B.SC. 2ND YEAR
ZOOCC-409
UNIT-3

C0UNTER CURRENT MECHANISM

BY

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Objective

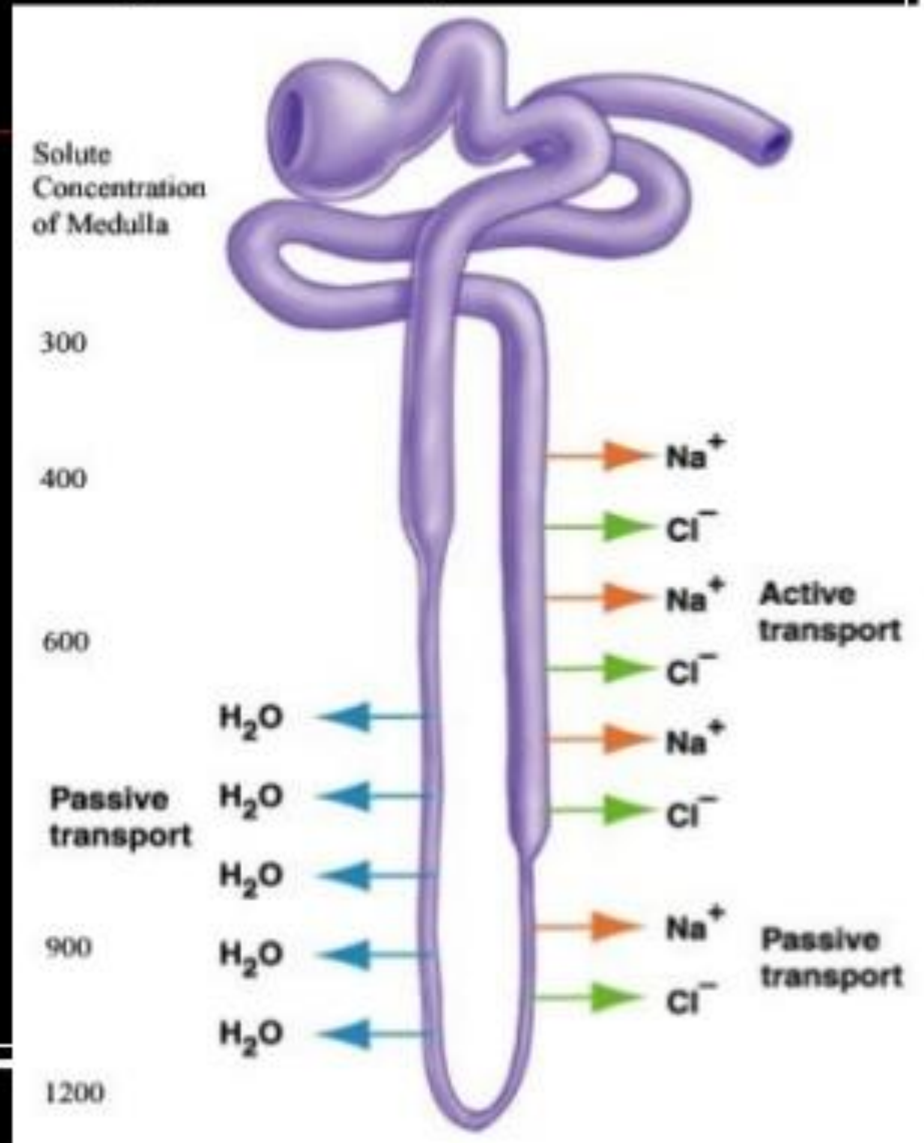
- At the end of the lecture you should know:
  - What is concurrent & countercurrent flow
  - Examples of countercurrent flow
  - Mechanisms of excretion of dilute & concentrated urine
  - Countercurrent multiplier
  - Countercurrent exchanger

Things you need to know before starting the main topic

- Physiological anatomy of nephrons
- Cortical & juxtamedullary nephrons
- Vasa recta
- Mechanism of urine formation
- Role of ADH
- Osmosis
- Concurrent & countercurrent flow
- Gradient

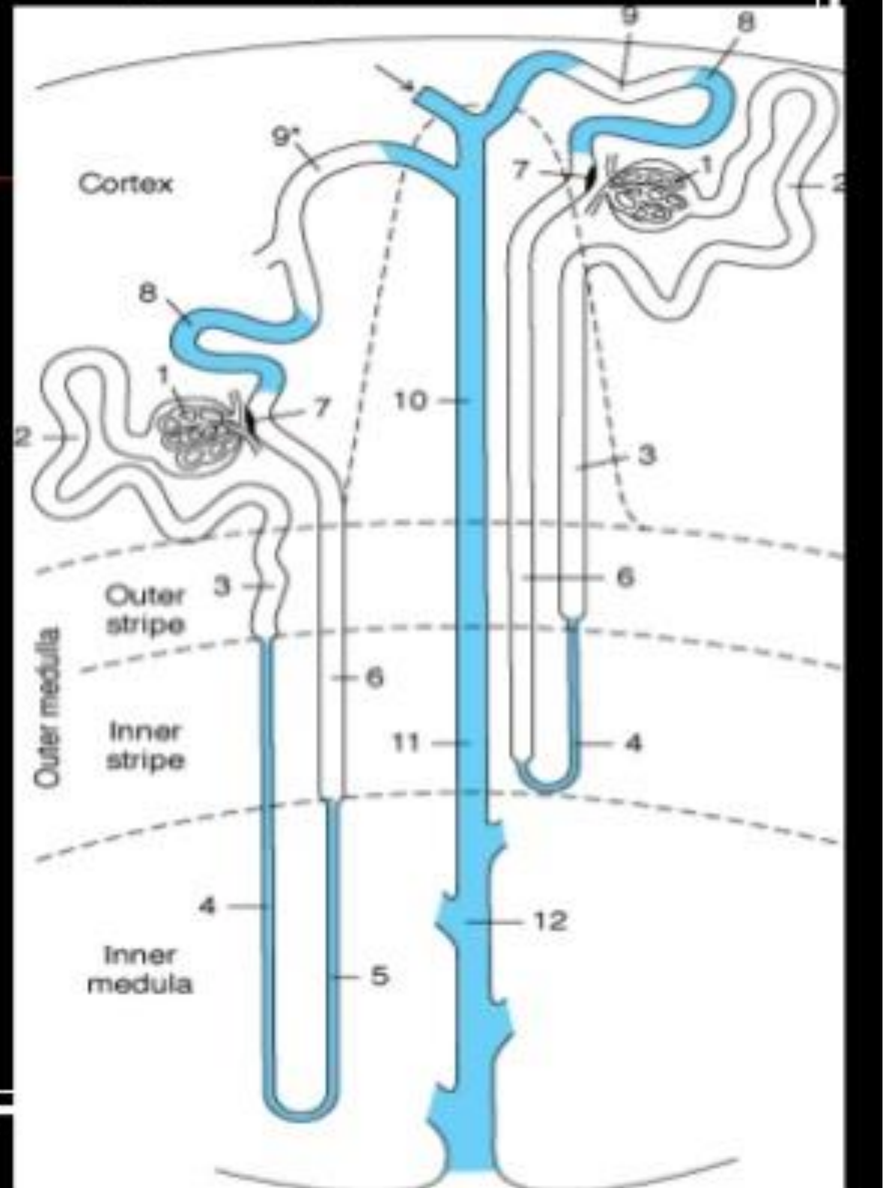
Physiological anatomy of nephron

- Descending limb of LOH is highly permeable to water, & less permeable to solutes.
- Ascending limb of LOH is virtually impermeable to water, but permeable to solutes.
- Solutes are transported out of the Thick Ascending limb of LOH by Na-K-2Cl co-transporter by active transport.



Cortical & Juxtamedullay nephrons

- Juxtamedullary nephrons have long LOH, dipping deep into the medulla.
- They are important in formation of concentrated urine.



