

Water & Electrolyte Balance

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Objectives



Physiology



Sodium



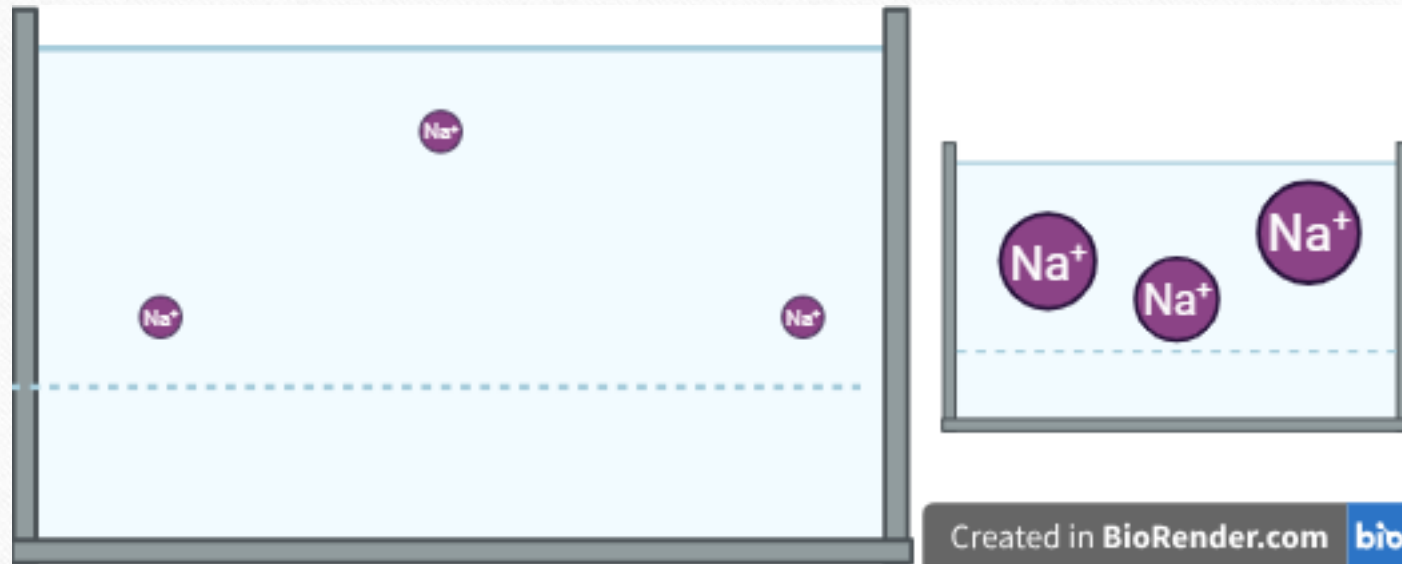
Potassium

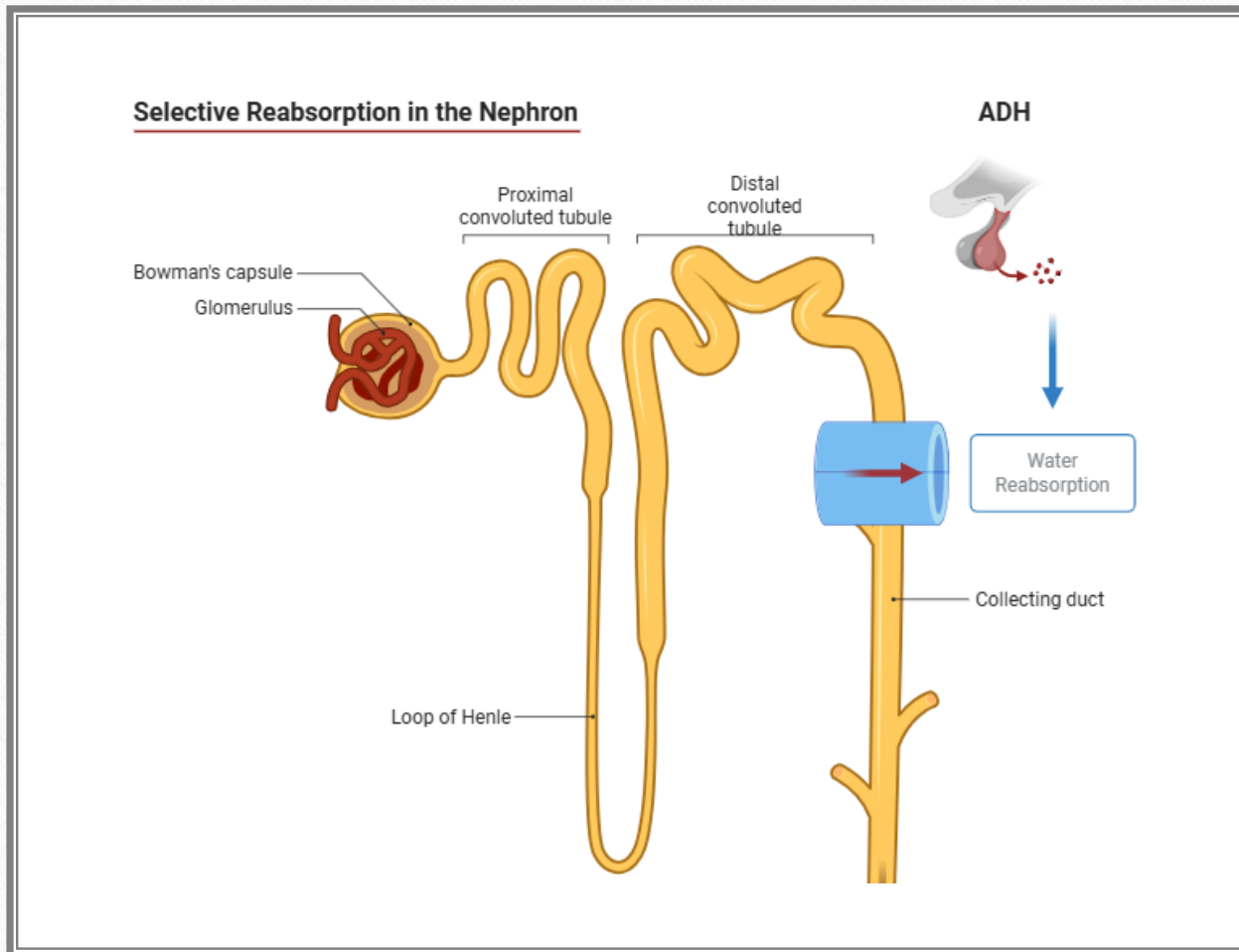
Physiology

- Plasma Na 135-145 mEq/L
- Plasma Osmolality 280-290 mOsm/Kg
 - Plasma osm = $2 \times [\text{Na}] + [\text{glucose}]/18 + [\text{urea}]/2.8$
 - $2 \times [\text{Na}]$
- Plasma Na disturbances are primarily water disorders



