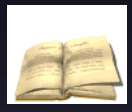
RENAL PHYSIOLOGY
EXCRETING A CONCENTRATED URINE
COUNTER CURRENT MECHANISM



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COUNTER CURRENT MECHANISM

- KIDNEYS HAVE
  - MECHANISMS FOR EXCRETING EXCESS WATER
  - MECHANISMS FOR EXCRETING EXCESS SOLUTES

Obligatory Urine Volume

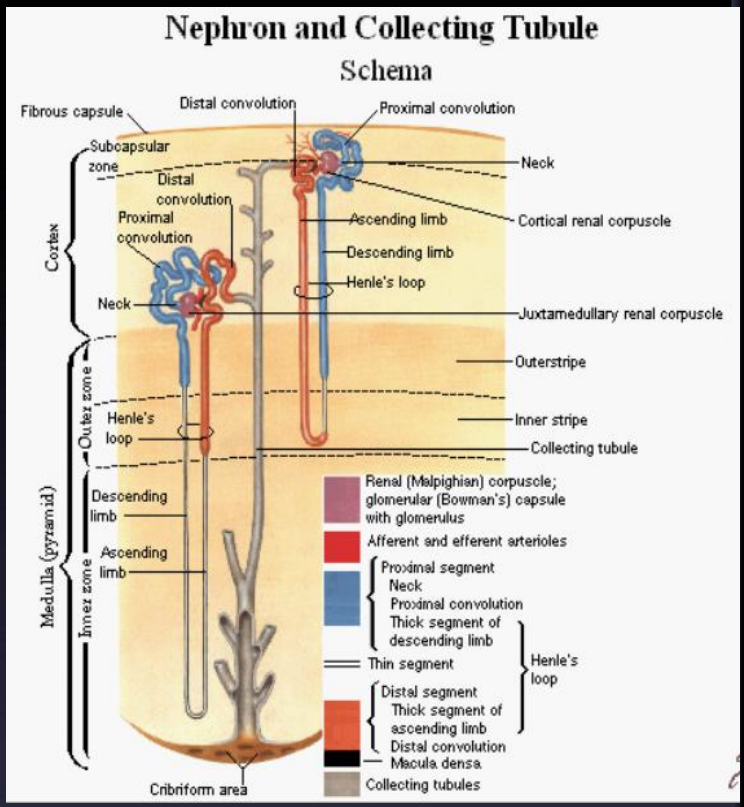
$$\frac{600\ \text{mOsm/day}}{1200\ \text{mOsm/L}} = 0.5\ \text{L/day}$$

