Solute

Solvent.

Solution.

Excretory Products & their Elimination - V

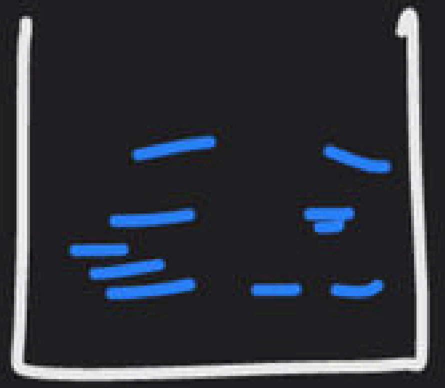
Solute ↑ ∝ Conc^n ↑

Solvent ↑ ∝ Volume ↑

Conc^n ↓

Course on Human Physiology: Excretory Products & their Elimination

Solution



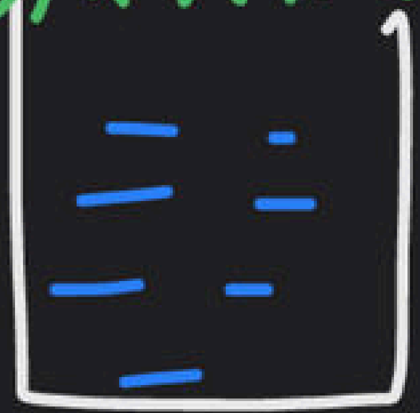
only some solute is Removed

Conc^n ↓, Volume ⟷

Solution

only some solvent is removed ⟹ Conc^n ↑ Volume ↓

Solute & Solvent both removed equally



Conc^n ⟷ Volume ↓

Solution.

Dr Amit Gupta • Lesson 6 • Aug 21, 2021

normal urine w.r.t. Plasma (300)

