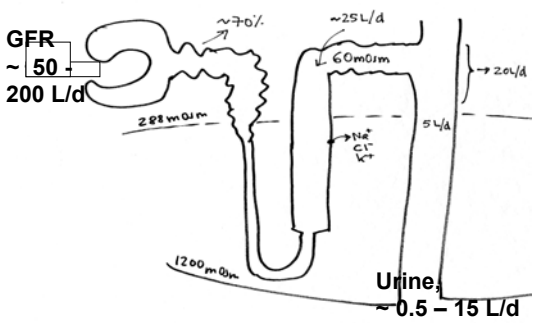
## Volume of Urine




**Intake:**
$Na^+$ ~ 5-200 mmoles/day
$K^+$~ 50-300 "
$H_20$ ~ 0.5-3 L/day
$H^+$ ~ 50-100 mEq/day

Air water ~ 3000 mOsm/Kg $H_20$

**Extracellular Fluid**
Volume ~ 1/3 body water; Osmol 290 mOsm/Kg $H_2O$
$Na^+$ 142 mM; $K^+$ 4 mM; $H^+$ 40 nM (pH 7.40)

Cells

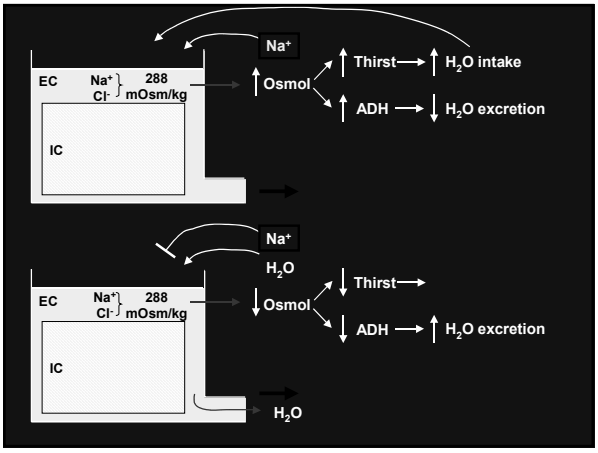
urine

## How do we maintain ECF Volume?

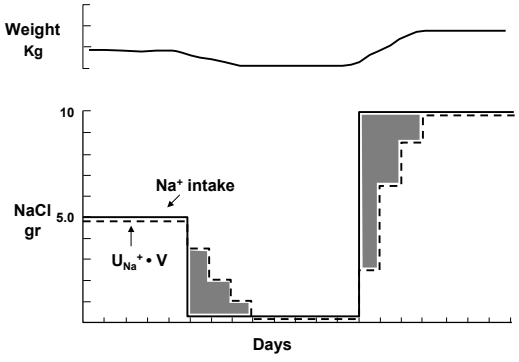
**By keeping ECV $Na^+$ content,**

**ECFV (~ 10-15 L) x [$Na^+$] (140 mEq/L)**
**~ 1,400 – 2,100 mEq**

**fairly constant despite variations on intake**

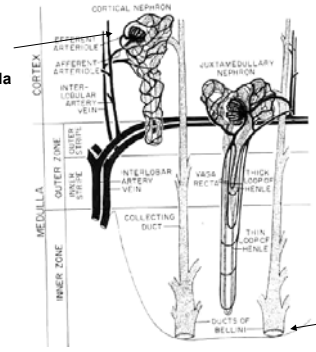



## Effect of Changing NaCl in Diet



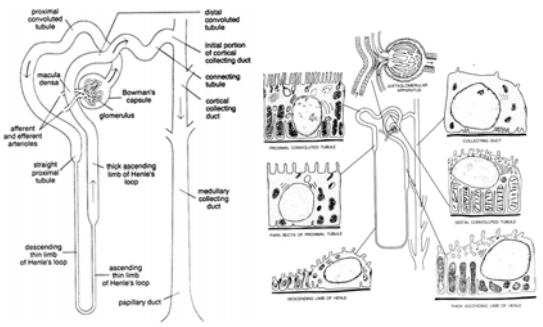

## Renal Architecture

Na filtered
= GFR x $P_{Na}$

