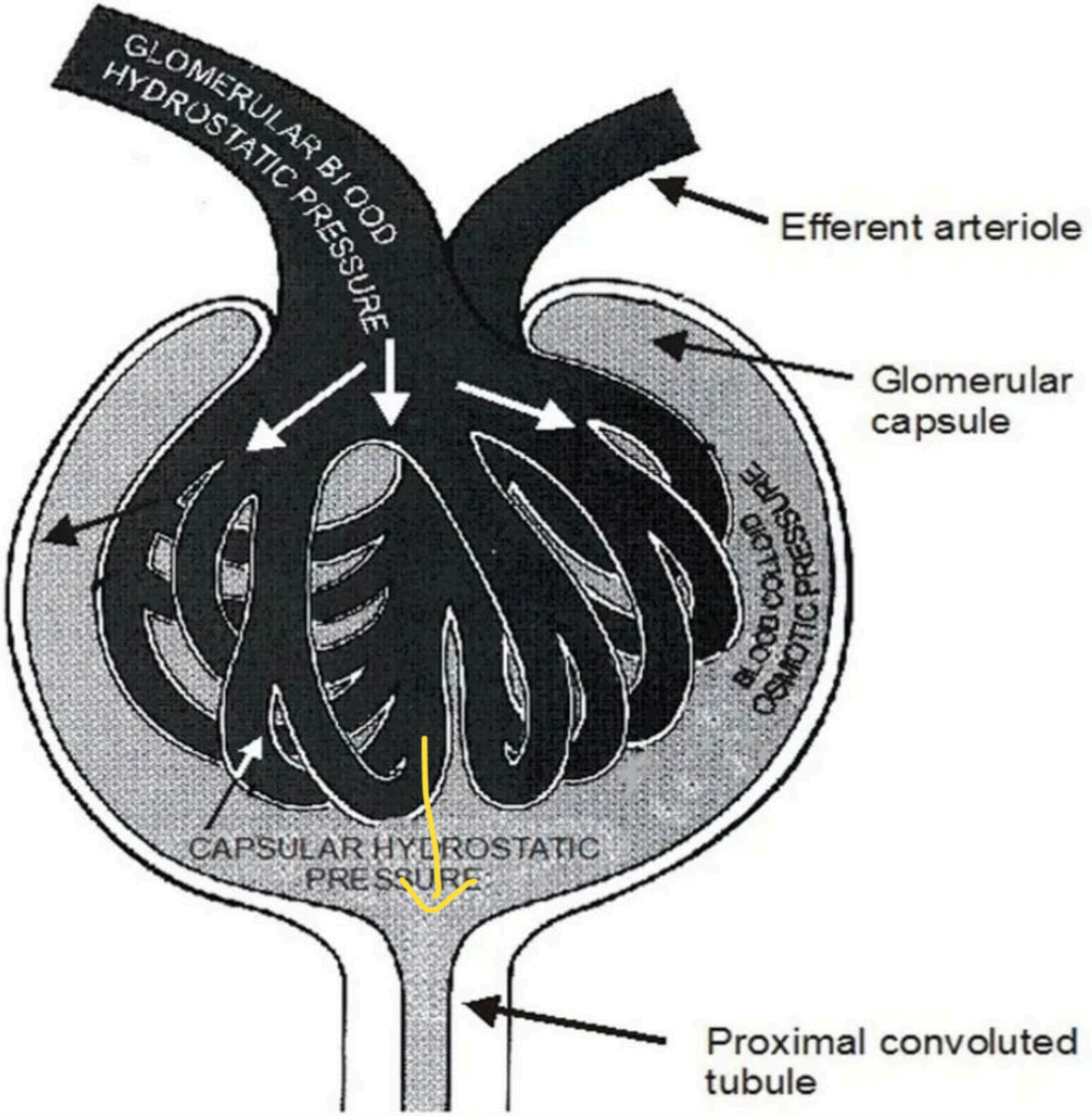
Excretory Products & their Elimination - IV

