Counter current mechanism (Cc4, unit5)

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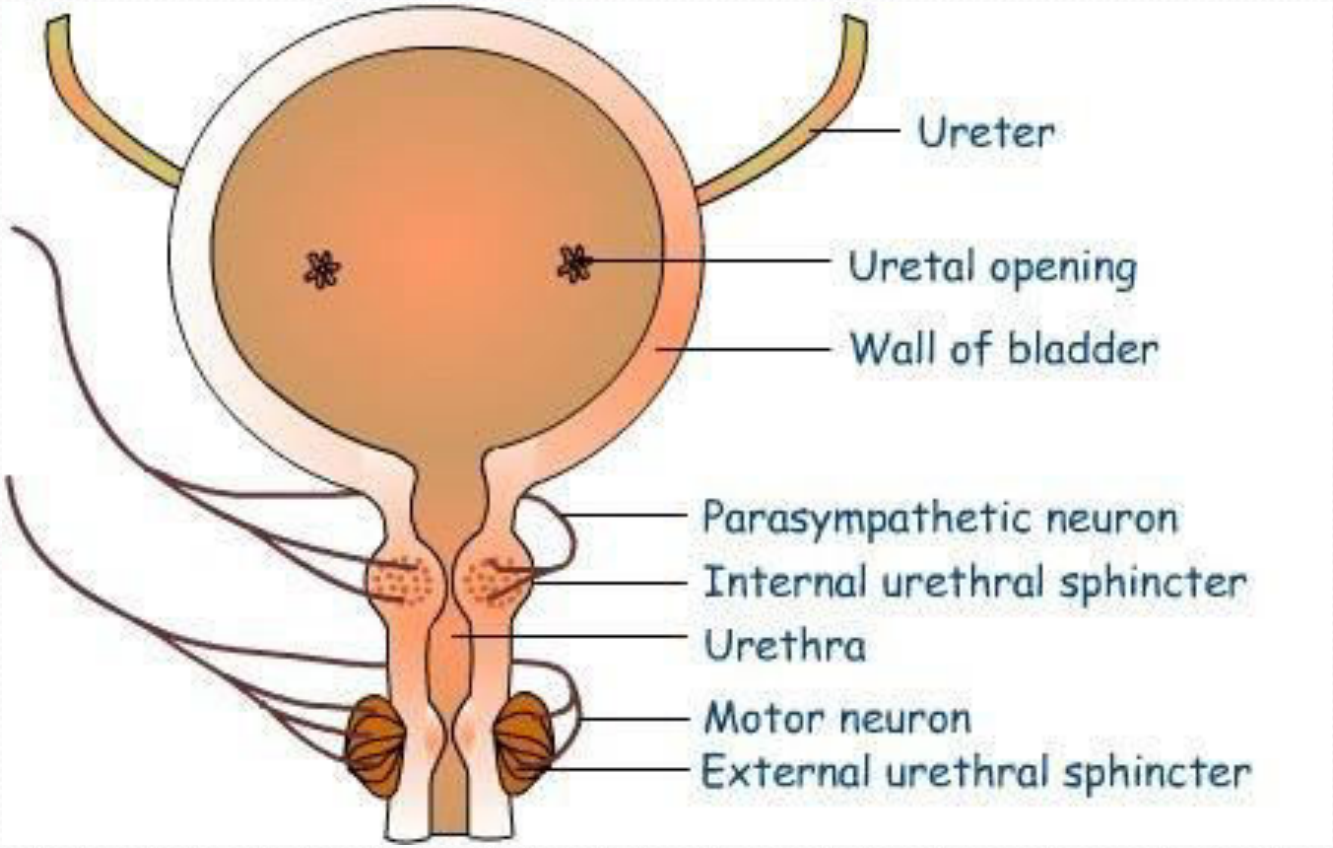
Countercurrent Mechanism

- **countercurrent multipliers – The loop of henle produce high osmotic medullary gradient -1200 mosm / lit at the bottom.**

maintained by the operation of the vasa recta act as a **countercurrent exchangers as the flow of fluid & solute is in the opposite direction**


Ureter
Uretal opening
Wall of bladder
Parasympathetic neuron
Internal urethral sphincter
Urethra
Motor neuron
External urethral sphincter

Renal Mechanisms for Excreting a Dilute Urine

- excrete as much as 20 L/day of dilute urine,
- continue reabsorbing solutes from the distal segments of the tubular system while failing to reabsorb water.
- further diluted in the late distal tubule and collecting ducts,

- large volume of dilute urine is excreted.

The Kidneys Conserve Water by Excreting a Concentrated Urine

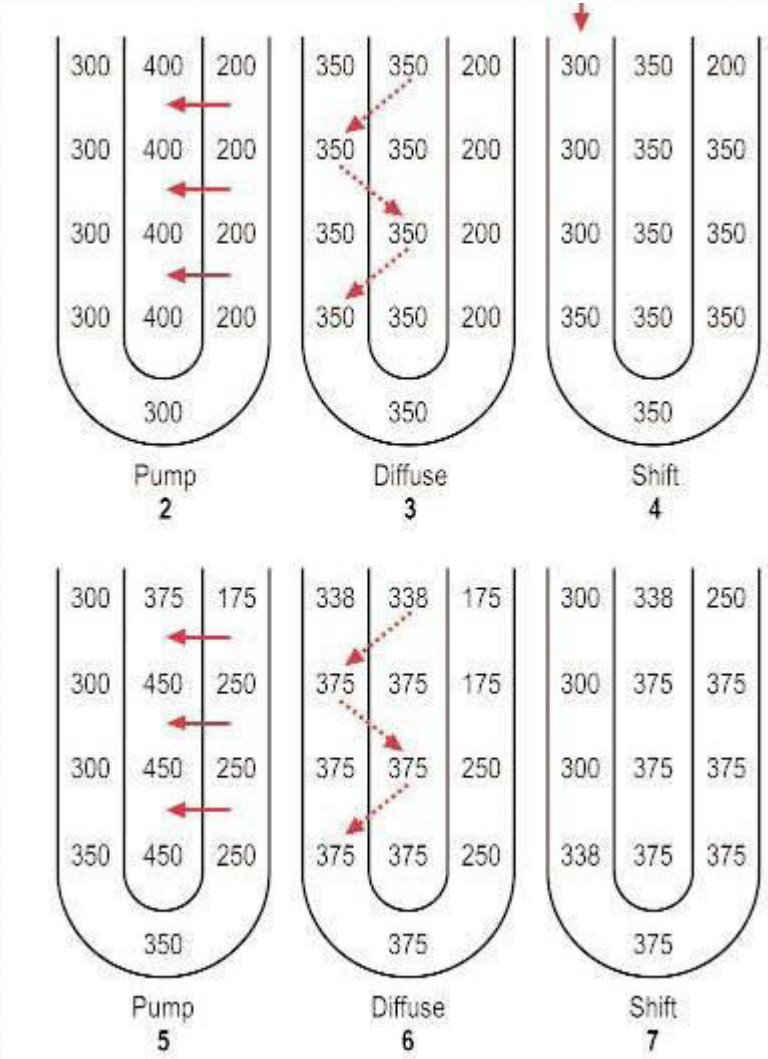
- by continuing to excrete solutes while increasing water reabsorption
- can produce a maximal urine concentration of 1200 to 1400 mOsm/L,
- **Obligatory Urine Volume** the *minimal volume of urine that must be excreted – 500 ml*
- a *high level of ADH*
- *a high osmolarity of the renal medullary interstitial fluid*
- The renal medullary interstitium surrounding the collecting ducts normally is very hyperosmotic,

