Urinary System: Renal Physiology for Medical Students

Chapter 28: Urine Concentration and Dilution; Regulation of Extracellular Fluid Osmolarity and Sodium Concentration

Part II

Reference: Guyton & Hall, Jordanian first edition

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Factors contributing to urine concentrating capability of the kidney

- High ADH
- High osmolarity of medullary interstitial
- Sodium Chloride build up by counter current multiplier (mainly actively)
- Urea build up and recirculation (passively)

Recirculation of urea absorbed from medullary collecting duct into interstitial fluid.

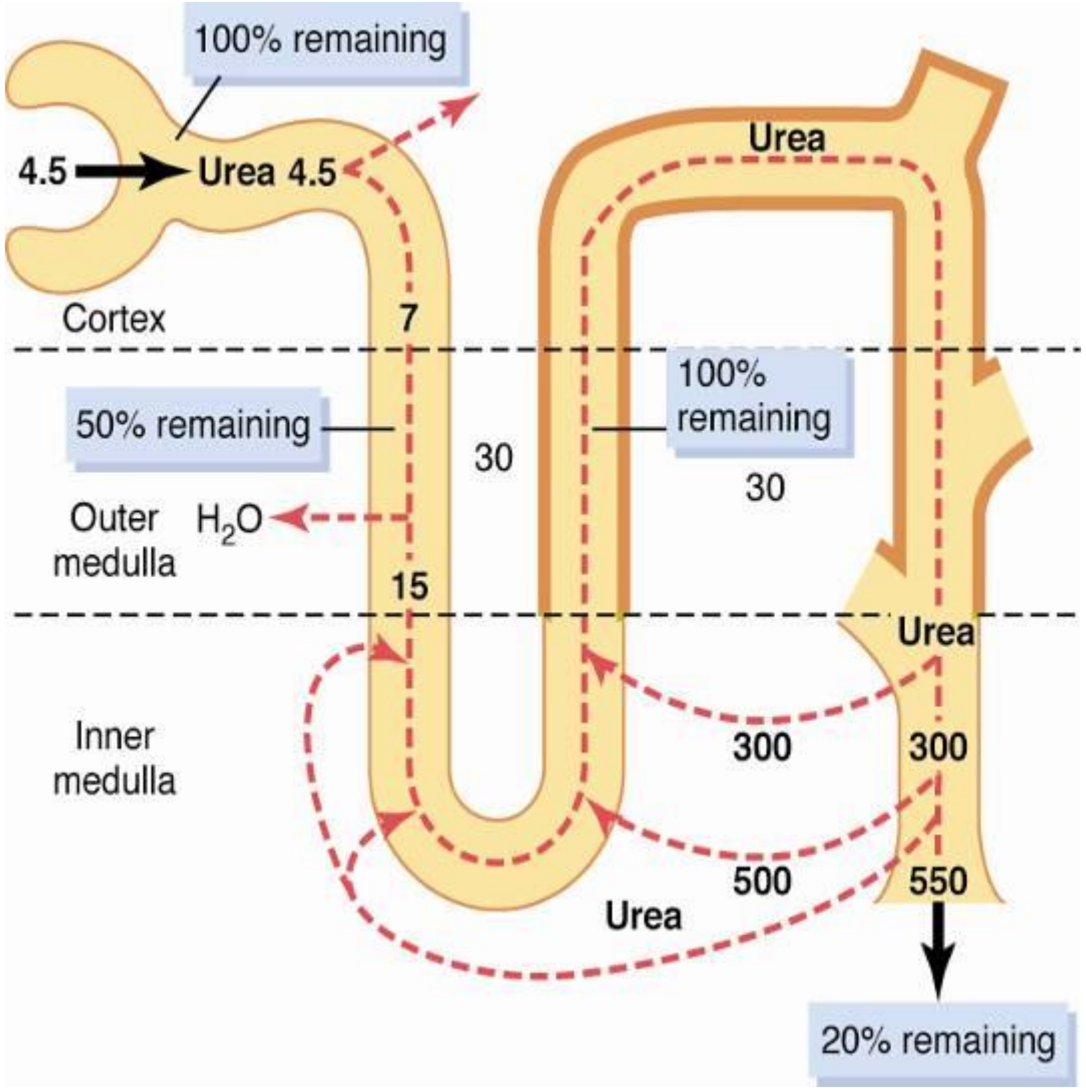


Figure 28-5

Urea Recirculation

- Urea is passively reabsorbed in proximal tubule (~ 50% of filtered load is reabsorbed), but secreted by UTA-2 in TDL.
- In the presence of ADH, water is reabsorbed in distal and collecting tubules, concentrating urea in these parts of the nephron
- The inner medullary collecting tubule is highly permeable to urea, which diffuses into the medullary interstitium
- ADH increases urea permeability of medullary collecting tubule by activating urea transporters (UTA-1) and (UTA-3)

The Vasa Recta Preserve Hyperosmolarity of Renal Medulla

- The vasa recta serve as countercurrent exchangers; they don’t create medullary hyperosmolarity but they preserve it

- Vasa recta blood flow is low (only 1-2 % of total renal blood flow)

