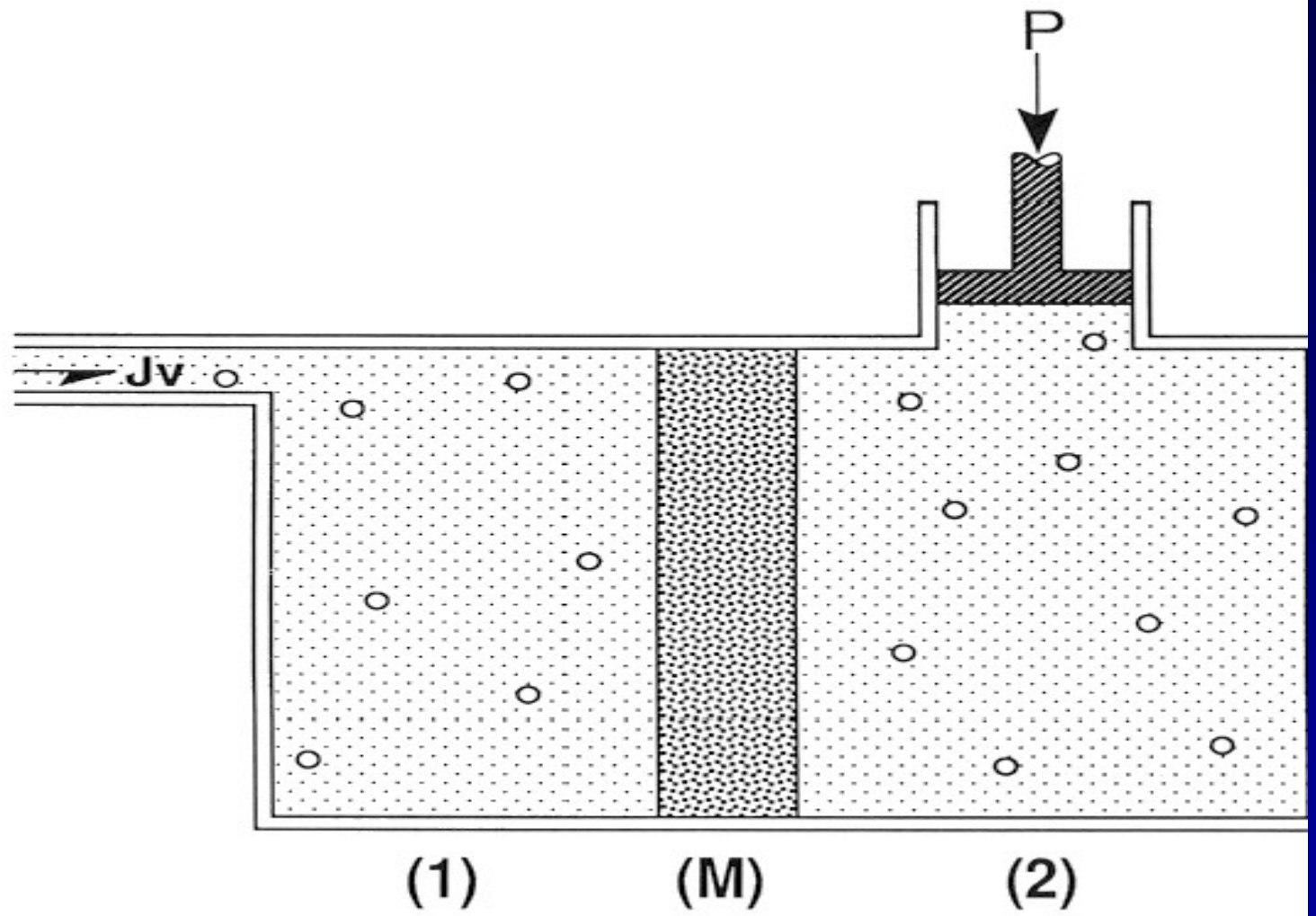


Osmosis and Osmoregulation

Robert Alpern, M.D.
Southwestern Medical School



Water Transport Across Semipermeable Membranes

- In a dilute solution,

$$J_v = L_p (\Delta P - RT\Delta C_s)$$

- J_v - volume or water flux
- L_p - hydraulic conductivity or permeability
- ΔP - hydrostatic pressure gradient
- R - gas constant
- T - absolute temperature (Kelvin)
- ΔC_s - solute concentration gradient

Osmotic Pressure

- If $J_v = 0$, then

$$\Delta P = RT\Delta C_s \quad \text{van't Hoff equation}$$

$$\Delta \Pi = RT\Delta C_s \quad \text{Osmotic pressure}$$

- $\Delta \Pi$ is not a pressure, but is an expression of a difference in water concentration across a membrane.

Osmolality

- $\Delta\Pi = RT \sum \Delta C_s$
- **Osmolarity** - solute particles/liter of water
- **Osmolality** - solute particles/kg of water

$$\text{Osmolality} = \sum a_s C_s$$

- **Colligative property**

Pathways for Water Movement

- Solubility-diffusion across lipid bilayers
- Water pores or channels

Concept of Effective Osmoles

- Effective osmoles pull water.
- Ineffective osmoles are membrane permeant, and do not pull water
- **Reflection coefficient (σ)** - an index of the effectiveness of a solute in generating an osmotic driving force.

$$\Delta\Pi = RT \sum \sigma_s \Delta C_s$$

- **Tonicity** - the concentration of effective solutes; the ability of a solution to pull water across a biologic membrane.
- Example: Ethanol can accumulate in body fluids at sufficiently high concentrations to increase osmolality by 1/3, but it does not cause water movement.