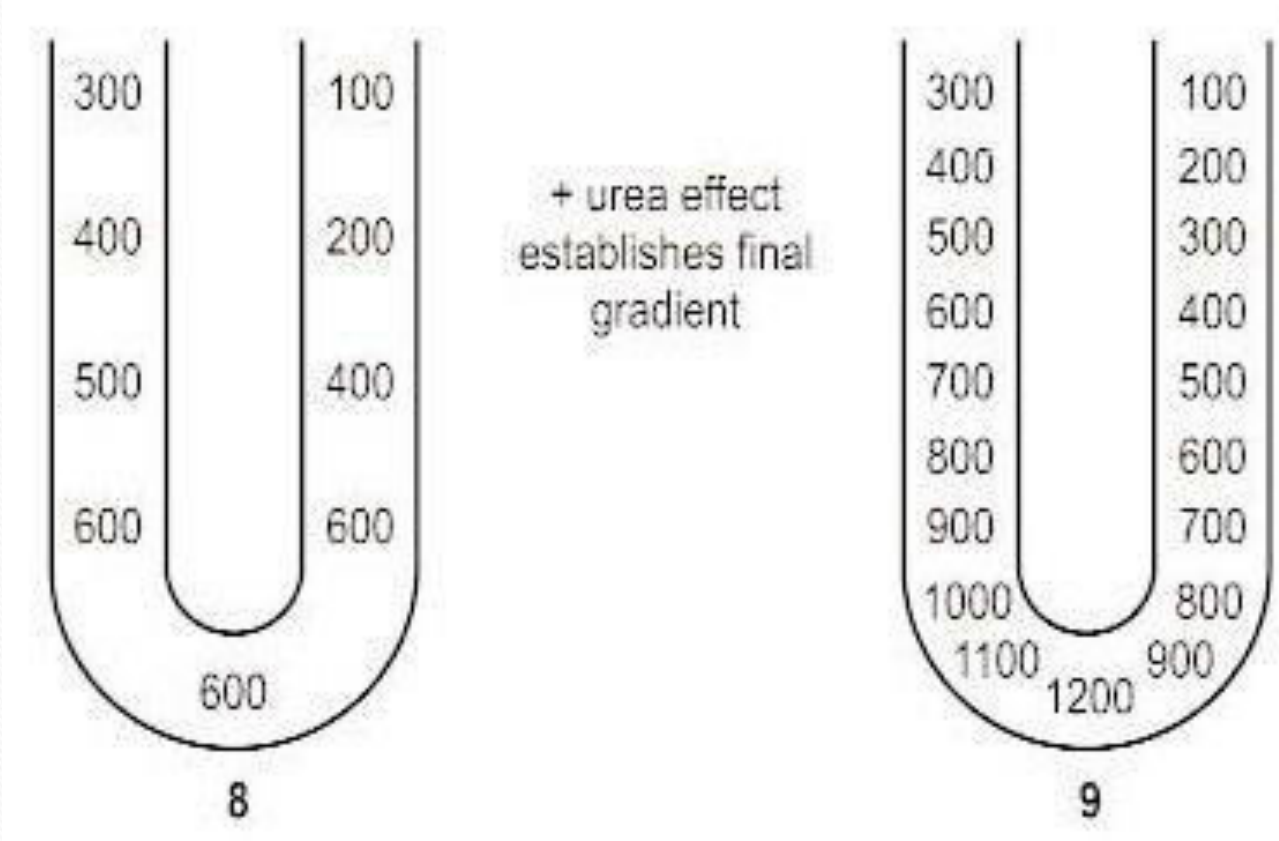
Countercurrent Mechanism Produces a Hyperosmotic Renal Medullary Interstitium