Course on Human Physiology: Excretory Products & their Elimination

Dr Amit Gupta • Lesson 5 • Aug 19, 2021

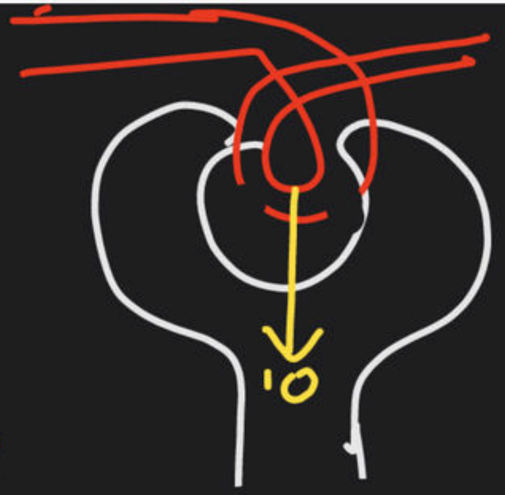

GLOMERULAR BLOOD HYDROSTATIC PRESSURE
Efferent arteriole
Glomerular capsule
BLOOD COLLOID OSMOTIC PRESSURE
CAPSULAR HYDROSTATIC PRESSURE
Proximal convoluted tubule

Filteration Co-efficient

if EFP had been 1 mm Hg.

Then a total of 12·5 ml plasma would have filtered per minute from both kidneys.

But Actual EFP is 10 mm Hg



∴ Actual plasma filtered per minute = 12·5 ml × 10

Glomerular filtration Rate = Amount of Plasma filtered by all the Glomerulus of Both Kidneys.

G.F.R. = 125 ml/mt

Cardiac output = 5 Litre / minute

25% of Cardiac output ⟶ Kidneys (1·25 Litre/mt)

Renal Blood Flow **R.B.F. = 1250 ml/mt**

Blood
- Plasma 50 to 55% ≅ 52%
- formed element RBC / WBC / Platelet 45 to 50%

∴ 52% of Blood is Plasma.

∴ Renal Plasma Flow

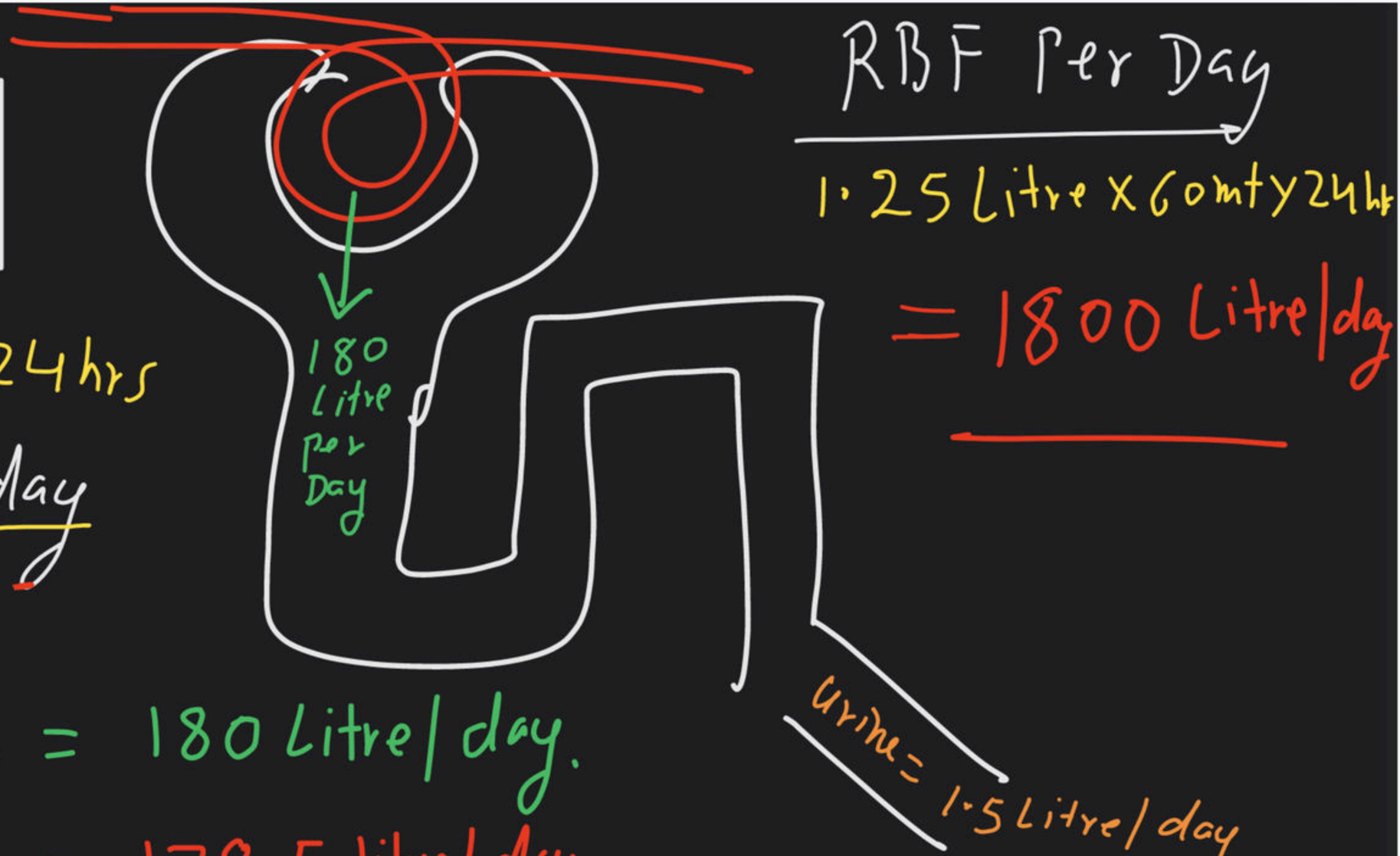
RPF = 650 ml/mt.