Components of Extracellular Fluid Osmolality

- The composition of the extracellular fluid is assessed by measuring plasma or serum composition.
- Plasma osmolality ~ 290 mOsm/l
 - Na salts 2 x 140 mOsm/l
 - Glucose 5 mOsm/l
 - Urea 5 mOsm/l
- Therefore, clinically, physicians frequently refer to the plasma (or serum) Na concentration as an index of extracellular fluid osmolality and tonicity.

Biologic Consequences of Water Movement

- Water moves in and out of cells
 - Cells swell or shrink
- This has profound effects on the brain.
 - Neurologic function is altered.
 - Rapid shrinking can tear vessels and cause hemorrhage.
 - Rapid swelling can cause herniation. Because the skull is rigid, the brain cannot increase its volume by more than 10% without being forced down the neck (herniation).

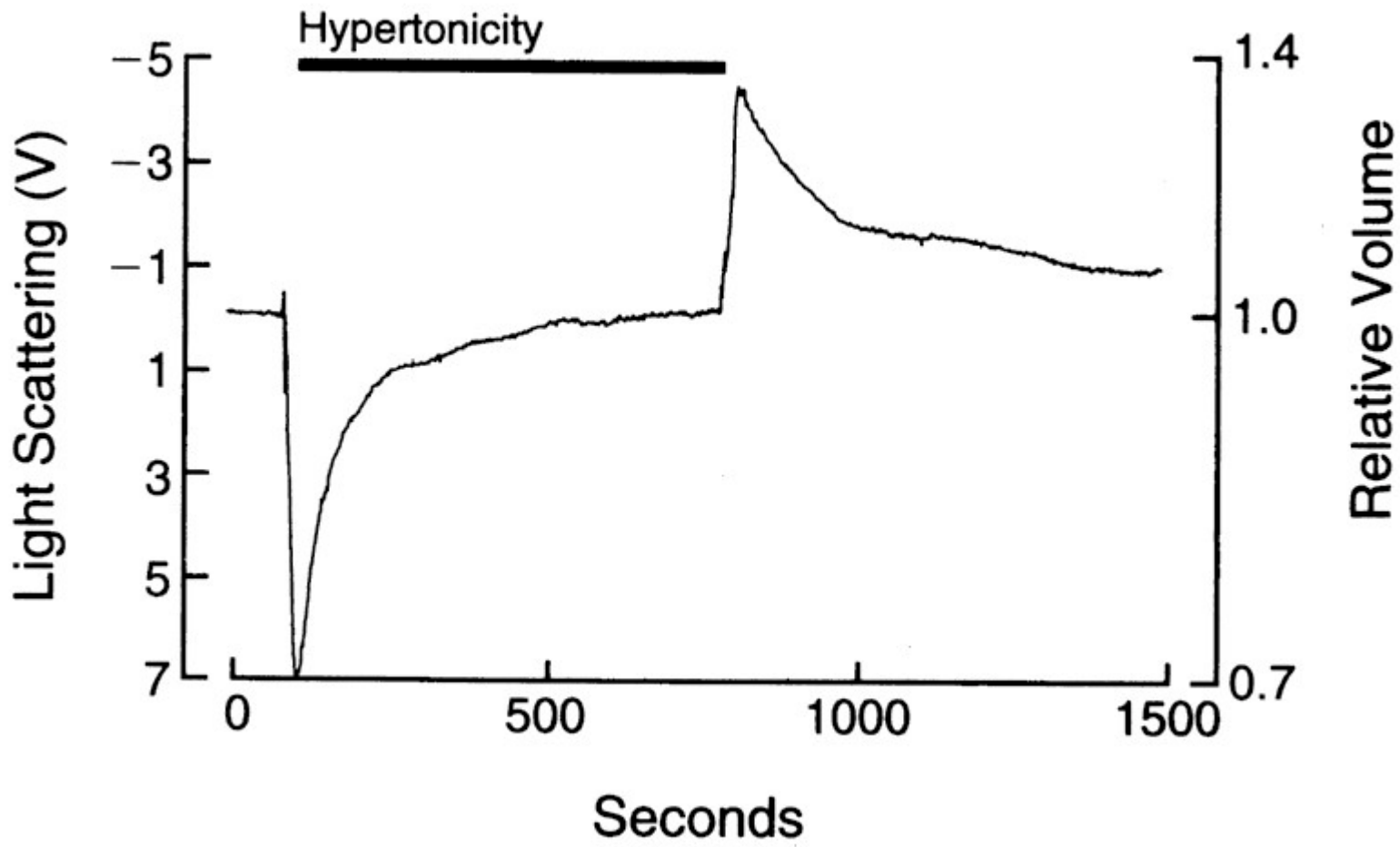
Cells Defend Volume

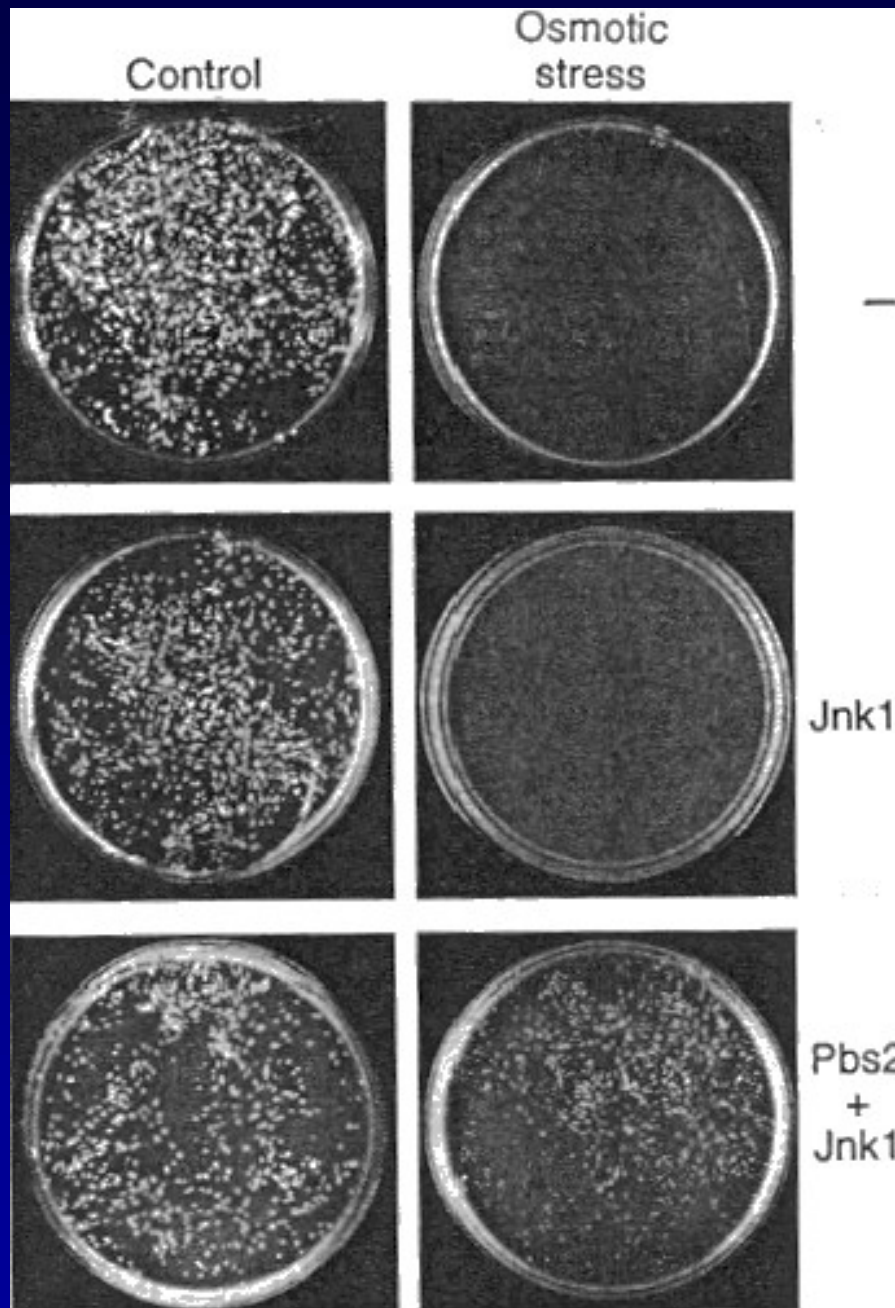
- Extracellular hypertonicity increases expression of genes encoding proteins that increase intracellular osmoles.