Na Disorders = Disorders of **Water** Homeostasis



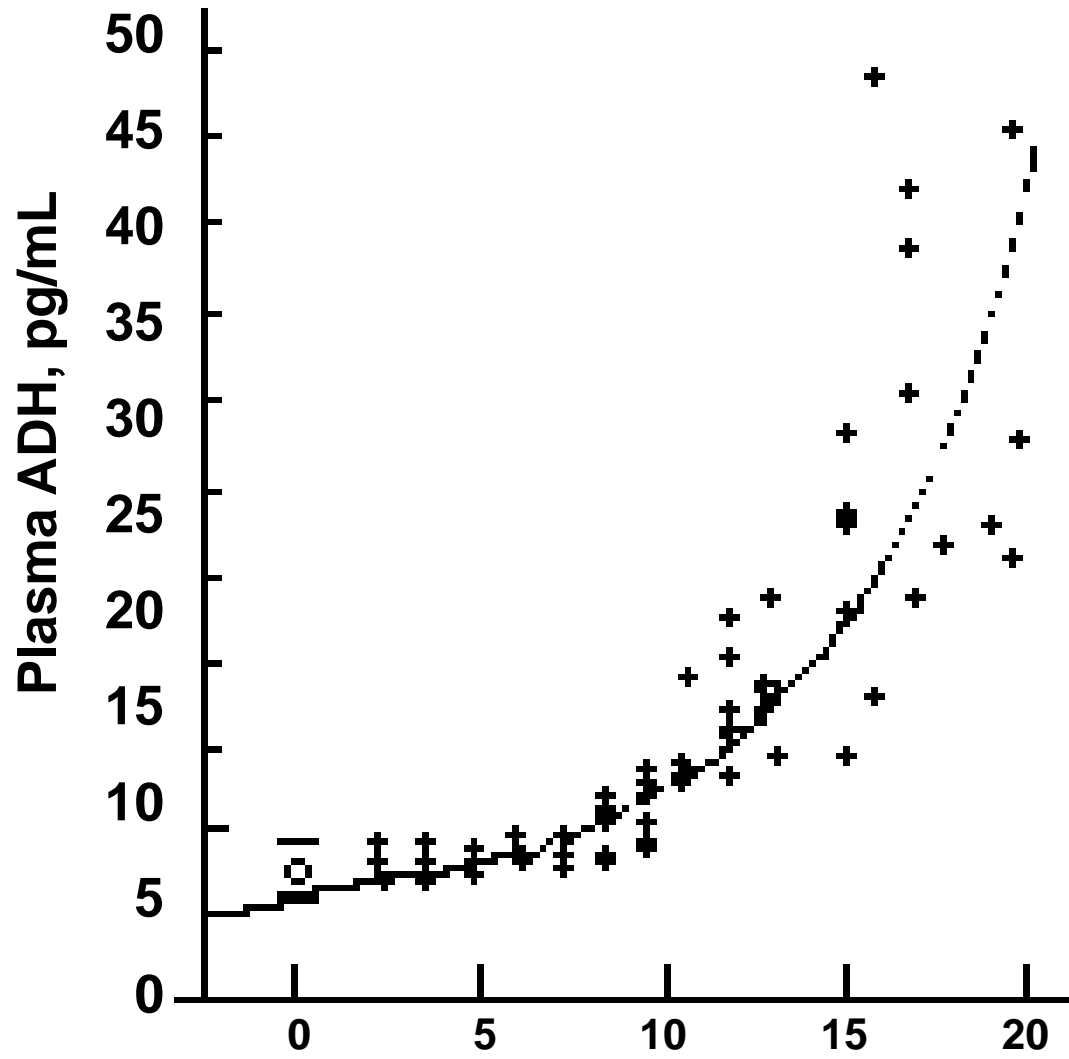


NO Na REABSORPTION OR SECRETION !!!

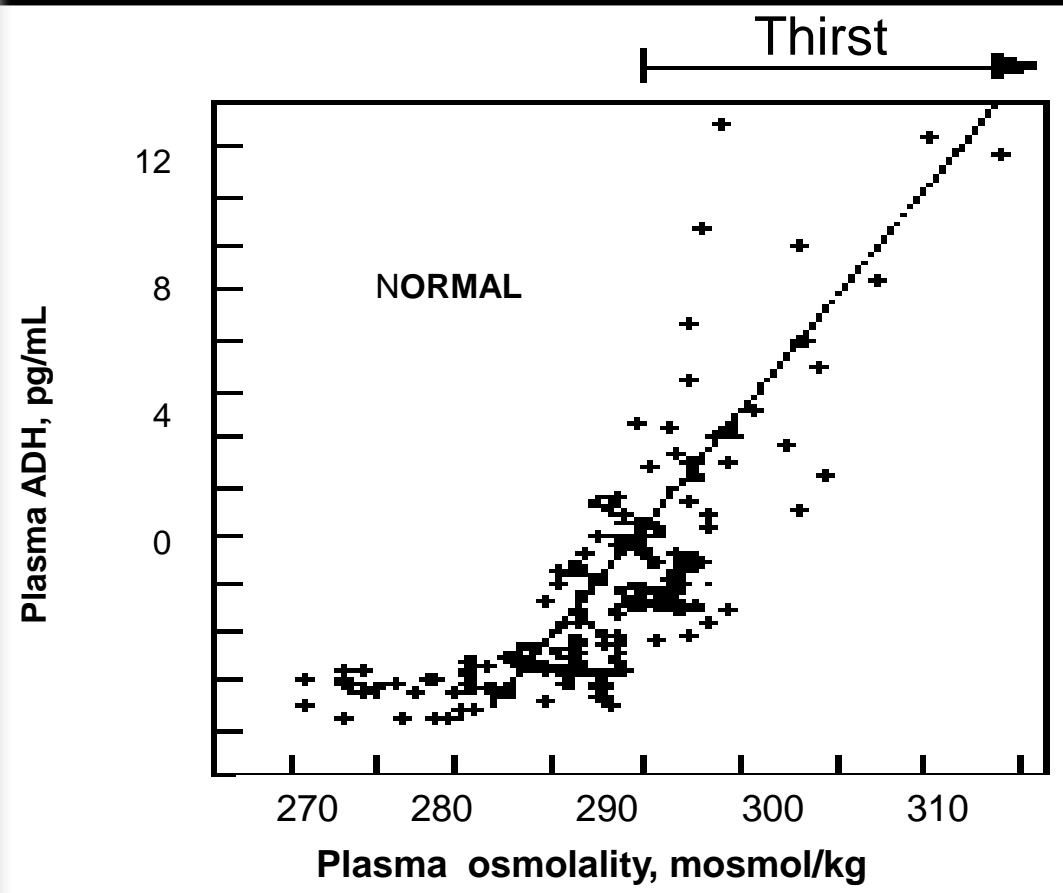
Antidiuretic Hormone (ADH)

- Hypothalamus > stored and released from posterior pituitary
- Aquaporin channels in collecting duct
 - V2 Receptors
- Renal mediated *free water* reabsorption