Filteration Fraction (for Plasma) $= \frac{GFR}{RPF} = \frac{125\ ml/mt}{650\ ml/mt} = \frac{1}{5}$ or 20%.

GFR Per Day

125 ml x 60 mt x 24 hrs

= 180 Litre/day



RBF Per Day

1·25 Litre x 60 mt x 24 hr

= 1800 Litre/day

Ultrafiltration = 180 Litre/day.

Reabsorption. = 178·5 litre/day.

Urine = 1·5 Litre/day

Glomular filtrate	Urine.
Water = 180 L/day	1.5 L/day.
Electrolyte = Large Amount	Less Electrolyte.
Glucose, Amino Acid, Aceto Acetic Acid Ketone body, Creatine Vitamin, Hormone	X
Urea, Uric Acid	Slightly less Urea, Uric Acid.
Creatinine, Inulin, SO_4^{-2}	Equal Amount of Creatinine Inulin SO_4^{-2}
Para Amino hippuric Acid PAH	More PAH.

High Threshold Compounds. — 100% Reabsorbed

Exception → Vit-C, HCG, Post Menopause FSH

Low Threshold Compounds — Very less Reabsorbed

A threshold compound — 0% Reabsorbed

Variable Threshold Compounds. — Sometimes more, Sometime less Reabsorbed.

Glomerular Filtrate	Urine.
X	Certain Drugs/Dyes

Renal Threshold

After ultra filtration, The maximum amount of a substance that can be Reabsorbed from the glomerular filterate

OR

The maximum amount of a substance that can be Tolerated in Blood without starting its Urinary Excretion