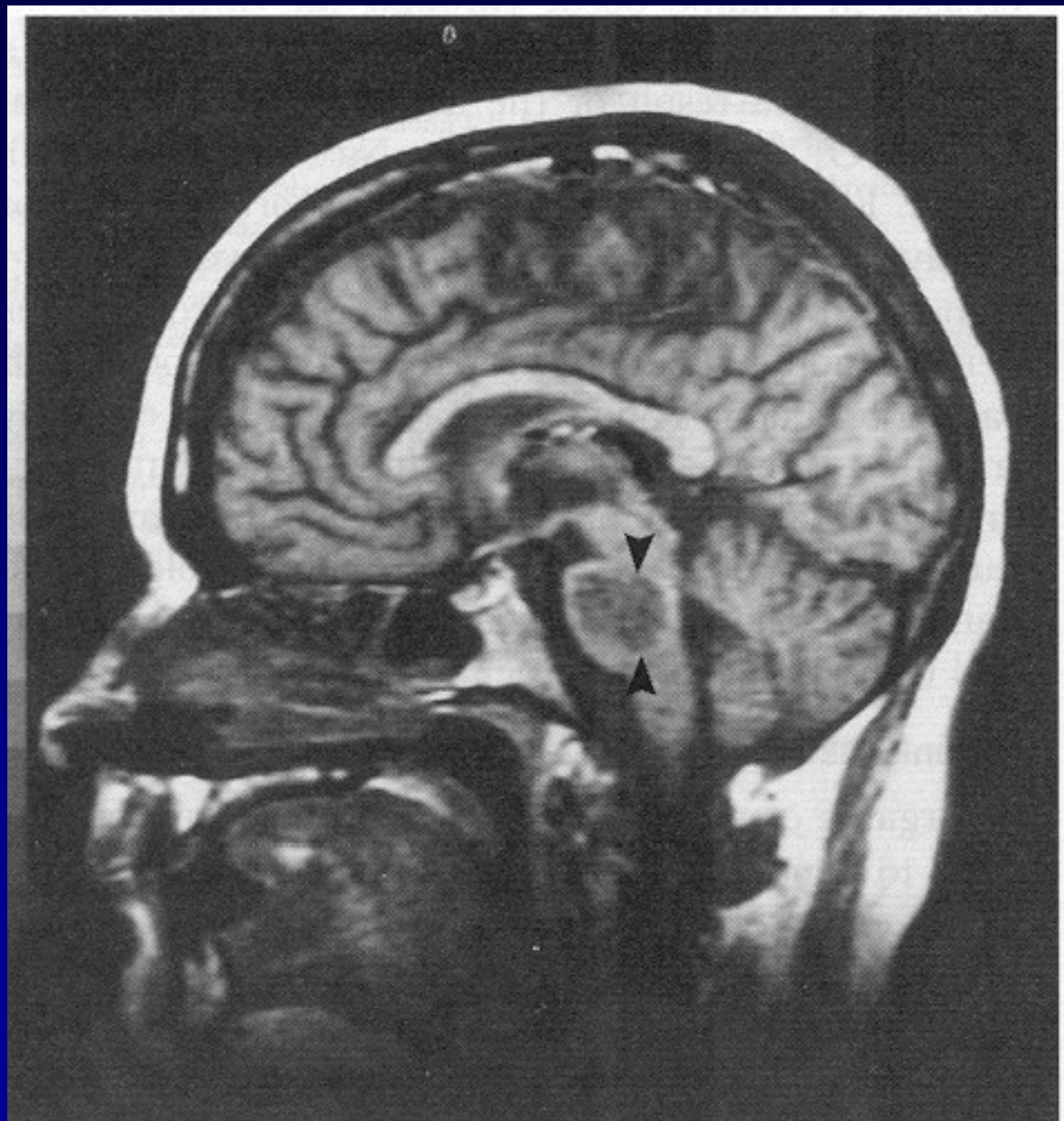
Membrane transporters

Enzymes that synthesize intracellular solutes

- Clinical correlate: Rapid changes in extracellular fluid tonicity alter cell volume and cause neurologic complications, while slow changes are without an effect on cell volume and without an apparent clinical effect.