CORTICAL AND JUXTAMEDULLARY NEPHRONS

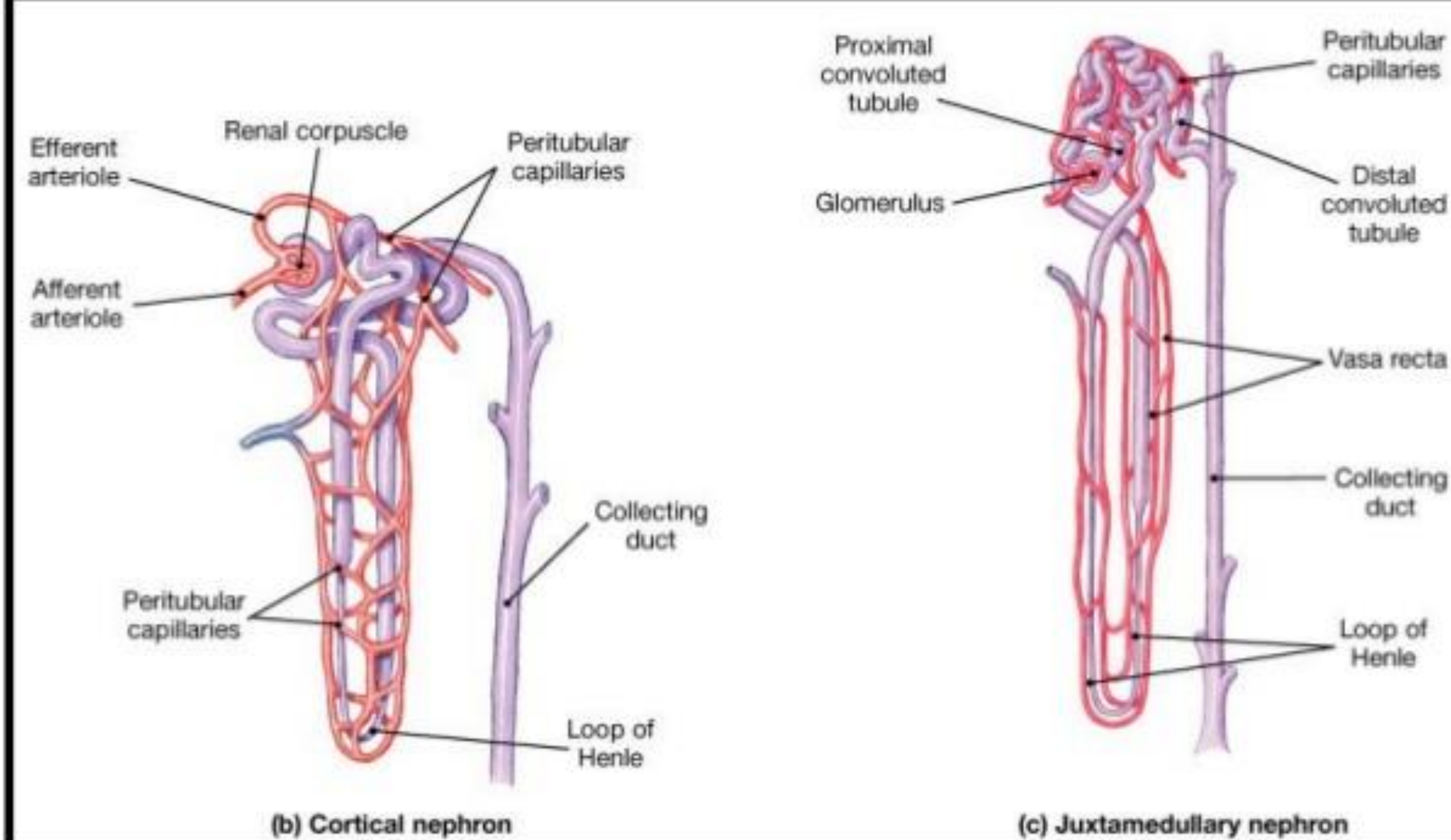
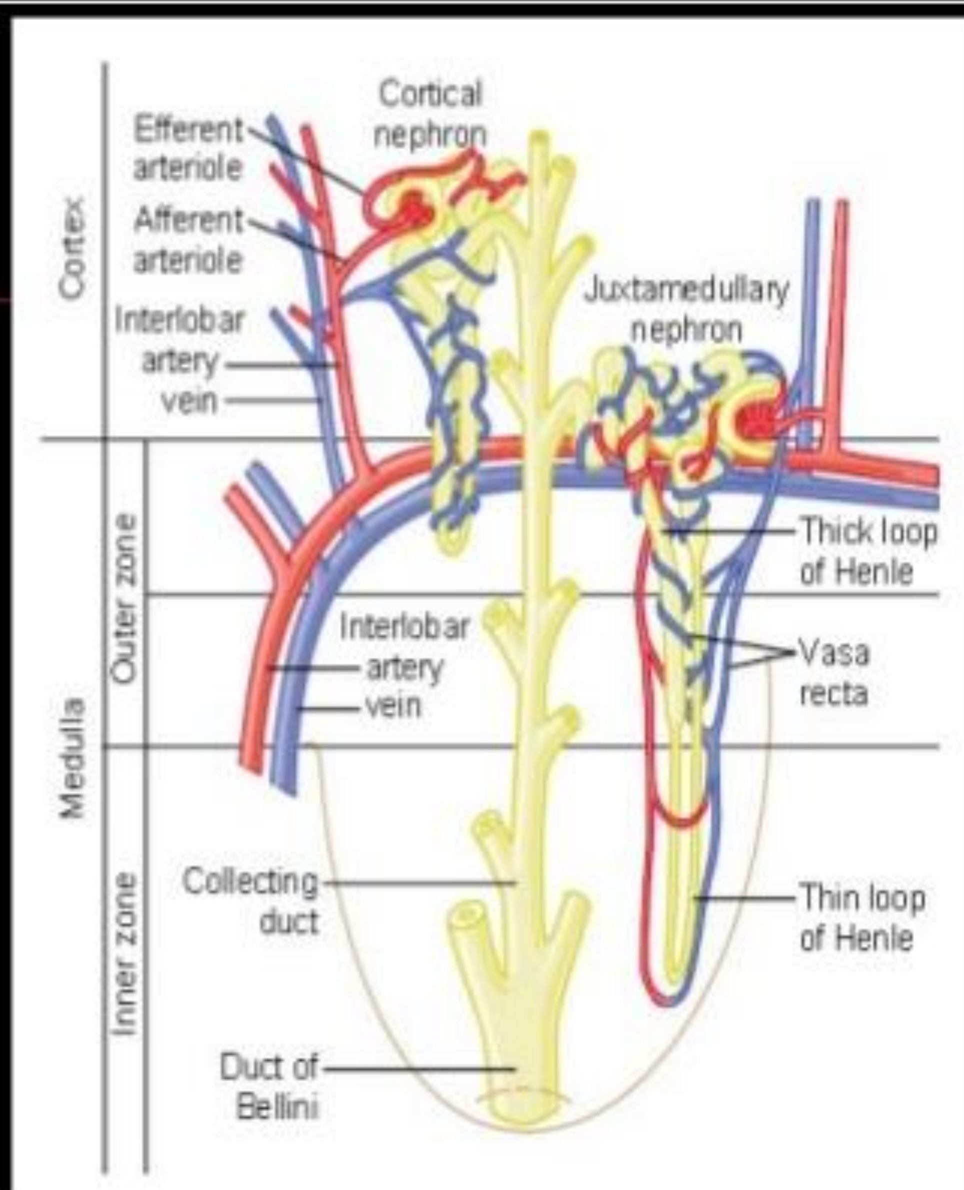


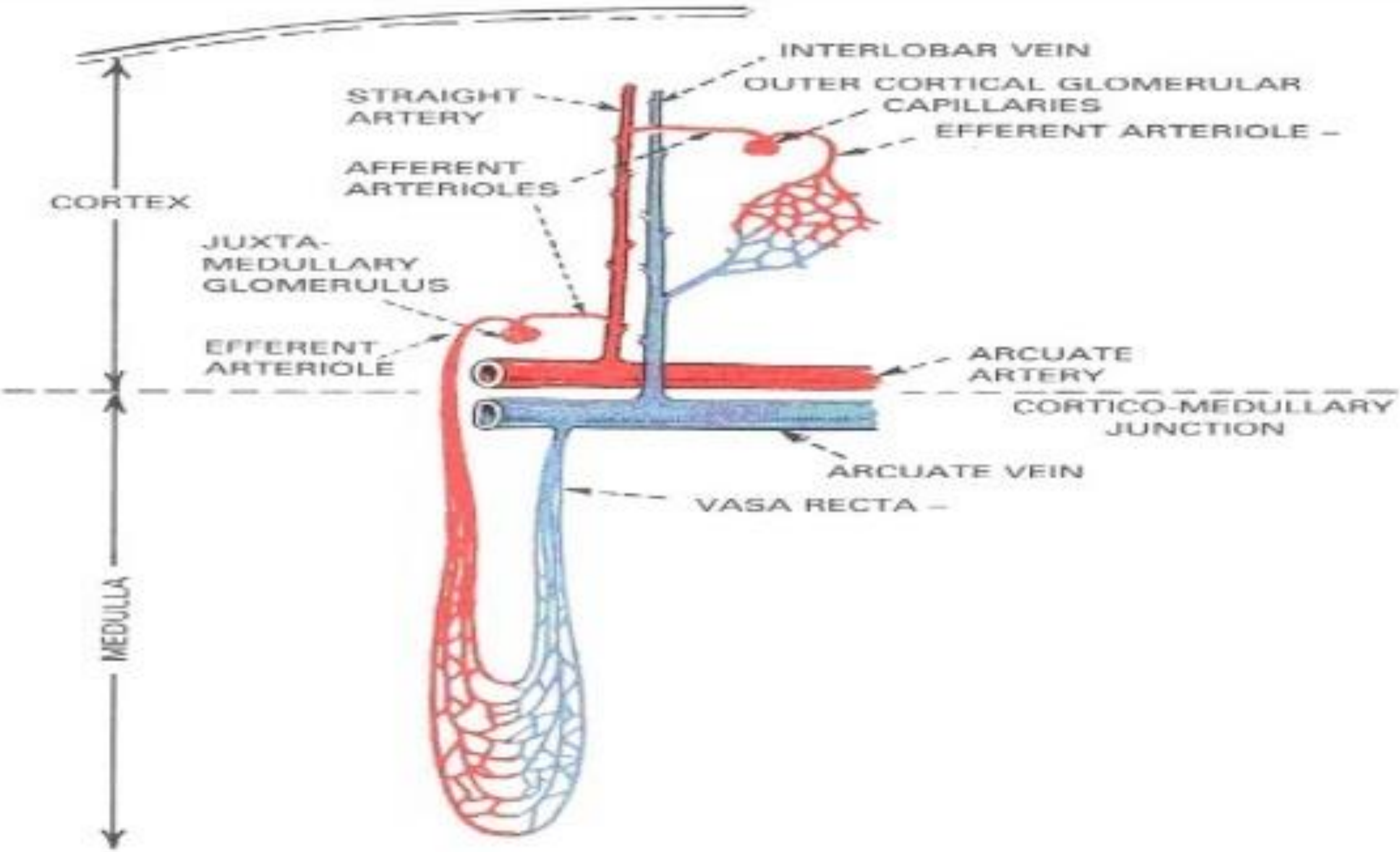
Figure 26.7b, c

Vasa Recta

- Efferent arterioles of the Nephrons further divide into a set of capillaries that surround the Nephrons.
- These capillaries in case of JMN are arranged as long hair-pin loop, k/a Vasa recta.



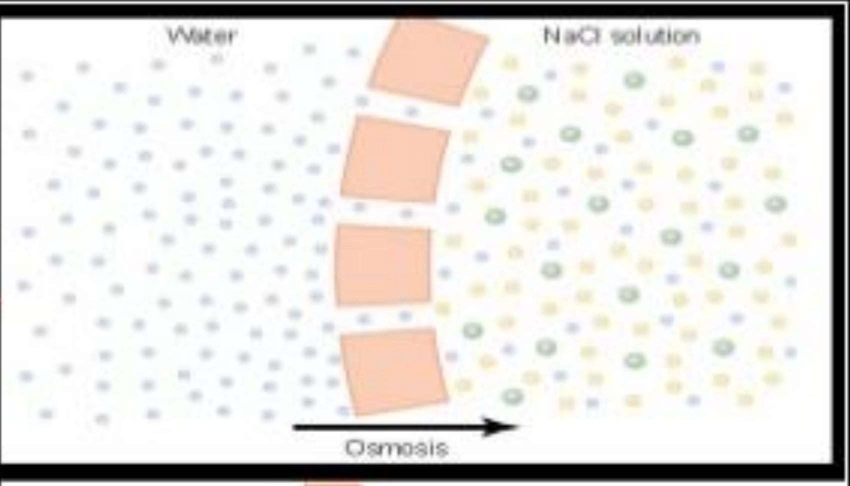
Vasa Recta

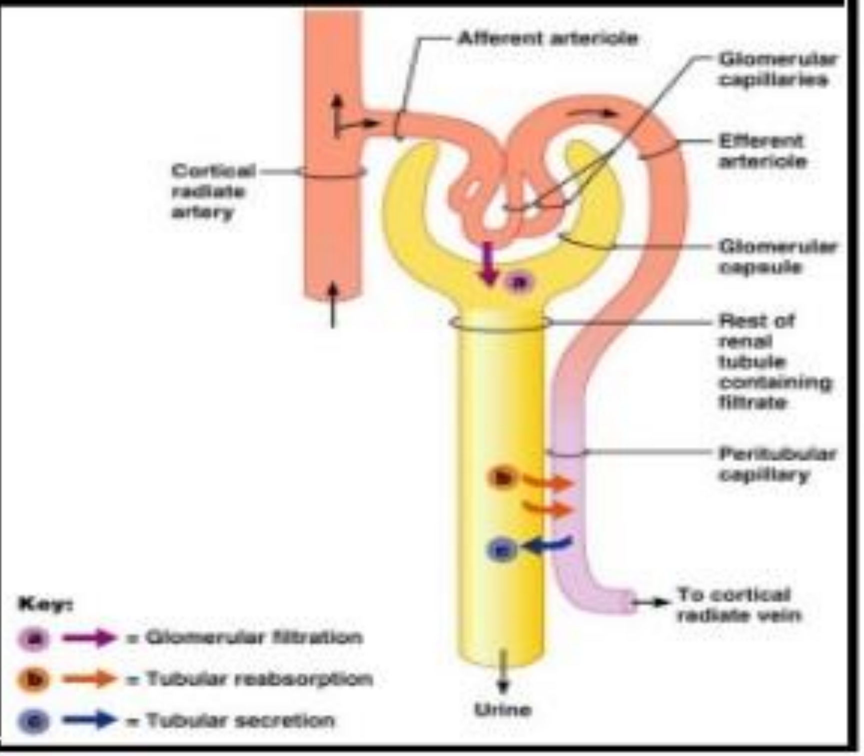


INTERLOBAR VEIN
STRAIGHT ARTERY
OUTER CORTICAL GLOMERULAR CAPILLARIES
EFFERENT ARTERIOLE –
AFFERENT ARTERIOLES
CORTEX
JUXTA-MEDULLARY GLOMERULUS
EFFERENT ARTERIOLE
ARCUATE ARTERY
CORTICO-MEDULLARY JUNCTION
ARCUATE VEIN
VASA RECTA –
MEDULLA