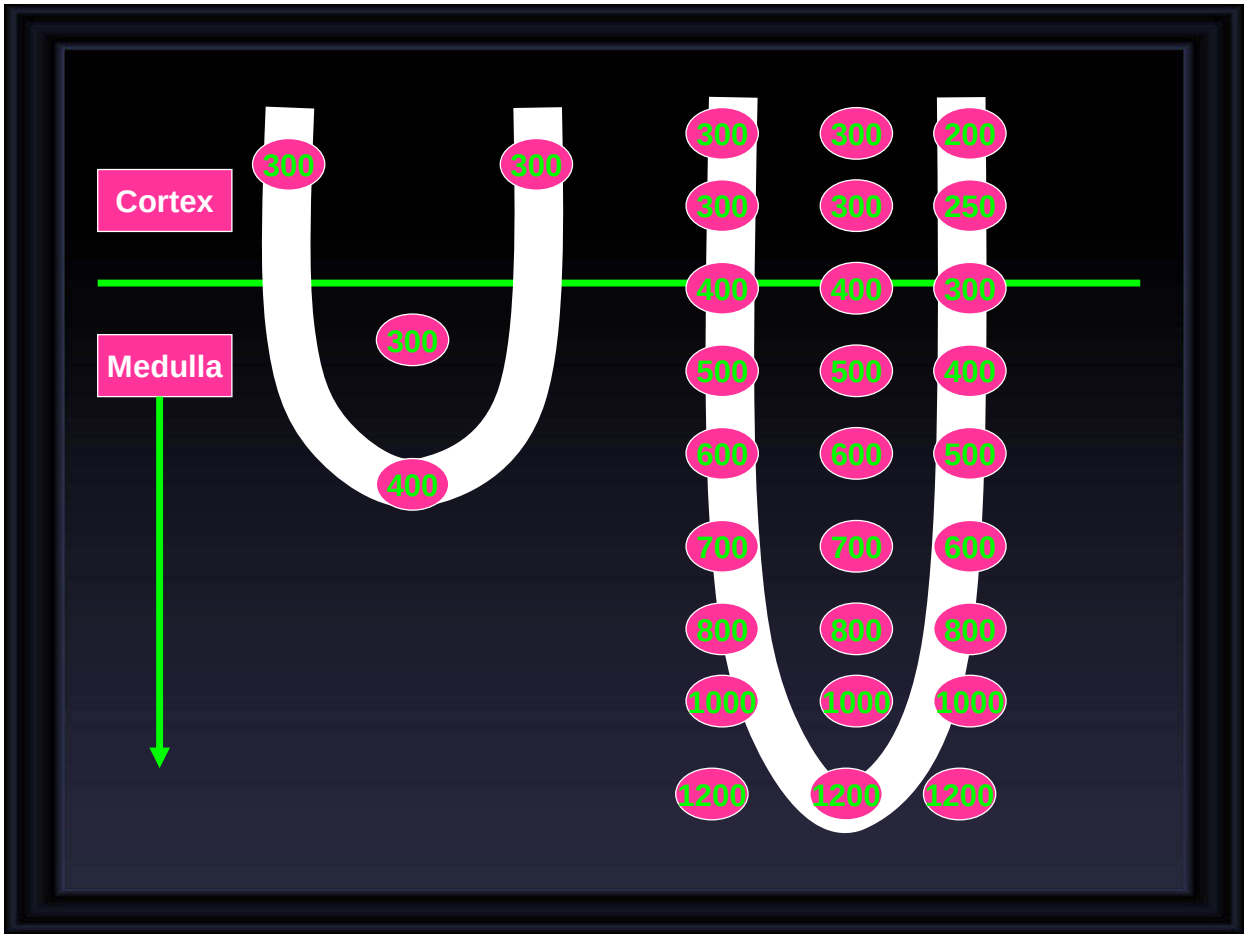
NEPHRON TYPES

- Superficial (cortical) [85 %]
  - Capable of forming dilute urine
- Juxtamedullary [15 %]
  - Capable of forming concentrated (> 300 mOsm/kg) urine

NEPHRON TYPES
Cortical and Juxtamedullary Nephrons

1-2 % Blood Flows Through Juxta Medullary Nephrons




Cortex
Medulla
300
300
300
400
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300
300
250
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400
300
500
500
400
600
600
500
700
700
600
800
800
800
1000
1000
1000
1200
1200
1200

NEPHRON TYPES

- Cortical Nephrons have
  - Peritubular Capillaries
- Juxtamedullary Nephron have
  - Vasa Recta

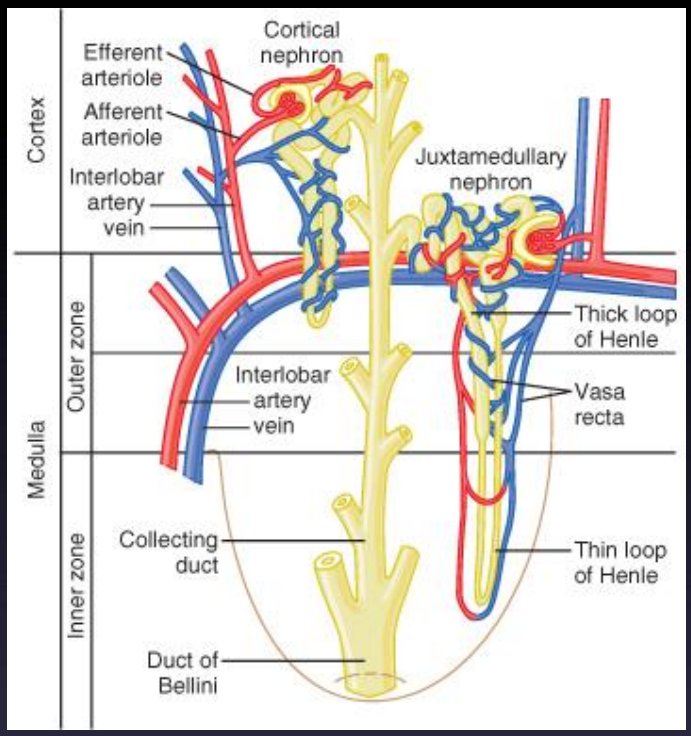
EXCRETION LIMITS

Obligatory Urinary Output

- **At least 600 mmol must be excreted each day**
  - **minimum volume = 600/1200 = 0.5 L**
  - **maximum volume = 20 L**

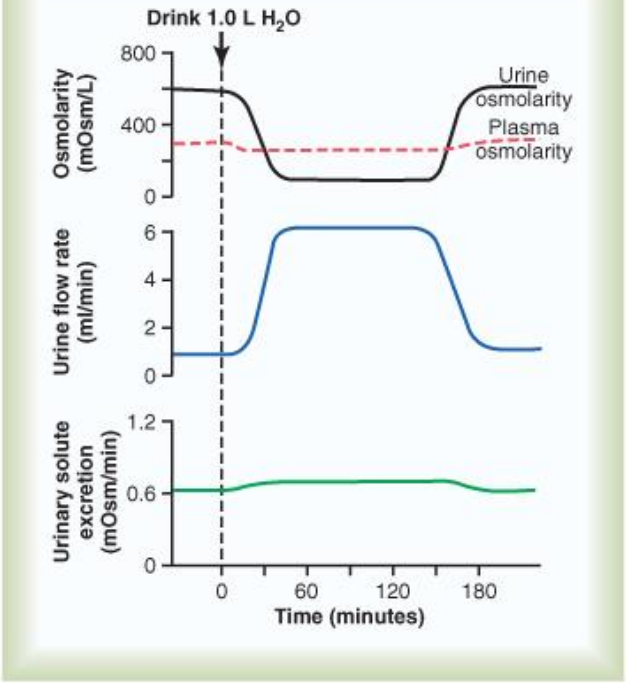
NEPHRON TYPES
Cortical and Juxtamedullary Nephrons

1-2 % Blood Flows Through Juxta Medullary Nephrons



COUNTER CURRENT MECHANISM

- **LOOPS OF HENLE OF JUXTA MEDULLARY NEPHRONS establish hyperosmolality of interstitium of medulla. They are called COUNTER CURRENT MULTIPLIERS**
- **VASA RECTA maintain hyperosmolality established by counter current multipliers. They are called COUNTER CURRENT EXCHANGERS**