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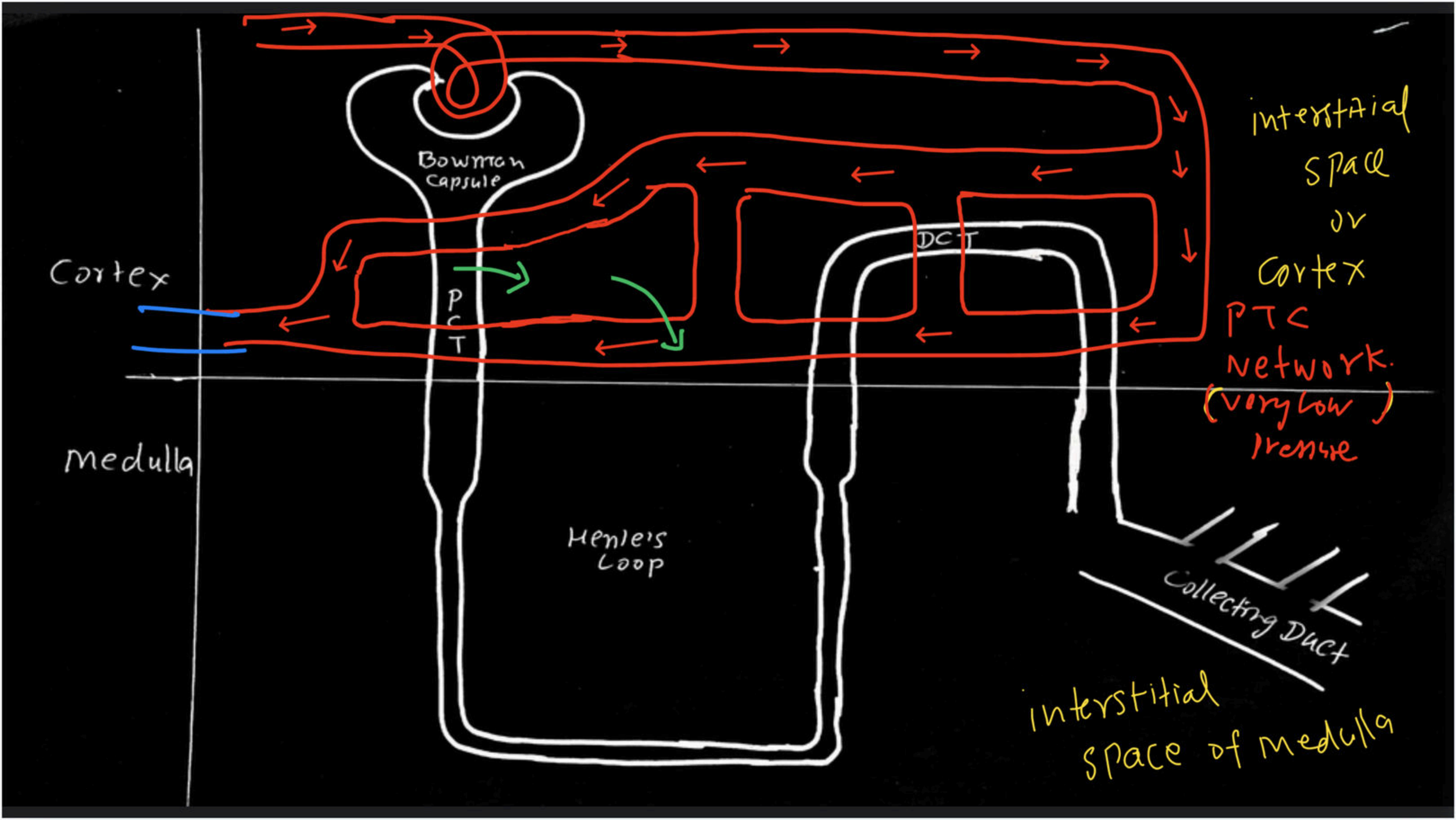