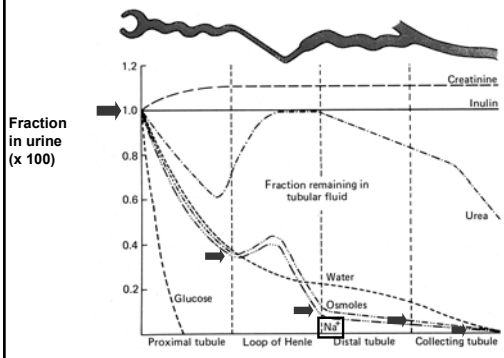



Na excreted
= V x $U_{Na}$

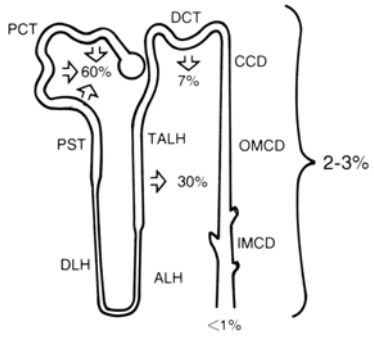
## Nephron Segments



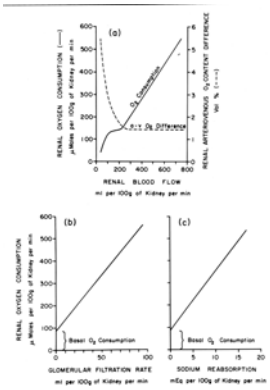

## Fractional $Na^+$ in Urine along the Nephron



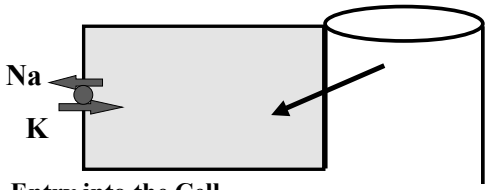

## % Reabsorption of Filtered NaCl




## Renal Oxygen Consumption



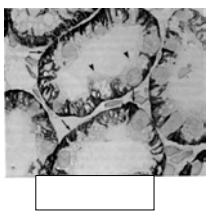

## Sodium Absorption




**Entry into the Cell**
**down an electrochemical gradient**
**Na channel, or Na coupled solute carriers**

**Exit into the blood by the Na:K ATPase**

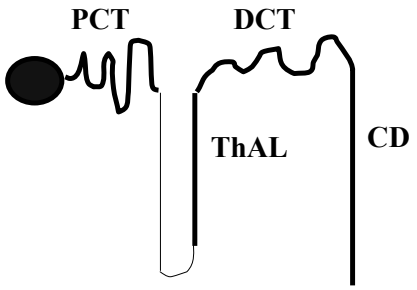
## The $Na^+ K^+$ ATPase



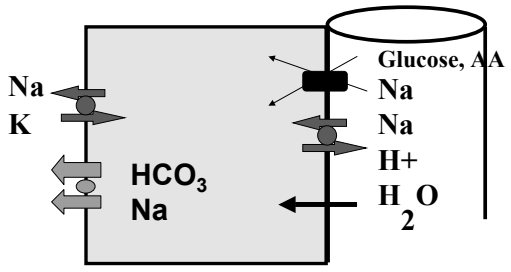
Located in the basolateral membrane of Renal Tubular Cells
Inhibited by the cardiac glycosides digoxin and ouabain