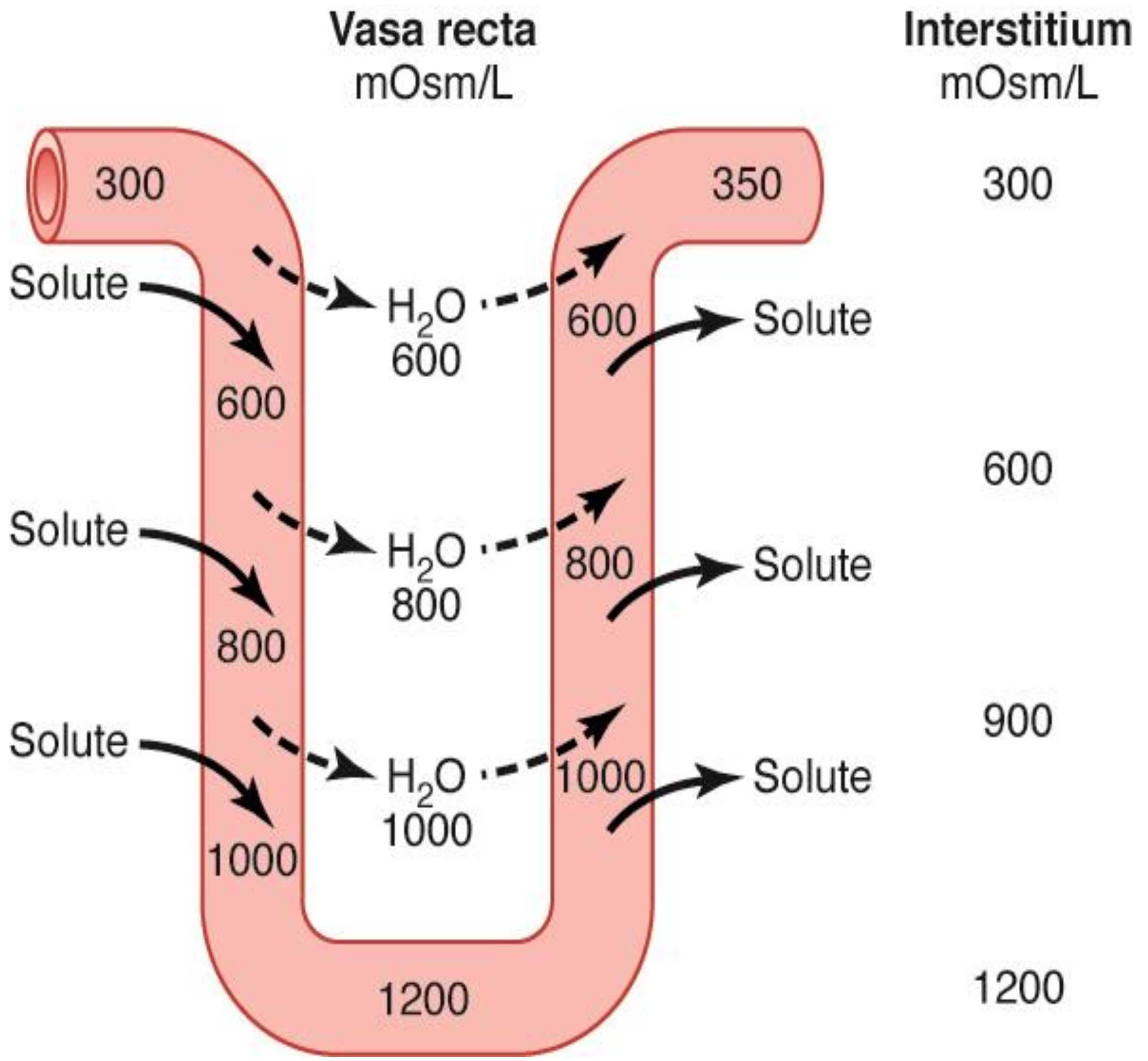


Figure 28-7

Changes in osmolarity of the tubular fluid

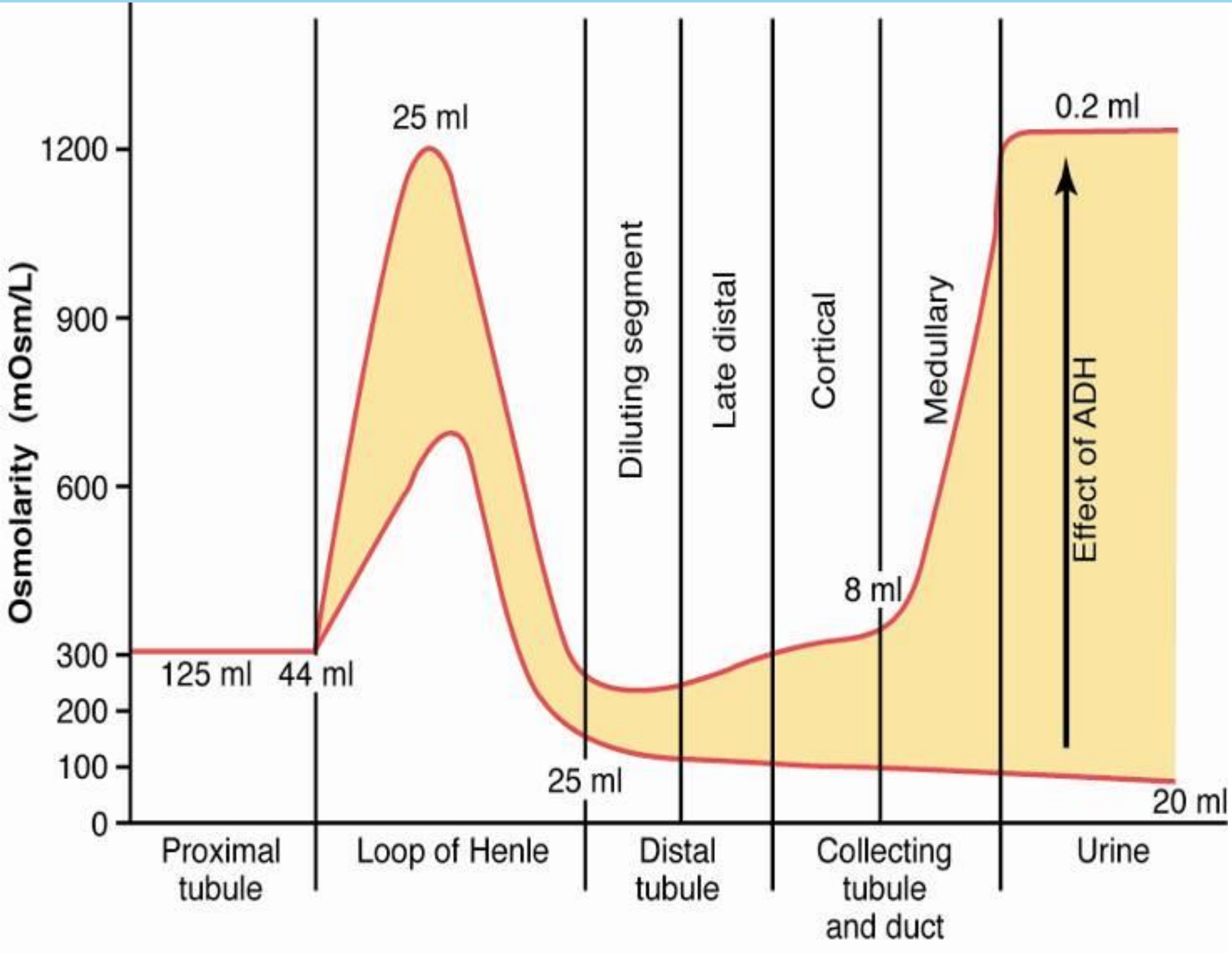


Figure 28-8

Changes in osmolarity of the tubular fluid

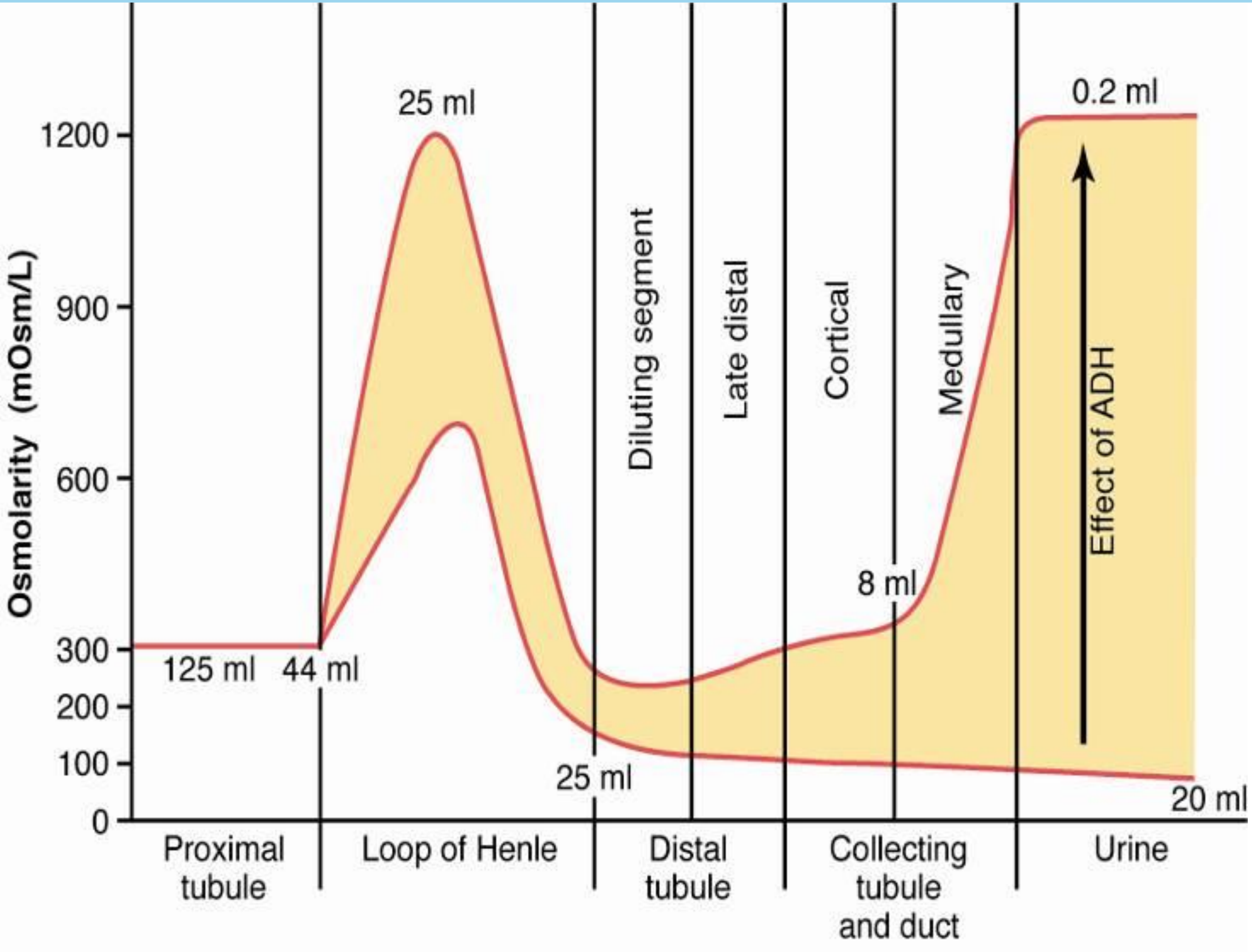


Figure 28-8

Summary of water reabsorption and osmolarity in different parts of the tubule

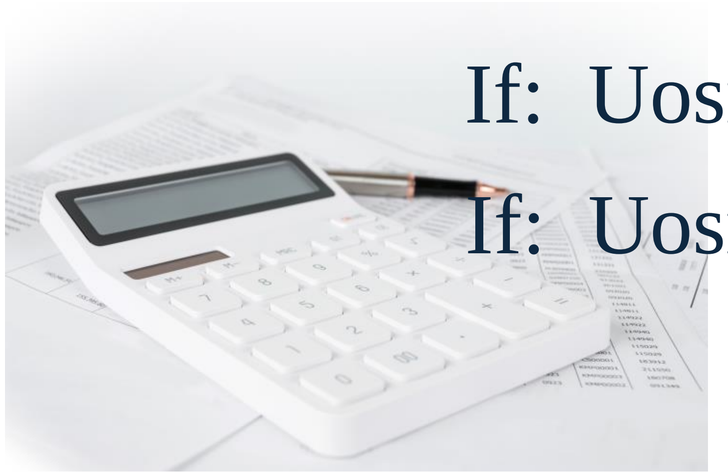
- Proximal Tubule: 65 % reabsorption, isosmotic
- Desc. loop: 15 % reasorption, osmolarity increases
- Asc. loop: 0 % reabsorption, osmolarity decreases
- Early distal: 0 % reabsorption, osmolarity decreases
- Late distal and coll. tubules: ADH dependent water reabsorption and tubular osmolarity
- Medullary coll. ducts: ADH dependent water reabsorption and tubular osmolarity

"Free" Water Clearance (C_{H_2O}) (rate of solute-free water excretion)

$$CH_2O = V - \frac{Uosm \times V}{Posm}$$

where:

- Uosm = urine osmolarity
- V = urine flow rate
- P = plasma osmolarity



If: Uosm < Posm, CH_2O = +

If: Uosm > Posm, CH2O = -

Question

Given the following data, calculate “ free water” clearance :

urine flow rate = 6.0 ml/min
urine osmolarity = 150 mOsm /L
plasma osmolarity = 300 mOsm / L

Is free water clearance in this example positive or negative ?