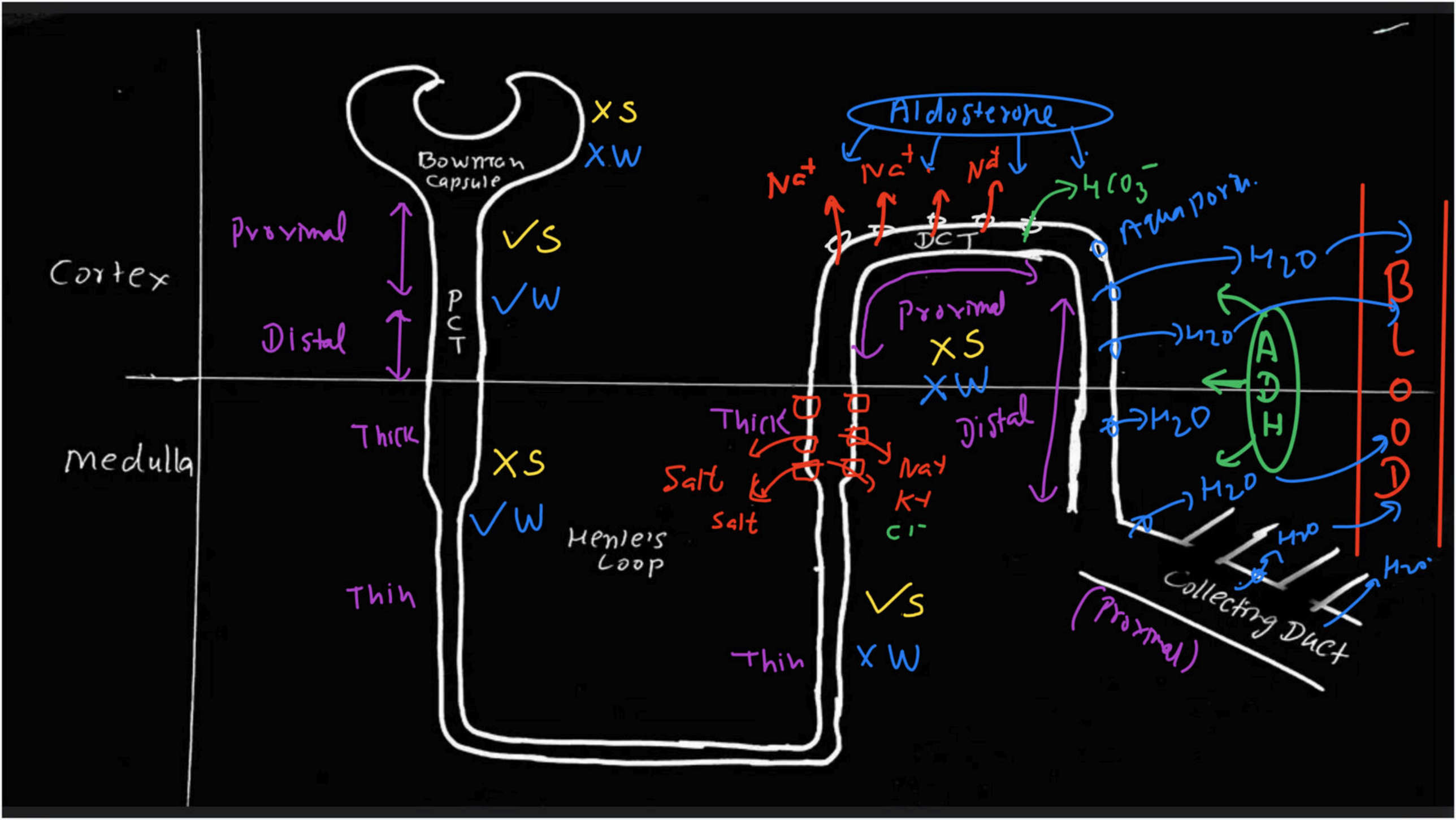
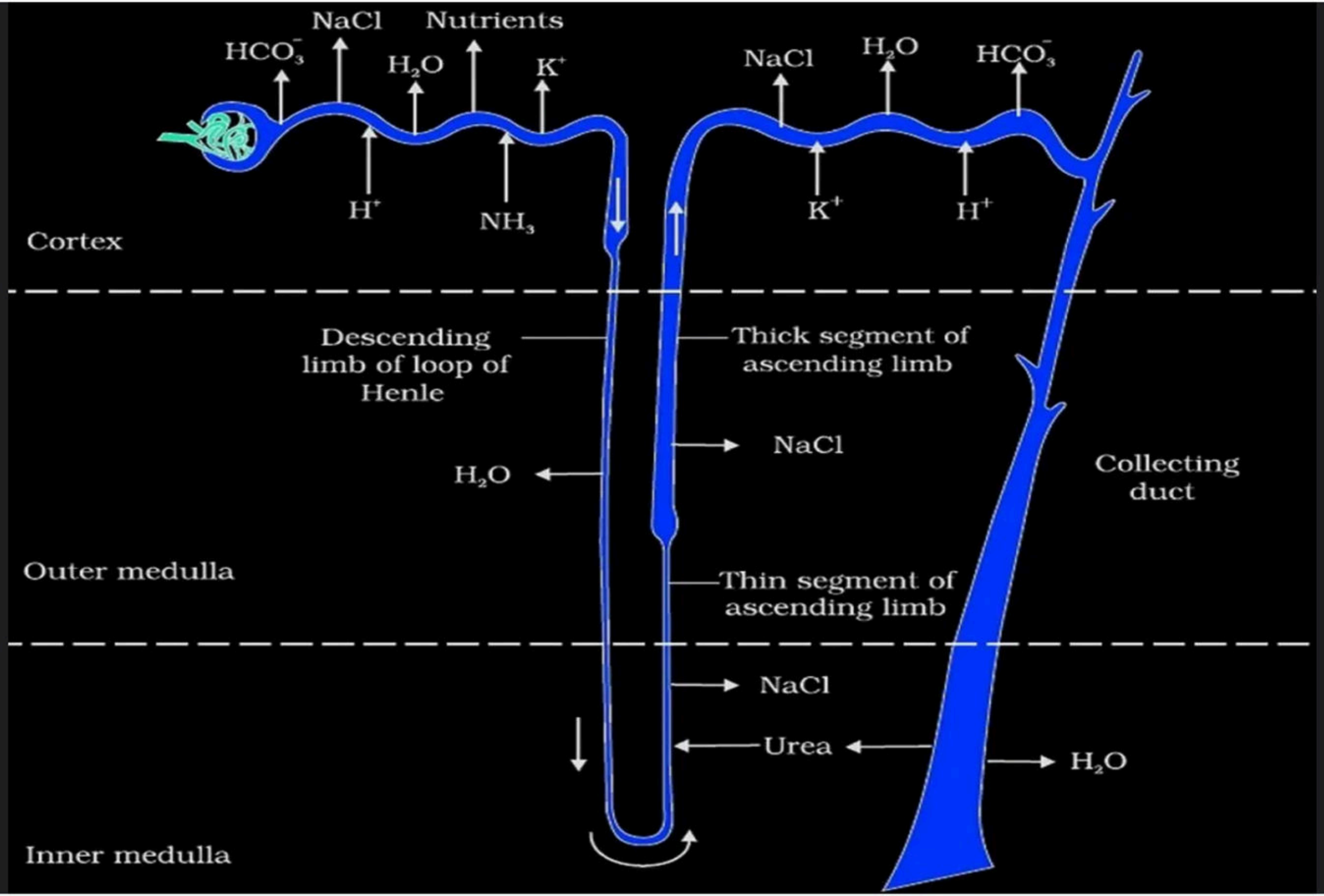
Creatine → Creatinine.