Nielsen et al., Amer. J. Physiol.277:F257. 1999

## Tubular Segments

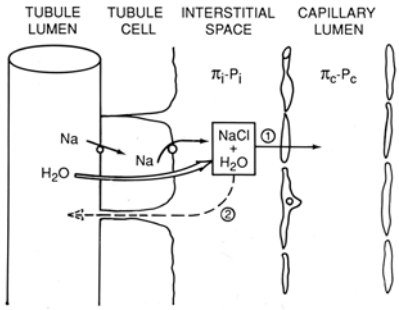



## Proximal Tubule $Na^+$ Reabsorption



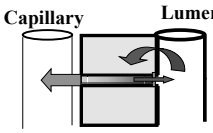

Na/H exchanger
Na/solute co-transporter

## Starling's Forces in Peritubular Capillary




$P_R = Kf\ (B_C - B_i) - (P_C - P_i)$
$P_R = Kf\ (\ )B - \ )P)$

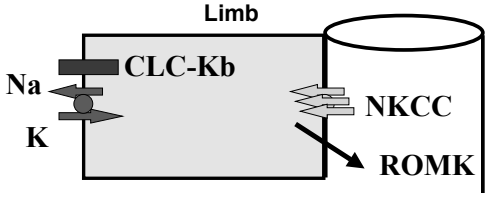
## Driving Forces for Salt and Water Absorption in the Proximal Tubule




**Trans-cellular** — **Active transport of Na and $HCO_3$**

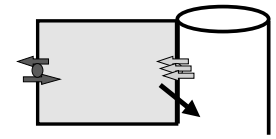
**Intercellular Leak** — **Starling Forces across capillary ($\Delta P - \Delta\Pi$)**

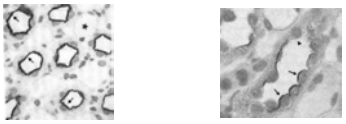
## Sodium Absorption in Thick Ascending Limb




| | |
|---|---|
| NKCC | Na:K:2Cl Co-transporter<br>Furosemide sensitive cotransporter |
| ROMK | K channel |
| CLC-Kb | Chloride Channel |

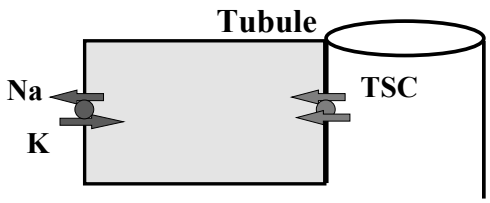
## Apical Transporters of the Thick Ascending Limb