Answer

$$CH_2O = V - \frac{Uosm \times V}{Posm}$$

$$= 6.0 - \frac{(150 \times 6)}{300}$$

$$= 6.0 - 3.0$$

$$= +3.0 \text{ ml / min (positive)}$$

Disorders of Urine Concentrating Ability

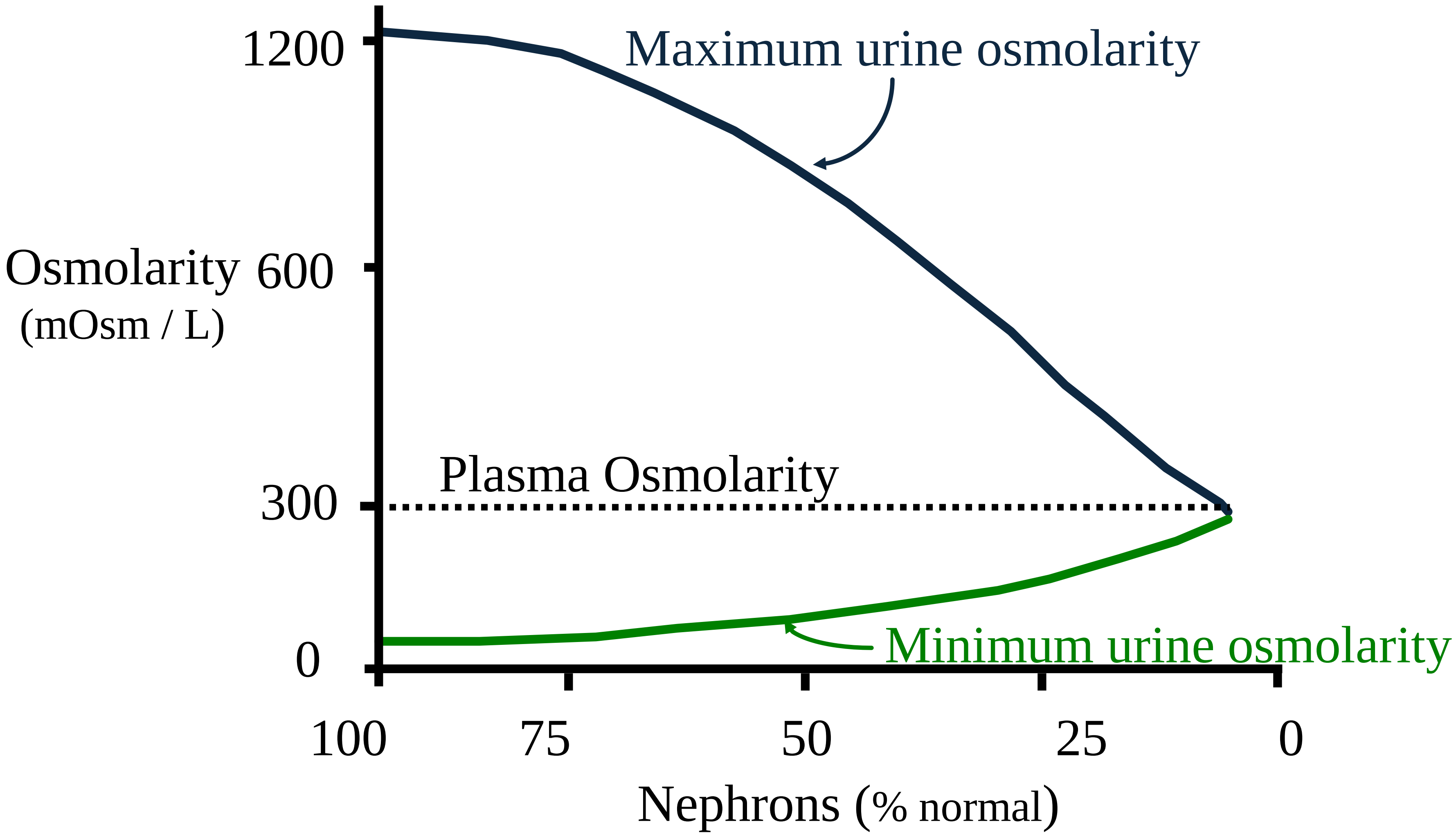
- Failure to produce ADH :
  "Central" diabetes insipidus

- Failure to respond to ADH:
  "nephrogenic" diabetes insipidus

  - impaired loop NaCl reabs. (loop diuretics)
  - drug induced renal damage: lithium, analgesics
  - malnutrition (decreased urea concentration)
  - kidney disease: pyelonephritis, hydronephrosis, chronic renal failure

Development of Isosthenuria With Nephron Loss in Chronic Renal Failure

(inability to concentrate or dilute the urine)



Total Renal Excretion and Excretion Per Nephron in Renal Failure

	Normal	75 % loss of nephrons
Number of nephrons	2,000,000	500,000
Total GFR (ml/min	125	40
GFR per nephron (nl/min)	62.5	80
Total Urine flow rate (ml/min)	1.5	1.5
Volume excreted per nephron (nl/min)	0.75	3.0

Osmoreceptor–antidiuretic hormone (ADH) feedback mechanism for regulating extracellular fluid osmolarity.

