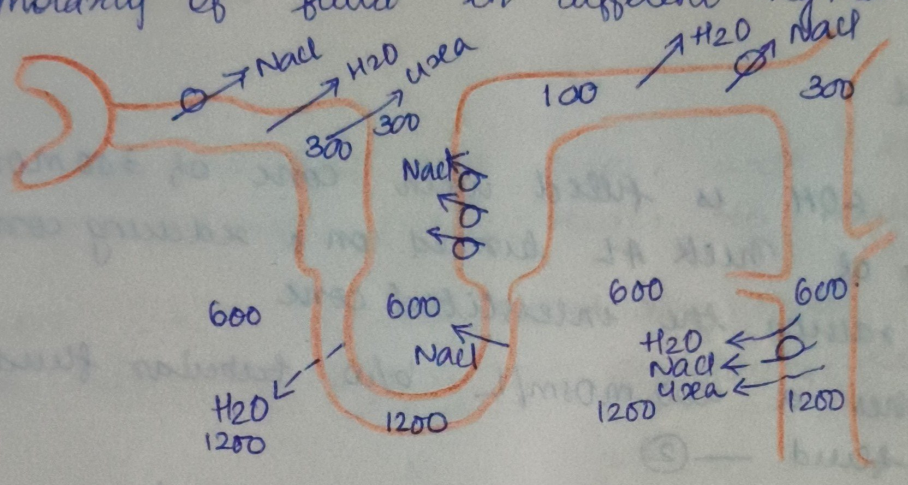
Concentration of urine
- Countercurrent Mechanism

- Kidneys have the capacity to pass urine with extremes of osmolarity ranging from 30 mOsm/kg to 1400 mOsm/kg
- Though GFR is 180 L/day, only about 1.5 L of urine is excreted daily
- Thus, kidney normally excretes a conc urine to prevent volume depletion from the body

○ Osmolarity of fluid in different segments of tubule



Requirements for excreting a concentrated urine

a) High level of ADH → ↑ses the permeability of DCT & CD to reabsorb water

b) High osmolarity of renal medullary interstitial fluid

- The process by which renal medullary ISF becomes hyperosmotic
  Countercurrent system

Countercurrent Mechanism produces a Hyperosmotic Renal Medullary interstitium

→ Osmolarity of ISF in almost all part of body is 300 mOsm/L.
→ Osmolarity of ISF in medulla of kidney is much higher - ↑sing progressively to 1200-1400 mOsm/L in the pelvic tip of medulla
→ This means that the renal Medullary interstitium has accumulated solutes in great excess of water

Major factors causing the buildup of solute conc in Renal medulla are

→ 1) Active transport of sodium and co transport of K and Cl- out of thick ascending limb of LOH into interstitium

2) Active transport of ions from CD's into interstitium

3) Facilitated diffusion of large Amounts of urea from inner medullary CDs into medullary interstitium

4) Diffusion of only small amounts of water from medullary tubules into interstitium

steps involved →

- First assume that LOH is filled with conc of 300 mOsm/L — ①
- Next active pump of Thick AL turned on, reducing conc inside tubule & raising the interstitial conc
- The pump establishes a 200 mOsm/L b/w tubular fluid and interstitial fluid — ②.

+ The limit to the gradient is about 200 mOsm/L — Because paracellular diffusion of ions back to tubule counterbalances transport of ions out of lumen when 200 mOsm/L gradient is achieved

Step ③

Tubular fluid in the DL of LOH and ISF quickly reach Osmotic equilibrium due to Osmosis of water out of DL

→ The interstitial Osmolarity is maintained to 400 mOsm/L because of continued transport of ions out of Thick AL

Step ④

Additional flow of fluid into LOH from Proximal tubule

Hyperosmotic fluid previously formed in the Descending limb flows into Asc limb

Step 5

Additional ions are pumped into interstitium, with water remaining behind until osmolarity rises to 500 mOsm/L