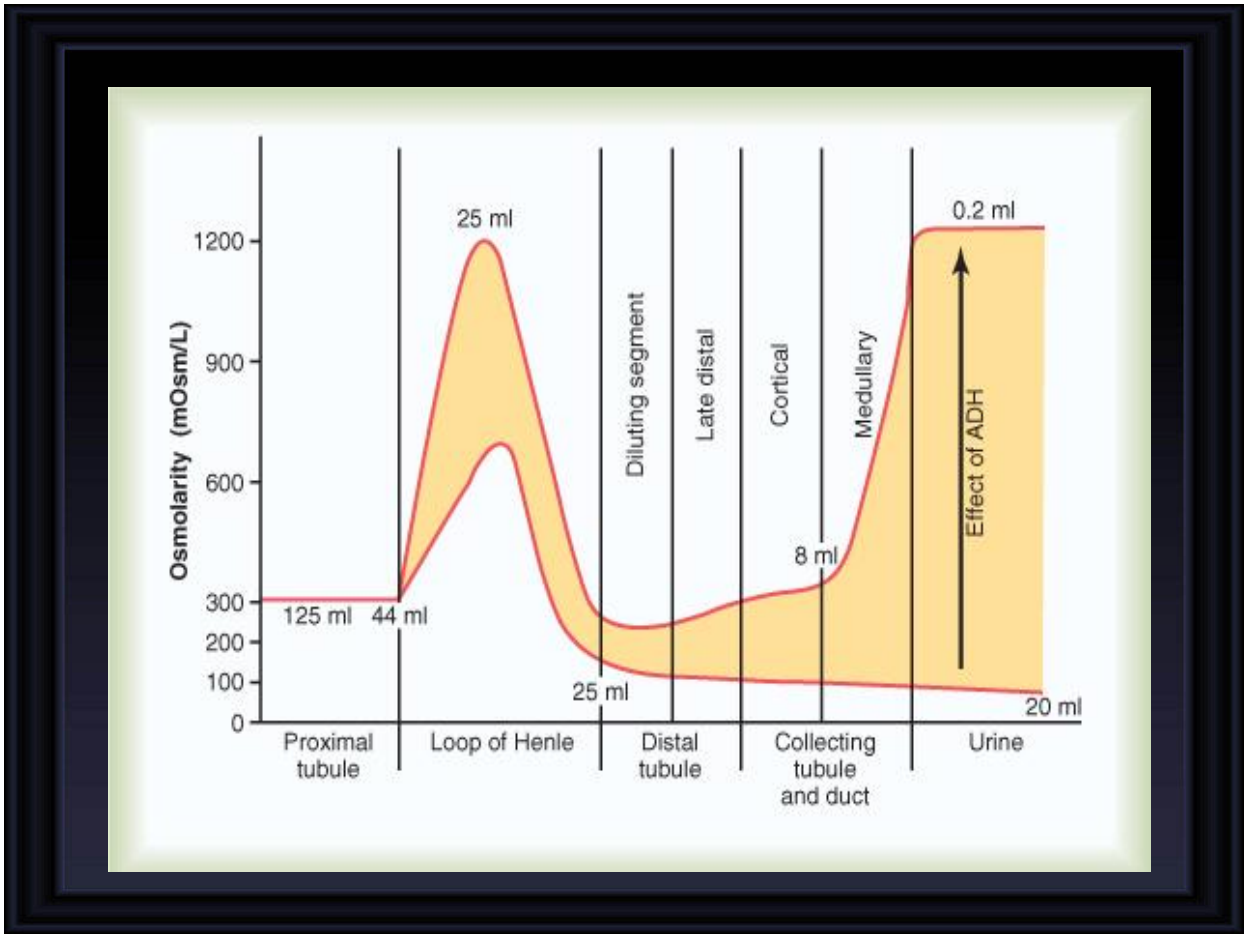
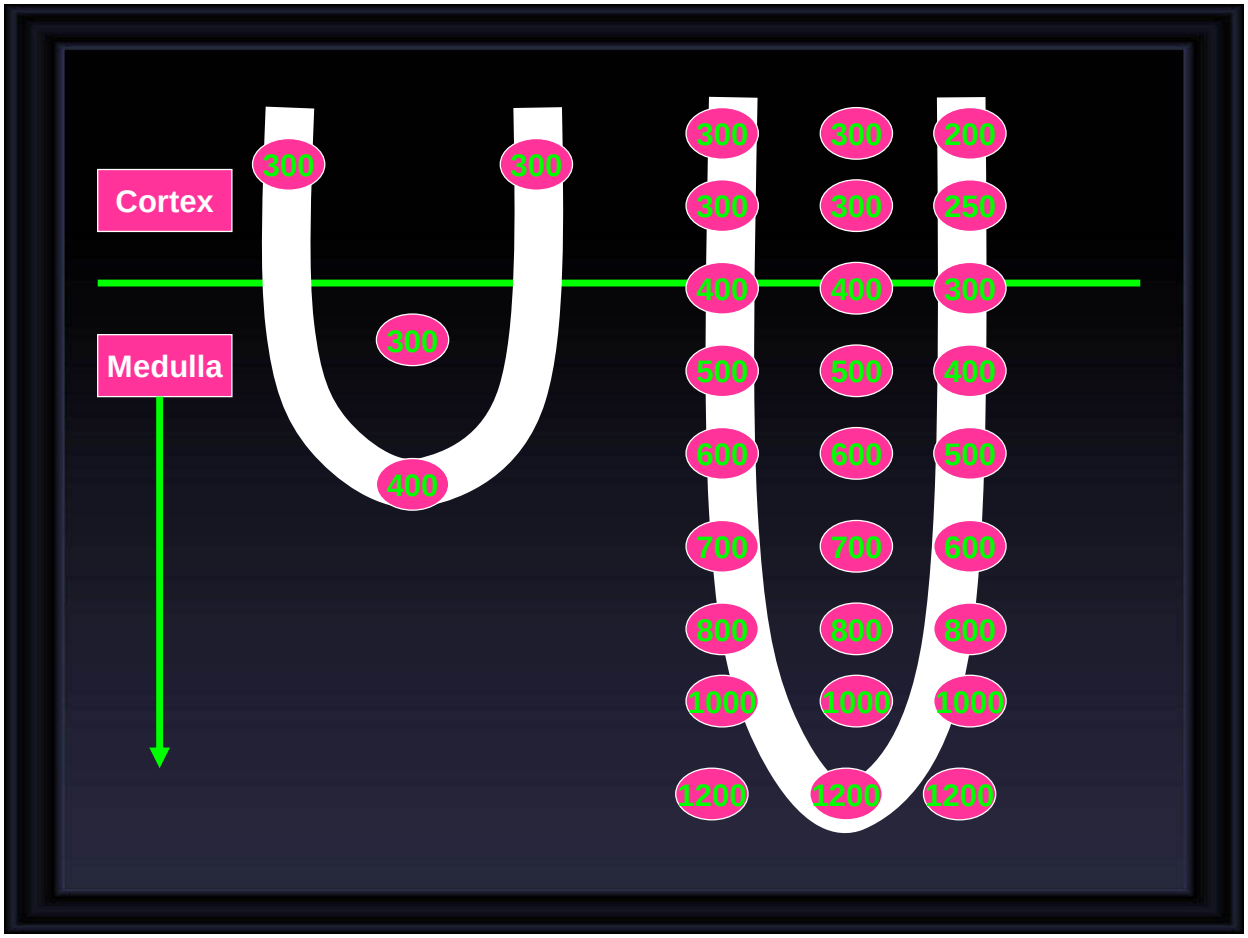