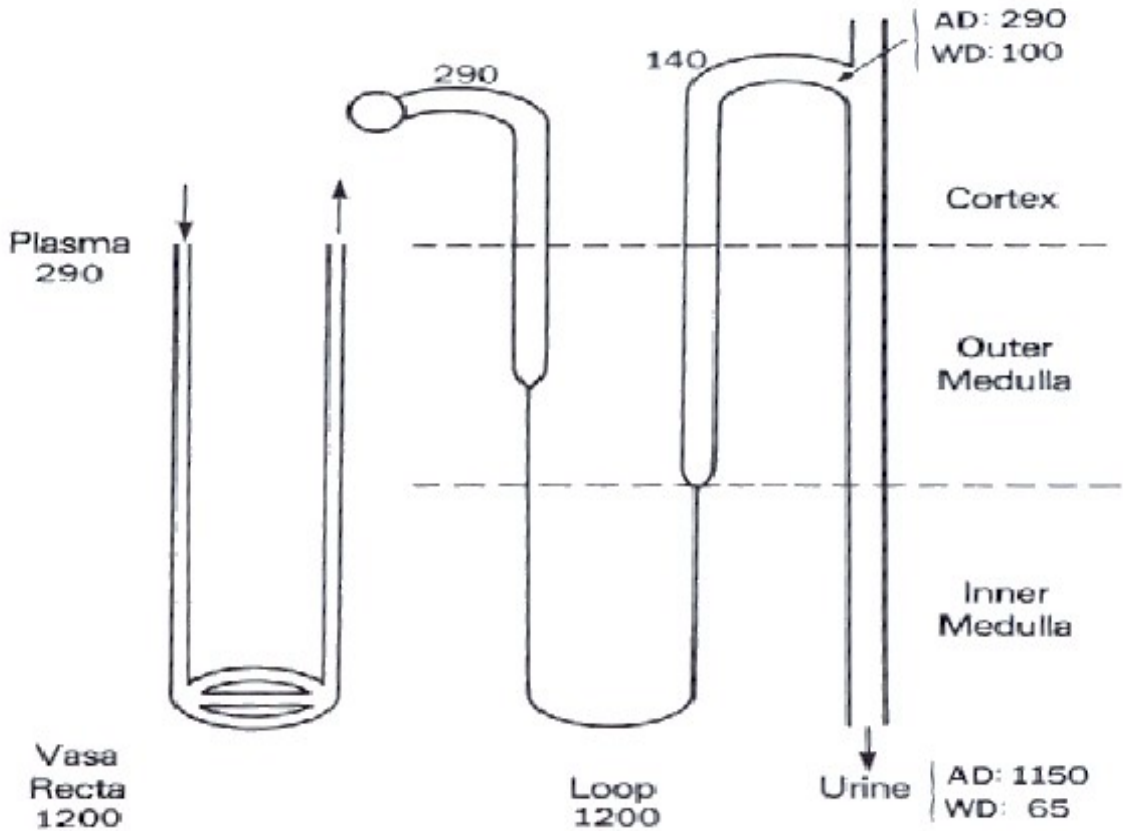


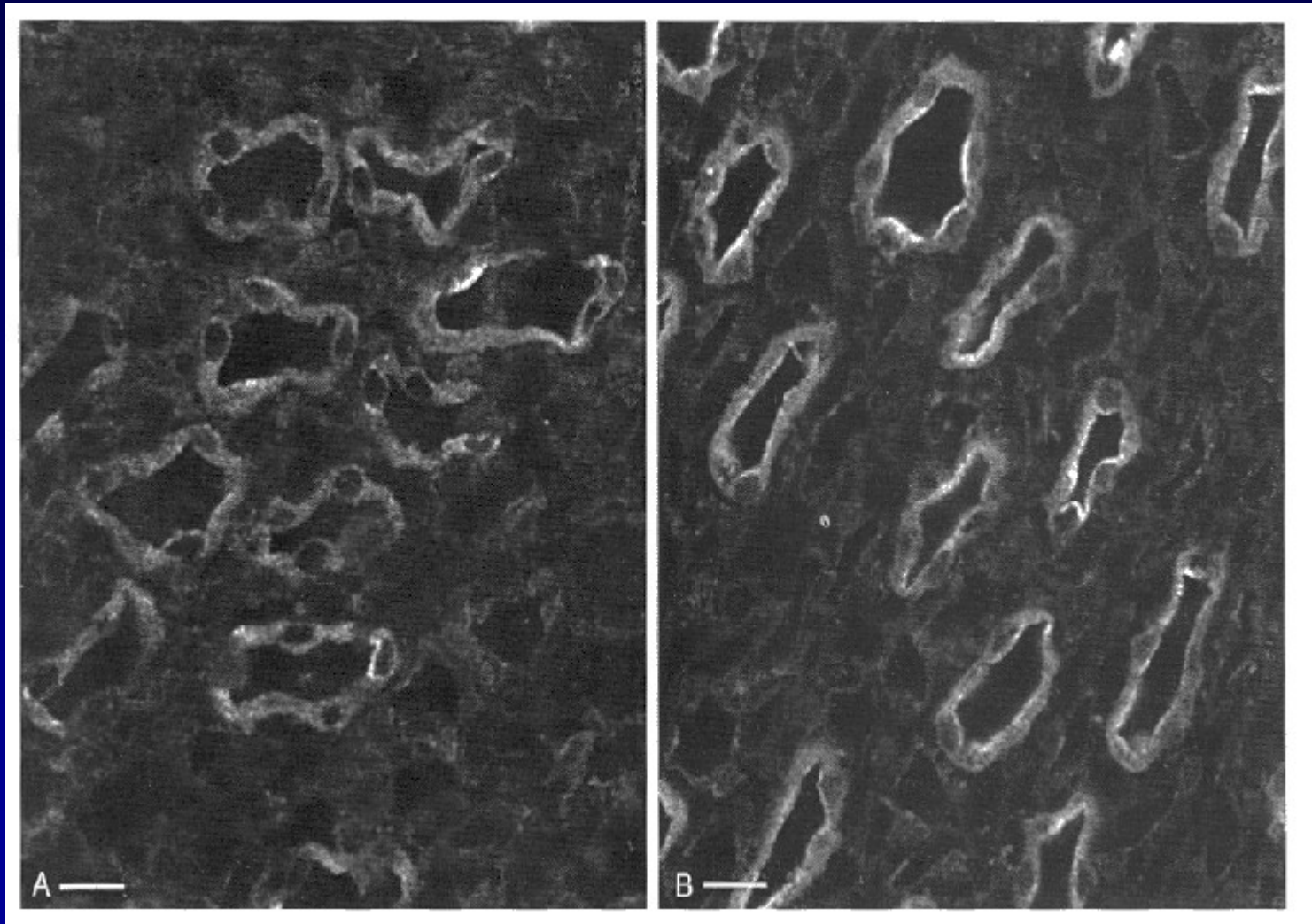
Regulation of Extracellular Fluid Osmolality

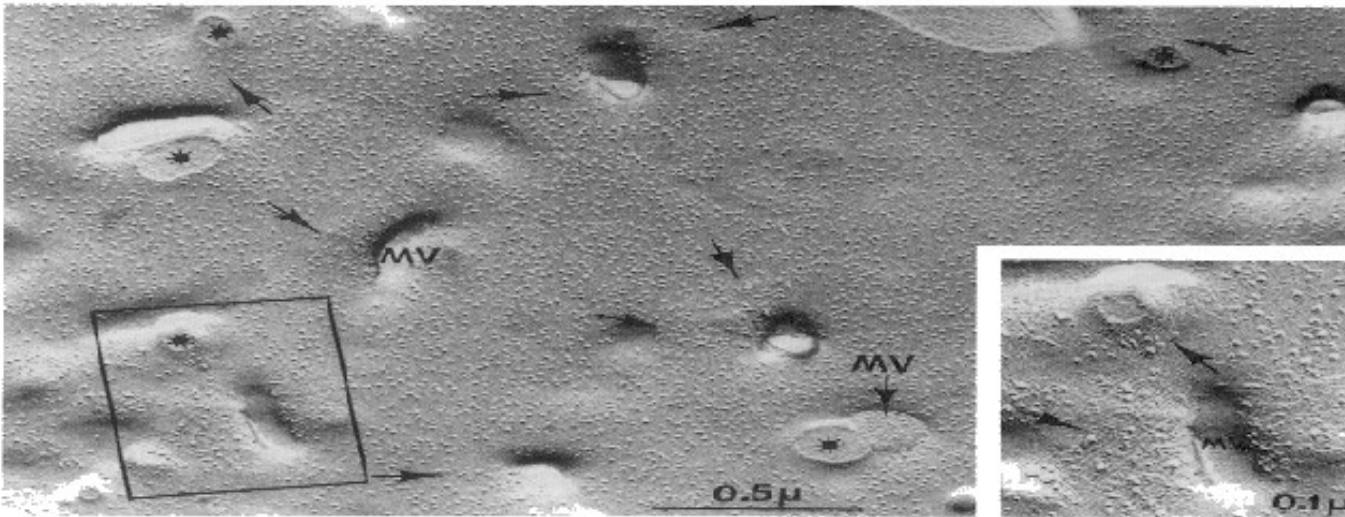