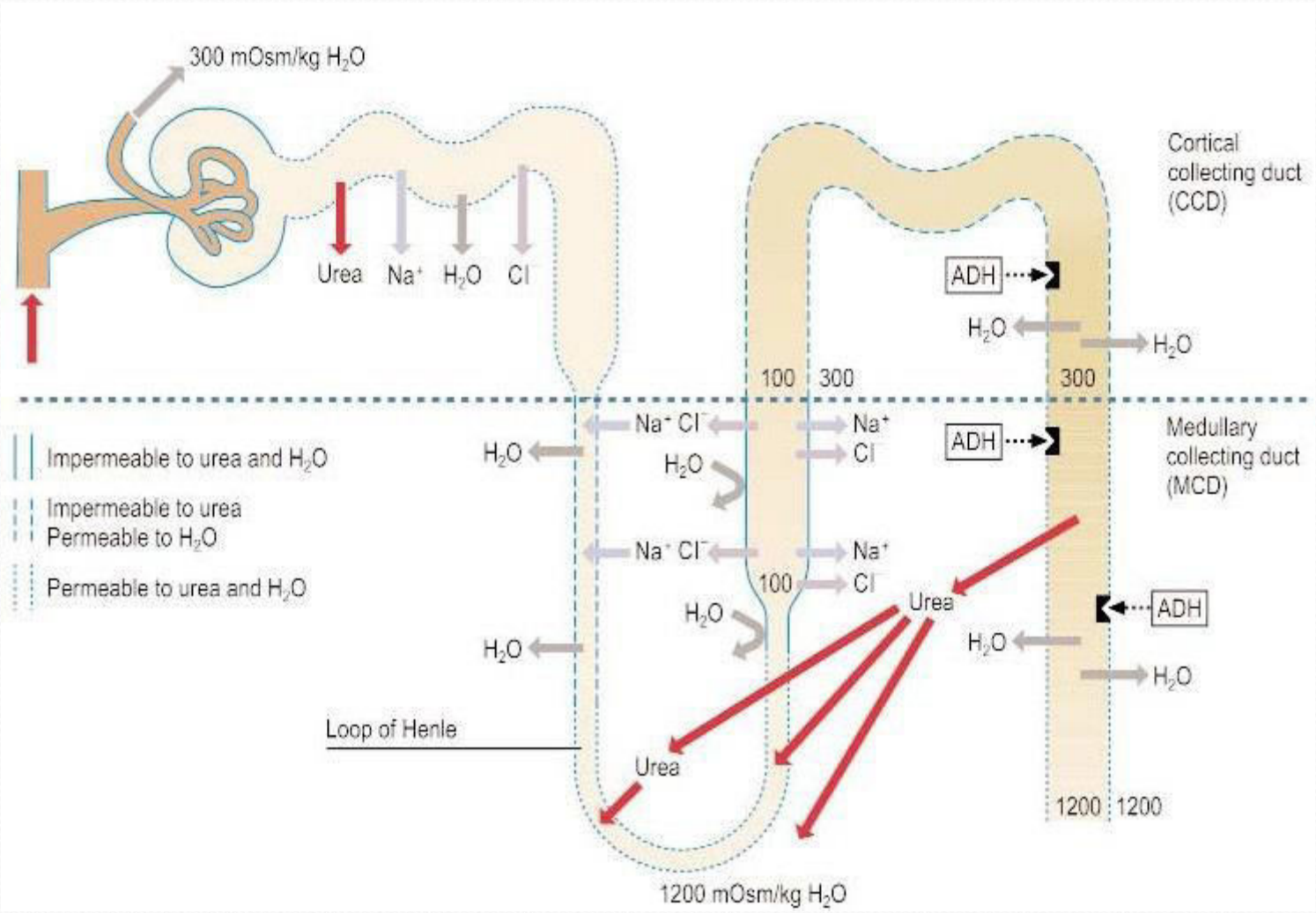
- Active transport of sodium ions and co-transport of potassium, chloride, and other ions
- Active transport of ions from the collecting ducts into the medullary interstitium
- Facilitated diffusion of large amounts of urea from the inner medullary collecting ducts into the medullary interstitium
- Diffusion of only small amounts of water from the medullary tubules into the medullary interstitium

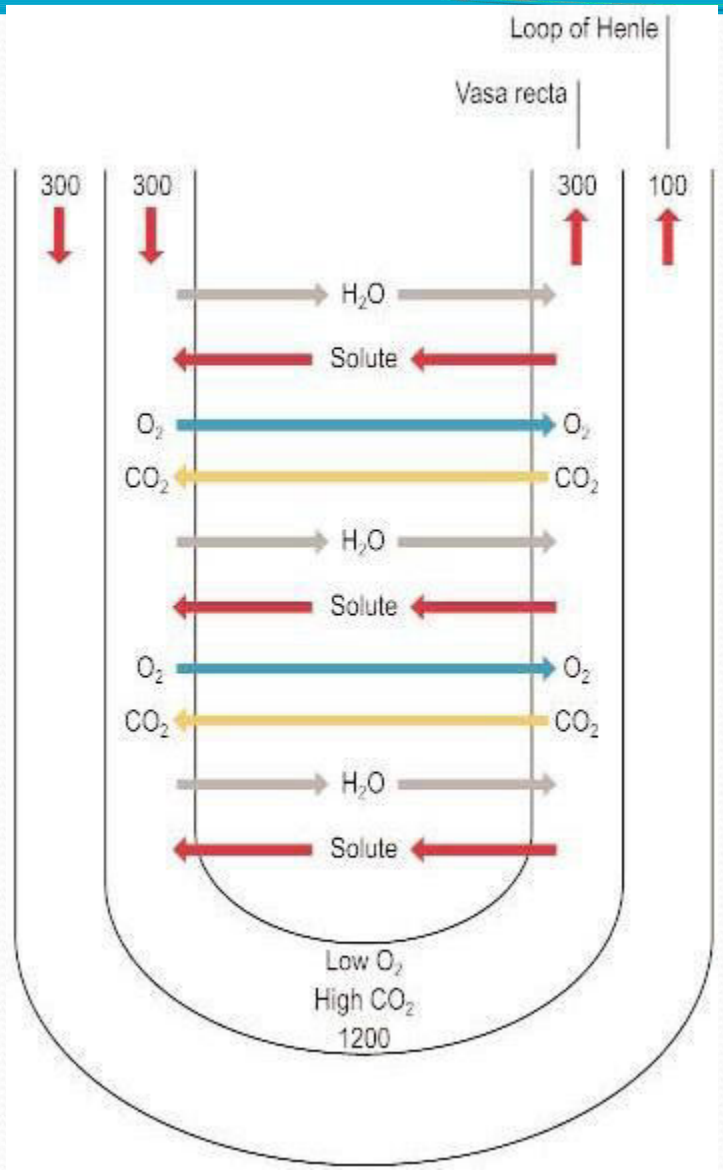
Countercurrent Mechanism

the repetitive reabsorption of sodium chloride by the thick ascending loop of Henle and continued inflow of new sodium chloride from the proximal tubule into the loop of Henle is called the *countercurrent multiplier.*


300 400 200
300 400 200
300 400 200
300 400 200
300
Pump
2
350 350 200
350 350 200
350 350 200
350 350 200
350
Diffuse
3
300 350 200
300 350 350
300 350 350
350 350 350
350
Shift
4
300 375 175
300 450 250
300 450 250
350 450 250
350
Pump
5
338 338 175
375 375 175
375 375 250
375 375 250
375
Diffuse
6
300 338 250
300 375 375
300 375 375
338 375 375
375
Shift
7