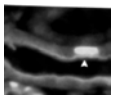



Nielsen et al., Amer. J. Physiol. 282: F34.2002

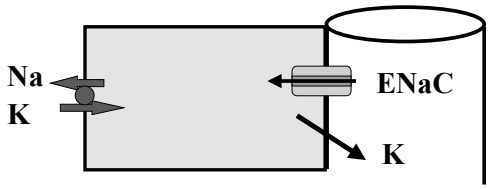
## Sodium Absorption in Distal Tubule




TSC Na:Cl Co-transporter
Thiazide sensitive cotransporter

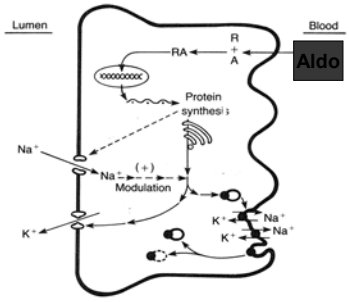


## Sodium Absorption in Collecting Duct




ENaC Epithelial Na Channel
Amiloride sensitive
K K channel

## Aldosterone Effect on $Na^+$ and $K^+$ in the Collecting Duct

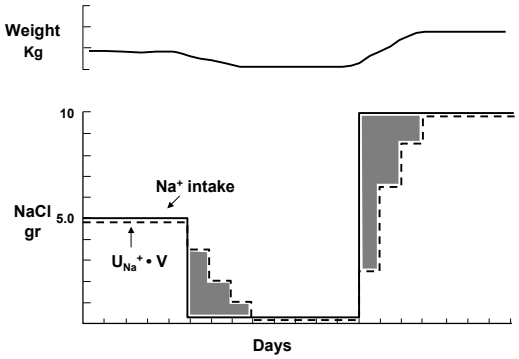



## Renin-Angiotensin System

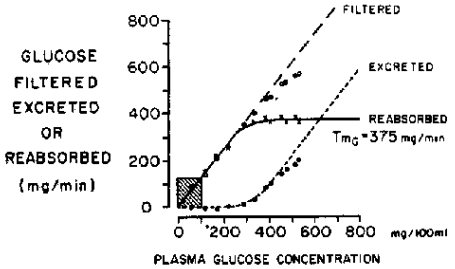
angiotensinogen
renin

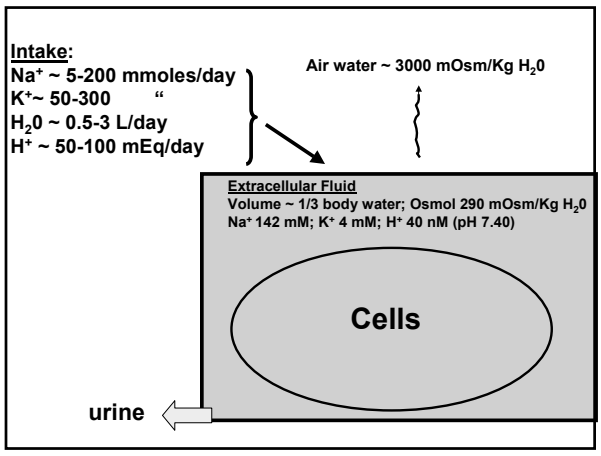
angiotensin I
converting enzyme
angiotensin II
efferent constriction;
↑ PT reabsorption
vasoconstriction
↑ aldosterone; ↑ CD reabsorption