Osmolarity (mOsm/L)
1200
900
600
300
200
100
0
125 ml
44 ml
25 ml
25 ml
8 ml
0.2 ml
20 ml
Diluting segment
Late distal
Cortical
Medullary
Effect of ADH
Proximal tubule
Loop of Henle
Distal tubule
Collecting tubule and duct
Urine

Table 28–1

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

0, minimal level of active transport or permeability; +, moderate level of active transport or permeability; ++, high level of active transport or permeability; +ADH, permeability to water or urea is increased by ADH.


Cortex
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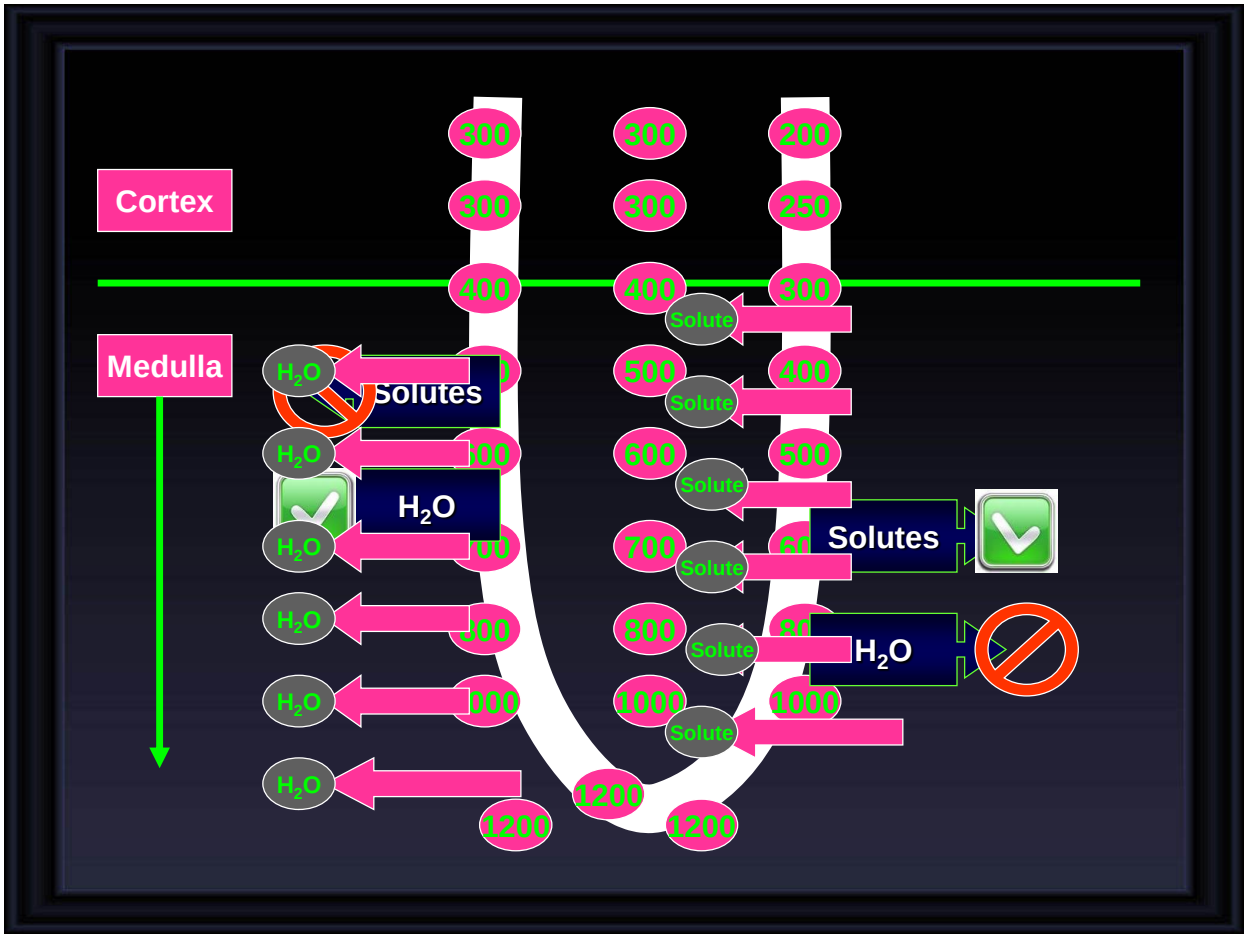
1200
1200
1200

