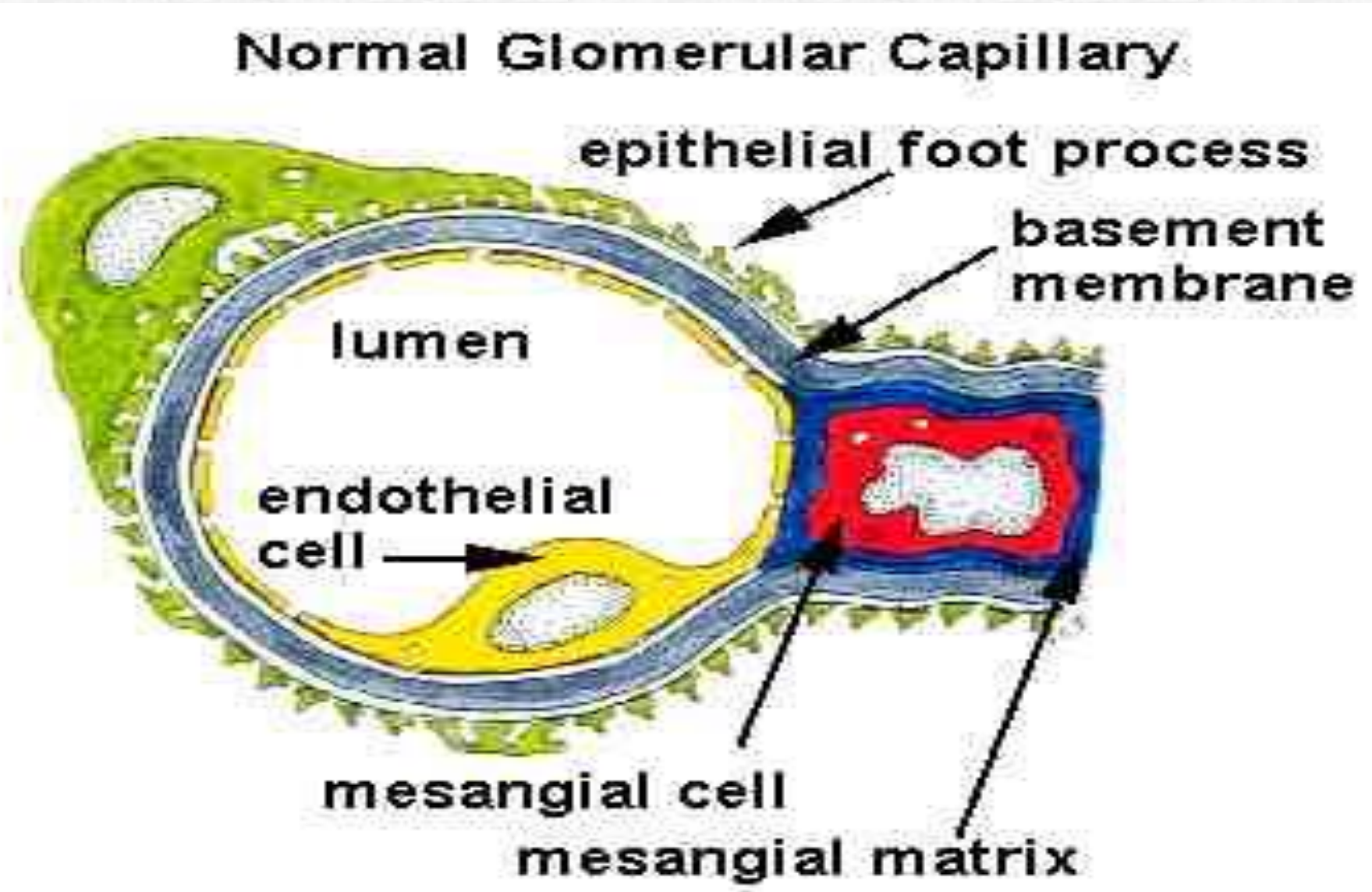
- The third layer of the glomerular membrane is formed by the inner layer of Bowmans capsule.It bears many elongated foot processes. Slit between adjacent foot processes are functionally filtration slits which provide a pathways through which fluid exiting the glomerular capillaries can enter the lumen of Bowmans capsule.(Glomerular filtrate).
- The filterability of solutes is inversely related to their size.
- The glomerular capillary membrane is **thicker** than most other capillaries but more **porous.**
- Glomerular filtration barrier is selective and based on their size and electric charge.
- A filterability of 1.0 means that the substance is freely filtered as water, a filterability of .75 percent as rapidly as water.
- Glucose and sodium are freely filtered.
- The molecular diameter of the plasma protein is 6 nanometer.
- The pores of Glomerular membrane is 8 nanometer (80 angstroms).
- Albumin is restricted from filteration because of Negative charge and the lectrostatic repulsion exerted by negative charge of the glomerular capillary wall proteoglycans