300
400
500
600
100
200
400
600
600
8
+ urea effect establishes final gradient
300
400
500
600
700
800
900
1000
1100
1200
100
200
300
400
500
600
700
800
900
9


300 mOsm/kg H2O
Urea
Na+
H2O
Cl
Cortical collecting duct (CCD)
ADH
H2O
H2O
100
300
300
Impermeable to urea and H2O
Impermeable to urea
Permeable to H2O
Permeable to urea and H2O
Na+ Cl−
H2O
Na+
Cl
ADH
Medullary collecting duct (MCD)
Na+ Cl−
Na+
100
Cl
H2O
Urea
ADH
H2O
H2O
H2O
Loop of Henle
Urea
1200
1200
1200 mOsm/kg H2O

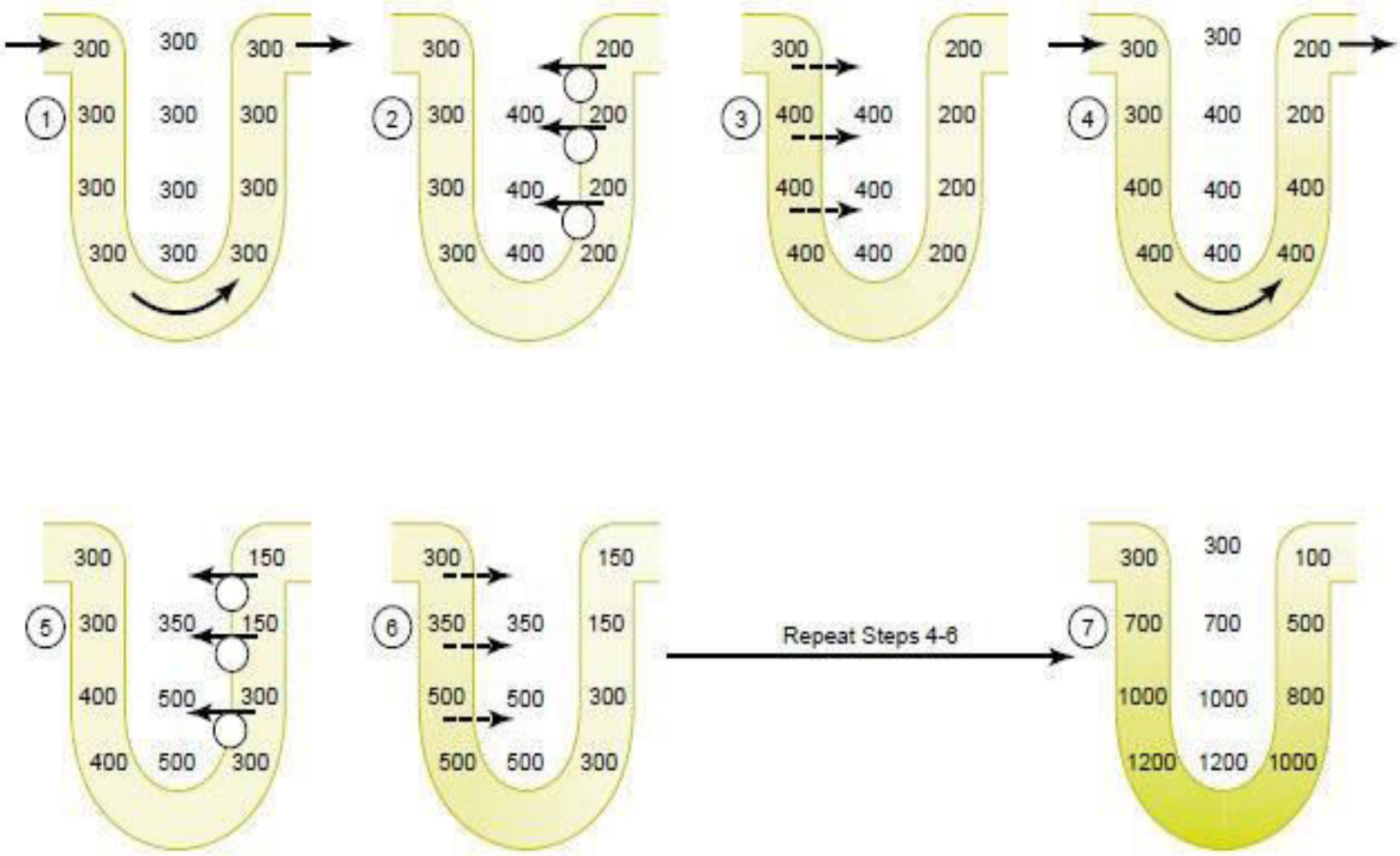

Loop of Henle
Vasa recta
300
300
300
100
H_2O
Solute
O_2
O_2
CO_2
CO_2
H_2O
Solute
O_2
O_2
CO_2
CO_2
H_2O
Solute
Low O_2
High CO_2
1200