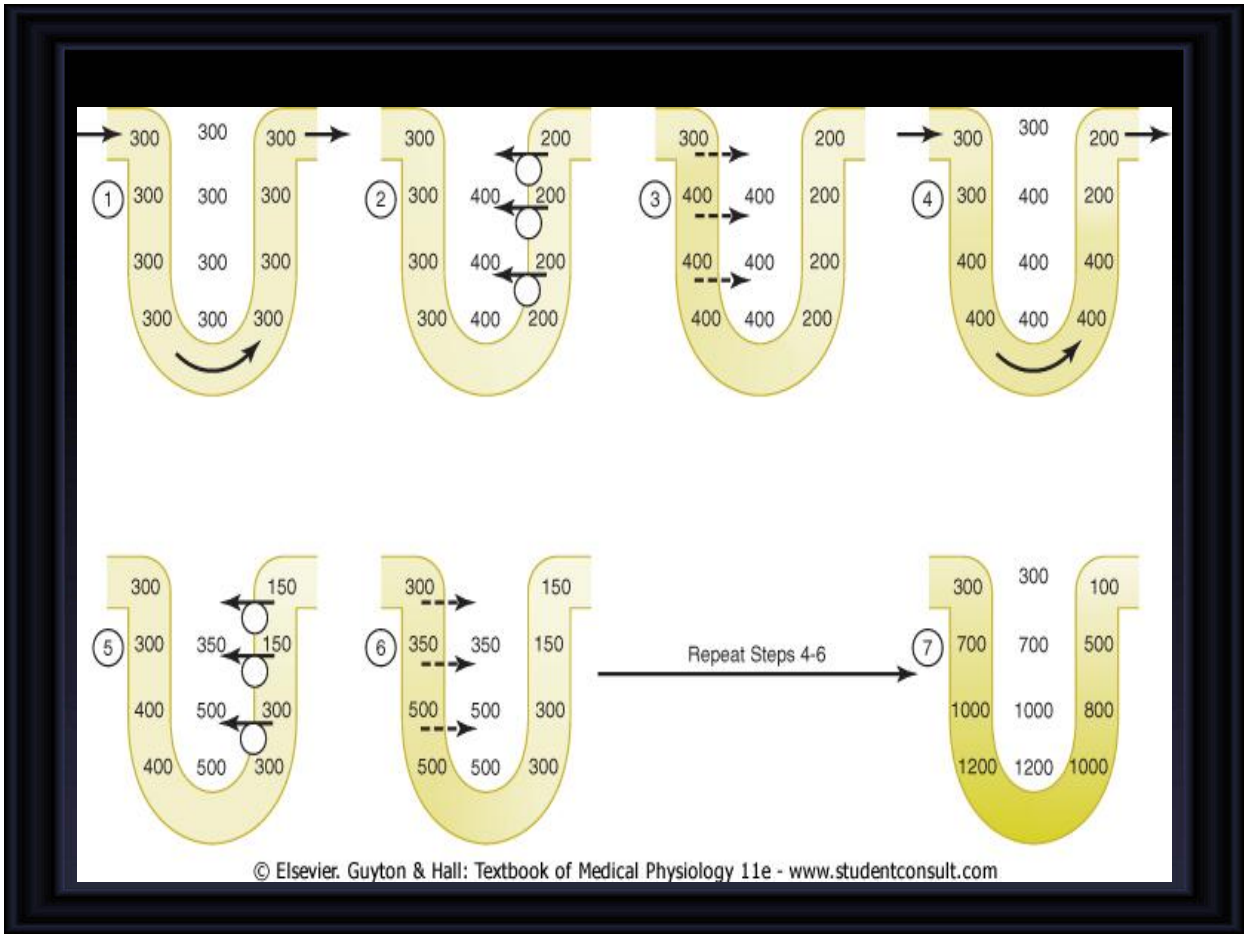

Cortex
Medulla
300
300
400
500
600
700
800
1000
1200
300
300
400
500
600
700
800
1000
1200
200
250
300
400
500
Solute
Solute
Solute
Solute
Solute
Solute
Solutes
H_2O
H_2O
H_2O
H_2O
H_2O
H_2O
H_2O
Solutes
H_2O