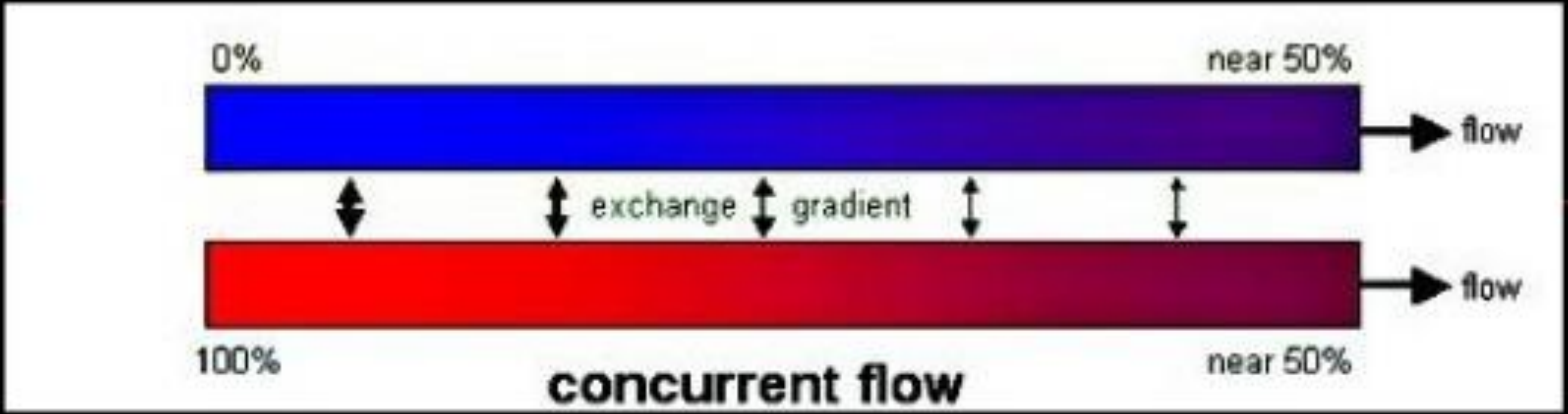
Osmosis

- Movement of solvent from lower concentration of solution to higher concentration.
- Movement of water from tubules to interstitium to peritubular capillaries occurs by osmosis.
- Solute particles move by various other transport processes.



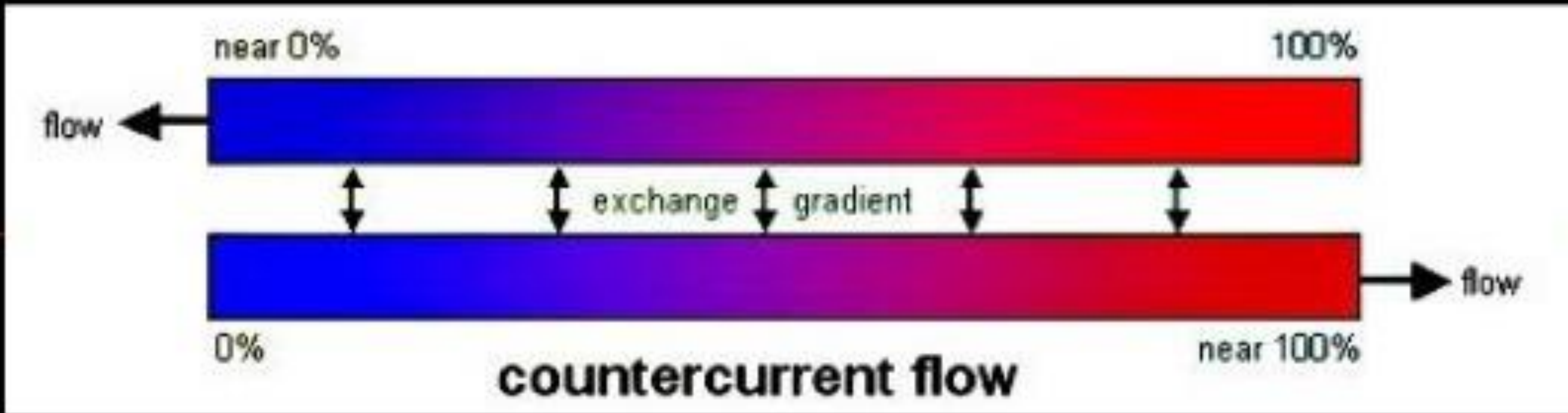


Concurrent & Countercurrent Flow



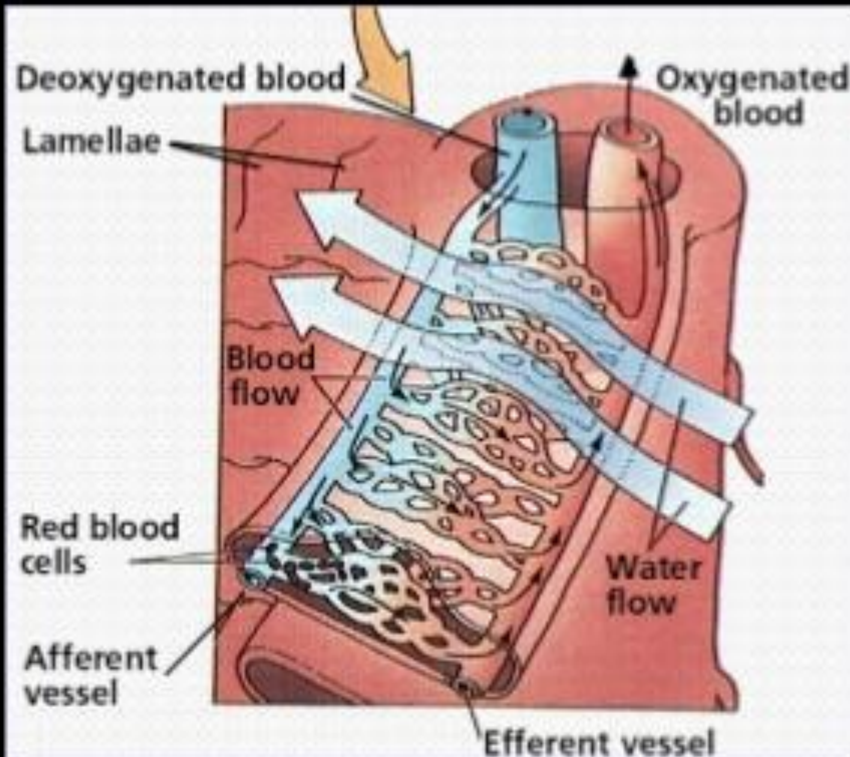
- The two fluids flow in the same direction.
- variable gradient over the length of the exchanger.
- capable of moving half of the property from one flow to the other, no matter how long the exchanger is.
- Exchange stops when equilibrium is reached and gradient declines to zero.

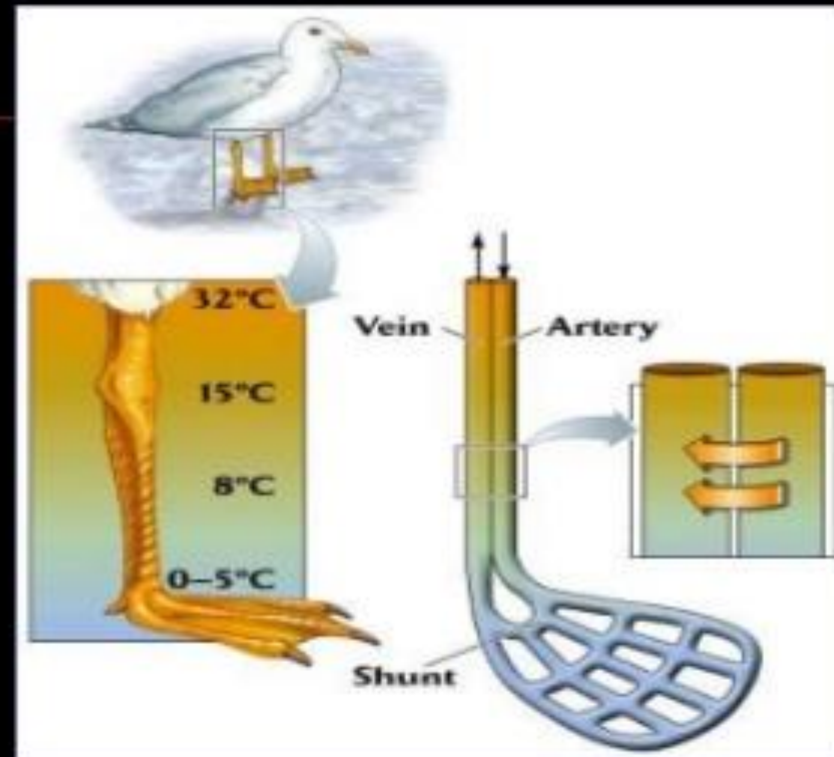
Concurrent & Countercurrent Flow



- The two fluids flow in the opposite direction.
- nearly constant gradient between the two flows over their entire length.
- With long length & low flow rate its capable of transferring all the property from one fluid to the other.