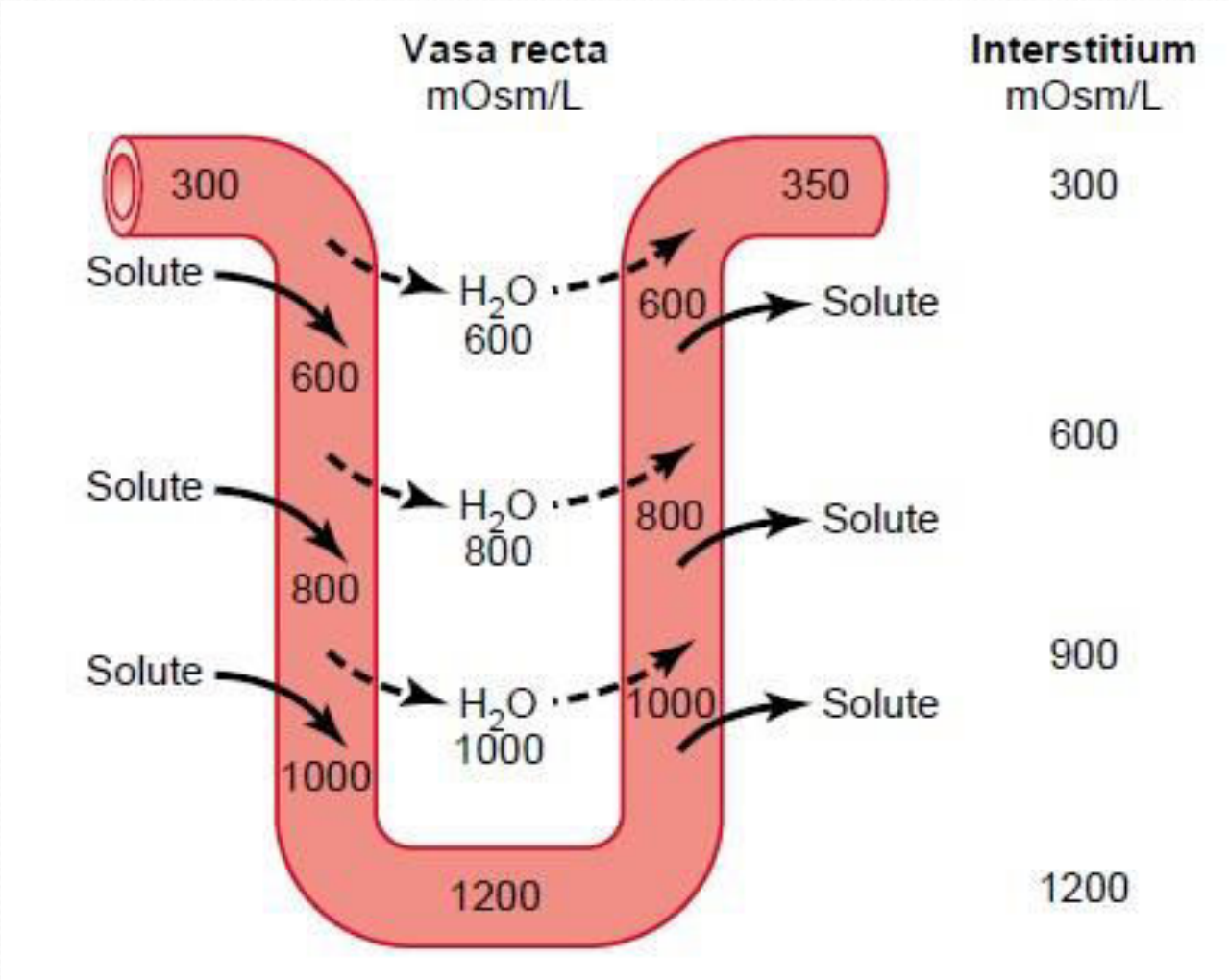
Important features of the concentrating process

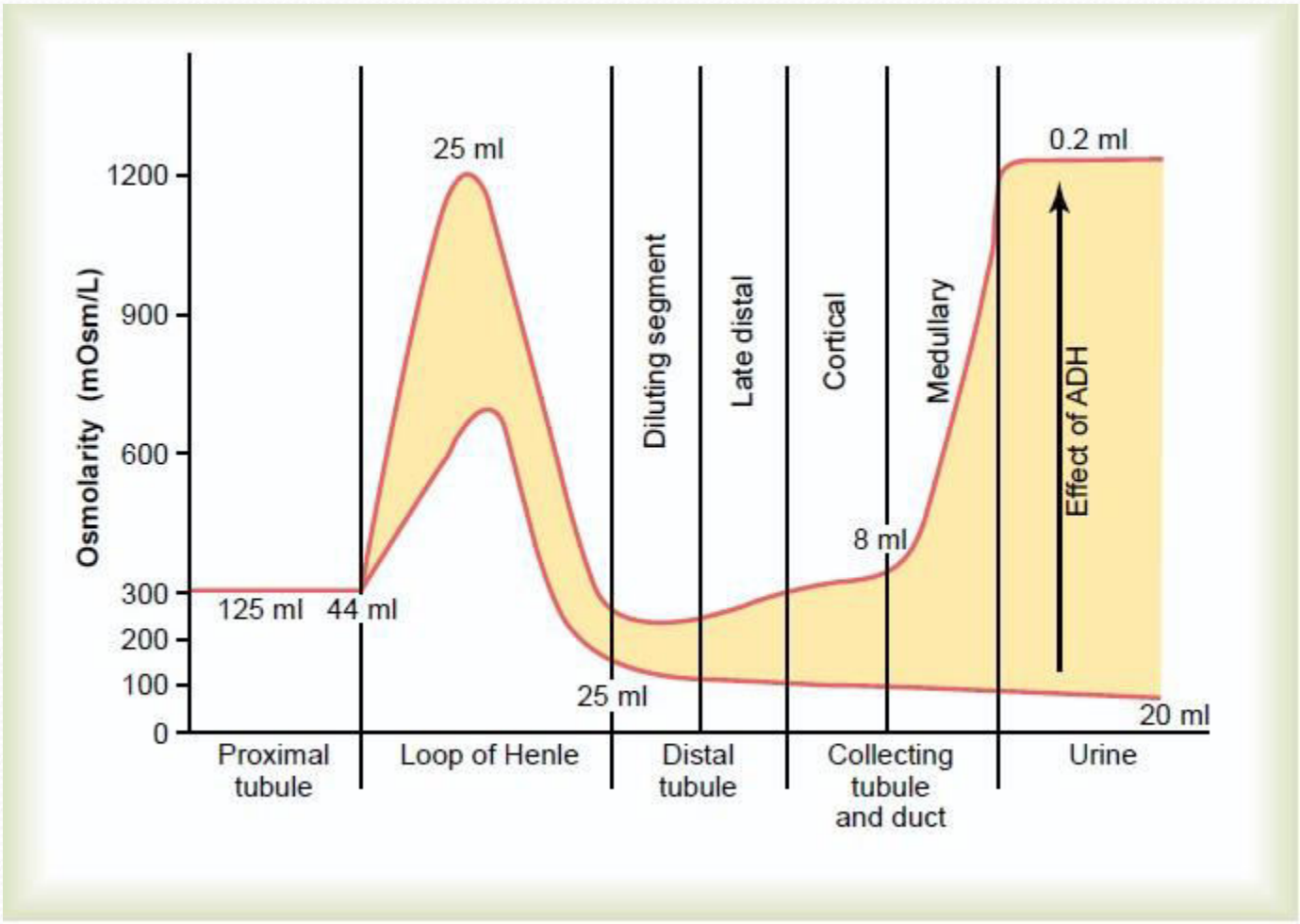
- The descending limb of the loop of Henle has a high permeability to water and a low permeability to solutes.
- The ascending limb of the loop of Henle has a low permeability to water, but actively reabsorbs Na+.
- The distal tubule and collecting duct also actively reabsorb Na+. In the presence of ADH they are permeable to water.
- The descending and thin ascending limbs of the loop of Henle are permeable to urea.
- The thick ascending limb and cortical part of the collecting duct have low permeability to urea
- . The medullary part of the collecting duct has a high permeability to urea that can be increased by ADH.