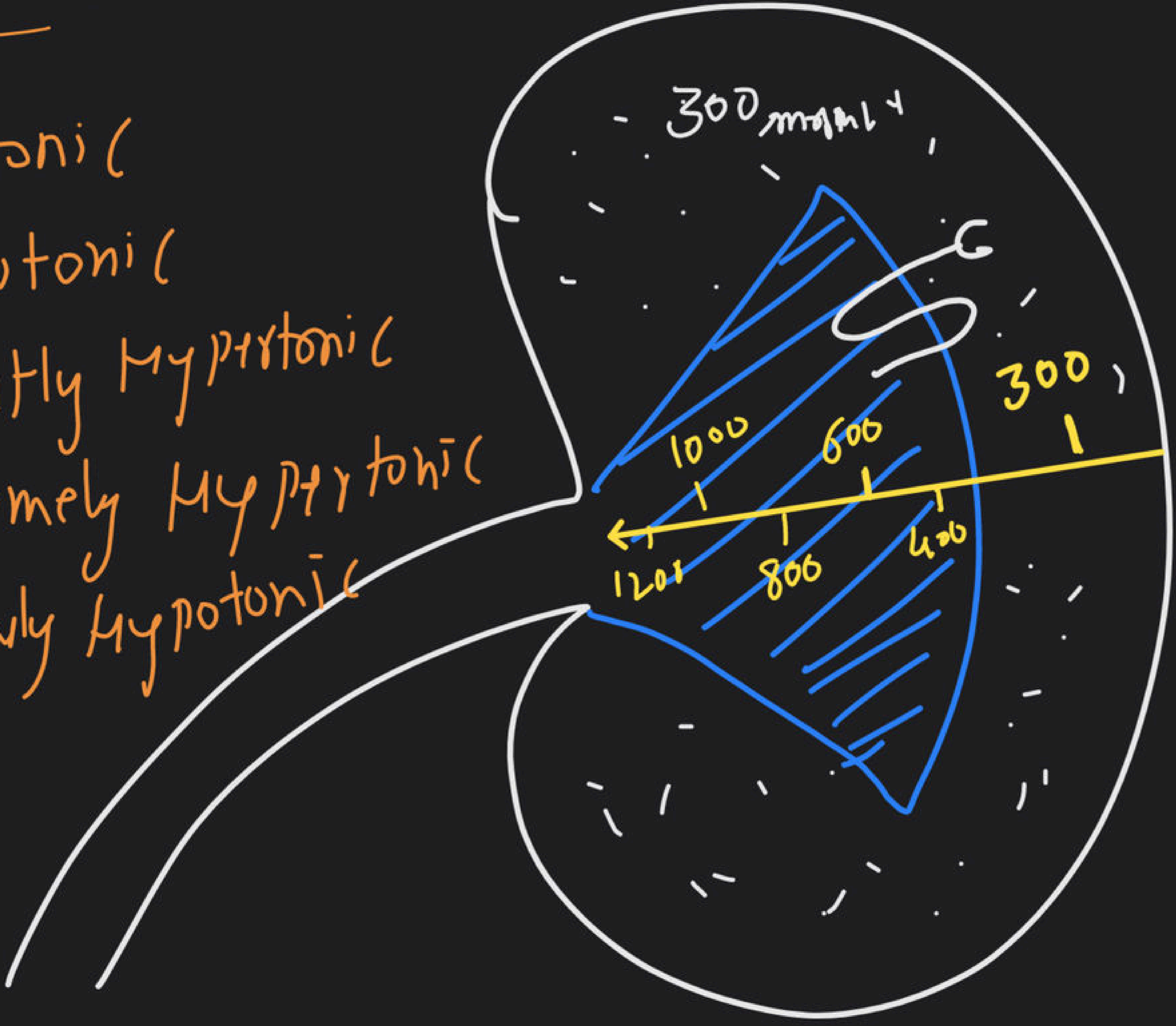
(A) isotonic

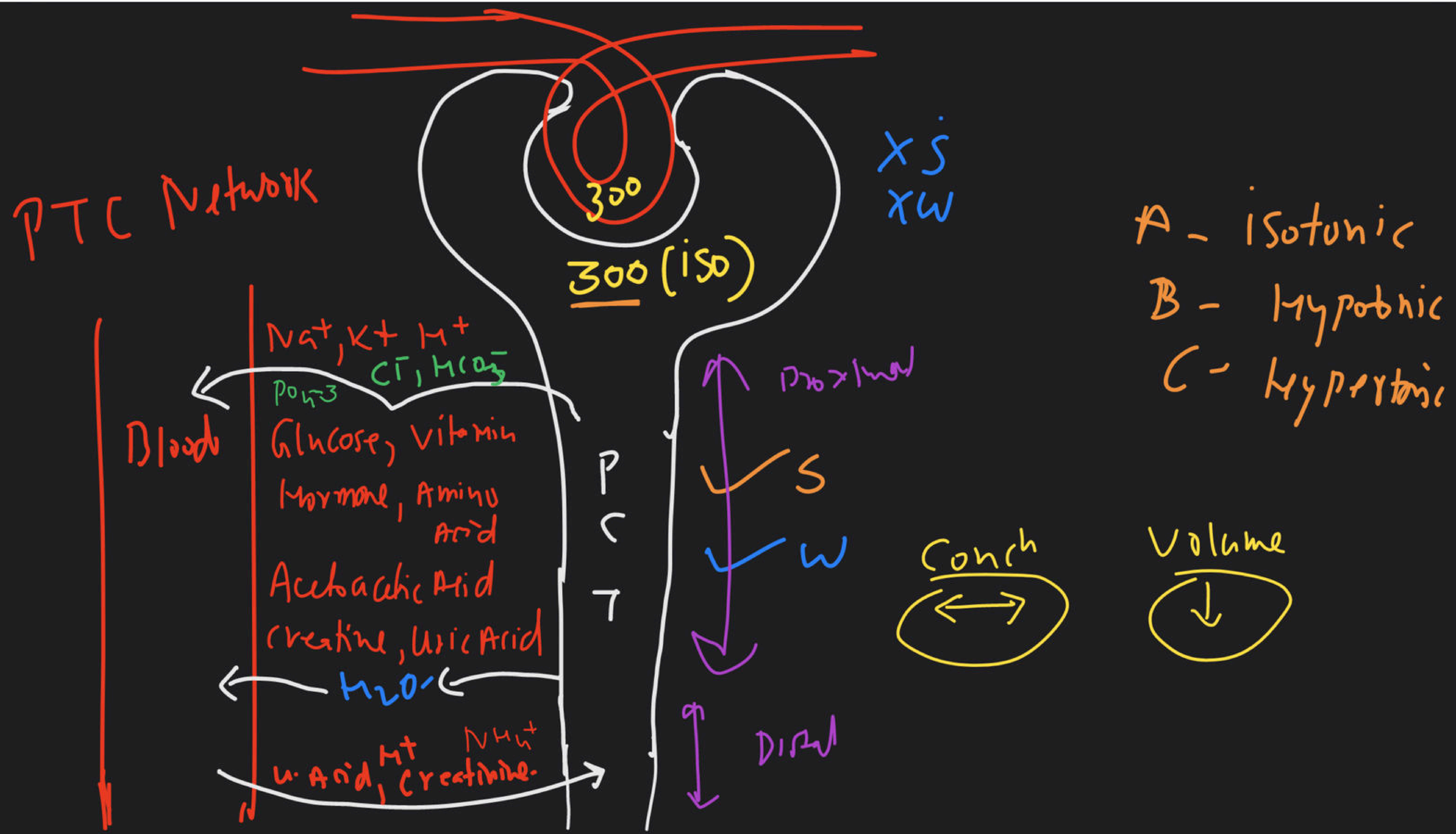
(B) Hypotonic

(C) Slightly Hypertonic

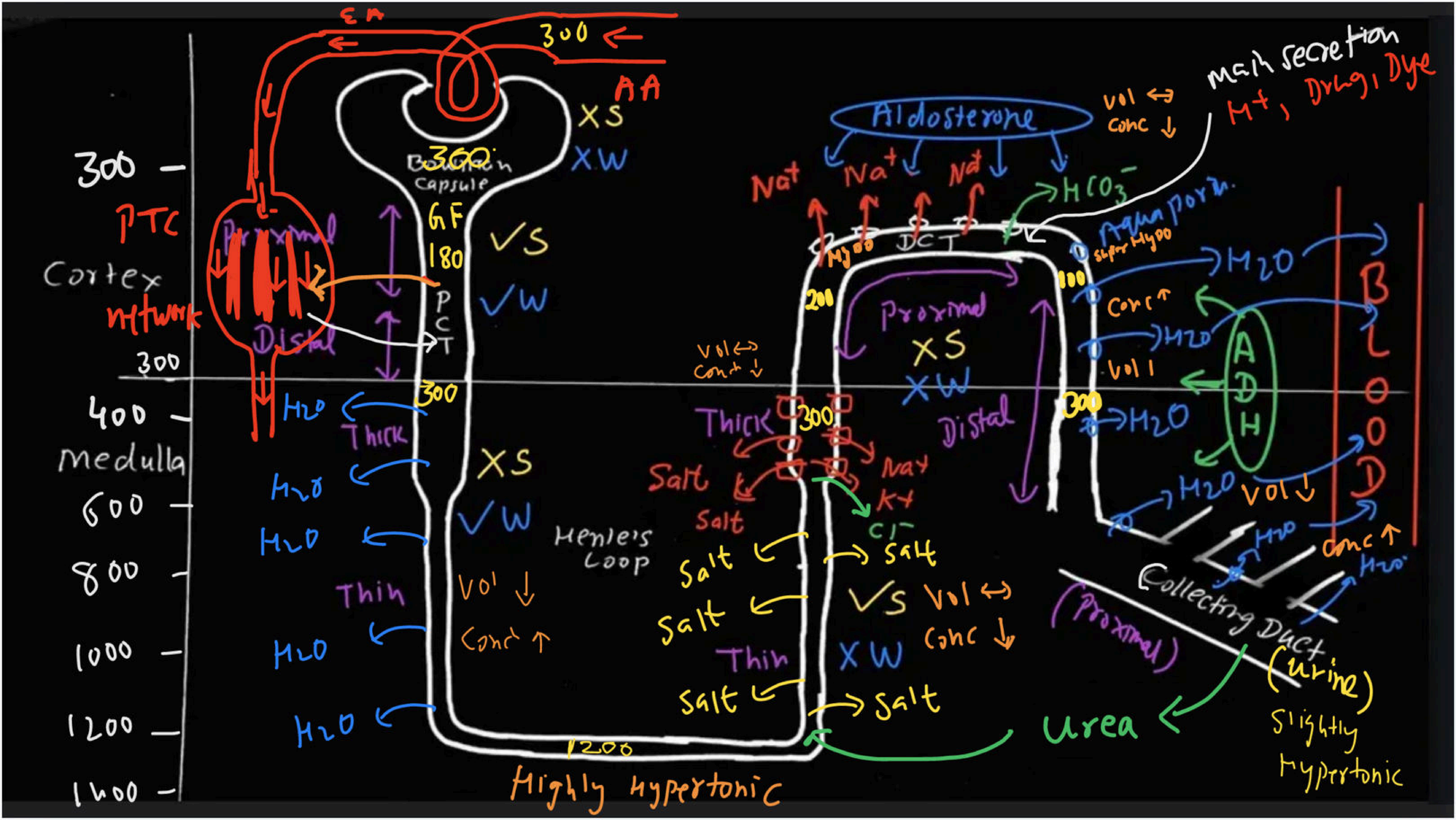