Countercurrent Flow - Examples

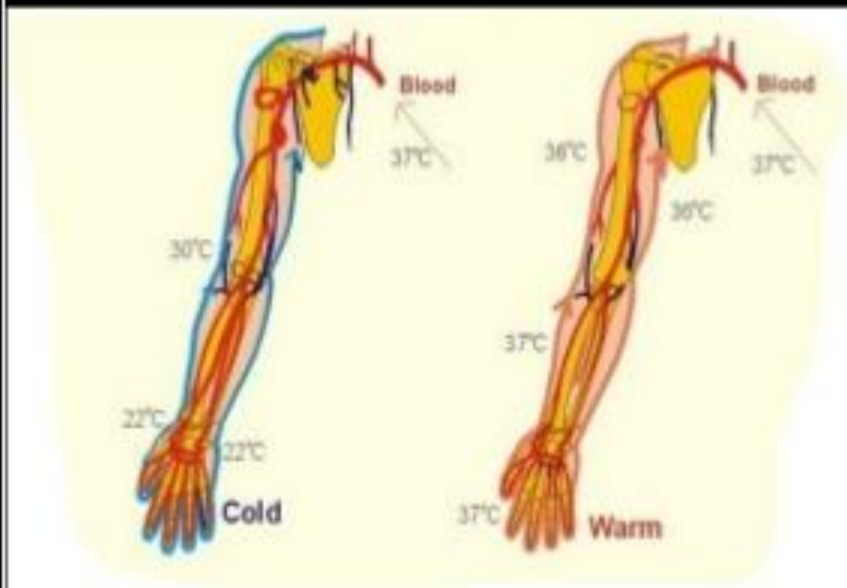


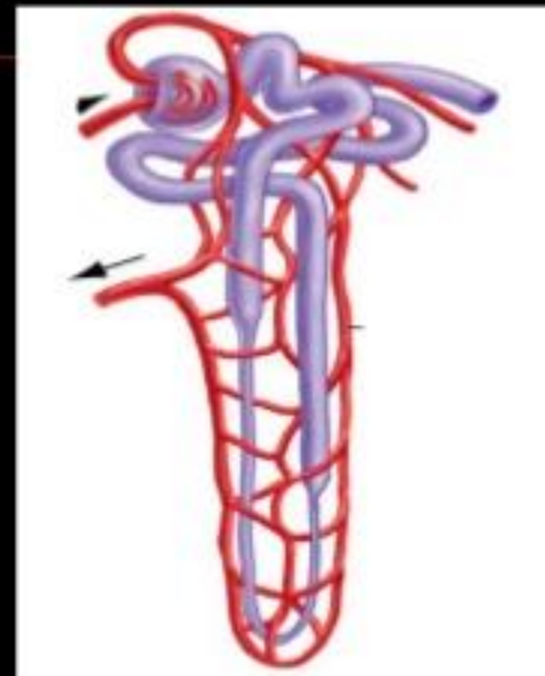


Fishes use it in their gills to transfer O_2 from surrounding water to blood

Birds use it in their legs to Conserve core body heat.

Countercurrent Flow – Examples in humans



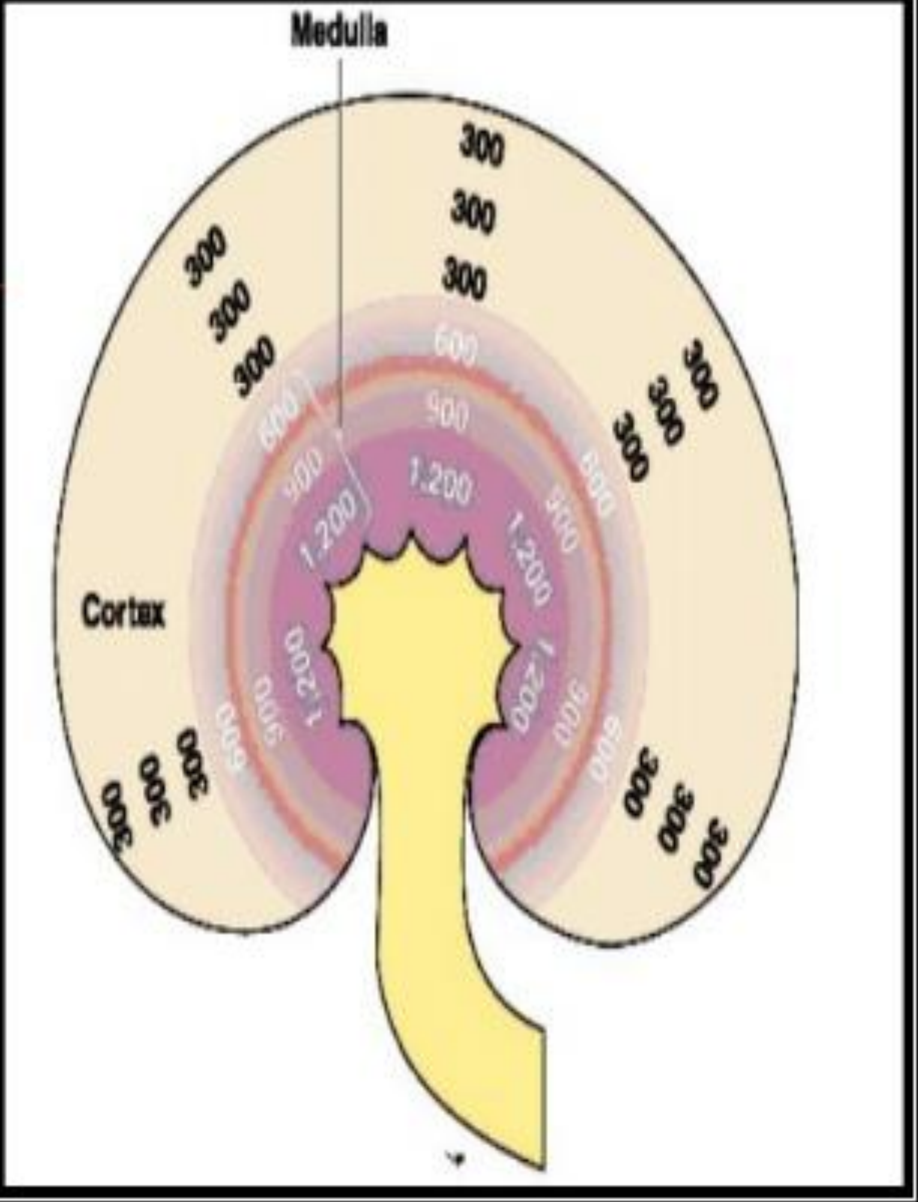


To conserve heat in acral parts of the body.

Human kidney uses CCF in LOH & VR to produce concentrated urine.

Gradient

- A graded change in the magnitude of some physical quantity or dimension in a given direction.
- A concentration gradient in renal medullary interstitium is present; which is important in formation of concentrated urine.
- This renal gradient is due to the CCM in LOH & VR.



In steady state water intake and output must be equal

- Water intake (per day)
  - Ingested fluids - 1200 ml
  - Ingested food- 1000 ml
  - Aerobic metabolism- 300 ml
  - Total- 2500 ml

- Water output (per day)
  - Urine- 1500 ml
  - Feces- 100 ml
  - Insensible loss- 900 ml
    - Skin- 550 ml
    - Lungs- 350 ml
  - Total- 2500 ml

Values are indicative only and will vary depending on diet, physical activity, environmental temperature, humidity etc.

Kidneys maintain water homeostasis by adjusting the volume of urine

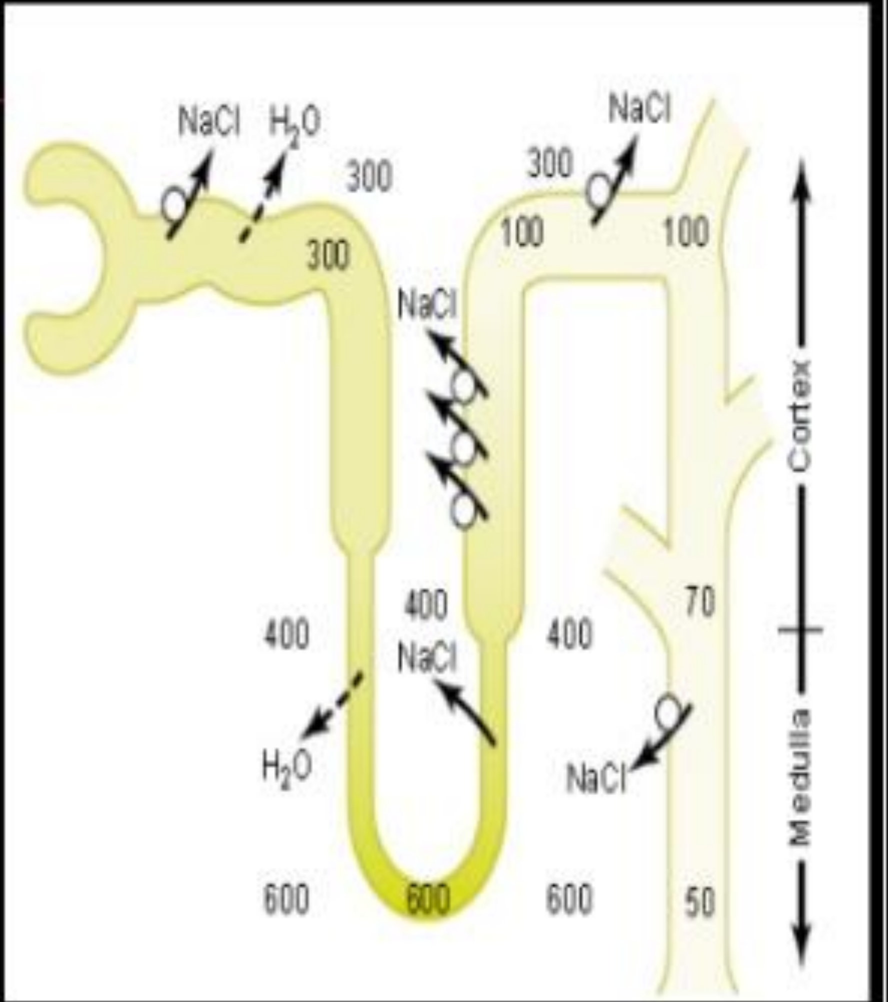
- High water intake → inc. urine volume (up to 20 l/d, 50 mosmol/l)

- Low water intake or → low urine volume
  high water loss
  (up to 0.5 l/d, 1200 mosmol/l)

Renal Mechanism for Dilute urine

- Formation of dilute urine depends on decreased secretion of ADH from pituitary.