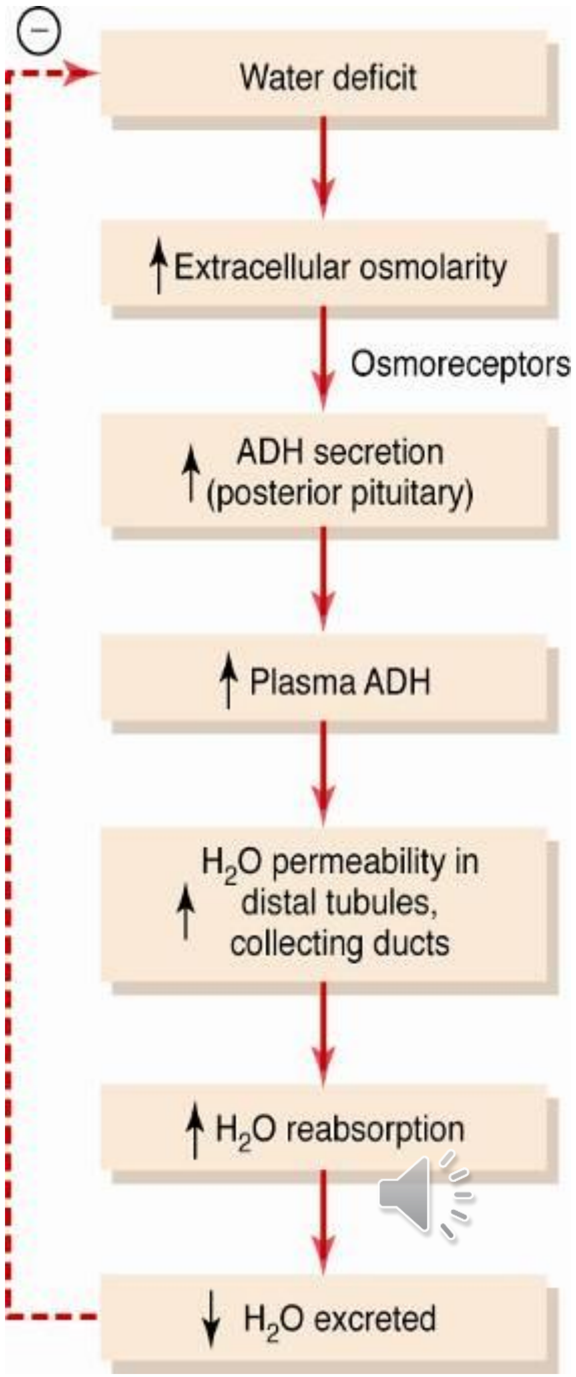