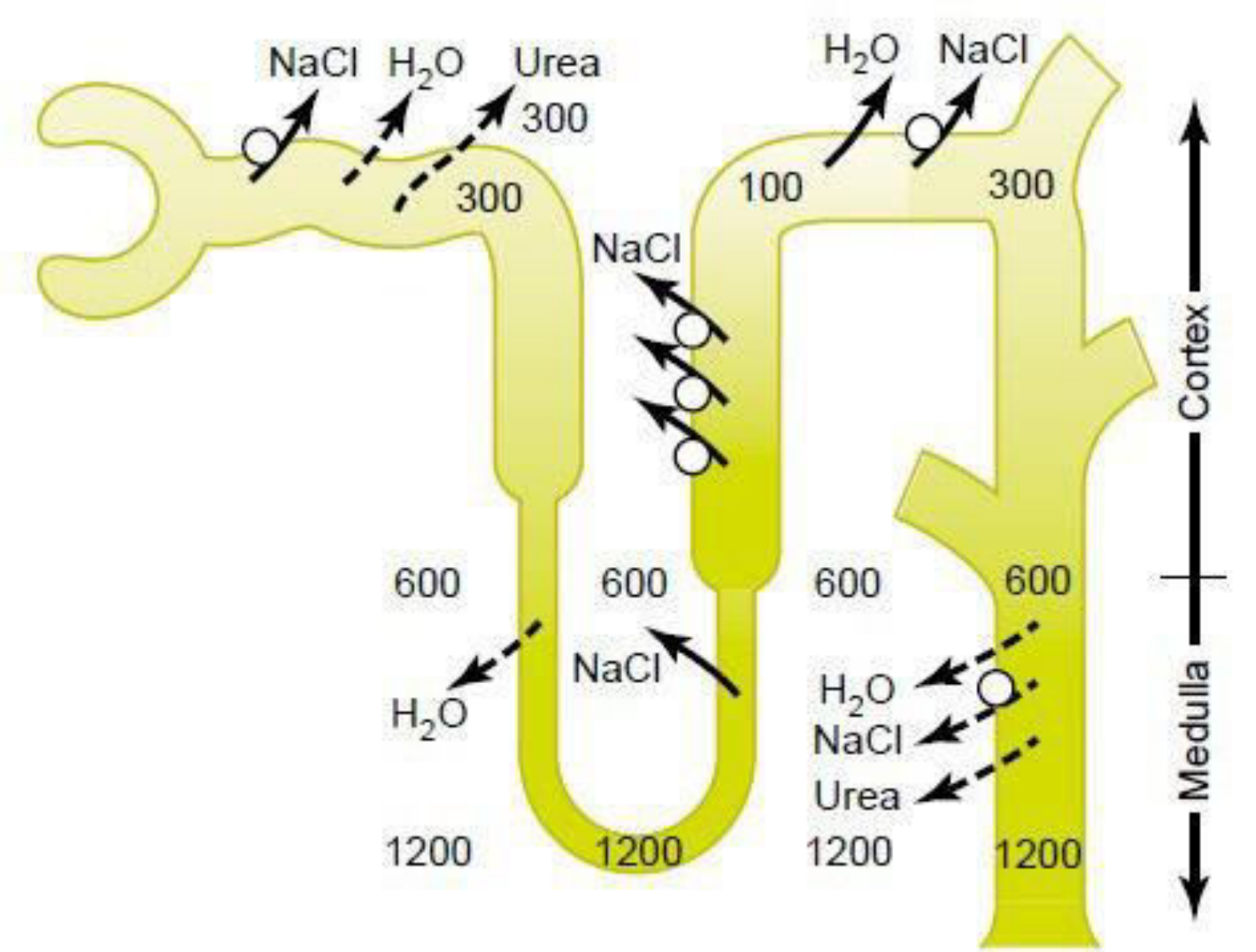
The vasa recta

- The anatomical arrangement of these blood vessels means that they do not dissipate the interstitial osmotic gradient created by the loop of Henle.
- Large changes in blood flow in the vasa recta can reduce or increase the medullar interstitial osmolality beyond its normal value.


1
300 300 300
300 300 300
300 300 300
300 300 300
2
300 200
300 400 200
300 400 200
300 400 200
3
300 200
400 400 200
400 400 200
400 400 200
4
300 300 200
300 400 200
400 400 400
400 400 400
5
300 150
300 350 150
400 500 300
400 500 300
6
300 150
350 350 150
500 500 300
500 500 300
Repeat Steps 4-6
7
300 300 100
700 700 500
1000 1000 800
1200 1200 1000