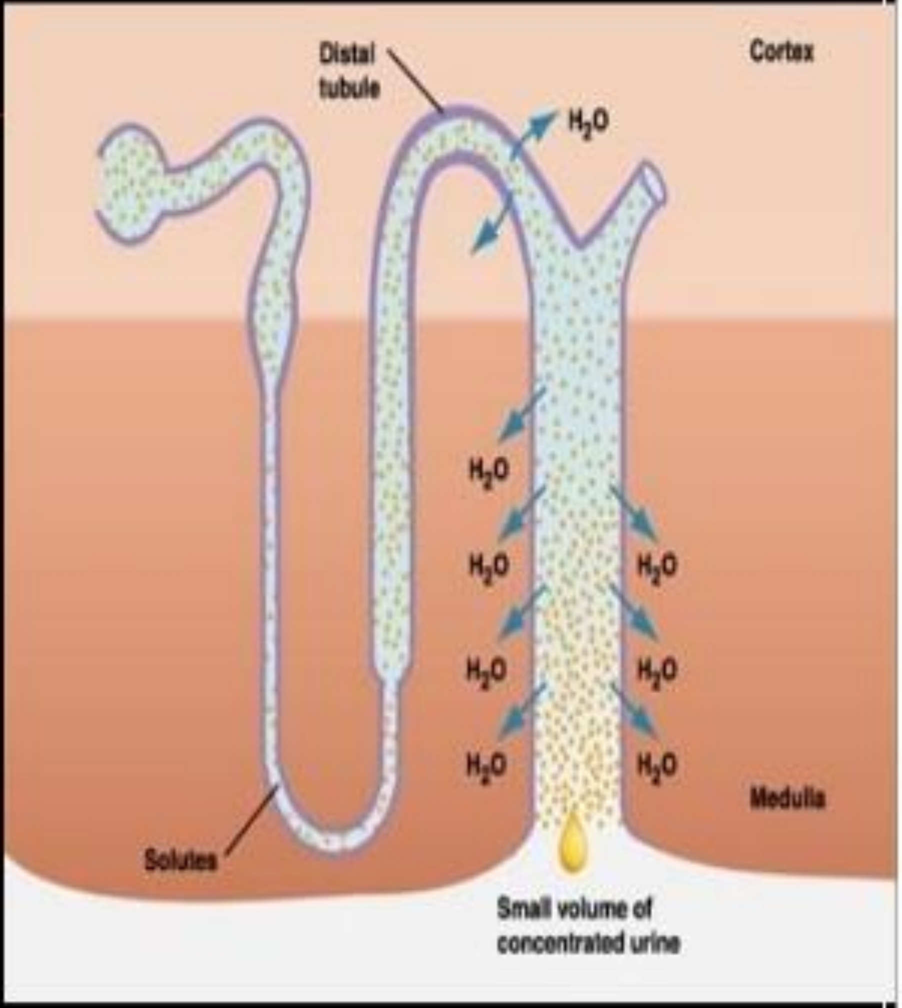
- Kidneys continue to absorb solute; while fail to absorb the water.



Renal Mechanism for Conc. Urine

- Achieved by continuing to secrete the solutes; while increasing the water reabsorption.

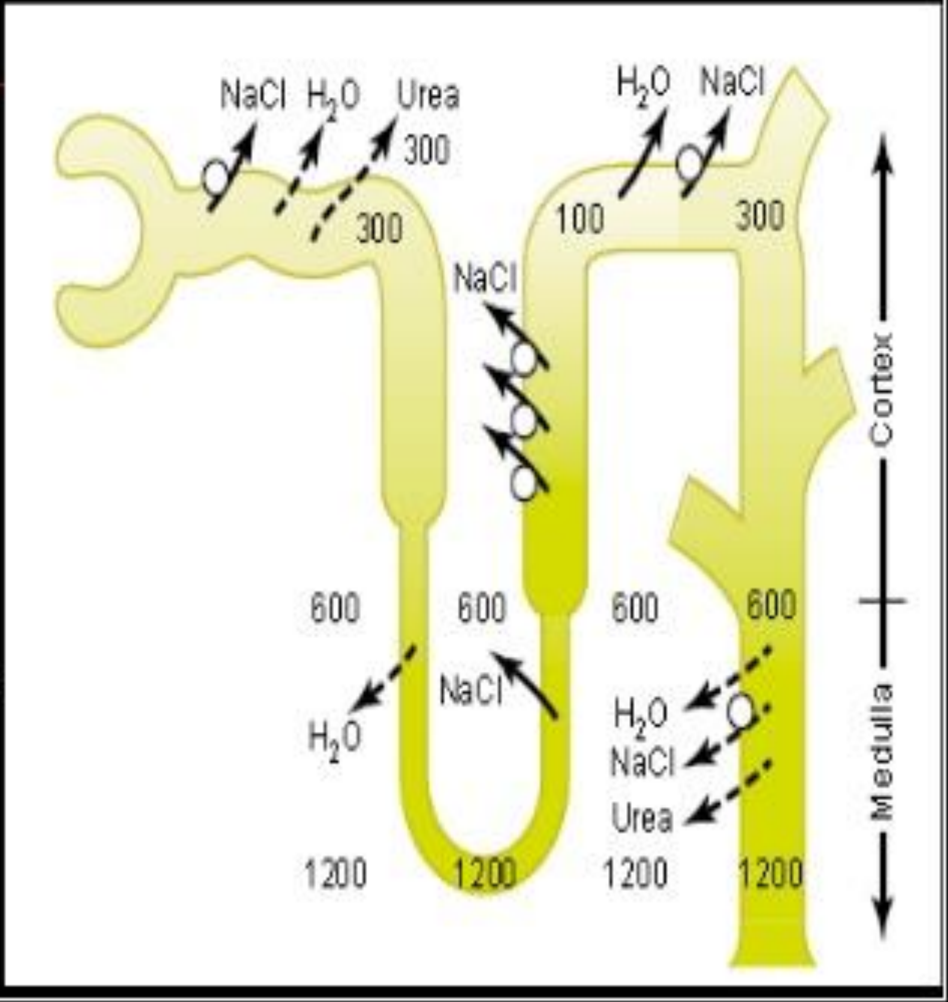
- This requires:
  - High level of ADH
  - Highly osmolar renal medullary interstitium



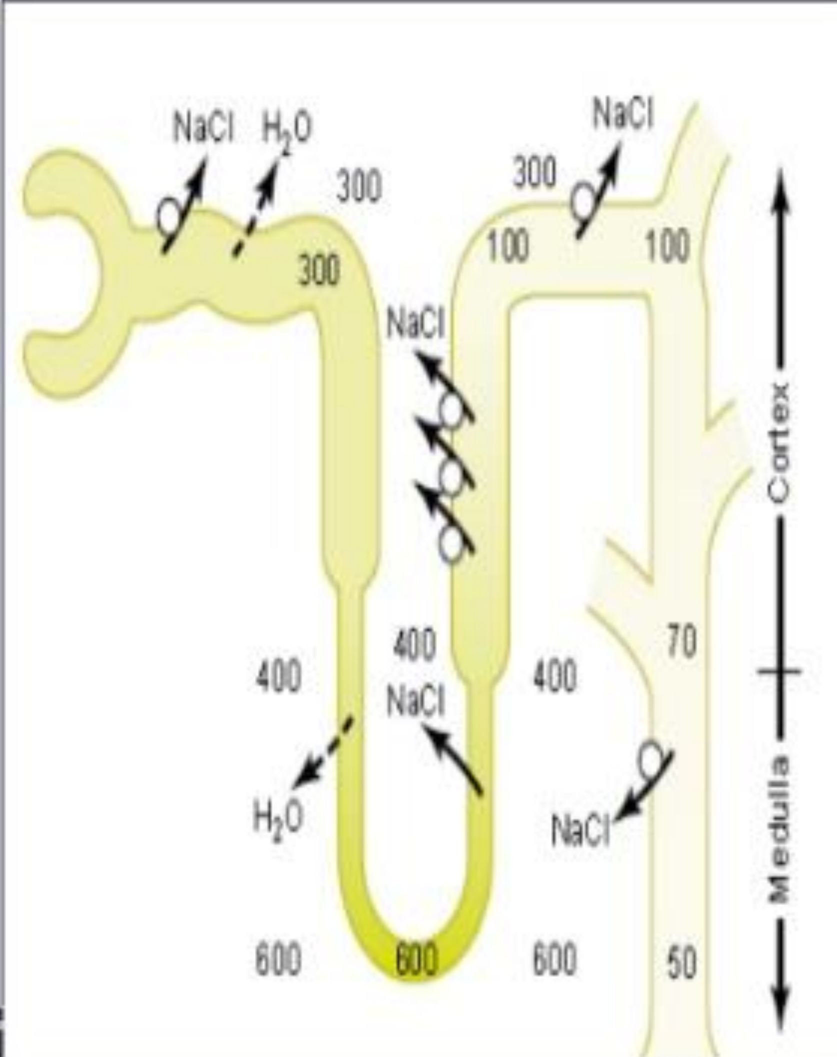
Renal Mechanism for Conc. Urine

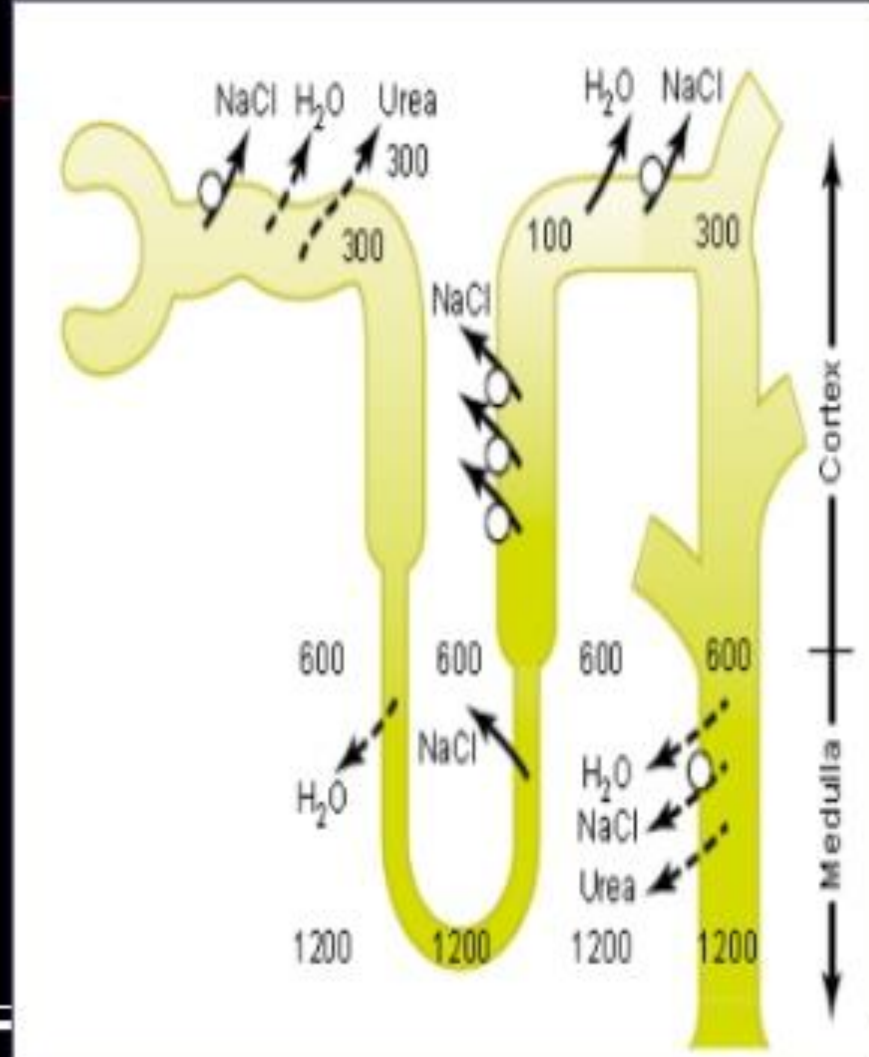
- ADH increases the permeability of the distal tubules & collecting ducts to water.

- Highly osmolar renal medullary interstitium provides osmotic gradient for water reabsorption in presence of ADH.