(D) Extremely Hypertonic

(E) Extremely Hypotonic

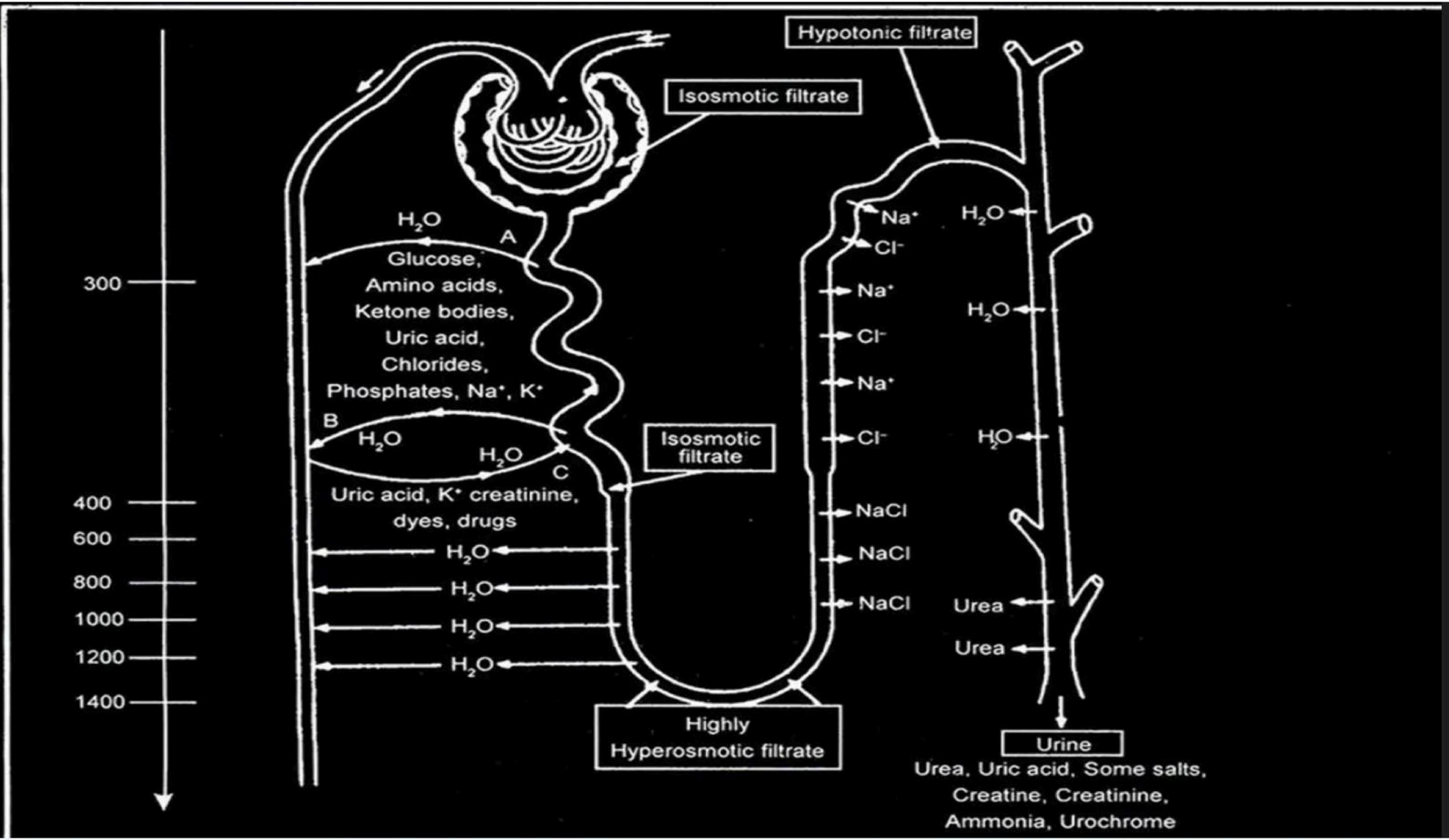




PTC Network
300
300 (iso)
Xs
XW
A - isotonic
B - Hypotonic
C - Hypertonic
Na+, K+ H+
Cl-, HCO3-
PO4-3
Blood
Glucose, Vitamin
Hormone, Amino Acid
Acetoacetic Acid
creatine, Uric Acid
H2O
u. Acid, H+ Creatinine. NH4+
P
C
T
Proximal
S
W
Distal
Concn
Volume