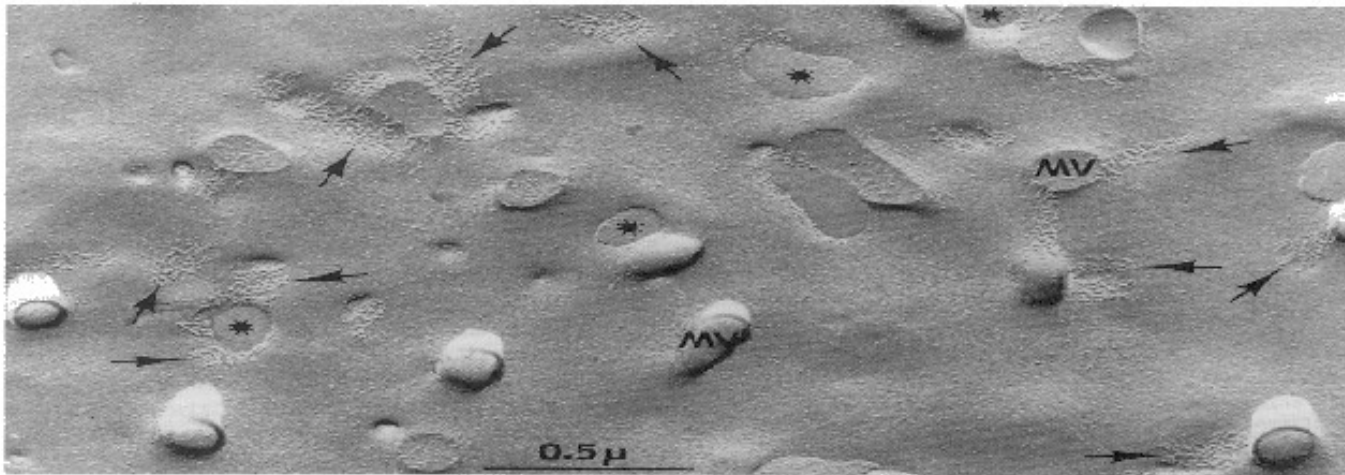
- Excess body water/low plasma osmolality → Increased renal water excretion
- Low body water/high plasma osmolality → Increased thirst and low renal water excretion