LOOP OF HENLE

Descending Loop	Ascending Loop
highly permeable to water	•impermeable to water
•impermeable to Na^+	•permeable to Na^+ (mediated by $Na^+/K^+/2Cl^-$ apical carrier - inhibited by furosemide (Lasix))
•water exit promoted	•Na^+/K^+-ATPase actively pumps out sodium of cell into interstitium

Buildup of solute concentration into the renal medulla

1. **Active transport of sodium ions and co-transport of potassium, chloride, and other ions** out of the thick portion of the ascending limb of the loop of Henle into the medullary interstitium
2. **Active transport of ions** from the collecting ducts into the medullary interstitium
3. **Facilitated diffusion of large amounts of urea** from the inner medullary collecting ducts into the medullary interstitium
4. **Diffusion of only small amounts of water** from the medullary tubules into the medullary interstitium,far less than the reabsorption of solutes into the medullary interstitium


1
2
3
4
5
6
7
Repeat Steps 4-6
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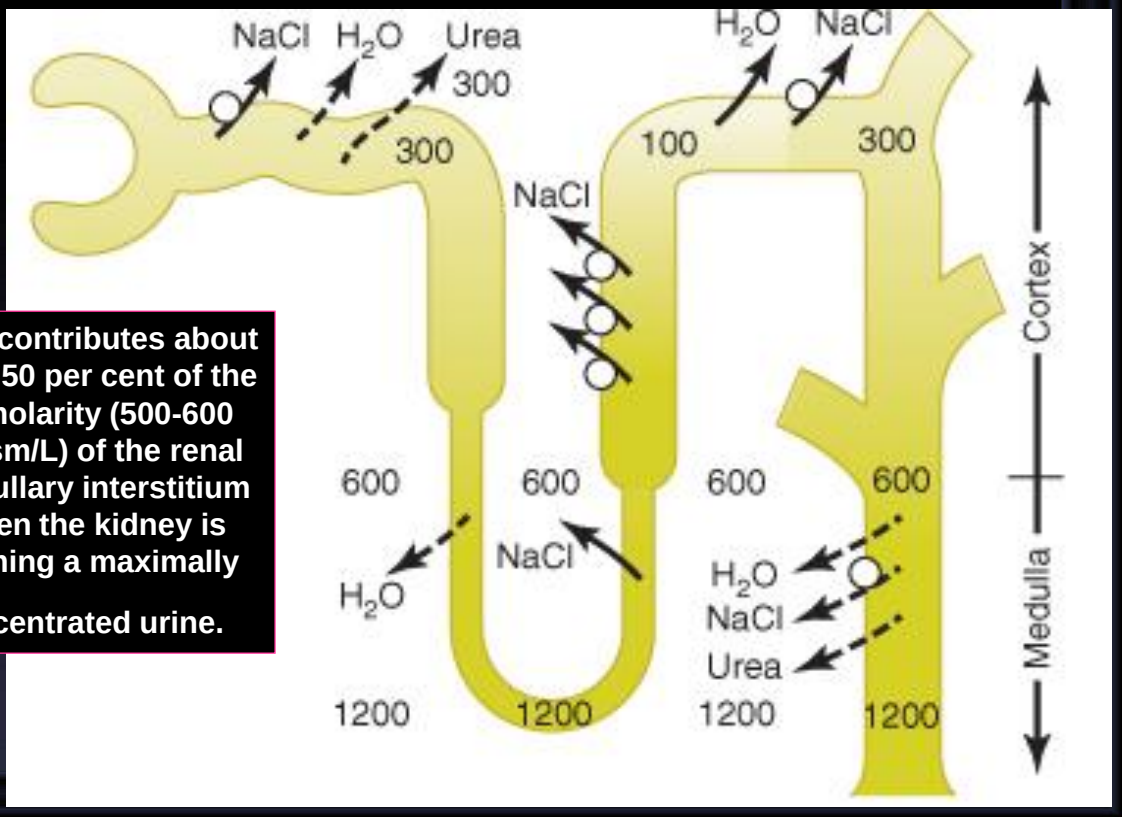
Role of DCT & CT in Excreting a Concentrated Urine



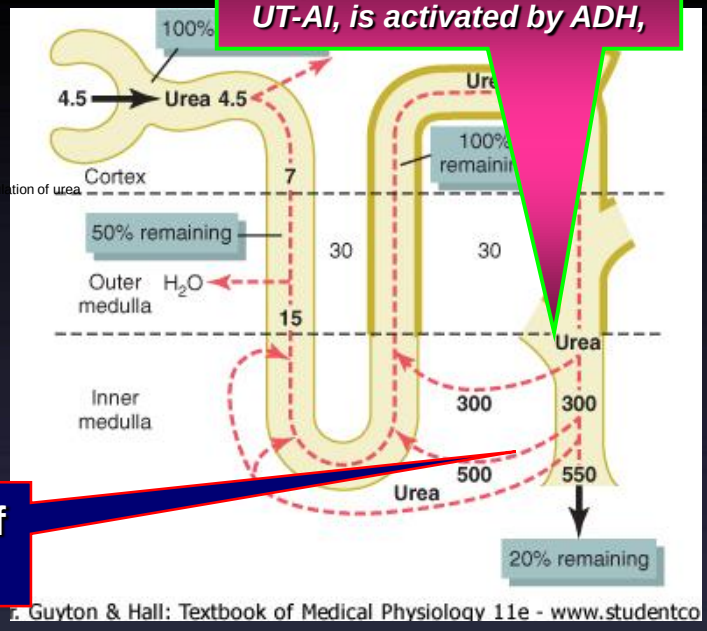
Urea contributes about 40 to 50 per cent of the osmolarity (500-600 mOsm/L) of the renal medullary interstitium when the kidney is forming a maximally

oncentrated urine.