EA
300
AA
XS
XW
300
Bowman capsule
GF
180
VS
VW
PCT
PTC
Cortex
network
Proximal
Distal
300
400
Medulla
600
800
1000
1200
1400
H_2O
H_2O
H_2O
H_2O
H_2O
Thick
XS
VW
Thin
Vol ↓
Conc ↑
Henle's Loop
1200
Highly hypertonic
Aldosterone
Na^+
Na^+
Na^+
HCO_3^-
Vol ↔
Conc ↓
Main secretion
H^+, Drugs, Dye
DCT
Hypo
200
Proximal
XS
XW
Distal
Vol ↔
Conc ↓
Thick
300
Salt
Salt
Na^+
K^+
Cl^-
Salt
Salt
Salt
Salt
Salt
Salt
VS
Vol ↔
Conc ↓
Thin
XW
Urea
aquaporin
Super Hypo
100
H_2O
Conc ↑
H_2O
Vol ↓
300
H_2O
ADH
H_2O
Vol ↓
H_2O
Conc ↑
H_2O
BLOOD
Collecting Duct
(Proximal)
(urine)
Slightly hypertonic



Hypotonic filtrate
Isosmotic filtrate
300
400
600
800
1000
1200
1400
H_2O
A
Glucose,
Amino acids,
Ketone bodies,
Uric acid,
Chlorides,
Phosphates, Na^+, K^+
B
H_2O
H_2O
C
Uric acid, K^+ creatinine,
dyes, drugs
Isosmotic filtrate
H_2O
H_2O
H_2O
H_2O
Na^+
Cl^-
Na^+
Cl^-
Na^+
Cl^-
NaCl
NaCl
NaCl
H_2O
H_2O
H_2O
Urea
Urea
Highly Hyperosmotic filtrate
Urine
Urea, Uric acid, Some salts,
Creatine, Creatinine,
Ammonia, Urochrome

Changes occurring stepwise in the filtrate while it flows through the tubules :

(1) **Bowman's capsule :** Since all plasma solutes, except proteins, freely enter into glomerular filtrate from blood, the total solute concentration (osmolality 300 milliosmoles per litre) of the filtrate is essentially the same as that of plasma. Here the filtrate is thus **isotonic** (isosmotic) to the plasma.

∴ *Concentration* $\leftrightarrow$; *Volume* $\leftrightarrow$

(2) **Proximal convoluted tubule :** The microvilli of the "brush-border" columnar cells of the epithelium of this tubule increase the internal surface of the epithelium about 20 times. Hence, this epithelium becomes most suitable for reabsorption. About 65 % to 80% of the filtrate is reabsorbed into the blood of peritubular capillaries through this epithelium and surrounding tissue fluid (renal interstitium). Most of the solutes like glucose, amino acids, vitamins, ketone bodies, acetoacetic acid, uric acid, chlorides, sodium. potassium, phosphates etc of the filtrate are reabsorbed into the blood by diffusion and active transport. Some urea is also reabsorbed. Sulphates, creatinine, inulin and PAH (para amino hippuric acid) are not reabsorbed.

As most of the solutes are reabsorbed, water automatically goes back into the blood by osmosis leaving the osmotic pressure in the filtrate unchanged . Thus, the filtrate is reduced in volume, but it **still remains isotonic** to the plasma.

∴ Concentration $\leftrightarrow$, volume $\downarrow$

(3) **Descending limb of henle's loop :** The loop of Henle is divisible into four parts, namely Thick descending limb, the Thin descending limb, the Thin segment of ascending limb, and the Thick segment of ascending limb.

In mammalian kidneys, the osmolality of renal interstitium is different in renal cortex and medulla. Where as the cortical interstitium has the normal osmolality of 300 mL osmol/liter, the medullary interstitium has a gradient of increasing osmollity from the cortex upto the tips of the papillae. (300 to 1400 mL osmol/liter)

The thin wall of descending limb of Henle's loop is *permeable to water, but not to the solutes.* As the isotonic tubular fluid flows down this limb, it gradually loses water by exosmosis due to increasing osmolality of medullary interstitium through which this limb extends. This leaves a small volume of concentrated (**hypertonic** to blood plasmaupto 1200 mosm/liter) tubular fluid to enter into the ascending limb of Henle's loop.