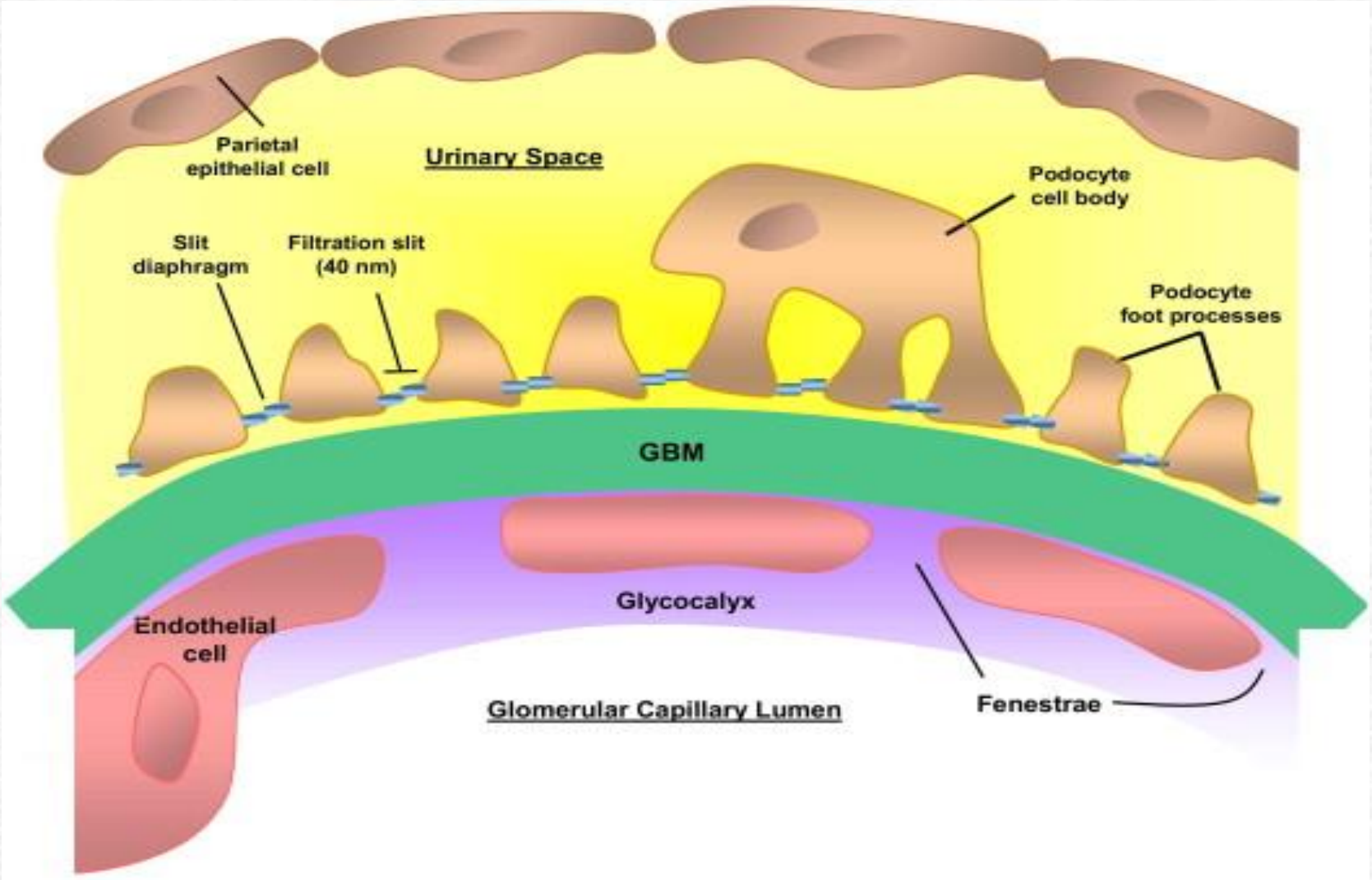
GLOMERULUS (CONTINUED)