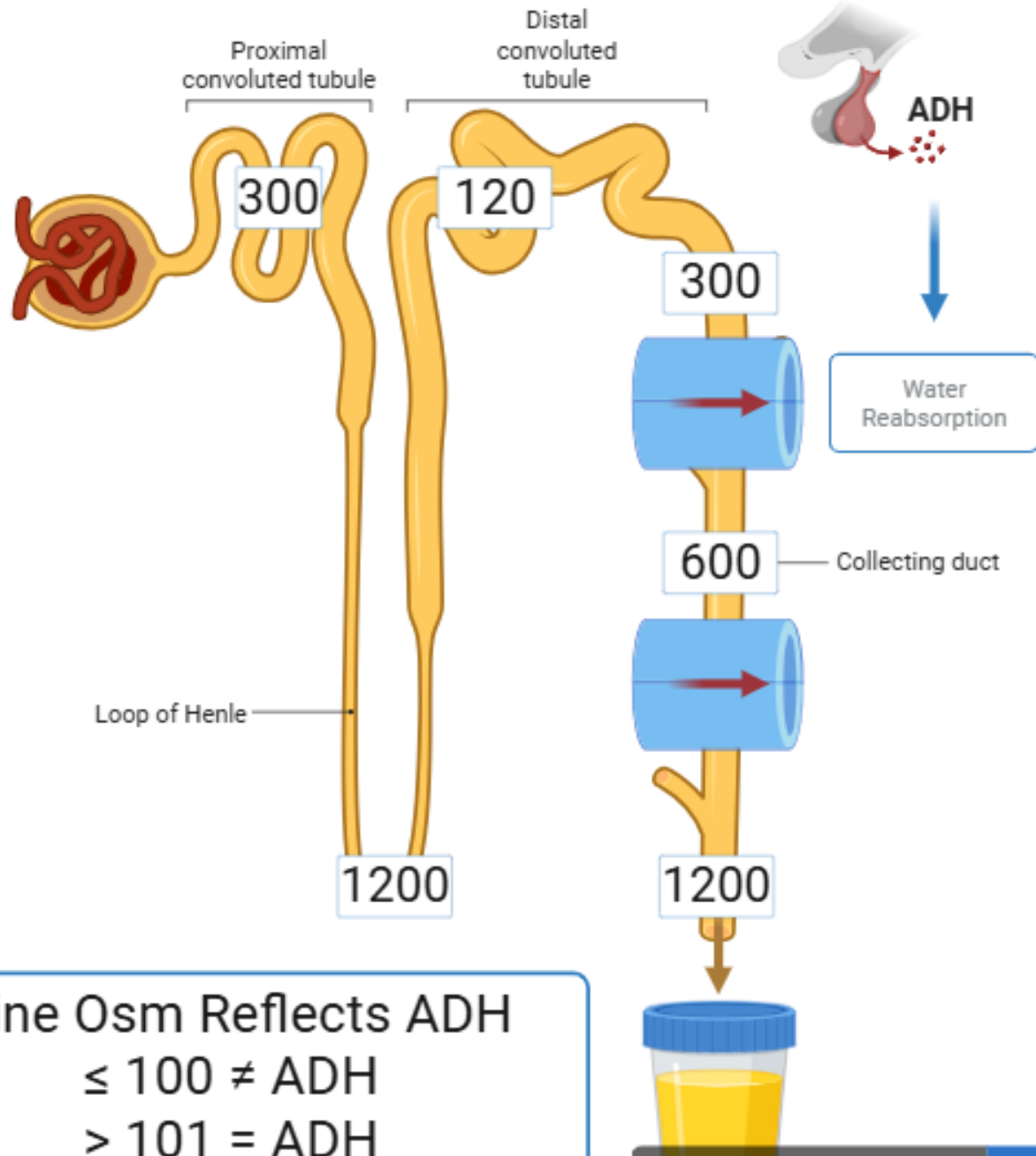




Hypotension / Dec Effective Circ Volume

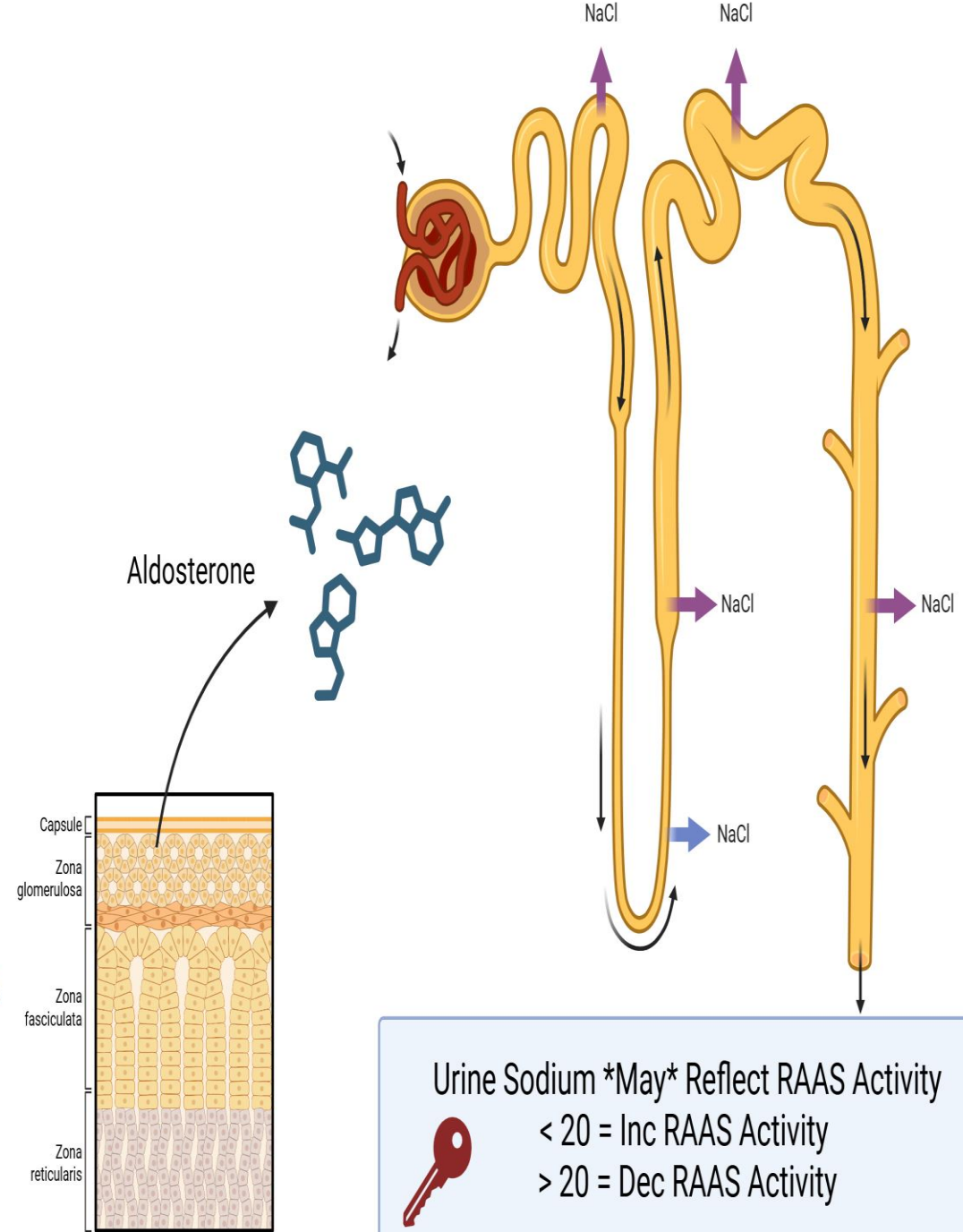


Urine Osmolarity



Urine Osm Reflects ADH

- ≤ 100 ≠ ADH
- > 101 = ADH



Urine Sodium *May* Reflect RAAS Activity

- < 20 = Inc RAAS Activity
- > 20 = Dec RAAS Activity



Objectives



Physiology



Sodium



Potassium

Hyponatremia Diagnosis

Hyponatremia
Check Plasma Osmolality

Low

Normal

High

Check Urine
Osmolality

> 100 mOsm

< 100 mOsm

**ADH Mediated
Hyponatremia**

**Psychogenic
Low Solute
(Beer
Potomania /
Tea & Toast)**

PSEUDOHYPONATREMIA

Hyperproteinemia

Hyperlipidemia

Lipoprotein X

**TRANSLOCATIONAL
HYPONATREMIA**

Hyperglycemia

Mannitol

Glycine

? WHY ?



ABIM Style Question

- 68-year-old male presents with failure to thrive, no significant medical history, physical exam is non-revealing.
- Which of the following is the likely cause of hyponatremia?
 - A. Multiple Myeloma
 - B. Beer Potomania
 - C. SIADH
 - D. Hypercalcemia

Laboratory Results

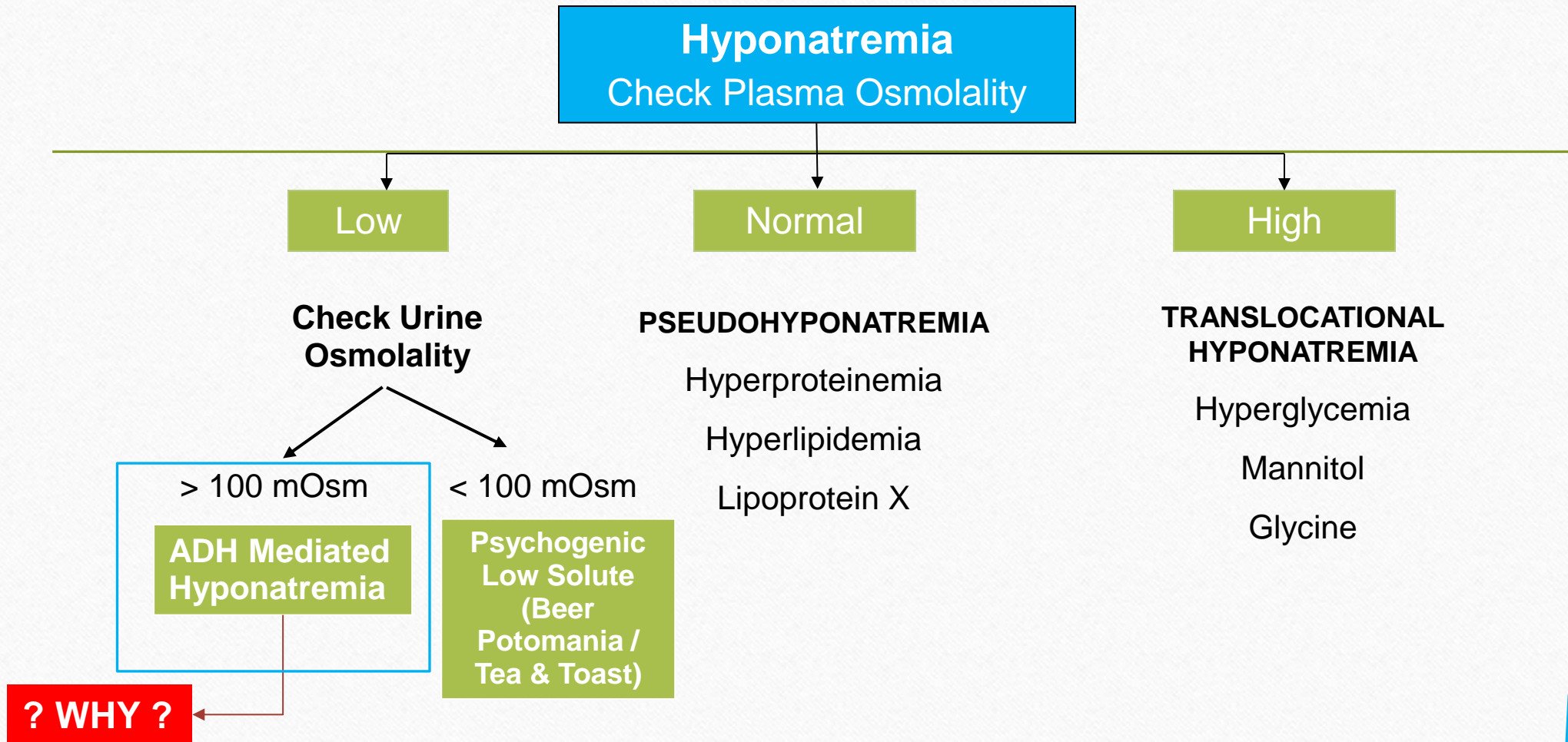
Hematocrit	28%
Albumin	2.0 g/dL
Calcium	10.2. mg/dL
Creatinine	1.9 mg/dL
Sodium	129 mEq/L
Potassium	4 mEq/L
Chloride	104 mEq/L
Bicarbonate	21 mEq/L
Osmolality	290 mOsm/kg H ₂ O
Total protein	8.6 g/dL
Urine osmolality	210 mOsm/kg H ₂ O
Urine sodium	30 mEq/L