$\therefore$ *Concentration* $\uparrow$, *Volume* $\downarrow$

(4) **Ascending limb of Henles loop :** The thin segment of the ascending limb of henle's loop is structurally like the descending limb, but its permeability is different. It is *quite permeable to NaCl but not to water.*

Due to decreasing osmolality of medullary interstitium towards cortex, the tubular fluid, therefore, loses Na^+ and Cl^- by diffusion, again becoming diluted and **isotonic** to plasma without changing in volume.

$\therefore$ *Concentration* $\downarrow$, *Volume* $\leftrightarrow$

The wall of the thick ascending limb of Henle's loop is virtually *impermeable to both water and solutes,* but the plasma membrane of its cells is very rich in $Na^+ - K^+$ *pumps*. These pumps pump out Na^+ by active transport, and Cl^- passively diffuse out following the outflux of Na^+ . Thus the process of dilution of the tubular fluid continues in this limb. Consequently, the tubular fluid becomes considerably **hypotonic** to blood plasma without a change in its volume.

$\therefore$ *Concentration* $\downarrow$, *Volume* $\leftrightarrow$

(5) **Distal convoluted tubule (DCT) :** In the distal convoluted tubule, under the influence of Aldosterone active reabsorption of Na^+ and Cl^- passively continues by facilitated diffusion and hence the tubular fluid becomes still more diluted . It also helps to regulate blood pH by reabsorption of HCO_3^- which is an important buffer.

In Distal seqment of DCT passive Rabsoption of water occurs under the influences of ADH.

$\therefore$ In proximal DCT *Concentration* $\downarrow$, *Volume* $\leftrightarrow$

While in distal DCT *Concentration* $\uparrow$, *Volume* $\downarrow$

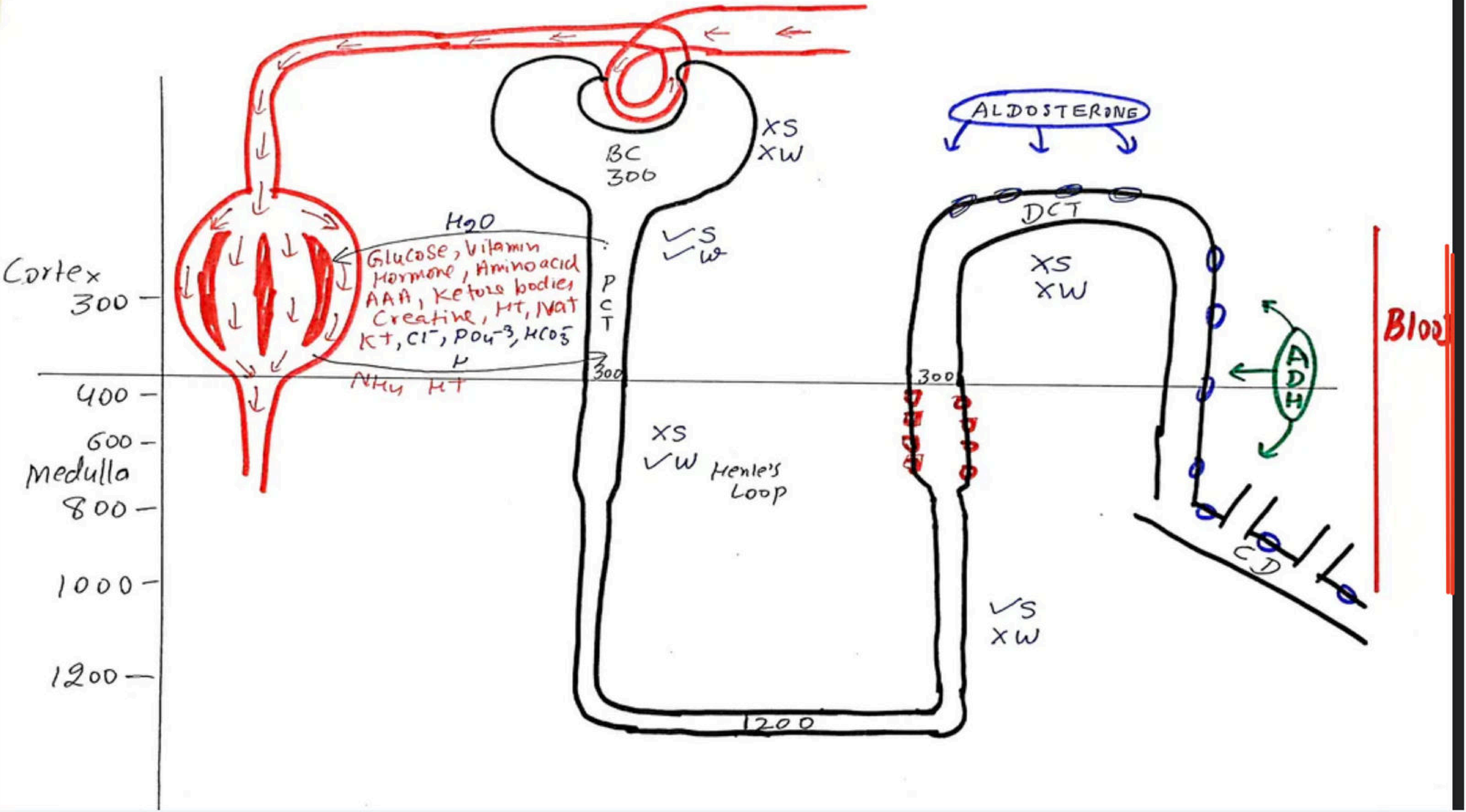
(6) **Collecting duct :** From the distal convoluted tubule, the hypotonic tubular fluid flows into a collecting duct. This duct is *quite permeable to water but not to salt* (in presence of some ADH). Hence the tubular fluid loses considerble amount of water by exosmosis as the duct runs down through the hypertonic medullary interstitium to empty into the calyx. The distal part of collecting duct is permeable to urea also.