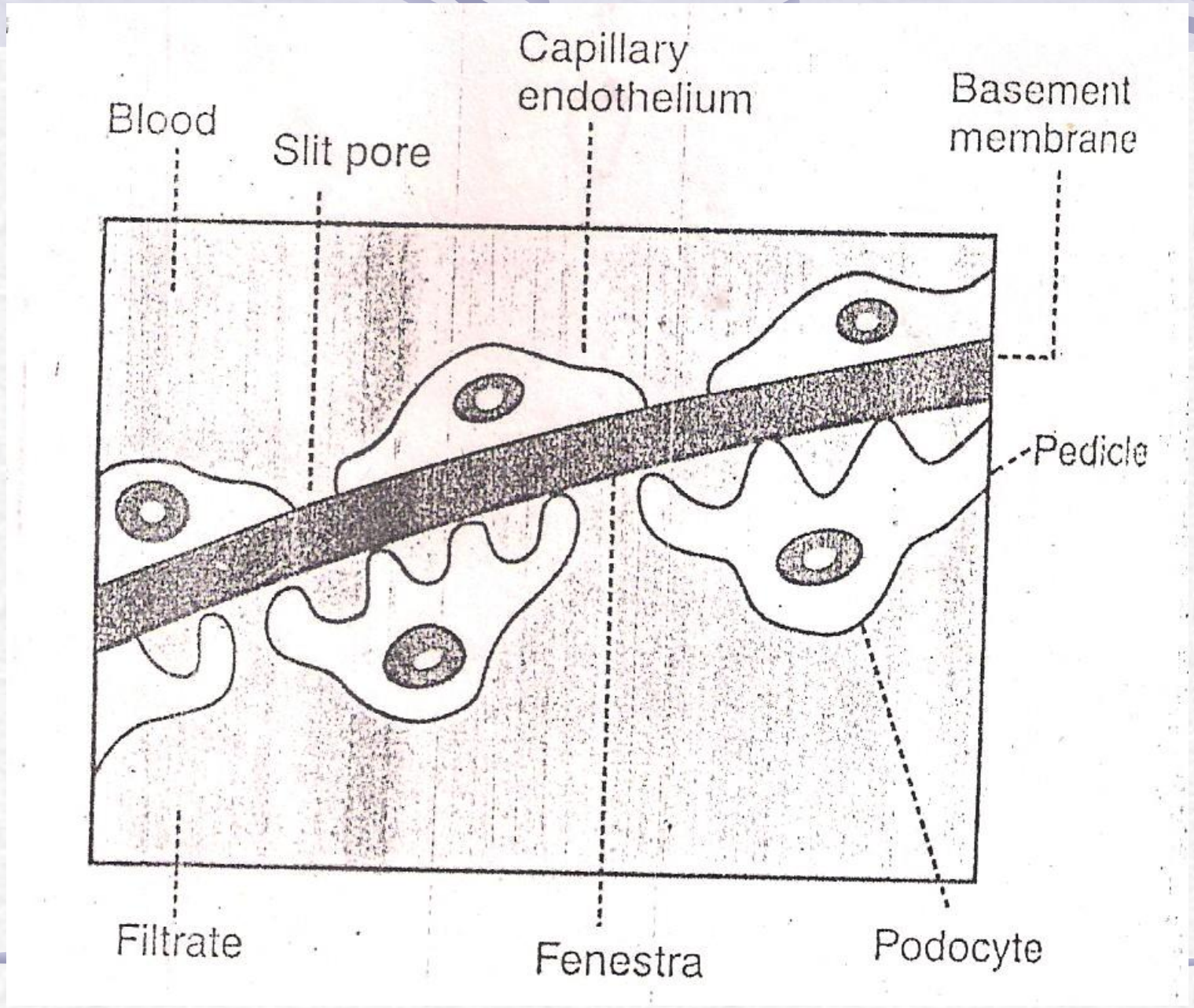
- For any given molecular radius, positively charged molecules are filtered much more readily than negatively charged molecules.
- The kidney diseases, the negatively charges on the basement membrane are losed before there are notice able changes in kidney histology minimal change nephropathy.
- Loss of negative charge on the basement membrane, and the low-molecular weight proteins ALBUMIN when filtered and appear in urine this condition is known as protein uria or Albuminuria.