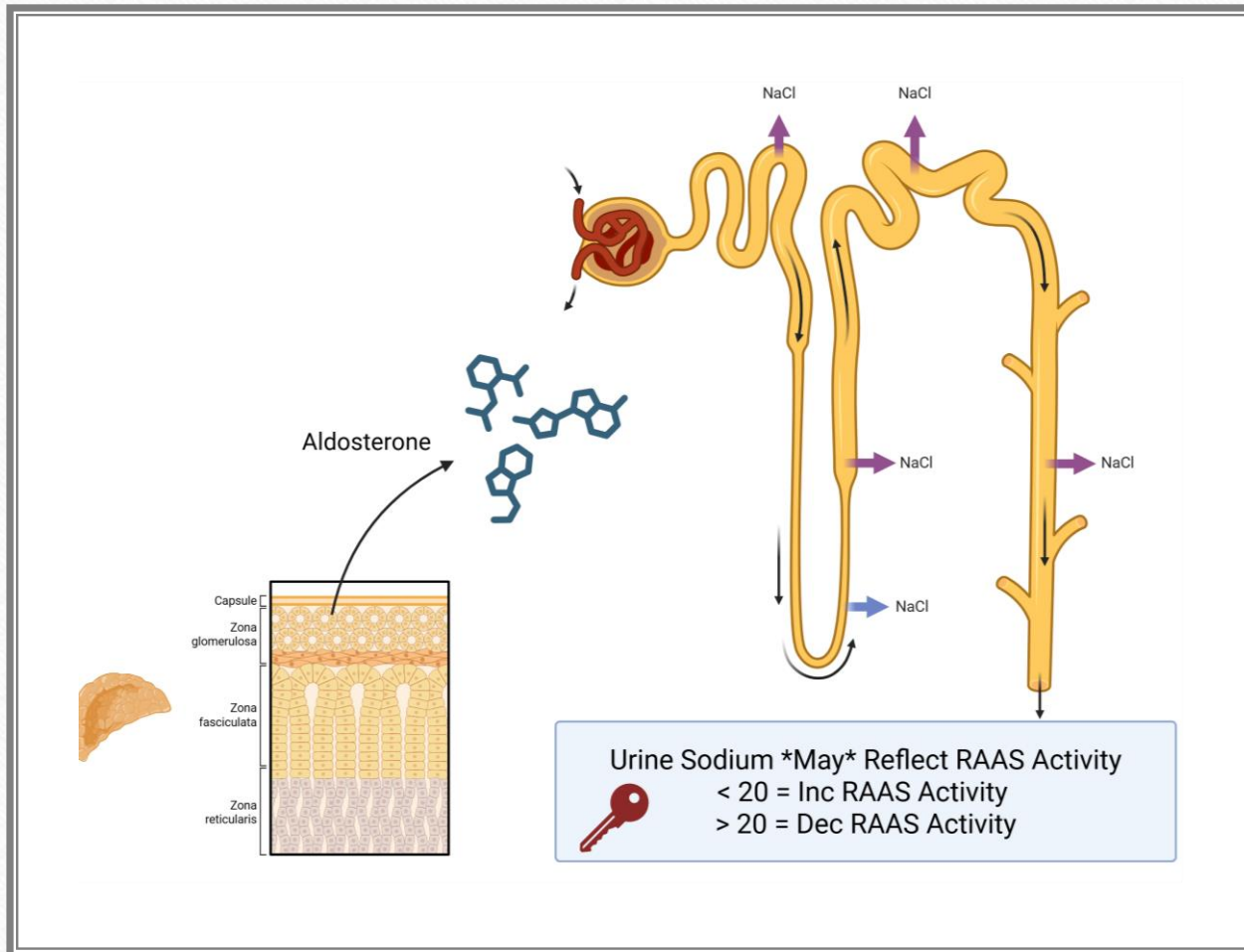
- Hyperlipidemia: Inc Triglycerides (pancreatitis)
- Lipoprotein X: Cholestatic liver injury with severely elevated bilirubin levels



Hyponatremia Diagnosis

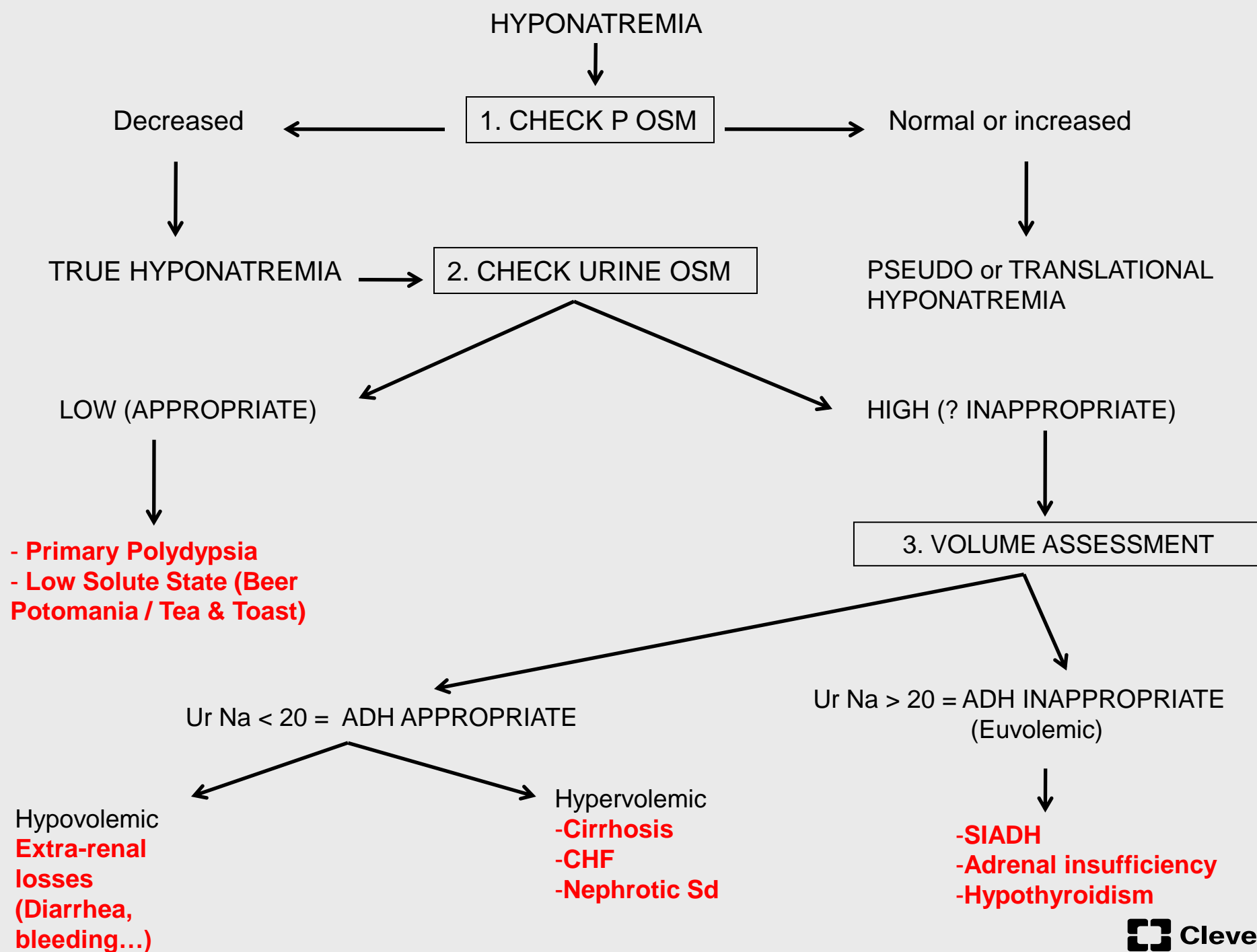


ADH Mediated Hyponatremia



- ADH Stimuli
 - Physiologic
 - ~~Elevated Plasma Osmolality~~
 - Decreased Effective Circulating Volume ?
 - Body sacrifices osmolality for the sake of volume