Hence same urea is also reabsorbed from tubular fluid and it adds to the hyperosmolality of medullary interstitium .

$\therefore$ *Concentration* $\uparrow$, *Volume* $\downarrow$

After loosing considerable amount of water and some urea, while flowing through the collecting ducts, the filtrate is now ultimately called **urine.**

Chemical composition and physical characteristics of urine : Normal urine contains about 95% water 2% electrolytes (ions of salts, mainly chlorides, sulphates, phosphates and bicarbonates of sodium, potassium, ammonium, etc), 2.6% urea, 0.3% uric acid and traces of creatinine, ammonia, creatine etc. It is transparent but pale yellow due to the presence of a trace of urochrome pigment. Urochrome is a by product of haemoglogin degradation found in blood and filtered into glomerular filtrateNormal urine is slightly acidic with a pH of 6.00 (range is 4.5 to 8.2). Its specific gravity is 1.015 to 1.02. On standing, it becomes cloudy an acquires ammonia odour due to formation of ammonium carbonate.



ALDOSTERONE
XS
XW
BC
300
H2O
Glucose, Vitamin
Hormone, Amino acid
AAA, Ketone bodies
Creatine, H+, Na+
K+, Cl-, PO4-3, HCO3-
NH4 H+
PCT
Cortex
300
400
600
Medulla
800
1000
1200
300
DCT
Henle's Loop
ADH
Blood
CD
1200

Kidney functions

1) Excretion of Nitrogenous waste. by urine formation

2) Maintenance of pH of Blood (7.4)

$\boxed{\text{more } H^+ \text{ concn in Blood}}$

⇓

Blood becomes more Acidic

⇓

more urinary Excretion of H^+

⇓

Blood H^+ concn reduces to normal.

⇓

Blood pH becomes normal.