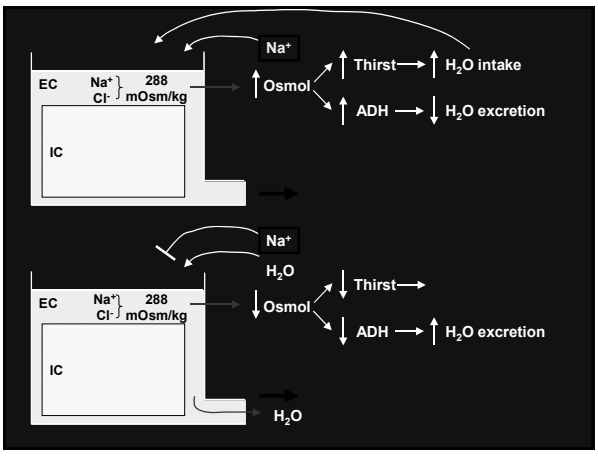
## Effect of Changing NaCl in Diet



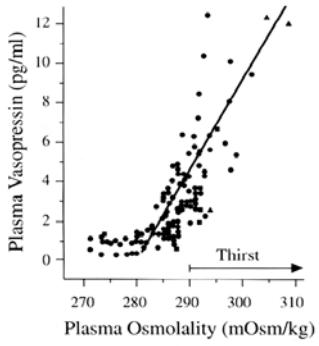

## Renal Handling of Glucose



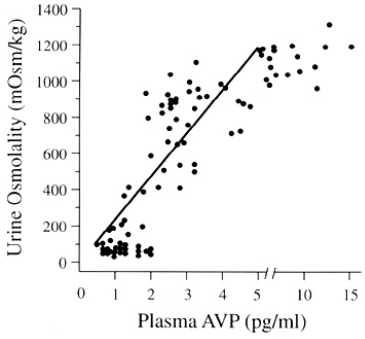


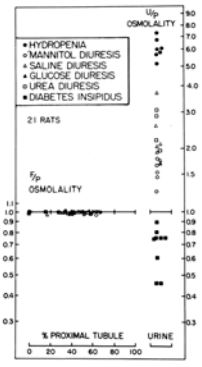

## Plasma ADH (AVP)




## Urine Osmolality as a function of Plasma ADH




## Urine/Plasma Osmolality in Rat




**Posmol**

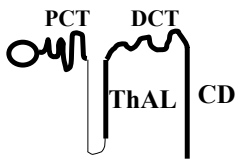
**290 mosm/Kg $H_2O$**

**Uosmol**

**max: 1200**

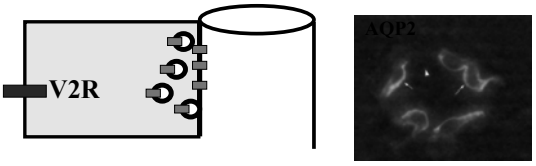
**min: 60 mosm/Kg $H_2O$**

## Tubular Fluid Osmolality




**PCT** iso-osmolar
**ThAL** hypo-osmolar
**DCT** hypo-osmolar
**CD** hypo-osmolar in the **absence** of vasopressin (Antidiuretic Hormone)
hyper-osmolar in the **presence** of vasopressin

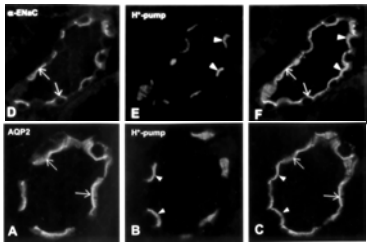
## Mechanism of action of Vasopressin



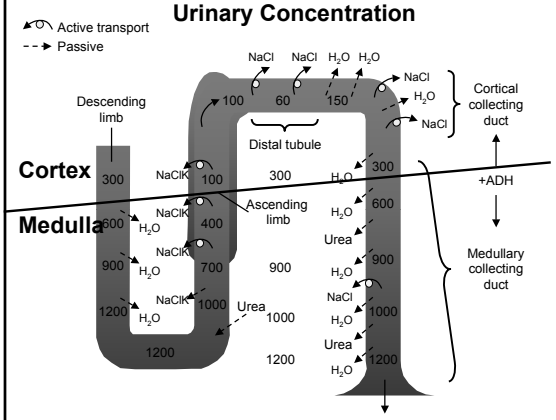

Binds to V2 Receptor in collecting tubule
Increases production of cyclic AMP
Causes fusion of vesicles containing
**Aquaporin 2** with the apical membrane

## Cell Types of the Collecting Tubule

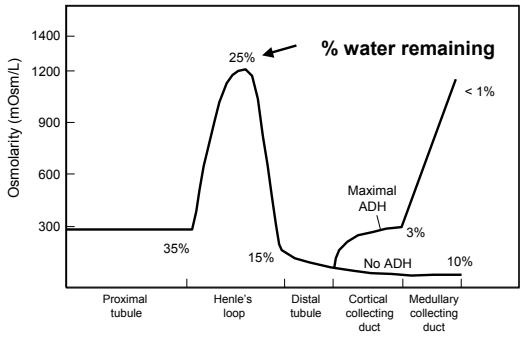
| | | |
|---|---|---|
| **Principal** | *$Na^+$ absorption* | **ENaC** |
| | *Water absorption* | **Aquaporin 2** |
| | *$K^+$ secretion* | ROMK |
| **Intercalated** | *$H^+$ Transport* | **$H^+$ ATPase** |



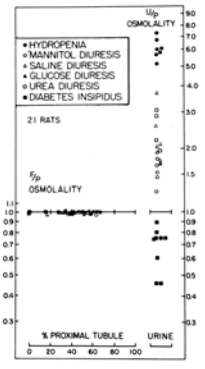

## Urinary Concentration




## Urinary Concentration and Dilution




## Urine/Plasma Osmolality in Rat




**Posmol**

**290 mosm/Kg $H_20$**

**Uosmol**

**max: 1200**

**min: 60 mosm/Kg $H_20$**