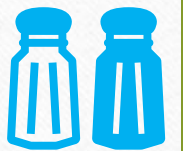


SIADH (Non-Osmotic Non-Volume Mediated ADH Release)



- Urine Osm > 100
- Urine Na > 20

- Increased Hypothalamic Production of ADH
 - CNS Disorders: Trauma, hematoma, infections, CVA...
 - Medications: SSRIs, SNRIs, Cyclophosphamide, TCAs, Vincristine...
 - Pulmonary Disease / Infections
 - Paraneoplastic: Small Cell Lung Cancer, pancreatic



ABIM Style Question

- 32-year-old female presents to the ED with confusion. Mucous membranes are dry, VS are significant for orthostatic hypotension.
- Which of the following is the likely cause of hyponatremia?
 - A. Multiple Myeloma
 - B. SIADH
 - C. Psychogenic Polydipsia
 - D. Hypovolemia

Laboratory Results

Hematocrit	28%
Albumin	4.0 g/dL
Calcium	10.2. mg/dL
Creatinine	1.0 mg/dL
Sodium	114 mEq/L
Potassium	4 mEq/L
Chloride	84 mEq/L
Bicarbonate	24 mEq/L
Osmolality	232 mOsm/kg H ₂ O
Total protein	8.0 g/dL
Urine osmolality	680 mOsm/kg H ₂ O
Urine sodium	15 mEq/L

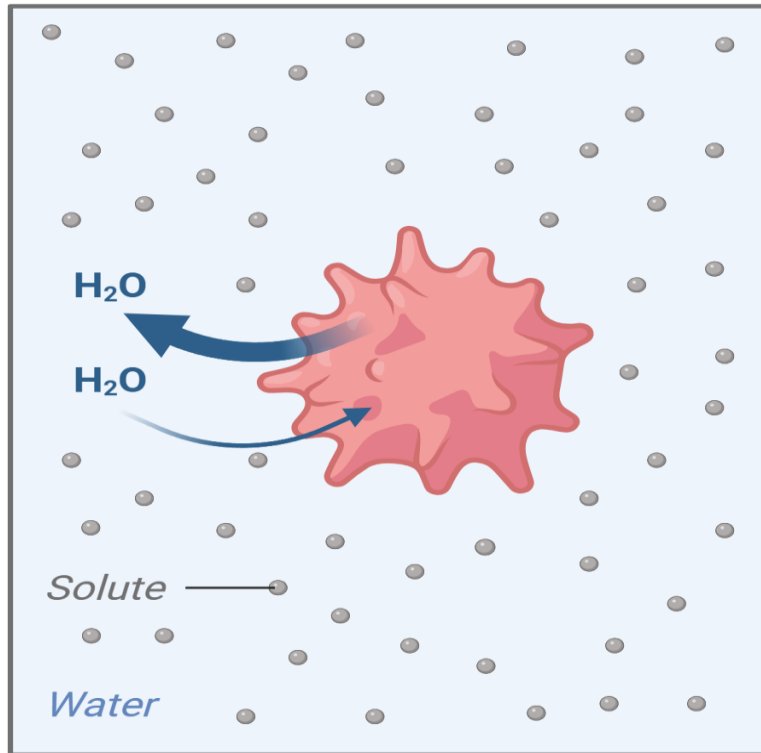
- Which of the following is the most appropriate next step ?

- A. 3% NaCl +
Desmopressin
- B. 1L Fluid Restriction
- C. 3% NaCl
- D. 0.9% NaCl



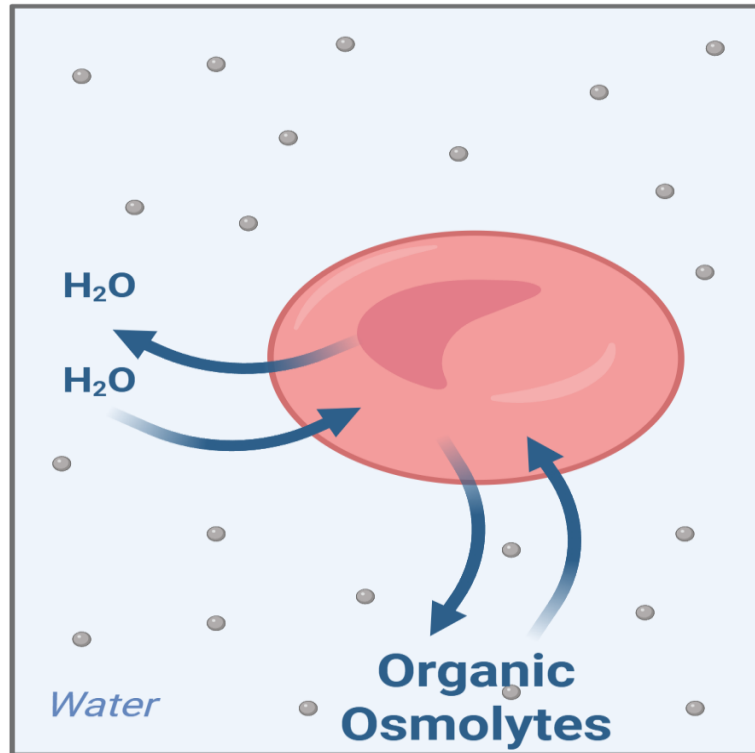
Osmoregulation in Cells

**Hypertonic solution:
Osmotic Demyelination
(Rapid Correction)**

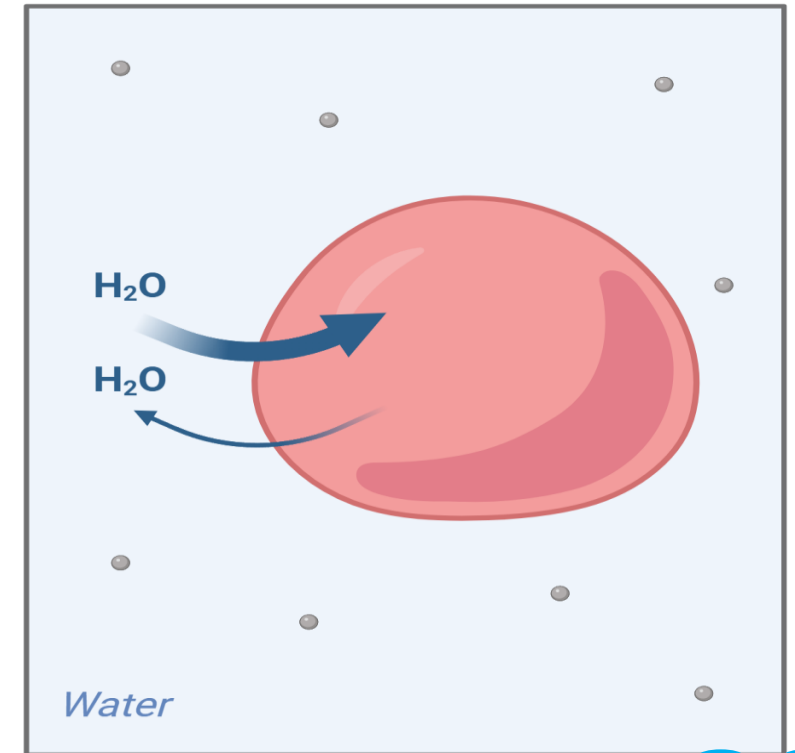


Prevent

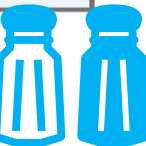
**Isotonic solution:
normal cell**



**Hypotonic solution:
Cerebral Edema (Acute
Hyponatremia)**



Treat



Treatment of SYMPTOMATIC Hyponatremia

- Reverse Brain Edema
 - Acutely increasing serum Na levels by 3-6 mEq/L with 3% NaCl
 - 100-150 cc bolus or 3% NaCl infusion (Requires central access)