$\boxed{\text{more } HCO_3^- \text{ in Blood}}$

⇓

Blood becomes more Basic

⇓

Less Reabsorption of HCO_3^- & more urinary Excretion of HCO_3^-

⇓

pH of Blood becomes normal

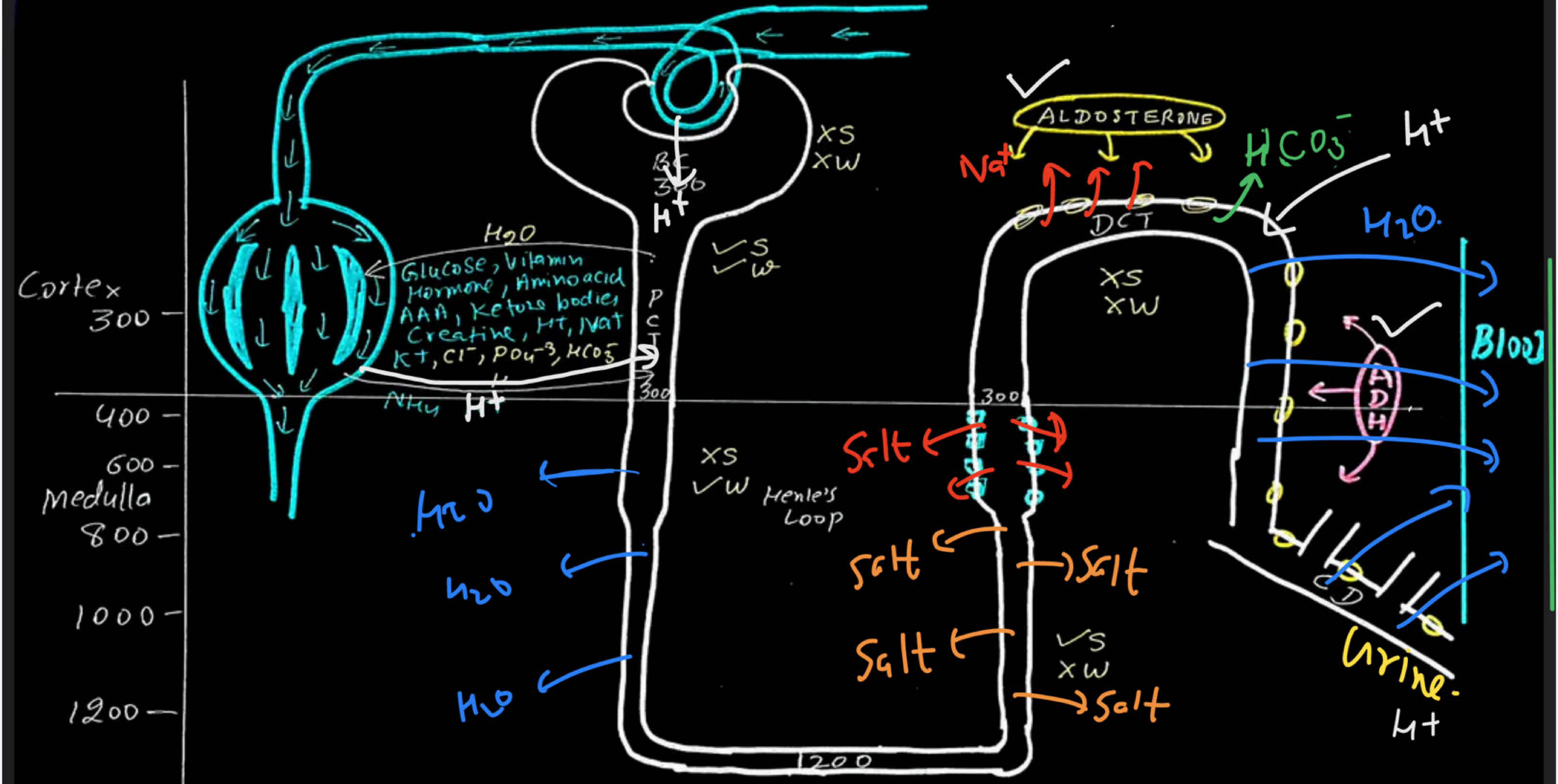
3) $\boxed{\text{Maintenance of Blood osmolarity}}$

(= 300 mosm L^{-1})

By

Dilution of urine

Concentration of urine.



ALDOSTERONE
Na^+
HCO_3^-
H^+
XS
XW
BC
300
H^+
H_2O
Glucose, Vitamin
Hormone, Aminoacid
AAA, Ketone bodies
Creatine, H+, Na+
K+, Cl−, PO4−3, HCO3−
NH_4
H^+
✓S
✓W
P
C
T
DCT
XS
XW
H_2O
Blood
ADH
Cortex
300
400
600
Medulla
800
1000
1200
300
300
XS
✓W
Henle's
Loop
H_2O
H_2O
H_2O
Salt
Salt
Salt
Salt
Salt
✓S
XW
1200
CD
Urine
H^+

↑ **Aldosterone**

- ↑ Salt in Blood
- ↓ Salt in Urine

↑ **ADH.**

- ↑ Water in Blood
- ↓ Water in Urine

What are A, B, C, D

(A) Blood, Blood, Urine, Urine

(C) Blood, Urine, Blood, Urine

(B) Urine, Blood, Urine, Blood

(D) Urine, Urine, Blood, Blood

During urine formation.

⇒ in order to make ~~urine~~ Blood. with an appropriate pH, the pH of ~~Blood~~ Urine Can be Altered.

True / False

Blood

A

Urine

B

↑ Salt in urine

(A) ↑ ADH

(B) ↓ ADH

(C) ↑ Aldosterone

(D) ↓ Aldosterone