OSMOLALITY

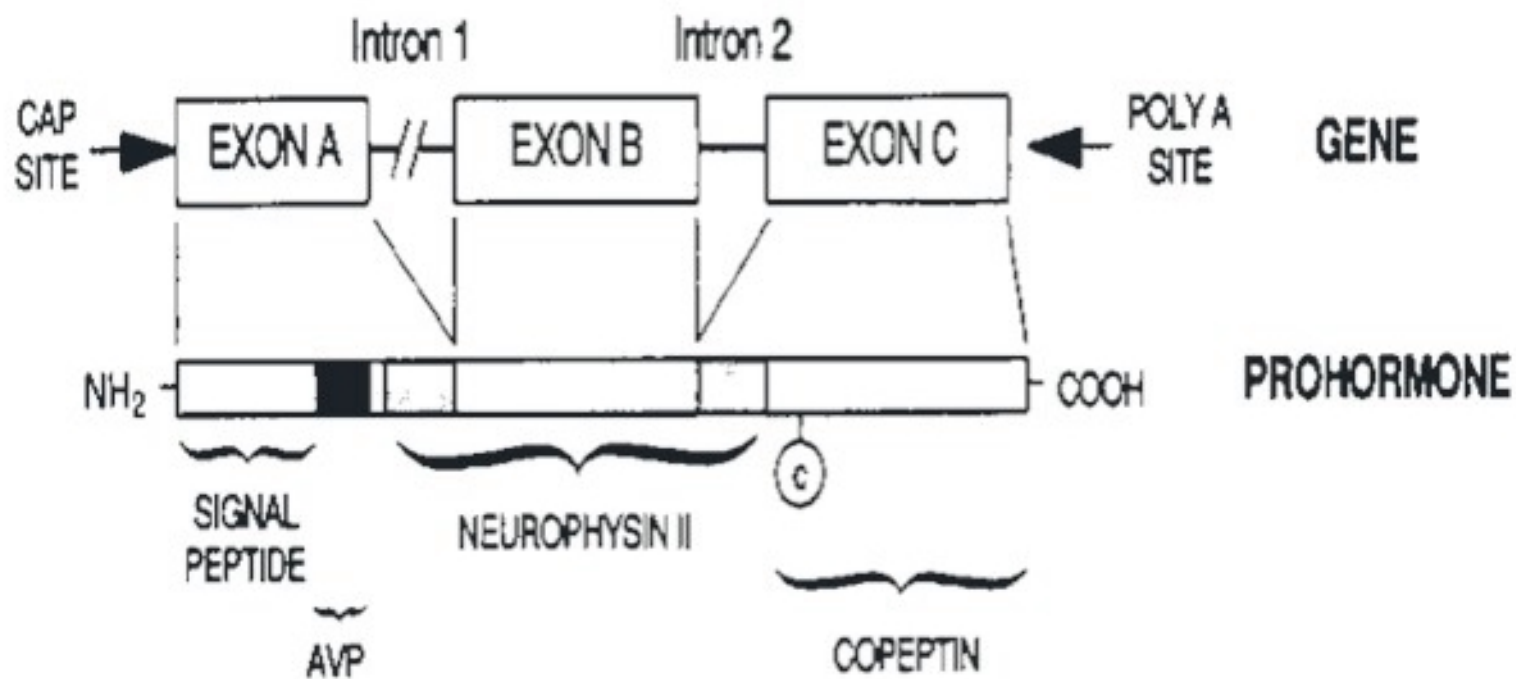
(mOsm/kg H₂O)