ROLE OF UREA IN MAKING A HYPEROSMOTIC RENAL MEDULLARY INTERSTITIUM AND CONCENTRATED URINE

About 40 to 50 % of the osmolarity (500-600 mOsm/L) of the renal medullary interstitium when the kidney is forming a maximally concentrated urine.

A specific urea transporter UT-AI, is activated by ADH,



Recirculation of UREA

Two special features of the renal medullary blood flow

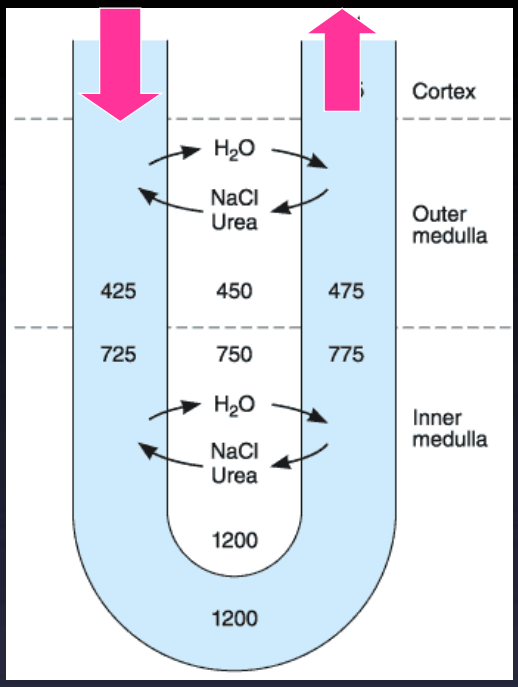
- The medullary blood flow is low, accounting for less than 5 per cent of the total renal blood flow. This sluggish blood flow is sufficient to supply the metabolic needs of the tissues but helps to minimize solute loss from the medullary interstitium.
- The vasa recta serve as countercurrent exchangers, minimizing washout of solutes from the medullary interstitium.