Compare the two situations

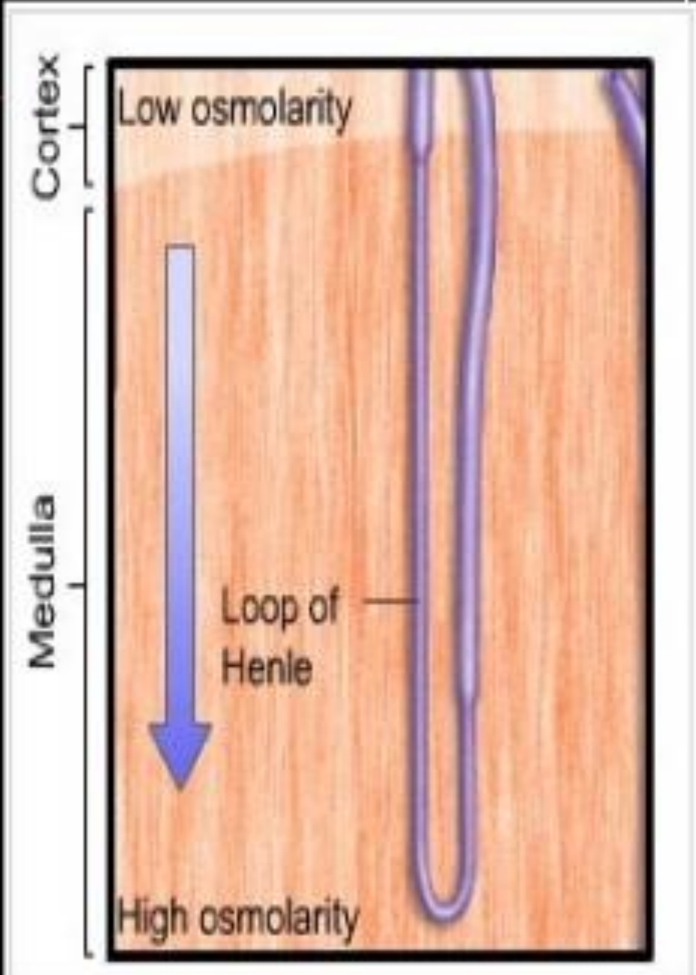




Hyperosmotic Medullary Interstitium

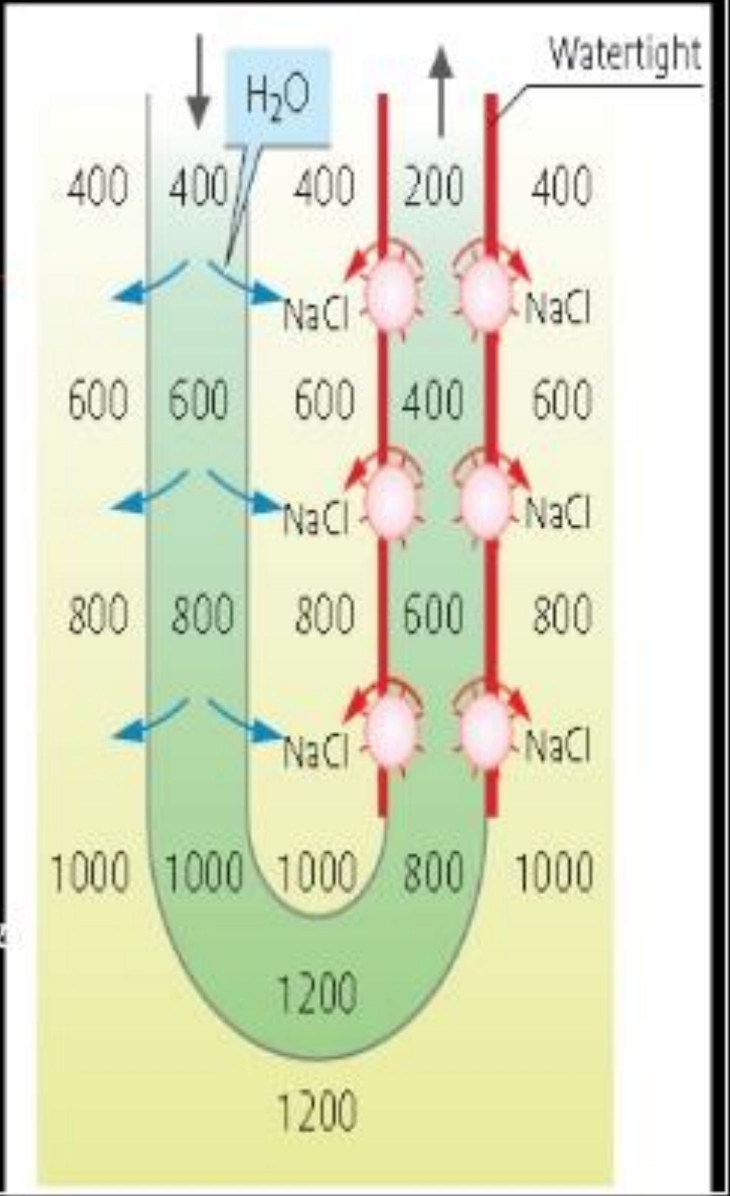
- There is a progressively increasing osmolar gradient in medulla.

- This gradient is due to:
  - LOH acting as Countercurrent Multiplier
  - Vasa Recta acting as Countercurrent Exchanger
  - Urea cycling also contributes to the medullary osmolarity.

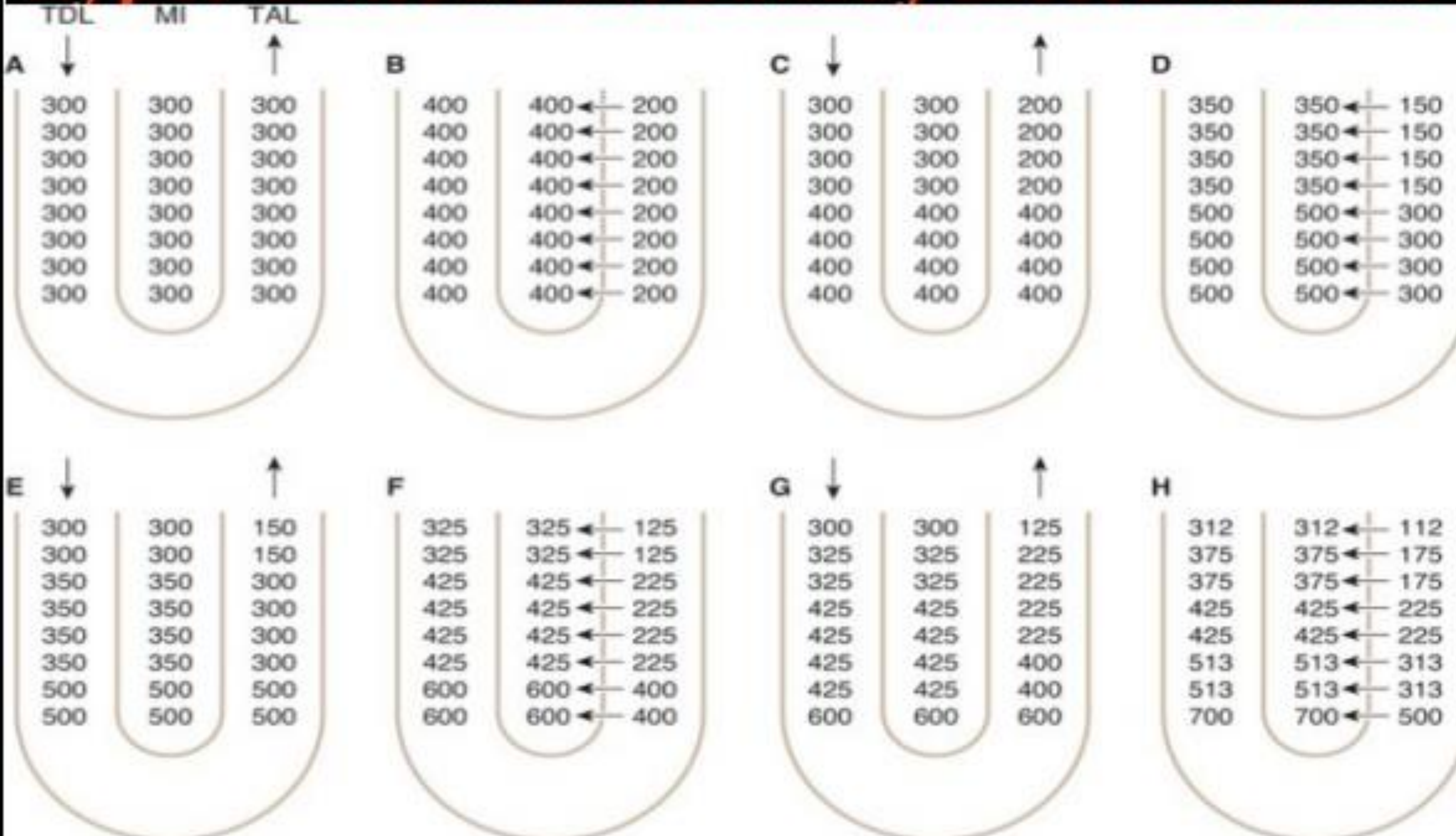


Countercurrent Multiplier

- LOH act as countercurrent multiplier to produce the medullary osmotic gradient.
- AL pumps out NaCl into the interstitium & is capable of producing an osmotic gradient of 200 mosmol/l b/w any part of tubule & interstitium.
- The countercurrent flow in LOH, with differing permeability of DL & AL is capable of multiplying this effect to produce an osmotic gradient.