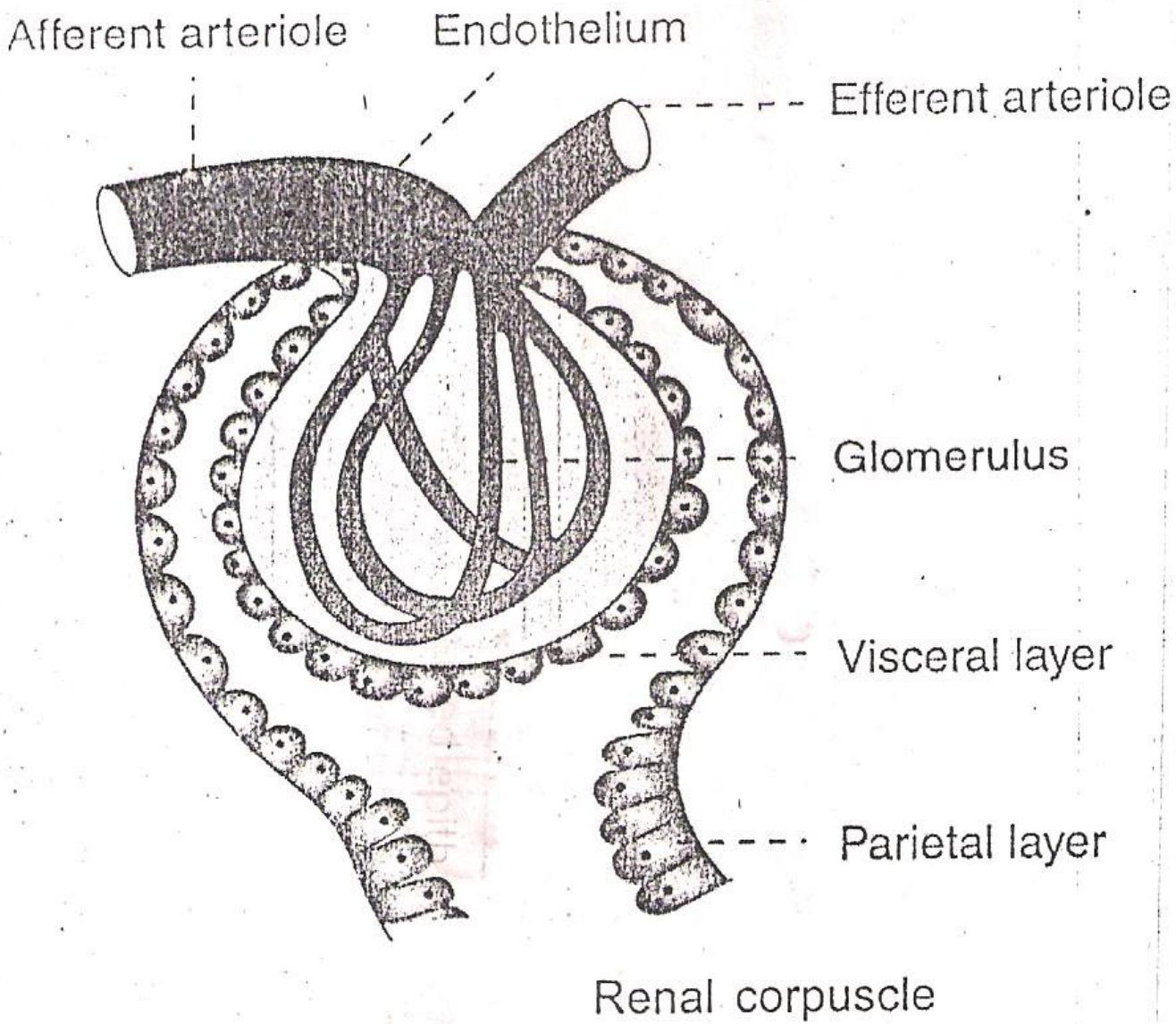

Proximal tubule
Podocytes
Capillary loops
Bowman's space
Bowman's capsule
Afferent arteriole
Efferent arteriole
A
Slit pores
Epithelium
Basement membrane
Endothelium
B
Fenestrations


Glomerular capillary lumen
Glomerular basement membrane
Glomerular capillary loop
Podocyte foot processes
Filtration slit
Bowman's capsule lumen
(a)
(b)


Normal Glomerular Capillary
epithelial foot process
basement membrane
lumen
endothelial cell
mesangial cell
mesangial matrix


Parietal epithelial cell
Urinary Space
Podocyte cell body
Slit diaphragm
Filtration slit (40 nm)
Podocyte foot processes
GBM
Glycocalyx
Endothelial cell
Glomerular Capillary Lumen
Fenestrae


Capillary endothelium
Blood
Slit pore
Basement membrane
Pedicle
Filtrate
Fenestra
Podocyte



Renal corpuscle

AFFERENT ARTERIOLE

- Renal artery subdivides to many small vessels known as afferent arteriole one of which supplies each nephron.
- Afferent arterioles supplies blood to the glomerulus.

Efferent arteriole

- Blood was not filtered into the tubular component leaves the glomerulus.
- **Efferent arterioles are the only arterioles in the body that drain from capillaries.**
- Efferent arterioles quickly subdivides into a second set of capillaries, the peritubular capillaries which supply the renal tissue with blood.

Peritubular capillaries(Peri means around)

- Important in exchange between the tubular system and blood during conversion of filtered fluid into urine.
- Peritubular capillaries are inter twined around the tubular system peri means around the peritubular capillaries rejoin to form venules and drain into renal vein.

TUBULAR COMPONENT

- Tubular componenet of each nephron is a hollow, fluid filled tube formed by a single layer of epithelial cells.
- The tubular component begins with.

Bowman's capsule

- An expended, double walled invagination that cups around the gromerulus to collect the fluid filtered from the glomerular capillaries.

Proximal tubule

- From the Bowman capsule the fluid filtered passes into the proximal tubule.
- This is the coiled portion arising from Bowman's capsule. This occupies the cortex near glomerulus. Length of proximal convuluted tubule is 14mm diameter is 55 μ.
- **Lies entirely within the cortex.**
- Highly coiled or convoluted throughout much of its course.