COUNTER CURRENT EXCHANGERS

- Sluggish blood flow (1-2 %)
- Close proximity
- High permeability

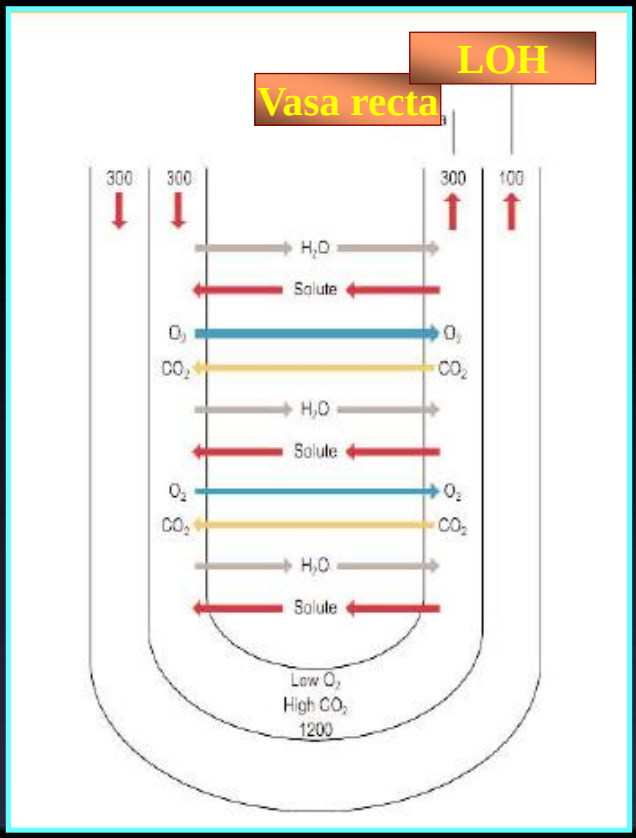
COUNTER CURRENT EXCHANGERS

A PASSIVE PROCESS

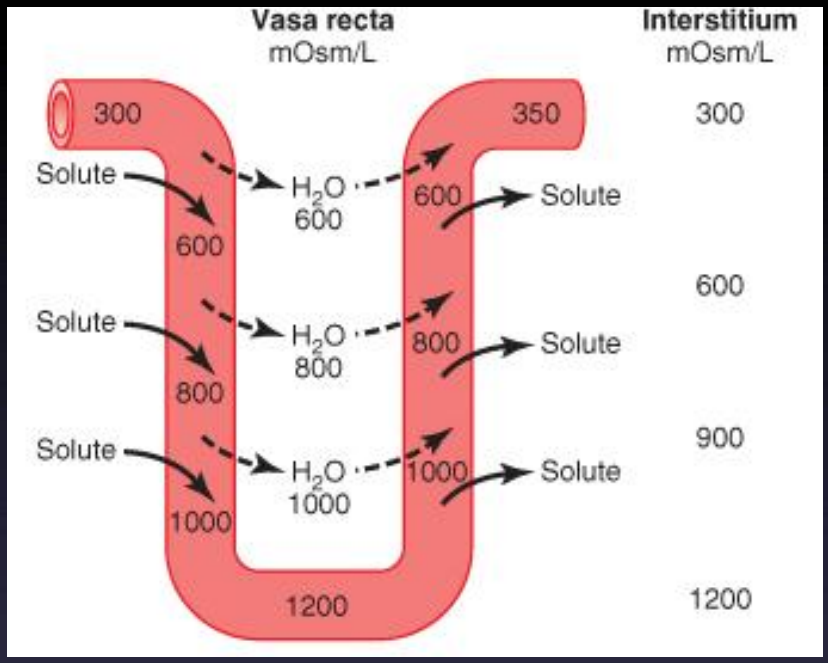


COUNTER CURRENT EXCHANGERS

COUNTER CURRENT MULTIPLIERS



COUNTER CURRENT EXCHANGERS



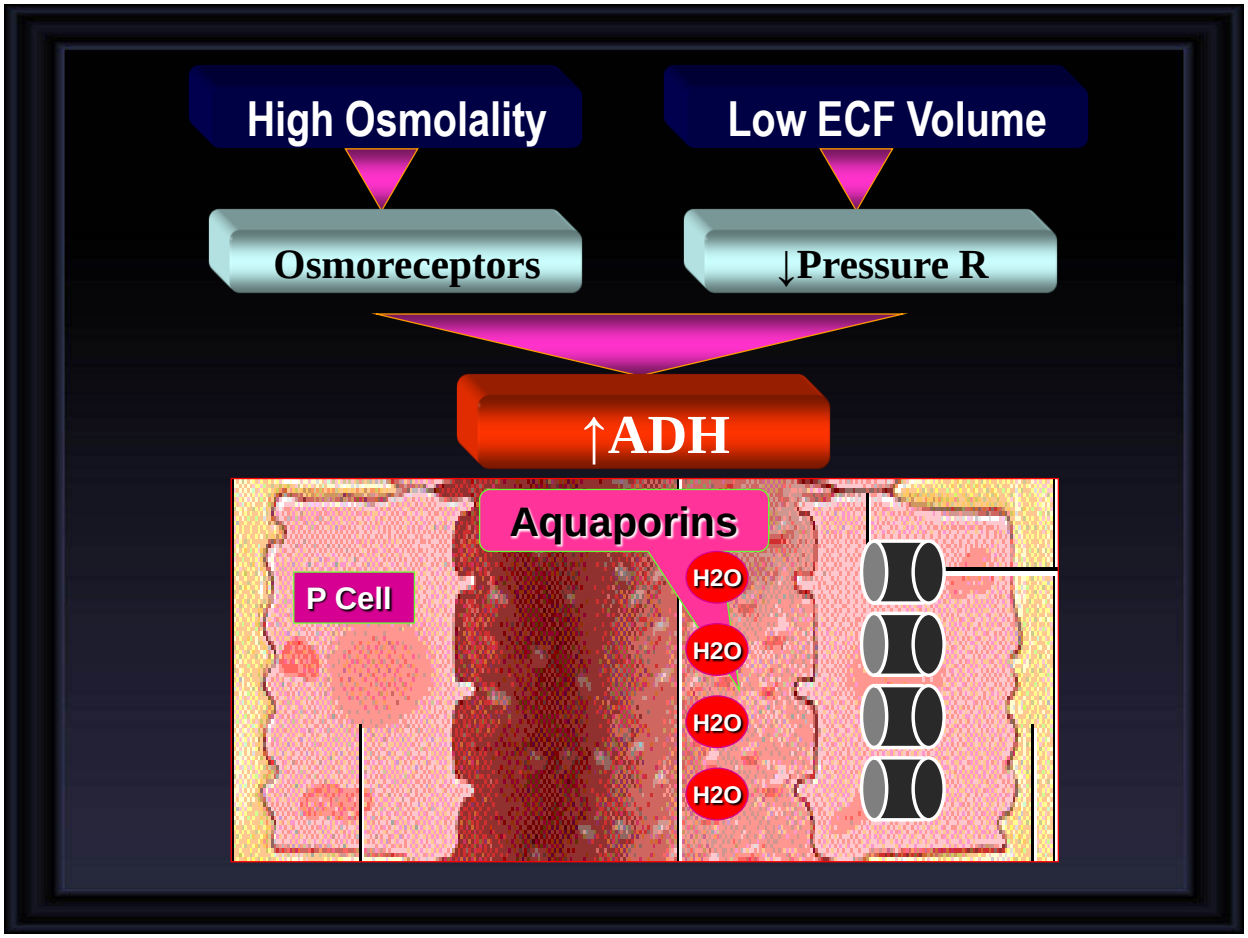

High Osmolality
Low ECF Volume
Osmoreceptors
↓Pressure R
↑ADH
Aquaporins
P Cell
H2O
H2O
H2O
H2O

Table 28–2

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)

DISORDERS OF URINARY CONCENTRATING ABILITY

- Failure to Produce ADH: "Central" Diabetes Insipidus.
- Inability of the Kidneys to Respond to ADH: "Nephrogenic"

  Diabetes Insipidus.

DISORDERS OF URINARY CONCENTRATING ABILITY

- Inappropriate secretion of ADH (SIADH)