RCT: Risk of Overcorrection in Rapid Intermittent Bolus vs Slow Continuous Infusion for Symptomatic Hyponatremia

POPULATION

80 Men, 98 Women



Adults aged >18 y with symptoms of hyponatremia and glucose-corrected serum sodium ≤ 125 mmol/L
Mean (SD) age: 73.1 (12.2) y

INTERVENTION

178 Patients randomized



87 Rapid intermittent bolus
 Hypertonic saline, 3%, infusion of 2 mL/kg over 20 min every 6 h

91 Slow continuous infusion
 Hypertonic saline, 3%, continuous infusion at a rate of 0.5-1 mL/kg/h

SETTINGS / LOCATIONS



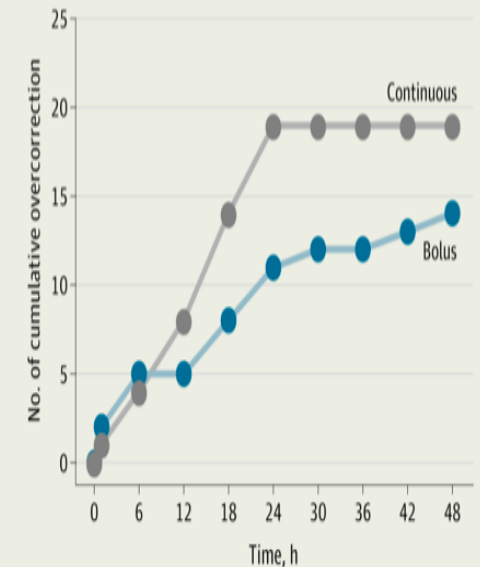
3 General hospitals in the Republic of Korea

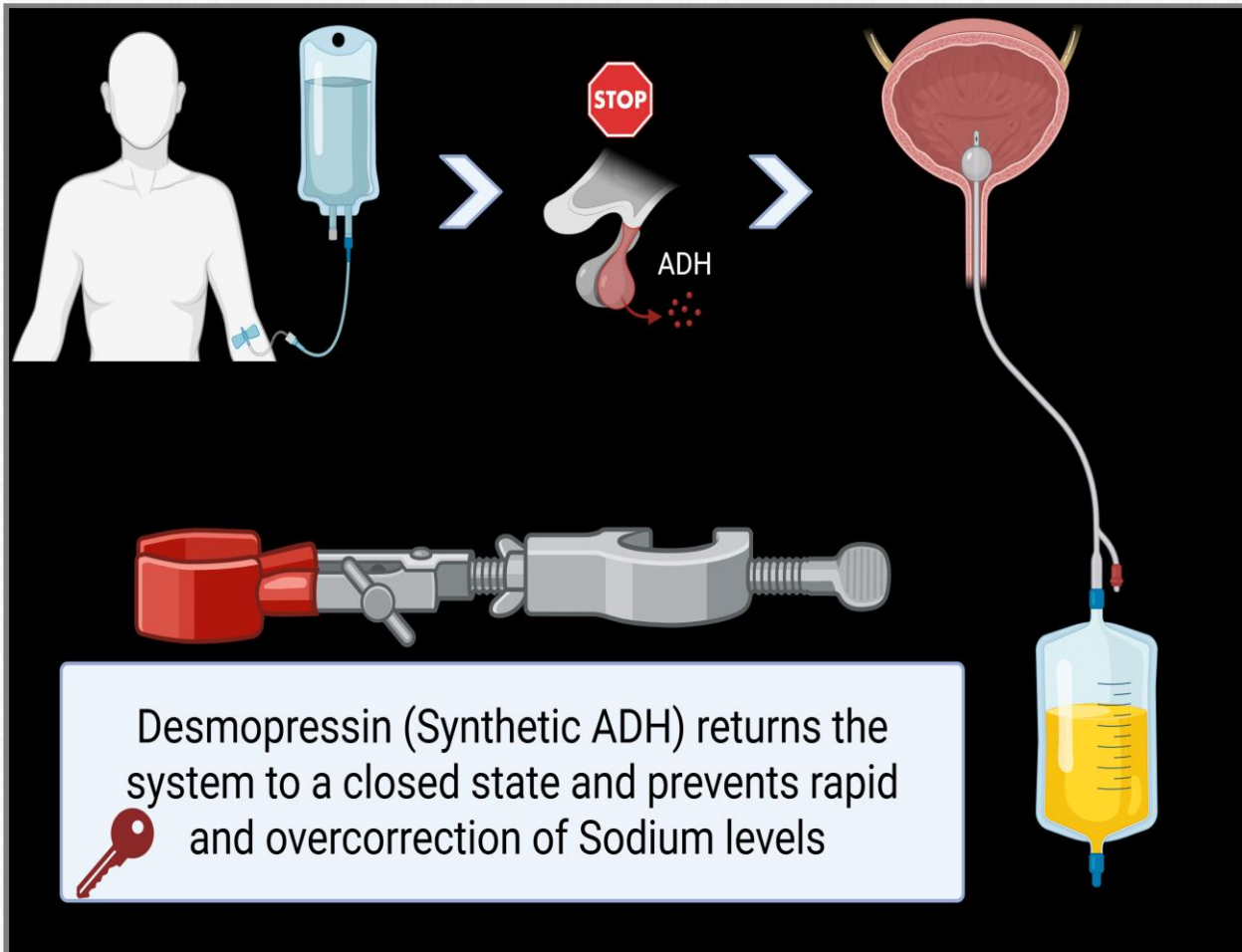
PRIMARY OUTCOME

Overcorrection at any given period, defined as increase in serum sodium level by >12 mmol/L within 24 h or >18 mmol/L within 48 h

FINDINGS

Both rapid intermittent bolus and slow continuous infusion for treating symptomatic hyponatremia are effective and safe with no difference in overcorrection risk (17.2% vs 24.2%, respectively; absolute risk difference, -6.9% (95% CI, -18.8% to 4.9%); $P = .26$)





Desmopressin

- Hypovolemic Hyponatremia
- Low Solute States (Beer Potomania / Tea & Toast)



What are the risk factors for rapid Na⁺ correction and osmotic demyelination in patients with an initial serum Na⁺ <120 mEq/L?

Methods and Cohort



1490
patients



Serum Na⁺
<120 mEq/L



7 hospitals in
Geisinger Health
System, 2001-2017



Retrospective
cohort study

Results



Rapid Na correction
>8 mEq/L in 24 h

606
patients



Younger age



Female



Schizophrenia

Increased risk



Lower initial
serum Na⁺



Initial urine Na
<30 mEq/L



Incident osmotic
demyelination

8
patients



7 with rapid Na⁺
correction



5 with beer
potomania



5 with hypokalemia

Conclusions Among patients presenting with severe hyponatremia, rapid correction occurred in 41%. Nearly all patients with incident osmotic demyelination had a documented episode of rapid correction.

Jason George, Waleed Zafar, Ion Dan Bucaloiu, and Alexander Chang.
Risk Factors and Outcomes of Rapid Correction of Severe Hyponatremia. doi: 10.2215/CJN.13061117



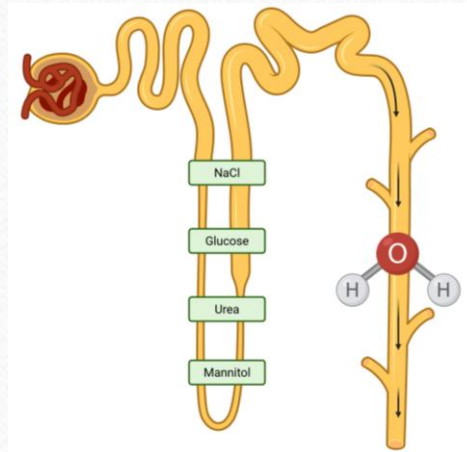
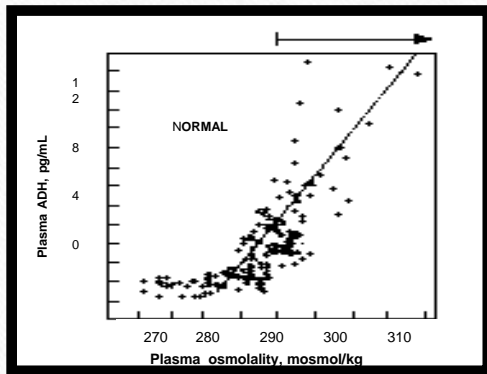
Hypernatremia

- Total body water **deficit**
 - **Extremely rare to have Na excess**
- Hypernatremia is hyperosmolarity = Extreme thirst