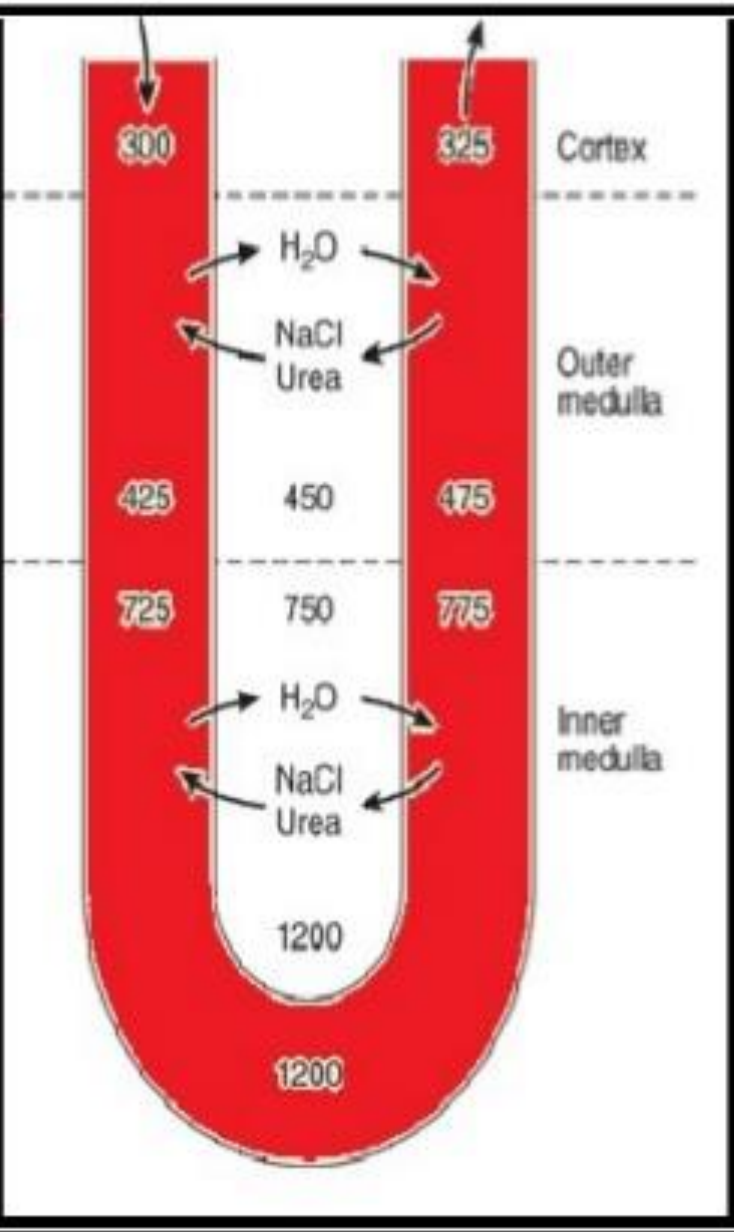


Steps involved in production of hyper osmotic medullary interstistium



Countercurrent Exchanger

- Vasa recta prevents the wash down of medullary concentration gradient while absorbing excess solutes & water from interstitium.
- It does not contribute to the production of medullary concentration gradient but helps to preserve it.
- Low blood flow (5-10% of total) to the medulla also helps in this.



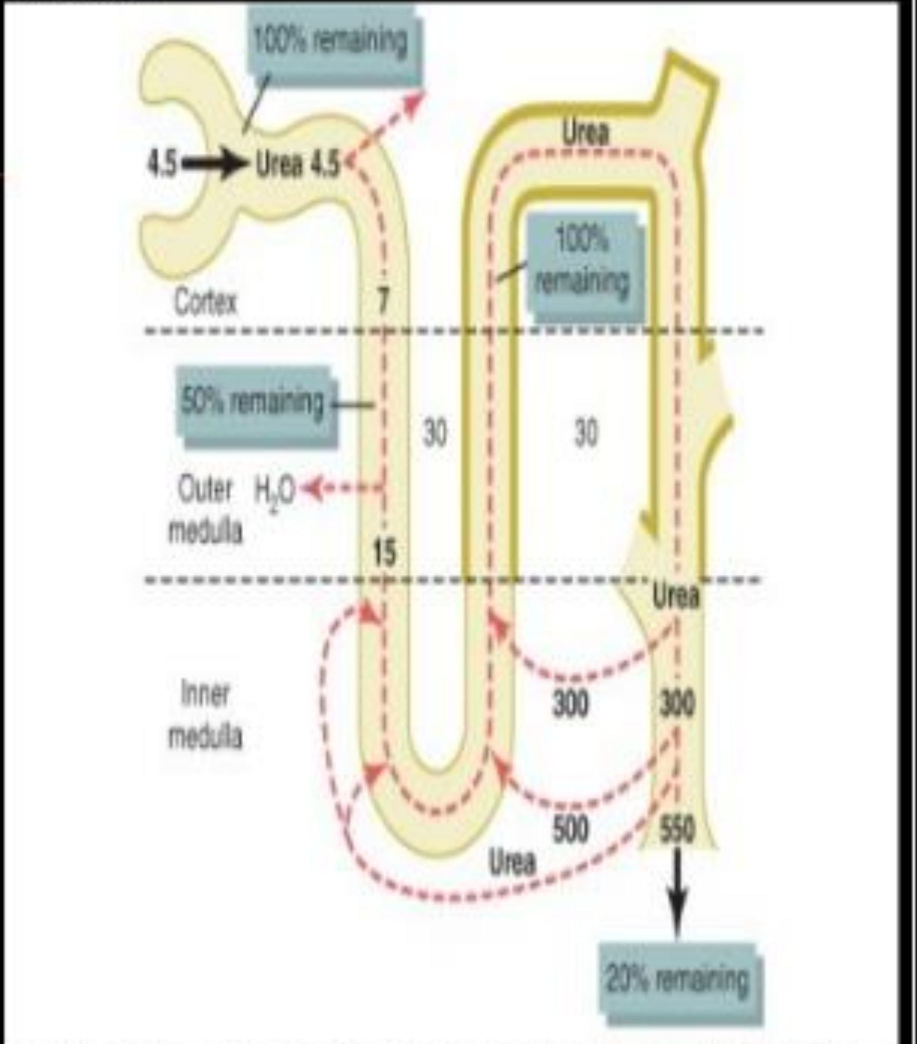
Remember

Loop of Henle: Countercurrent Multiplier

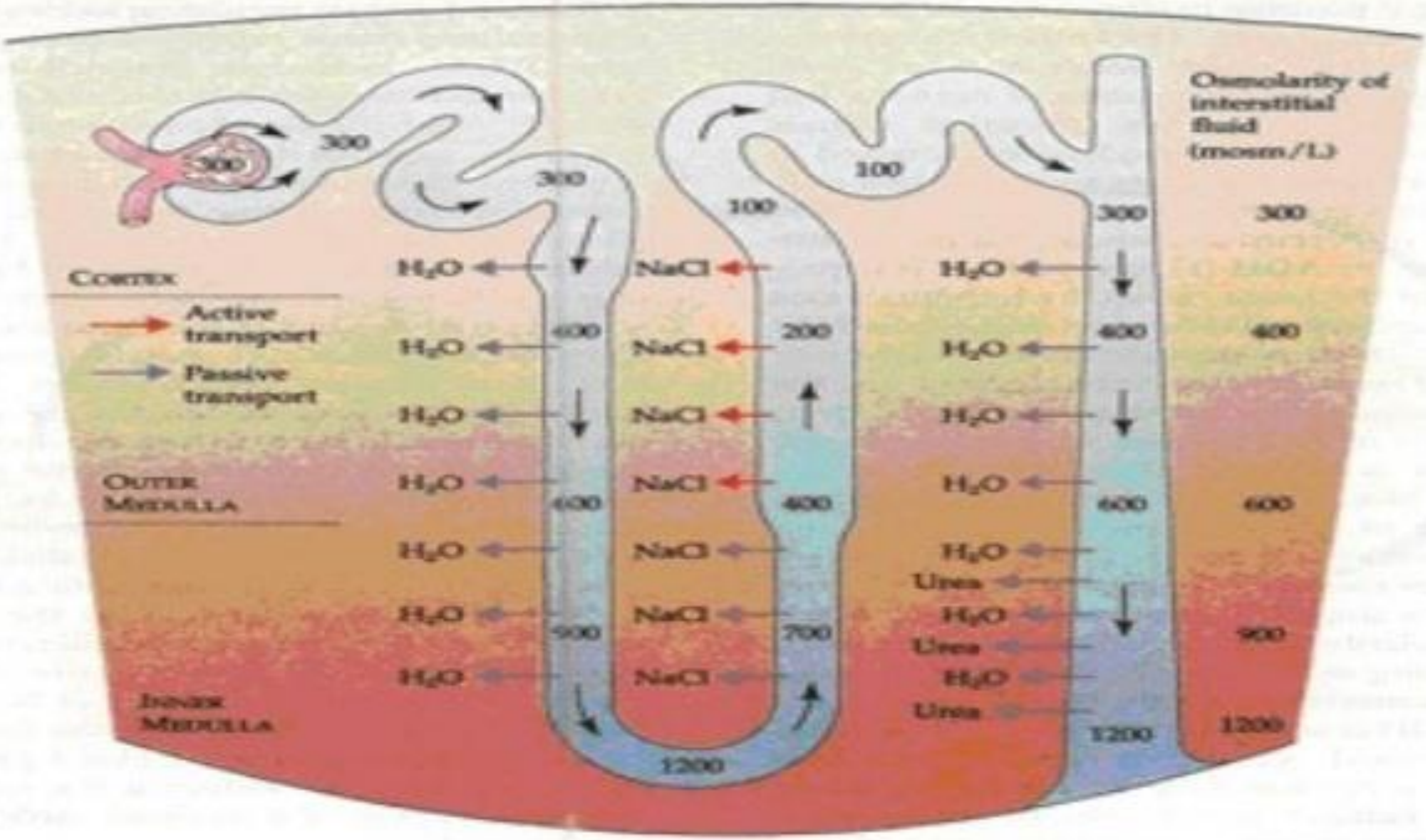
Vasa Recta: Countercurrent Exchanger

Contribution of Urea to the hyperosmotic renal medulla

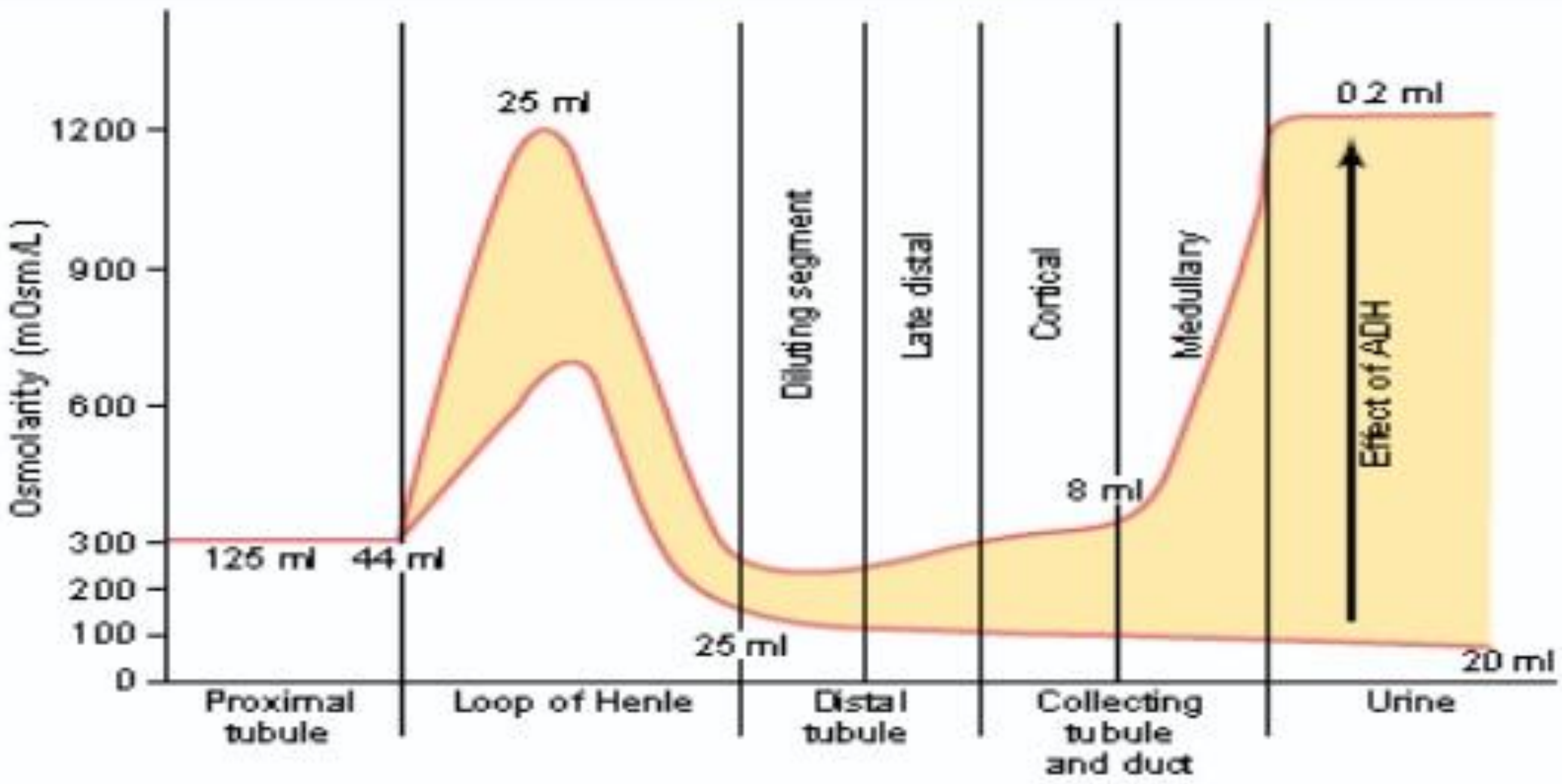
- urea contributes about 40 – 50% of the osmolarity of the renal medullary interstitium.
- Unlike sodium chloride, urea is passively reabsorbed from the tubule.
- When there is water deficit and blood concentrations of ADH are high, large amounts of urea are passively reabsorbed from the inner medullary collecting ducts into the interstitium