Benzoic Acid → PAH.


Bowman capsule
Cortex
PCT
DCT
Henle's Loop
Medulla
Collecting Duct
interstitial space of Medulla
interstitial space of Cortex
PTC network.
(very low pressure)


Cortex
Medulla
Bowman Capsule
XS
XW
Proximal
Distal
PCT
VS
VW
Thick
XS
VW
Thin
Henle's Loop
Salt
Salt
Na+
K+
Cl-
VS
XW
Aldosterone
Na+
Na+
Na+
HCO3-
DCT
Proximal
XS
XW
Distal
H2O
H2O
H2O
H2O
ADH
Collecting Duct
(Proximal)
BLOOD


NaCl
Nutrients
HCO_3^-
H_2O
K^+
NaCl
H_2O
HCO_3^-
H^+
NH_3
K^+
H^+
Cortex
Descending limb of loop of Henle
Thick segment of ascending limb
NaCl
H_2O
Collecting duct
Outer medulla
Thin segment of ascending limb
NaCl
Urea
H_2O
Inner medulla

(III) Tubular secretion :

- During urine formation, the epithelial cells of renal tubules secrete excretory substance from the blood of peritubular capillary into the filtrate. This process is tubular secretion.
- It is an active process which occur in PCT & DCT.
- In PCT selective secretion of H^+, NH_3, Creatinine, Uric acid, Drugs, Hippuric acid etc. occur and in DCT secretion of H^+, K^+ Drugs and Dye occur. DCT is the main area of secretion.
- Tubular secretion is also an important step in urine formation as it helps in the maintenance of ionic and acid base balance of body fluid.
- Tubular secretion is the only method of urine formation in the organisms having aglomerular kidney. Like marine teleost fish, desert amphibian.

Permeability chart

PCT $\longrightarrow$ Water, NaCl

Descending loop $\longrightarrow$ Water only

Thin ascending loop $\longrightarrow$ NaCl only and urea (inwards)

Thick ascending loop $\longrightarrow$ Na^+, K^+ Pumps and Cl^- follows passively

MECHANISM OF URINE FORMATION

The mechanism of urine formation involves three steps or processes :

(I) Ultrafiltration or Glomerular filtration

(II) Selective tubular reabsorption

(III) Tubular secretion

(I) Ultrafiltration or Glomerular filtration :

The first step in urine formation is the filtration of blood, which is carried out by the glomerulus.