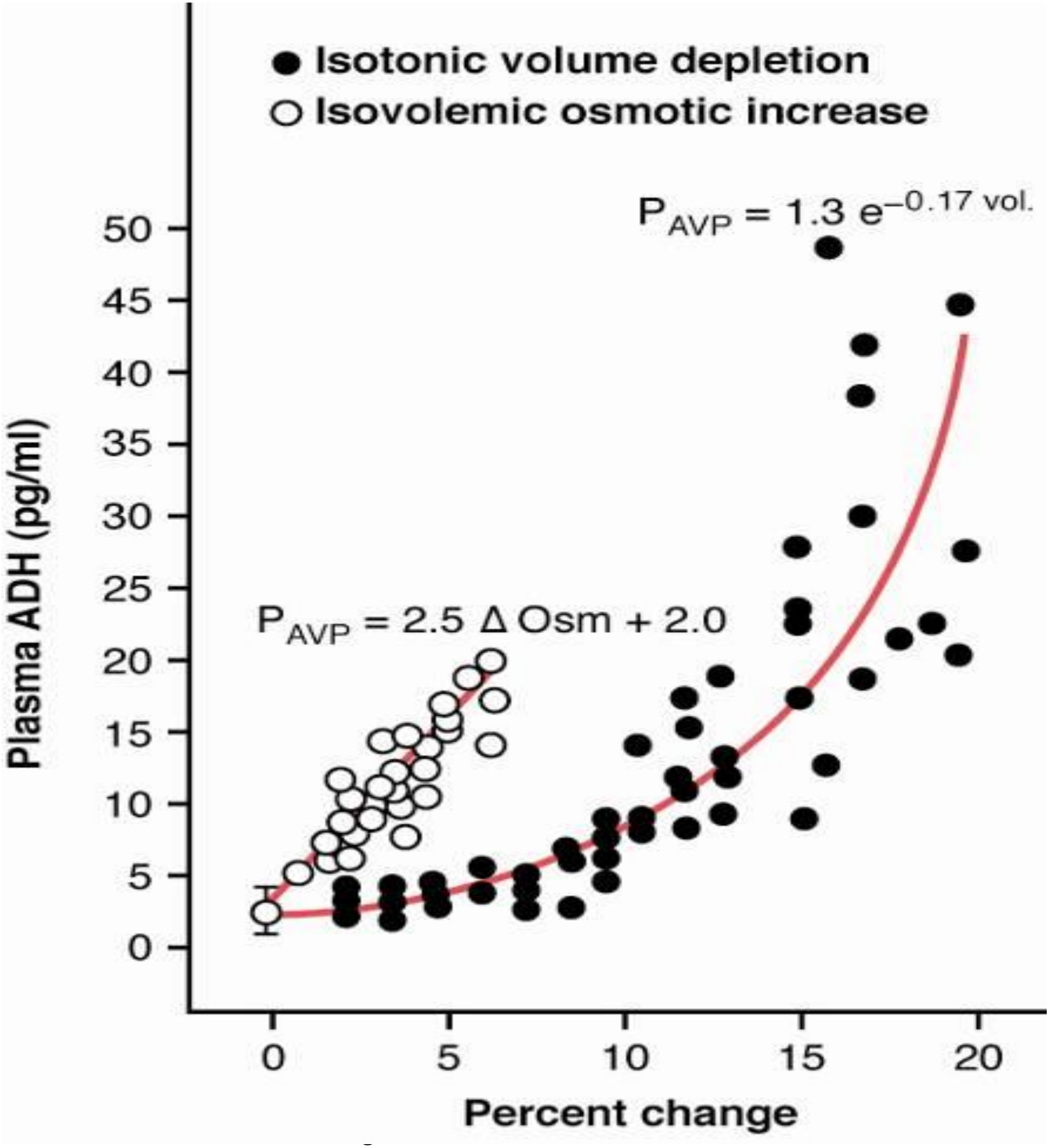