Loop of Henle

- Direct continuation of the proximal convoluted tubule.
- Length is 6mm and diameter is 55.
- The thick descending limb or segment.
- The thin descending limb or segment
- Hair bend
- Thin ascending limb or segment
- Thick ascending limb or segment
- Forms a sharp U shaped or hairpin loop
- **Dips into the renal medulla**

Descending Limb of Henle's Loop

- Planges from the cortex in to the medulla.
- The thin descending segment of Henle's loop connects the thick descending segment with the hairpin bend of the loop, which is continued as thin ascending segment.
- Thin ascending segment is continued as thick ascending segment.

Ascending limb of Henle's Loop

- Traverses back up into the cortex

THICK ASCENDING SEGMENT

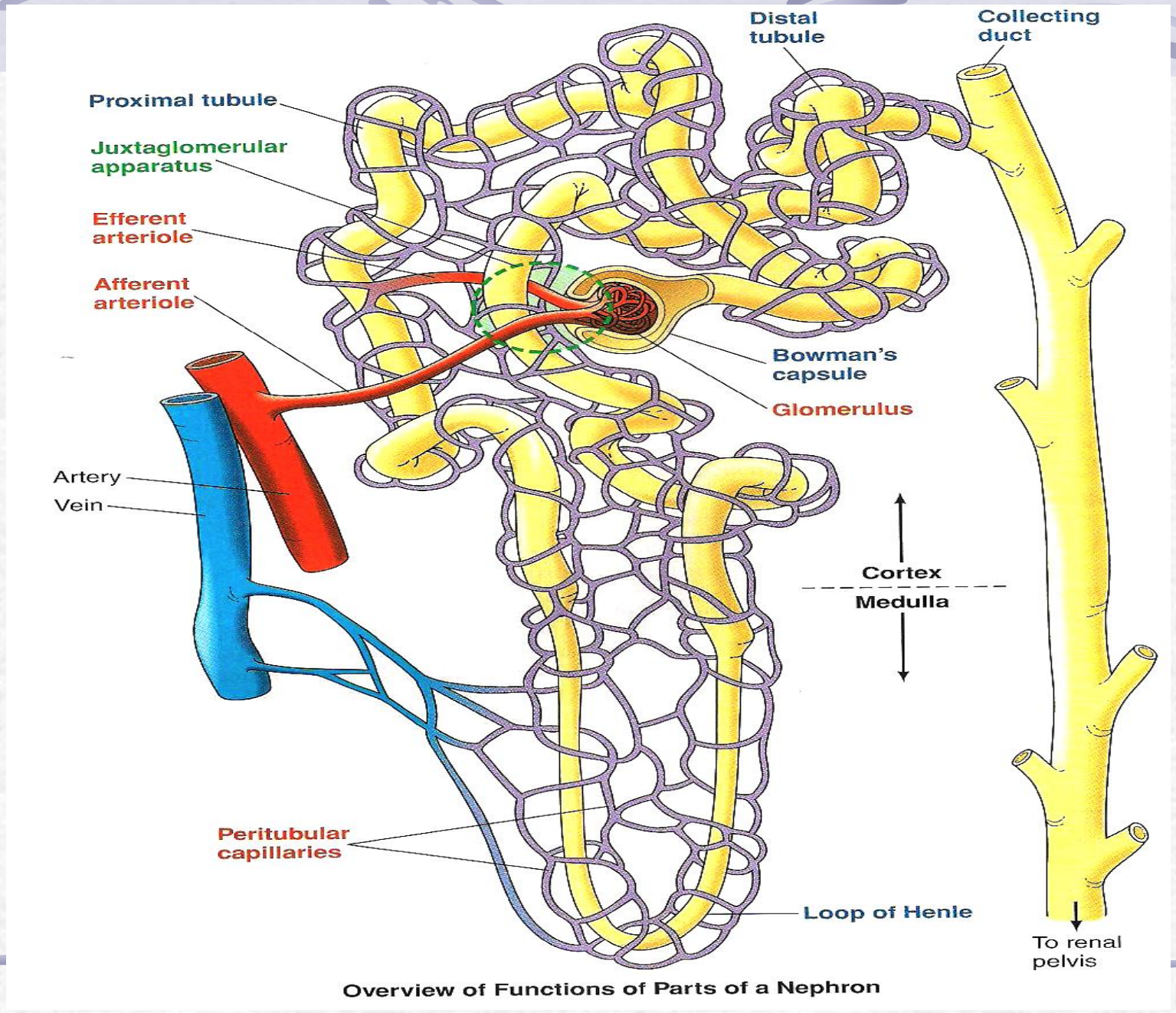
- This segment of the loop is continued from thin ascending segment.
- This segment **ascends to the cortex** and forms distal convoluted tubule.
- The length is 9mm and its diameter is 30 μ.
- The cuboidal cells that is closely packed in the thick ascending segment is called macula densa.