- This process occurs in the malphigian corpuscle of the nephron.
- The glomerular capsular membrane through which filtration of blood occur consists of three layers.
  - (i) The endothelium of glomerular blood vessels.
  - (ii) The epithelium of Bowmans capsule.
  - (iii) A basement membrane between these two layers.
- The epithelial cells of Bowmans capsule called podocytes are arranged in an intricate manner so as to leave some minute spaces called filtration slits or slit pores.
- The blood is filtered so finely through these membranes that most constituents of the plasma except the proteins ans blood cells pass on to the lumen of the Bowmans capsule. Therefore it is considered as a process of ultra filtration.
- The plasma fluid that filters out from glomerular capillaries is called glomerular filtrate. It is protein and corpucle less plasma.
- About 20% of plasma fluid filters out into Bowmans capsule.
- The effective filtration pressure that causes ultrafiltration is determined by three pressures : (1) glomerular hydrostatic pressure, (2) colloid osmotic pressure of blood and (3) capsular hydrostatic pressure.

Maximum Reabsorption of water occurs from

(A) Alimentary Canal

(B) Kidney 178.5 litre

(C) Lungs

(D) Urinary bladder

The **glomerular hydrostatic pressure** is the blood pressure in glomerular capillaries. It is the chief determinant of effective filtration pressure, It is due to the difference is diameter of afferent and efferent arteriole. i.e. the main driving force to cause filtration. (it is 60 to 75 mm Hg)

The **colloid osmotic pressure** is the osmotic pressure created in the blood of glomerular capillaries due to plasma proteins. It resists the filtration of fluid from the capillaries. (it is 30 to 32 mm Hg)

The **capsular hydrostatic pressure** is the pressure caused by fluid (filtrate) that reaches into Bowman's capsule and resists filtration. (It is about 10 to 18 mm Hg)

Net effective filtration pressure is about 10 i.e. (60) – (32 + 18) mm Hg.

EFP = GHP – [COP + CHP]

∴ **EFP ranges from 10 to 25 mm Hg. (10 mm Hg is the most correct value)**

- The amount of the filtrate formed by the kidney per minute is called **glomerular filtration rate** (GFR). GFR in a healthy individual is approximately 125 ml/min ie. 180 litres per day.
- On an average 1100-1200 ml of blood is filtered by kidney per minute (Renal blood flow) which constitute roughly 20-25% of the blood pumped by each ventricle of the heart in a minute (cardiac output) and of this blood about 650 ml is the blood plasma (55%). This 650 ml is called **Renal plasma flow (RPF).** About 20% of the blood plasma filtered by all nephrons of both kidney in a minute. We already known that It is 125 ml and is called glomerular filtration rate (GFR).
- Filtration fraction = $\frac{\text{GFR}}{\text{RPF}} = \frac{125\text{ml}}{650\text{ml}} = \frac{1}{5}$

(II) Selective tubular reabsorption :

A comparison of the volume of the filtrate formed per day (180 litres per day) with that of the urine released (1.5 litres), suggest that nearly 99% of the filtrate has to be reabsorbed by the renal tubules. This process is called **reabsorption.** The tubular epithelial cells in different segments of nephron per form this reabsorption involves both active and passive processes.

- **PCT** → is lined by simple cuboidal brush border epithelium which increases the surface area for reabsorption. Nearly all of the essential nutrients and 70-80% of electrolytes and water are reabsorbed by this segment.
- Glucose, Amino acids, Fatty acids are completely reabsorbed by active transport in PCT.
- Water & Cl^- are reabsorbed passively.

Henle's loop :

- Reabsorption in this segment is minimum. This region plays a significant role in the maintanence of high osmolarity of medullary interstitial fluid.
- The descending limb of loop of henle is permeable to water but almost impermeable to electrolytes so here water is reabsorbed passively. This limb concentrates the filtrate as it moves down.
- The ascending limb is impermeable to water but allows transport of eletrolytes actively or passively. Therefore, as the concentrated filtrate passes upwards, it gets diluted due to the passage of electolytes to the medullary fluid.

DCT :

- Conditional reabsorption of Na^+ and water takes place in this segment. In the presence of aldosterone hormone salts (Na^+) are reabsorbed actively and due to ADH water is reabsorbed passively. DCT is also capable of reabsorption of HCO_3^-.

Collecting duct :

- Large amount of water could be reabsorbed from this region to produce concentrated urine (in the presence of ADH)