Figure 28-9

Stimuli for ADH Secretion

- Increased osmolarity
- Decreased blood volume (cardiopulmonary reflexes)
- Decreased blood pressure (arterial baroreceptors)
- Other stimuli :
  - input from cerebral cortex (e.g. fear)
  - angiotensin II
  - nausea
  - nicotine
  - morphine

The effect of increased plasma osmolarity or decreased blood volume.



Factors That Decrease ADH Secretion

- Decreased osmolarity
- Increased blood volume (cardiopulmonary reflexes)
- Increased blood pressure (arterial baroreceptors)
- Other factors :
  - alcohol
  - clonidine (antihypertensive drug)
  - haloperidol (antipsychotic, Tourette’s)

Stimuli for Thirst

- Increased osmolarity
- Decreased blood volume
  (cardiopulmonary reflexes)
- Decreased blood pressure
  (arterial baroreceptors)
- Increased angiotensin II
- Other stimuli:
  - dryness of mouth

Factors That Decrease Thirst

- Decreased osmolarity
- Increased blood volume
  (cardiopulmonary reflexes)
- Increased blood pressure
  (arterial baroreceptors)
- Decreased angiotensin II
- Other stimuli:
  -Gastric distention

Maximal Urine flow rate ; water excretion rate

- Max water exc rate in adults=20-23 L/day, does not exceed 800-1,000 ml/hr
- Then water intake should not exceed 800-1,000 ml / hr to avoid hyponatremia and water intoxication
- Water intoxication: What happens when you drink too much water? (medicalnewstoday.com)