DISTAL CONVOLUTED TUBULE

- Continuation of thick ascending segment henle's loop and occupies the cortex of kidney.
- This segment opens into the collecting tubule.
- The length of distal convoluted tubule is 14.5 to 15mm.

COLLECTING DUCTS

- The distal convoluted tubule opens into the collecting duct which is in the cortex.
- The lower part of the collecting duct is in medulla.
- Seven to ten initial collecting ducts unite form the collecting duct, which passes through medulla.
- The straight tubule in the inner zone of medulla unite to form papillary ducts which open into minor calyces.
- Three or four minor calyces unite to form one major calyx. The major calyces open into the pelvis of the ureter.
- The pelvis is the extended portion of ureter present in the renal sinus.
- The length of collecting duct is 20-200mm.



Overview of Functions of Parts of a Nephron

Vascular component

- Afferent arteriole—carries blood to the glomerulus
- Glomerulus—a tuft of capillaries that filters a protein-free plasma into the tubular component
- Efferent arteriole—carries blood from the glomerulus
- Peritubular capillaries—supply the renal tissue; involved in exchanges with the fluid in the tubular lumen

Combined vascular/tubular component

- Juxtaglomerular apparatus—produces substances involved in the control of kidney function

Tubular component

- Bowman's capsule—collects the glomerular filtrate
- Proximal tubule—uncontrolled reabsorption and secretion of selected substances occur here
- Loop of Henle—establishes an osmotic gradient in the renal medulla that is important in the kidney's ability to produce urine of varying concentration
- Distal tubule and collecting duct—variable, controlled reabsorption of Na^+ and H_2O and secretion of K^+ and H^+ occur here; fluid leaving the collecting duct is urine, which enters the renal pelvis

BOWMAN'S CAPSULE

- Encloses the glomerulus.
- Formed by two layers.
- Inner layer is called visceral layers
- Outer layer is called parielal layer
- Visceral layer covers the glomerular capillaries
- It is continued as the parietal layer at the visceral pole.
- Parietal layer is continued with the wall of the tubular portion of nephron.
- The space between the visceral and parietal layers is continued as the lumen of the tubular portion.
- Diameter of bowman capsule is 200 μ.
- The basement membrane of the visceral layer fuses with the basement membrane of glomerular capillaries on which capillary endothelial cells are arranged.

BOWMAN'S CAPSULE (CONTINUED)

- Basement membranes which are fused together, form the separation between the glomerular capillary endothelium and the endothelium of visceral layer of Bowman's capsule.
- The epithelial cells of the visceral layer do not fuse continuously with basement membrane.
- Each epithelial cell of the visceral layer is connected with the basement membrane by series of processing called pedicles or feet.
- Pedicles are the cytoplasmic extensions of epithelial cells.
- These pedicles are arranged in an interdigitating manner leaving small cleft like space in between.
- **The epithelial cells with pedicles are called podocytes.**
- Urine formation begins with filtration from the glomerular capillaries into Bowman's capsule of large amount of fluid that is virtually free of proteins.