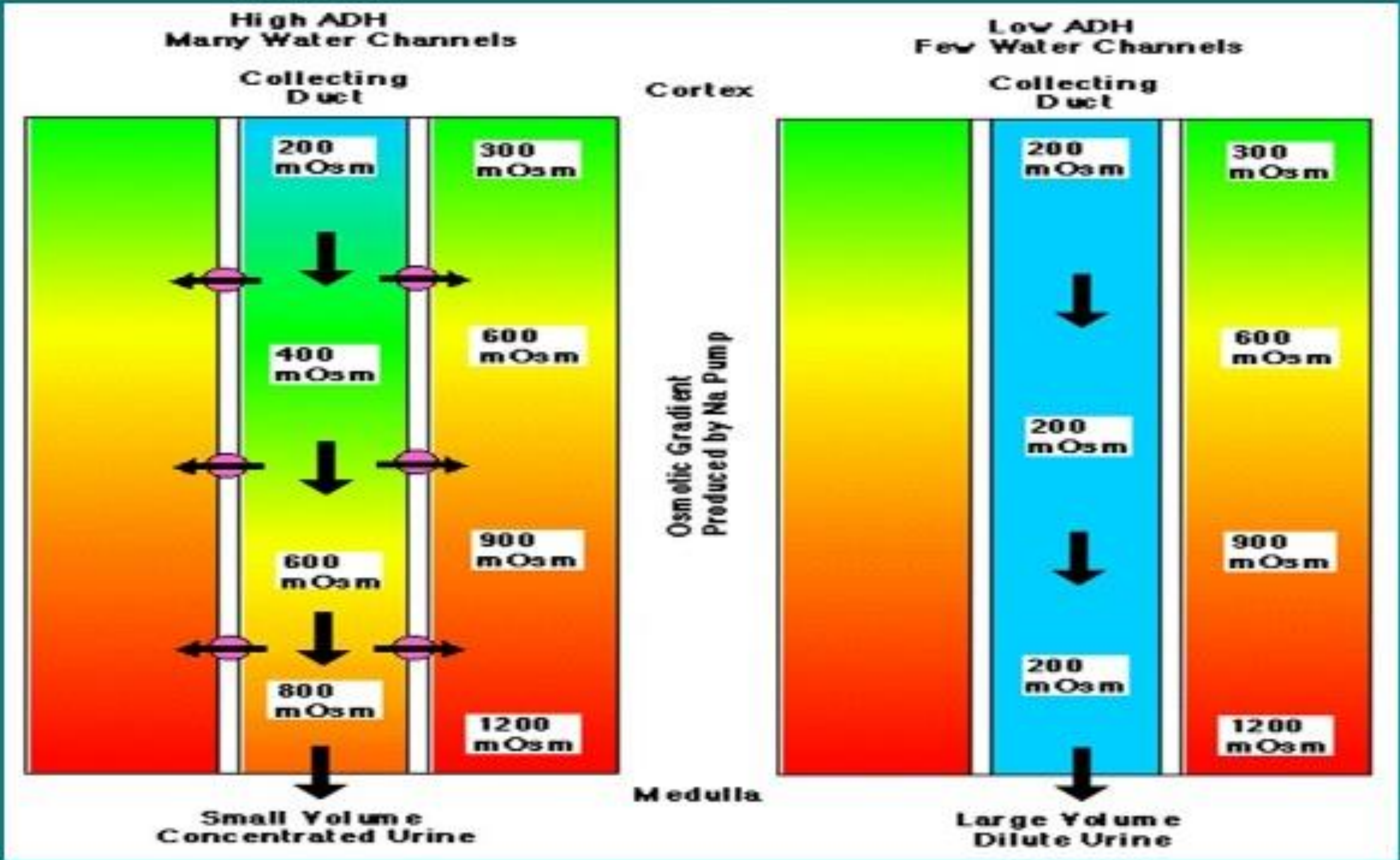
Mechanism of urine formation



ADH is mainly responsible for formation of dilute or concentrated urine



Role of ADH



High ADH
Many Water Channels
Collecting Duct
Cortex
Low ADH
Few Water Channels
Collecting Duct
200 mOsm
300 mOsm
400 mOsm
600 mOsm
600 mOsm
900 mOsm
800 mOsm
1200 mOsm
200 mOsm
300 mOsm
600 mOsm
200 mOsm
900 mOsm
200 mOsm
1200 mOsm
Osmotic Gradient
Produced by Na Pump
Medulla
Small Volume
Concentrated Urine
Large Volume
Dilute Urine

Obligatory Urine Volume

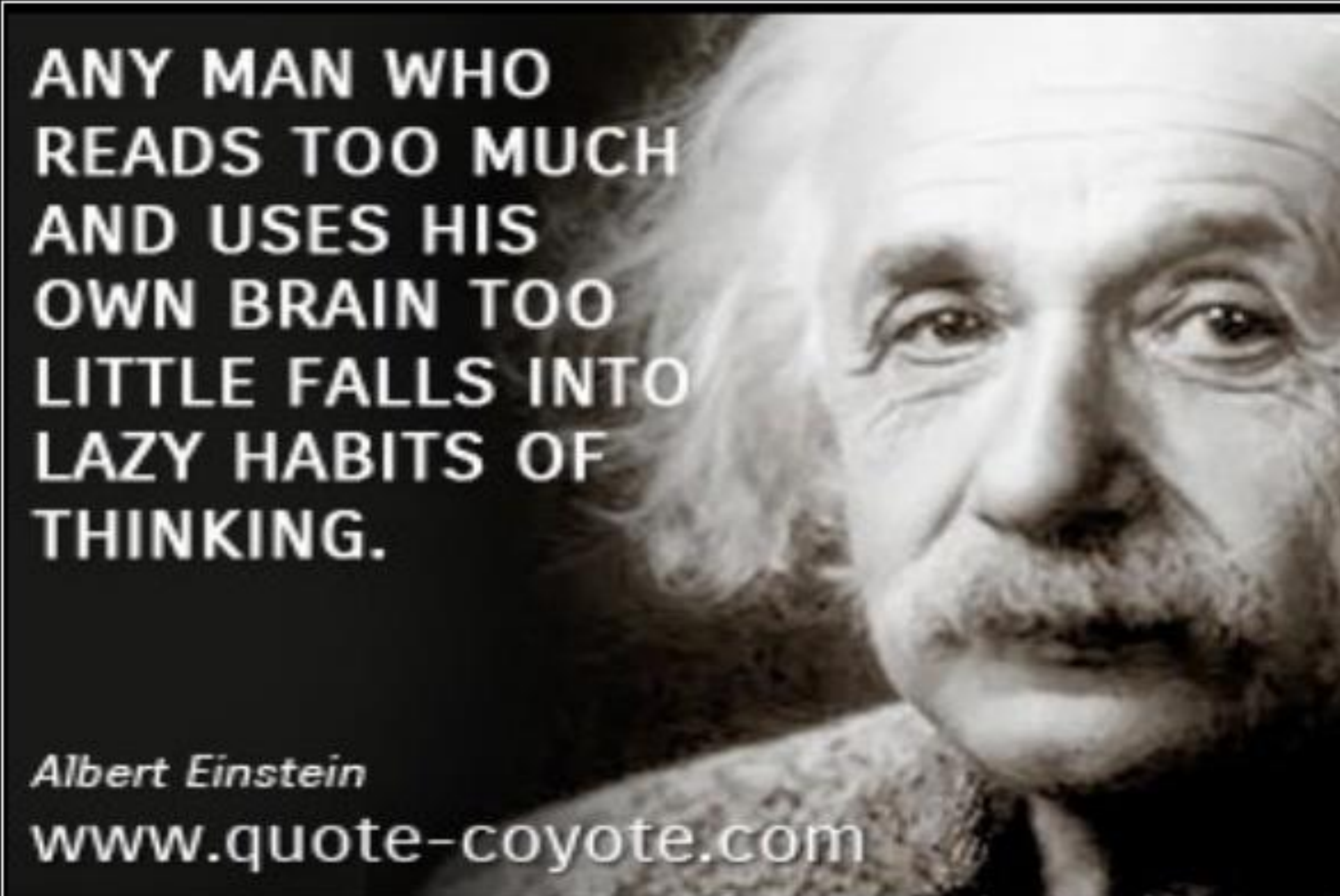
- It is the minimal volume of urine that must be excreted each day to get rid the body of the products of metabolism & ingested ions.
- It depends upon the maximal concentrating ability of the kidney.
- Total solutes to be excreted each day in 70 kg man = 600 mosmol

Maximum conc. ability of human kidney = 1200 mosmol/l

OUV = 600/1200 = 0.5 L/day

Disorders of urinary concentrating ability

- Inappropriate secretion of ADH:
  - ↓ ADH: Central Diabetes Insipidus
  - ↑ ADH: SIADH (Syndrome of Inappropriate secretion of ADH)
- Impairment of countercurrent mechanism:
  - High flow rate: osmotic diuresis
- Inability of tubules to respond to ADH:
  - Nephrogenic Diabetes Insipidus


ANY MAN WHO
READS TOO MUCH
AND USES HIS
OWN BRAIN TOO
LITTLE FALLS INTO
LAZY HABITS OF
THINKING.
Albert Einstein
www.quote-coyote.com


THANK YOU