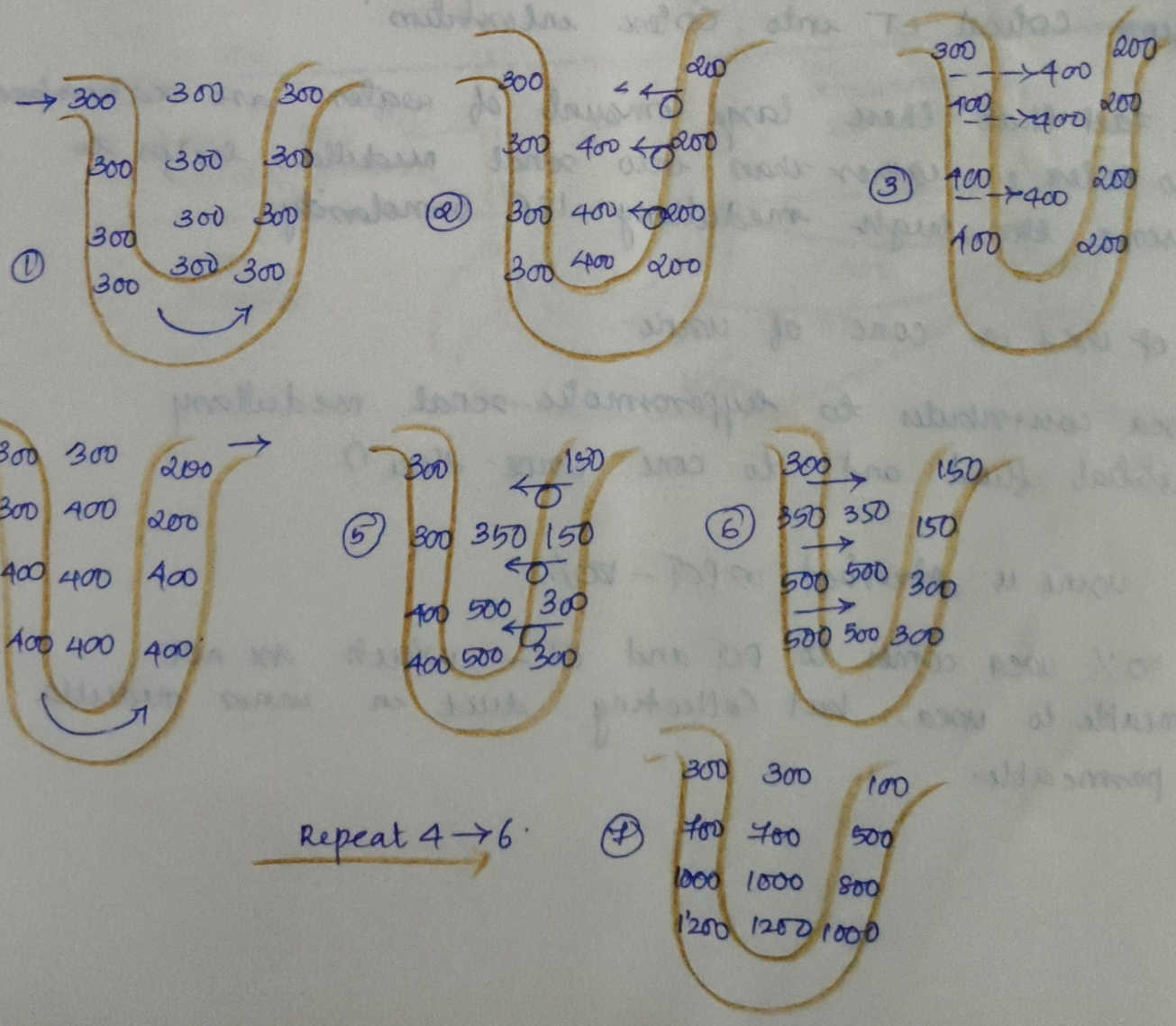
Step 6

- once again, fluid in the descending limb reaches equilibrium with the hyperosmotic medullary ISF
- As the hyperosmotic tubular fluid from the DL flows into AL, still more solute is continously pumped out of tubules and deported into medullary interstitium

Step (7)

more steps are repeated over and over, with the net effect of adding more and more solutes to medulla

with the time, this process gradually adds solutes in medulla, eventually raising ISF osmolarity to 1200-1400 mOsm/L



Thus the repetitive reabsorption of NaCl by the thick AL of LOH and continued inflow of new NaCl from PCT to LOH is called countercurrent multiplier system

- NaCl reabsorbed from ASC LOH keeps adding to the newly arrived NaCl, thus 'multiplying' its conc in medullary interstitium

Role of DCT and CDs in excreting conc urine

When tubular fluid leaves LOH & enters DCT, fluid is dilute:

early DCT further dilutes tubular fluid - as this segment actively transports NaCl out of tubule but impermeable to water

As fluid flows into cortical CT ⟶ Amount of water Reabsorbed depends on ADH

High conc of ADH ⟶ Large Amounts of water Reabsorbed from cortical CT into cortex interstitium

The fact that these large Amounts of water are reabsorbed into cortex, rather than into renal medulla, helps to preserve the high medullary ISF osmolarity

Role of urea in conc of urine

urea contributes to hyperosmotic renal medullary interstitial fluid and to conc urine. How?

urine is Absorbed in PCT - 50%.

50% urea comes to DCT and CT - which are not permeable to urea, but Collecting duct in inner medulla is permeable

Role of urea in conc of urine — urea cycle

→ when water is reabsorbed in DCT and CT under action of ADH, urea is more concentrated

→ Facilitated diffusion of urea occurs from CT in the inner medullary region by specific urea transporters and contributes to the conc of medullary interstitial fluid

→ increased urea present in the interstitial fluid diffuses into loop of henle, and then to DCT and CT, therefore, recirculates many times before it is excreted — called urea cycle.