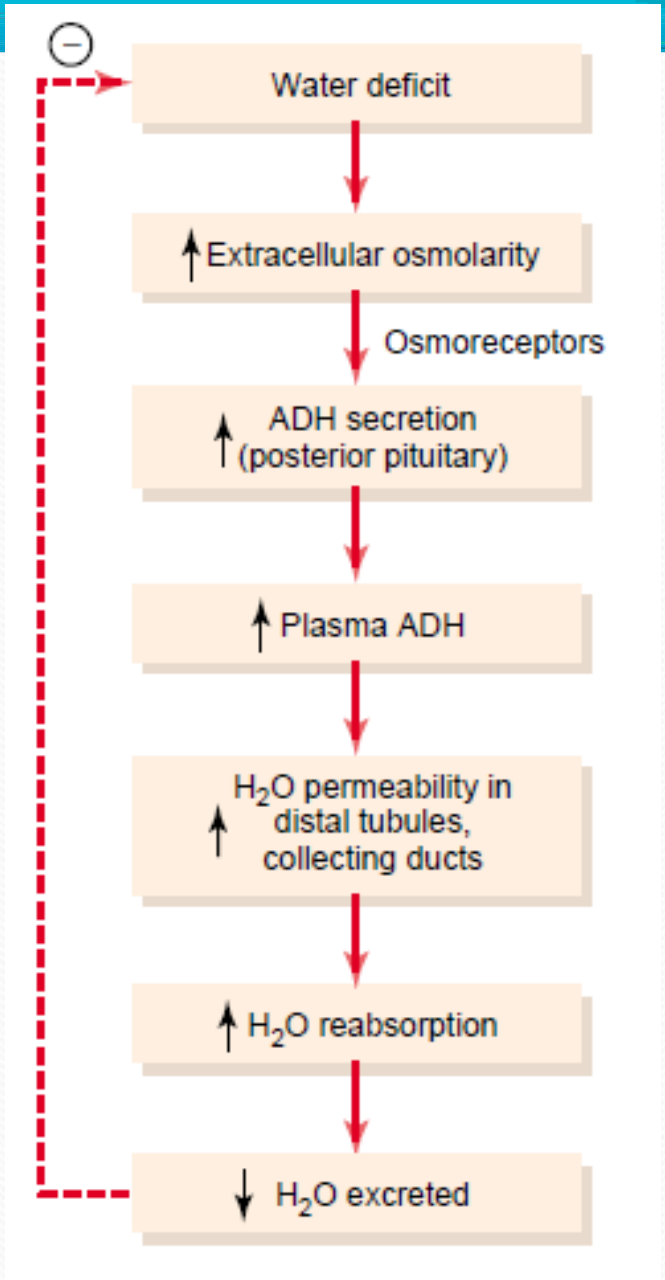

Vasa recta
mOsm/L
Interstitium
mOsm/L
300
350
300
Solute
H_2O
600
600
Solute
600
600
Solute
800
H_2O
800
800
Solute
900
Solute
1000
H_2O
1000
1000
1200
1200


Osmolarity (mOsm/L)
1200
900
600
300
200
100
0
125 ml
44 ml
25 ml
25 ml
8 ml
0.2 ml
20 ml
Diluting segment
Late distal
Cortical
Medullary
Effect of ADH
Proximal tubule
Loop of Henle
Distal tubule
Collecting tubule and duct
Urine


NaCl
H_2O
Urea
300
300
H_2O
NaCl
100
300
NaCl
Cortex
600
600
600
600
NaCl
H_2O
H_2O
NaCl
Urea
Medulla
1200
1200
1200
1200

Summary of Tubule Characteristics—Urine Concentration

	Active NaCl Transport	Permeability		
		H_2O	NaCl	Urea
Proximal tubule	++	++	+	+
Thin descending limb	0	++	+	+
Thin ascending limb	0	0	+	+
Thick ascending limb	++	0	0	0
Distal tubule	+	+ADH	0	0
Cortical collecting tubule	+	+ADH	0	0
Inner medullary collecting duct	+	+ADH	0	++ADH


Water deficit
↑ Extracellular osmolarity
Osmoreceptors
↑ ADH secretion (posterior pituitary)
↑ Plasma ADH
↑ H_2O permeability in distal tubules, collecting ducts
↑ H_2O reabsorption
↓ H_2O excreted

Regulation of ADH Secretion

Increase ADH	Decrease ADH
↑ Plasma osmolarity	↓ Plasma osmolarity
↓ Blood volume	↑ Blood volume
↓ Blood pressure	↑ Blood pressure
Nausea	
Hypoxia	
Drugs:	Drugs:
Morphine	Alcohol
Nicotine	Clonidine (antihypertensive drug)
Cyclophosphamide	Haloperidol (dopamine blocker)

Stimuli for ADH Secretion

Control of Thirst	
Increase Thirst	**Decrease Thirst**
↑ Osmolarity	↓ Osmolarity
↓ Blood volume	↑ Blood volume
↓ Blood pressure	↑ Blood pressure
↑ Angiotensin	↓ Angiotensin II
Dryness of mouth	Gastric distention

Regulation of ADH Secretion

Increase ADH

Plasma osmolarity

Blood volume

Blood pressure

Nausea

Hypoxia

Drugs: Drugs:

Morphine Alcohol

Nicotine Clonidine (antihypertensive drug)

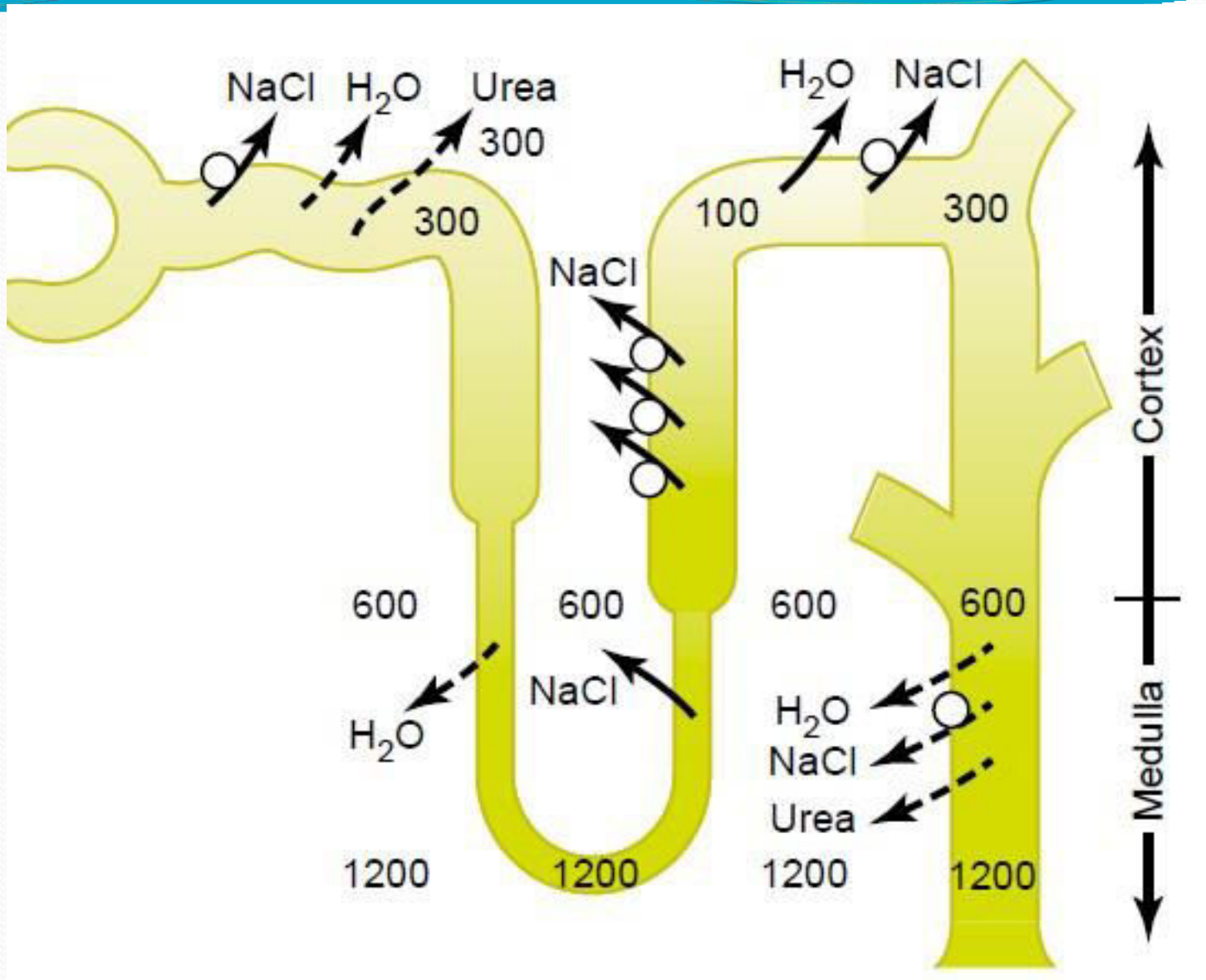
Cyclophosphamide Haloperidol (dopamine blocker)