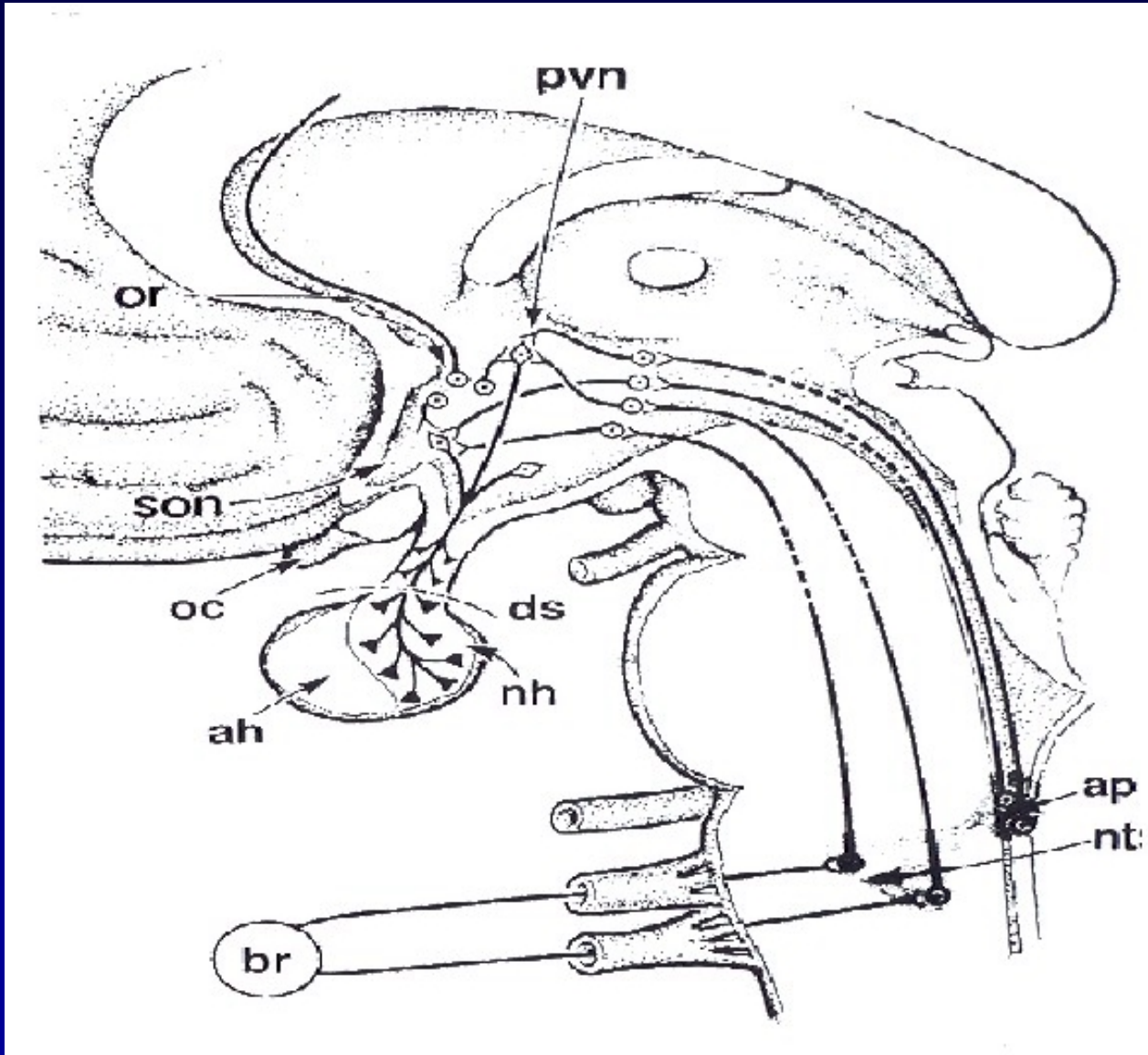




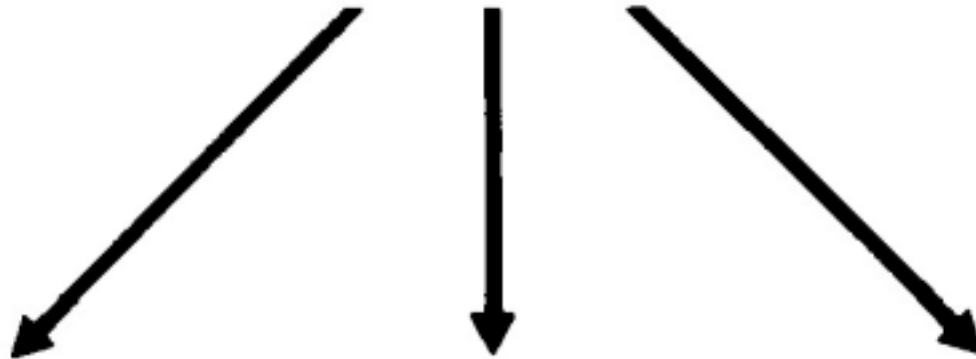


VASOPRESSIN





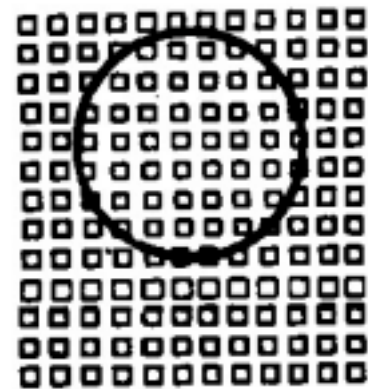
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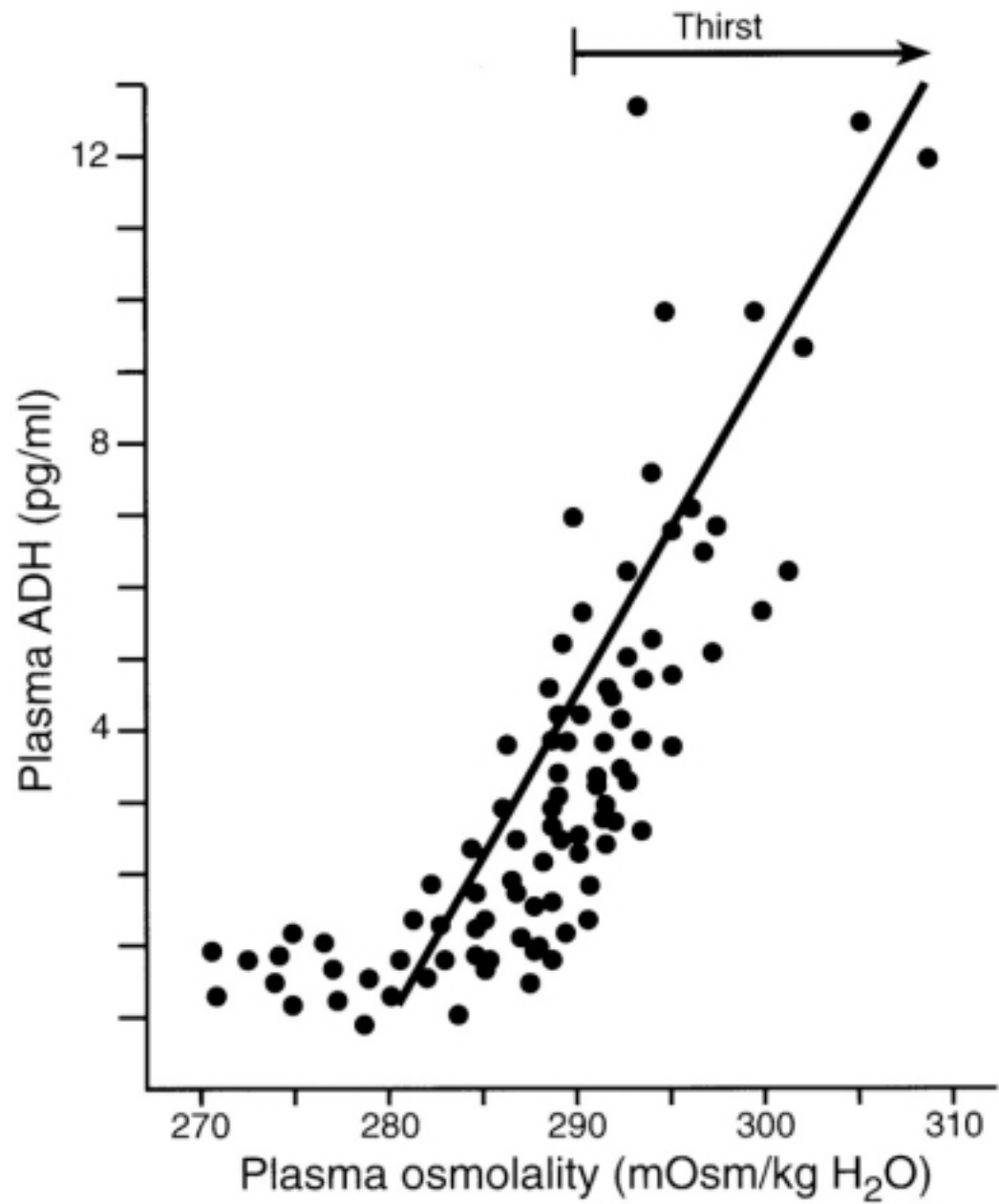
IMPERMEABLE