Hypernatremia Etiologies

- **Water Loss**
 - Insensible Losses (Sweating, breathing...) Typically ~ 700 mL/day
 - Increases with fevers, intubation, burns
 - Renal
 - Osmotic Diuresis
 - Diabetes Insipidus
 - GI
 - Osmotic diarrhea, malabsorption
 - Intracellular Water Shift
 - Seizures, Rhabdomyolysis
- Sodium retention / administration
 - 3% NaCl (Iatrogenic Hypernatremia)
 - Na Bicarb pushes
 - 8.4% Na

Renal Water Loss



- Absence of ADH
 - Arginine Vasopressin Deficiency aka Central Diabetes Insipidus (Pituitary Surgery, Tumor, Injury)
- Resistance to ADH (At level of kidneys)
 - Arginine Vasopressin Resistance aka Nephrogenic Diabetes Insipidus (Hypercalcemia, Hypokalemia, **lithium, demeclocycline**, Sjogren's, Sickle cell disease...)
- Osmotic Diuresis
 - Water is pulled alongside active osmole (BUN, Glucose, Mannitol, volume expansion)

POLYURIA

CHECK:
- Ur Osm
- 24h U solutes



Ur Osm > 300
24h U solutes > 900

Osmotic Diuresis

- Uncontrolled DM
- BUN (Renal failure, Catabolism)
- Volume expansion
- Mannitol

Ur Osm < 300 (< Plasma Osm)
24h U solutes ≤ 900

Water Diuresis

Check P [Na]

Low-Norm

PP

Normal-high

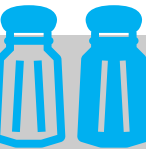
CDI, NDI

ABIM Style Question

- 40-year-old female is evaluated for polyuria after resection of a pituitary tumor
- Which of the following is the likely cause of hypernatremia ?
 - A. Urea Diuresis
 - B. Arginine Vasopressin Deficiency (Central DI)
 - C. Psychogenic Polydipsia
 - D. Arginine Vasopressin Resistance (Nephrogenic DI)

Laboratory Results

BUN	94
Albumin	4.0 g/dL
Calcium	10.2. mg/dL
Creatinine	2.0 mg/dL
Sodium	154 mEq/L
Potassium	3.1 mEq/L
Chloride	120 mEq/L
Bicarbonate	24 mEq/L
Glucose	112 mg/dL
Urine Osm	604 mOsm/kg H ₂ O
Urine sodium	40 mEq/L

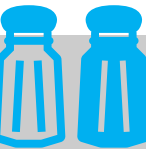


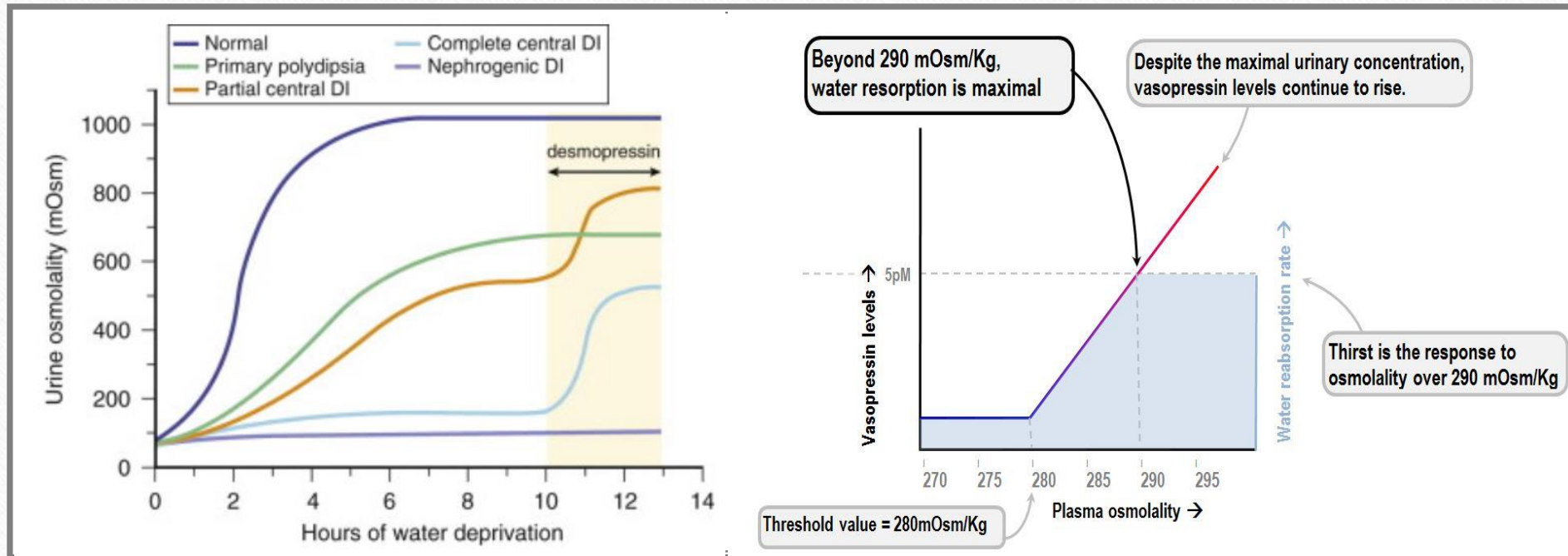
ABIM Style Question

- 40-year-old male is admitted for confusion
- Which of the following is the most appropriate treatment ?
 - A. IV 0.45% NaCl
 - B. IV 0.9% NaCl
 - C. IV D5W
 - D. Free Water Enterically

Laboratory Results

BUN	37
Albumin	4.0 g/dL
Calcium	10.2. mg/dL
Creatinine	1.4 mg/dL
Sodium	154 mEq/L
Potassium	3.1 mEq/L
Chloride	120 mEq/L
Bicarbonate	24 mEq/L
Glucose	480 mg/dL
Urine Osm	604 mOsm/kg H ₂ O
Urine sodium	40 mEq/L





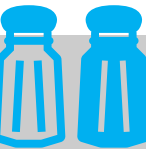
Water Diuresis (Urine Osm < 300)

ABIM Style Question

- 44-year-old male with bipolar disorder presents with polyuria after starting lithium
- Which of the following is the next best step ?
 - A. Diet Education
 - B. Amiloride
 - C. Fluid Restriction
 - D. HCTZ

Laboratory Results

BUN	15
Albumin	4.0 g/dL
Calcium	10.2. mg/dL
Creatinine	1.0 mg/dL
Sodium	144 mEq/L
Potassium	4.1 mEq/L
Chloride	108 mEq/L
Bicarbonate	24 mEq/L
Glucose	112 mg/dL
Urine Osm	470 mOsm/kg H ₂ O
Urine sodium	145 mEq/L