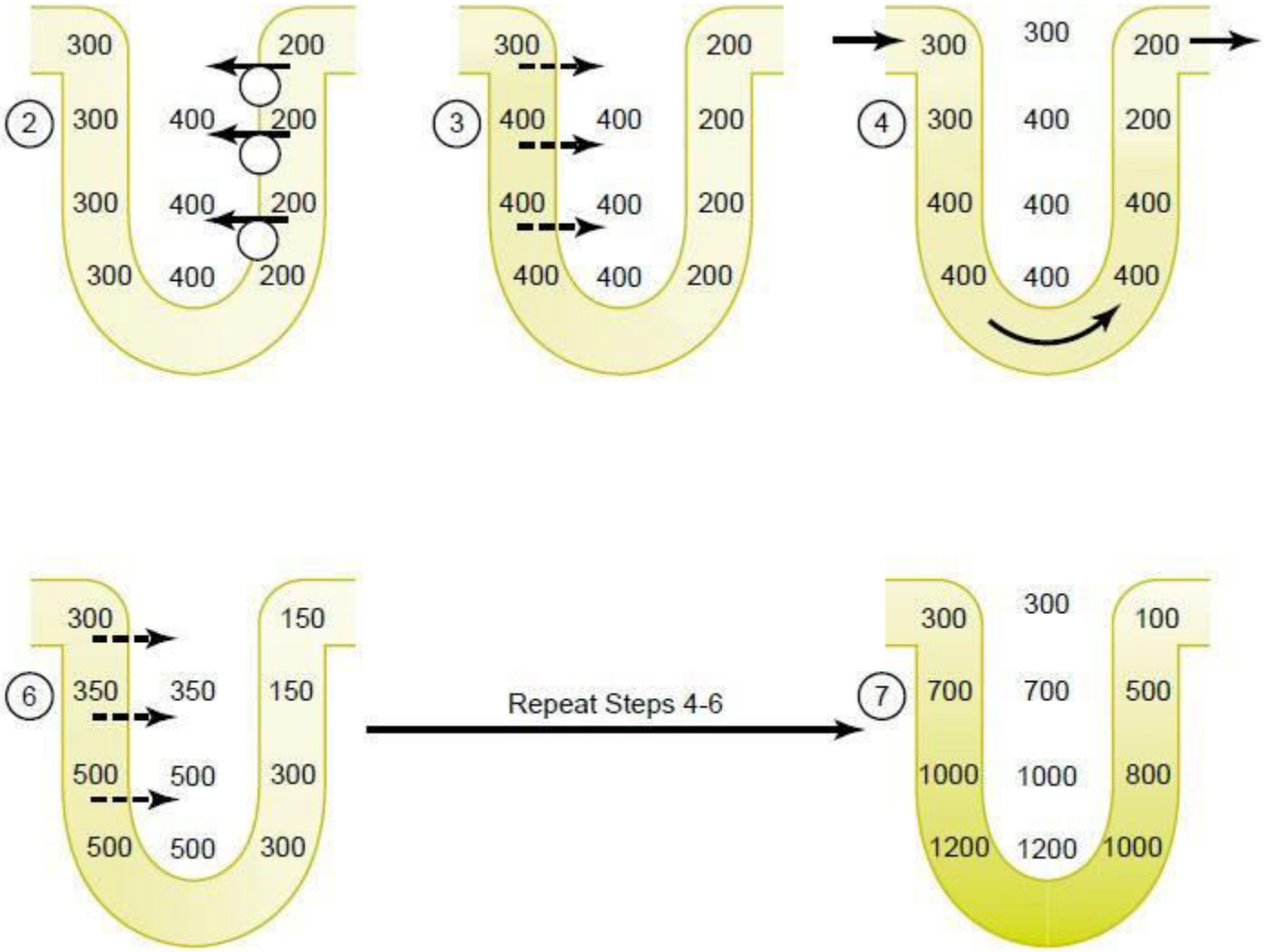
Decrease ADH

Plasma osmolarity

Blood volum

Blood pressure


NaCl
H_2O
Urea
300
300
H_2O
NaCl
100
300
NaCl
600
600
600
600
NaCl
H_2O
H_2O
NaCl
Urea
1200
1200
1200
1200
Cortex
Medulla


2
300
200
300
400
200
300
400
200
300
400
200
3
300
200
400
400
200
400
400
200
400
400
200
4
300
300
200
300
400
200
400
400
400
400
400
400
6
300
150
350
350
150
500
500
300
500
500
300
Repeat Steps 4-6
7
300
300
100
700
700
500
1000
1000
800
1200
1200
1000