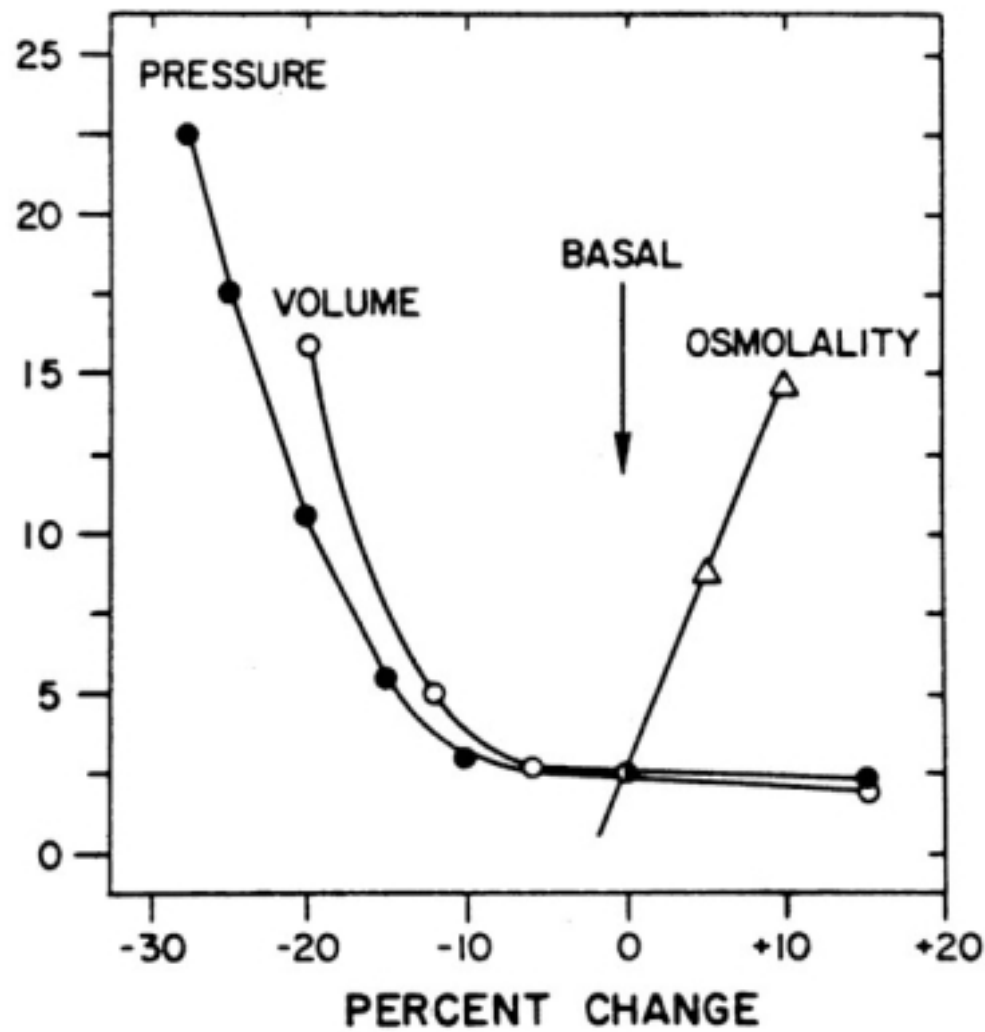
SEMIPERMEABLE



PERMEABLE



PLASMA
VASOPRESSIN
(pg/ml)



Thirst

- An important physiologic process.
- Precisely regulated in animals and presumably in humans.
- In humans, drinking behavior is so complex that it is difficult to accurately assess thirst.