Objectives



Physiology



Sodium



Potassium

Differential Diagnosis of Hypokalemia

Cellular shifts

GI losses

Renal losses

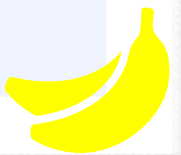
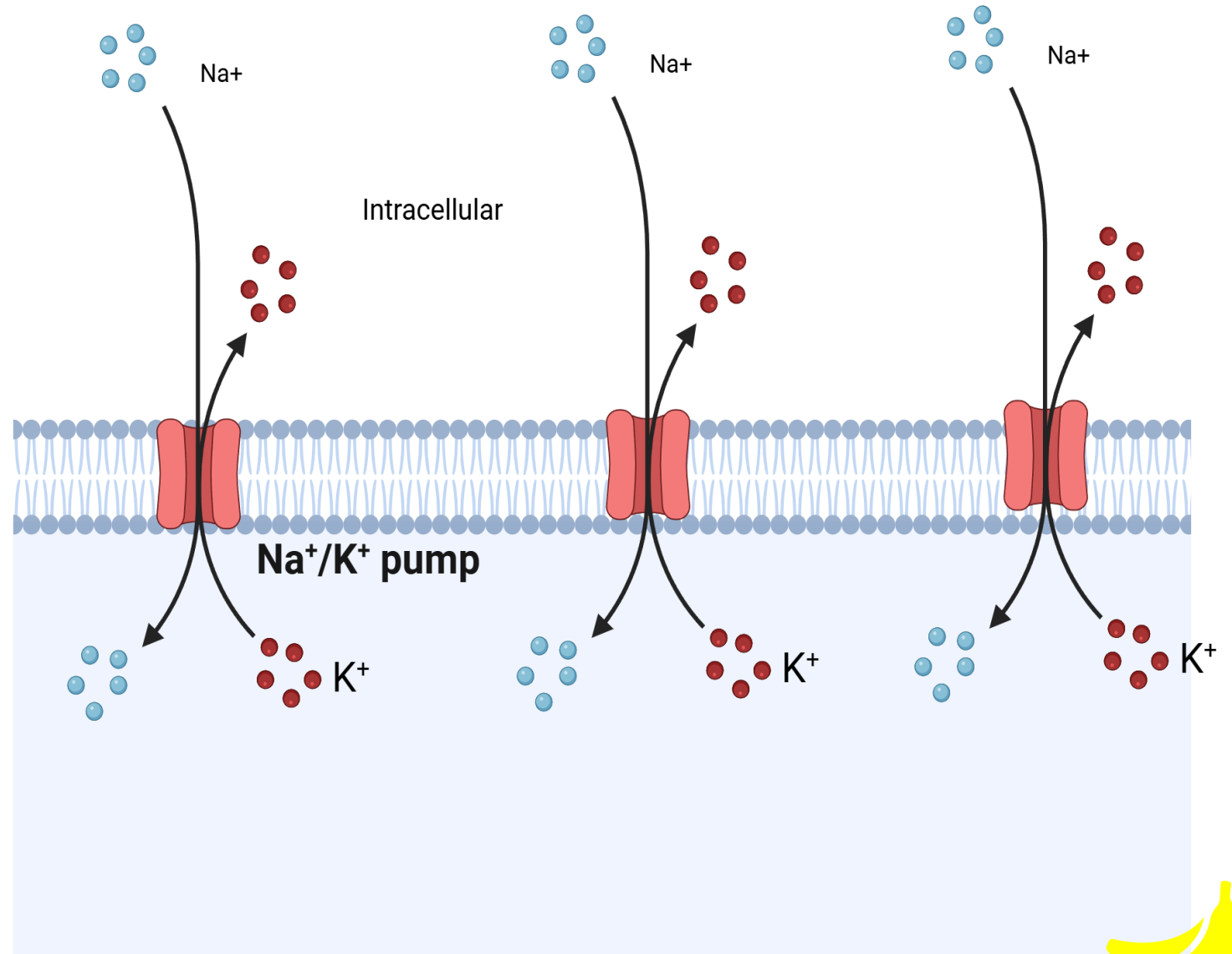
Urinary K wasting

24 hr urine K > 25 – 30 mEq/ day



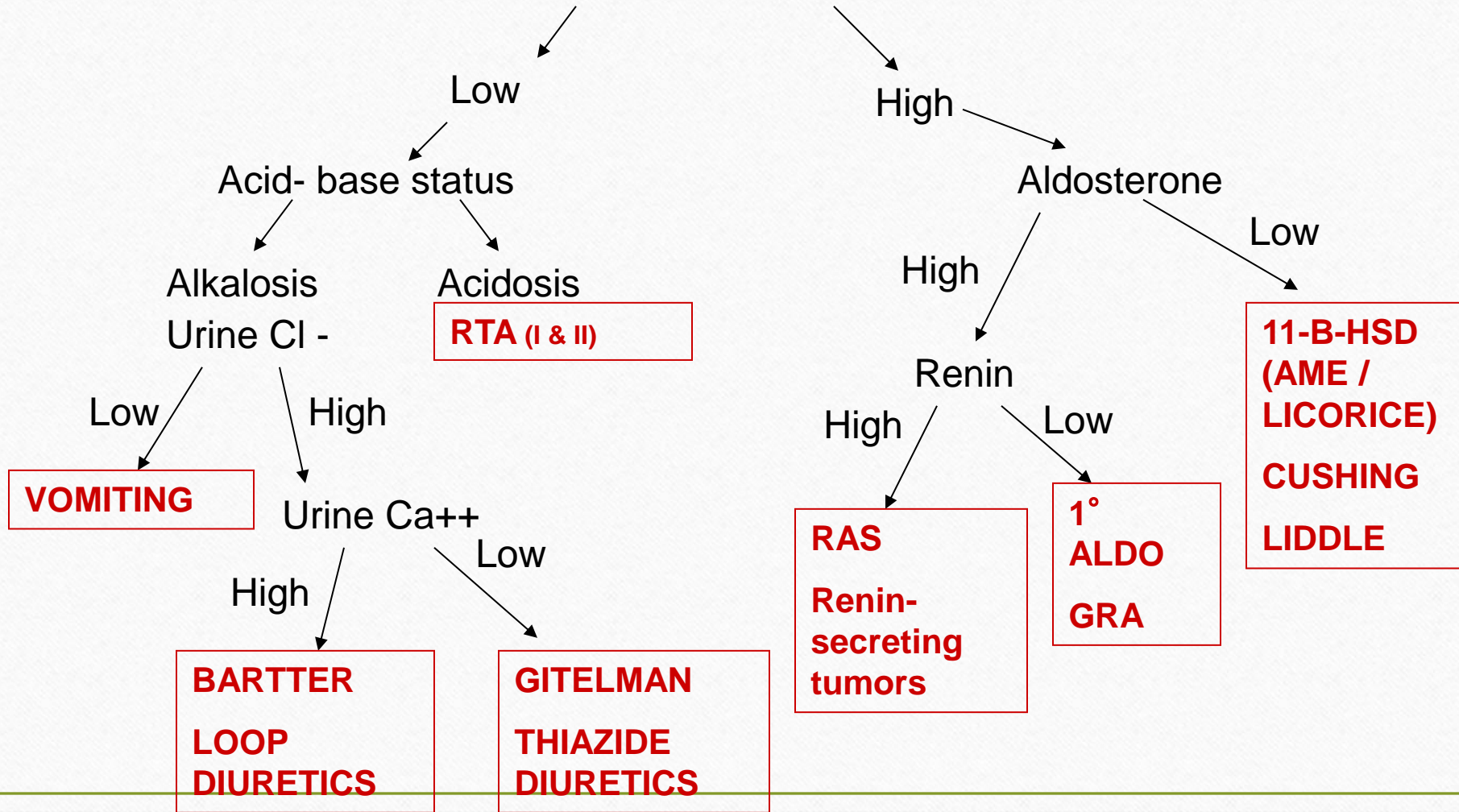
Intracellular Potassium Shift

Insulin, Beta-2 Agonists will increase Na^+/K^+ ATPase activity causing an intracellular shifting of potassium



Renal K Wasting

Blood pressure/ volume



ABIM Style Question

- 21-year-old female is evaluated for hypokalemia. Physical exam notable for orthostatic hypotension
- Which of the following is the most likely diagnosis?
 - A. Gitelman
 - B. Bartter
 - C. Laxative Abuse
 - D. Primary Aldosteronism

Laboratory Results

BUN	15
Albumin	4.0 g/dL
Magnesium	1.4 mg/dL
Creatinine	1.0 mg/dL
Sodium	139 mEq/L
Potassium	3.2 mEq/L
Chloride	99 mEq/L
Bicarbonate	28 mEq/L
Urine Na	54 mEq/L
Urine K	40 mEq/L
Urine Chloride	57 mEq/L
Diuretic Screen	Negative
Urine Ca/Cr	Low



ABIM Style Question

- 34-year-old male with history of GERD on omeprazole presents with weakness. VS are normal.
- Which of the following is the most likely cause of hypokalemia ?
 - A. Gitelman
 - B. Bartter
 - C. Laxative Abuse
 - D. Omeprazole

Laboratory Results

BUN	15
Albumin	4.0 g/dL
Magnesium	1.4 mg/dL
Creatinine	1.0 mg/dL
Sodium	139 mEq/L
Potassium	3.2 mEq/L
Chloride	103 mEq/L
Bicarbonate	24 mEq/L
Urine Na	30 mEq/L
Urine K	40 mEq/L
Urine Chloride	32 mEq/L
Diuretic Screen	Negative
Urine Mg	Low



Hyperkalemia: Etiology

Normal total body K^+

- Pseudohyperkalemia
hemolysis, tourniquet
- Redistribution
 - Acidosis
 - Hormonal
Decr insulin,
beta- blockers
 - Tissue Necrosis
 - Hyperosmolality (DM)

Excess total body K^+

- Defective Renal Excretion
 - Acute/ Chron Renal Failure
 - Hyporenin and/or Hypoaldo
 - Diabetes mellitus, NSAIDS,
 - Spironolactone, heparin,
 - Adrenal failure
 - ACE-I's, AII-Blockers's
 - Renal Tub. Resistance Aldo
 - Sickle cell disease, obstructive uropathy,
Type IV RTA

