Water (Dysnatremia) & Sodium (Dysvolemia) Disorders

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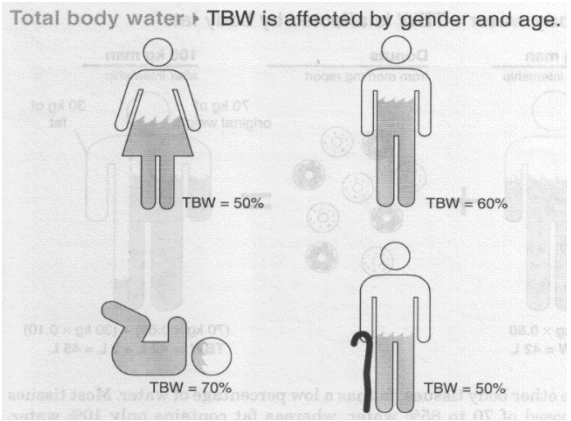
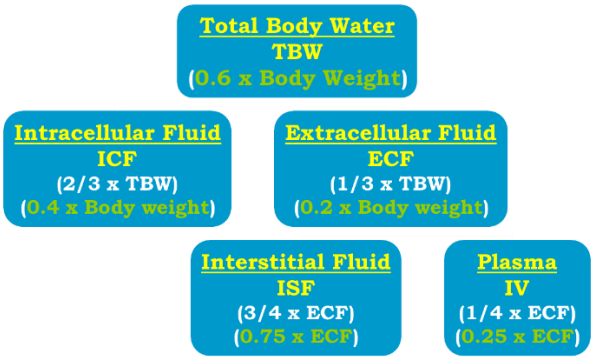
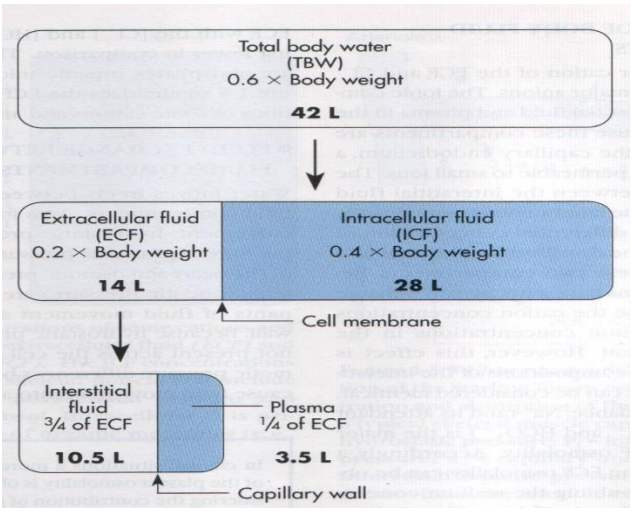
- ***Intended Learning Outcomes:*** By the end of this lecture the student should be able to:
    1. Recognize the systems that control body sodium and water contents
    2. Differentiate between total body sodium content (volume status) and serum sodium concentration (Hypo- and Hypernatremia)
    3. Use the different types of IV fluids in clinical practice
    4. Calculate the water deficit in Hypernatremia
    5. Explain the workup of Hyponatremia
- ***Structure:***
    1. Composition of the fluid compartments
    2. Mechanisms regulating fluid and sodium balance
    3. Disorders of sodium balance
    4. Disorders of water balance
- ***Homeostasis:*** A relative constancy in the internal environment of the body, naturally maintained by adaptive responses that promote cell function and survival
- ***Total Body Fluid & Compartments:*** →







- Electrolytes are substances dissolved in solutions and dissociated into particles called ions
  1. *Cations:* Positively charged ions
  2. *Anions:* Negatively charged ions
- ***Definitions:***

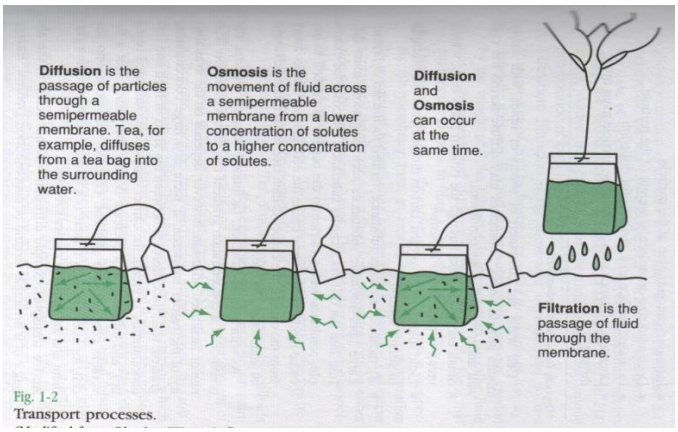


Fig. 1-2
Transport processes.

- **Osmosis:** movement of water
- **Diffusion:** movement of solutes
- **Filtration:** movement of both solutes and water
- **Osmolality & Osmolarity:**
  - Osmolality: Osmoles in Kg of water (mOsm/kg water), usually measured
  - Osmolarity: Osmoles in liter of solution (mOsm/L, for example, Plasma), usually calculated
  - Calculated Posm (mOsm/L) = (2 x serum Na^+) + blood urea (mmol/L) + glucose (mmol/L)
  - For Na+, K+ and Cl-: 1 mEq/L = 1 mmol/L = 1 mOsm/L
  - Normal measured serum osmolality: 283-292 mOsm/kg water
  - ECF and ICF are in ***osmotic equilibrium so*** **ICFosm = ECFosm = Posm**

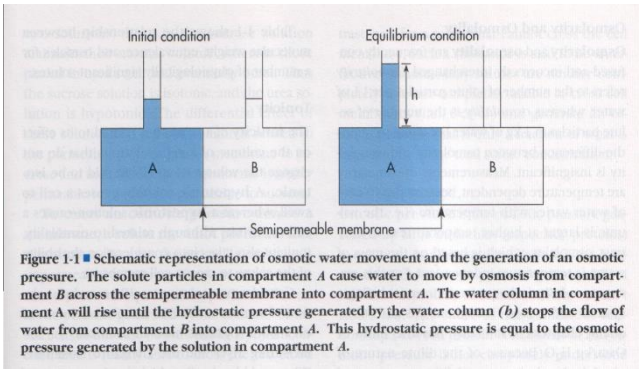
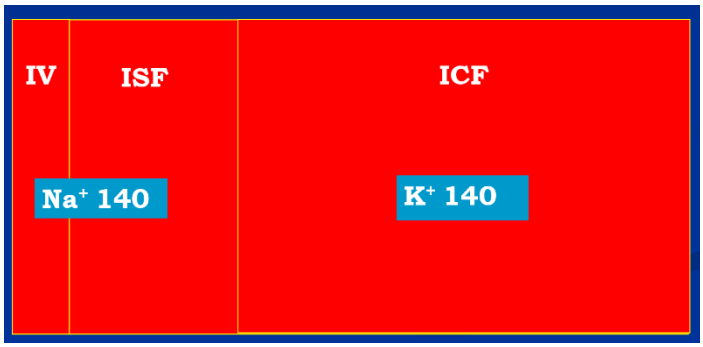


Figure 1-1 ■ Schematic representation of osmotic water movement and the generation of an osmotic pressure. The solute particles in compartment *A* cause water to move by osmosis from compartment *B* across the semipermeable membrane into compartment *A*. The water column in compartment A will rise until the hydrostatic pressure generated by the water column *(h)* stops the flow of water from compartment *B* into compartment *A*. This hydrostatic pressure is equal to the osmotic pressure generated by the solution in compartment *A*.



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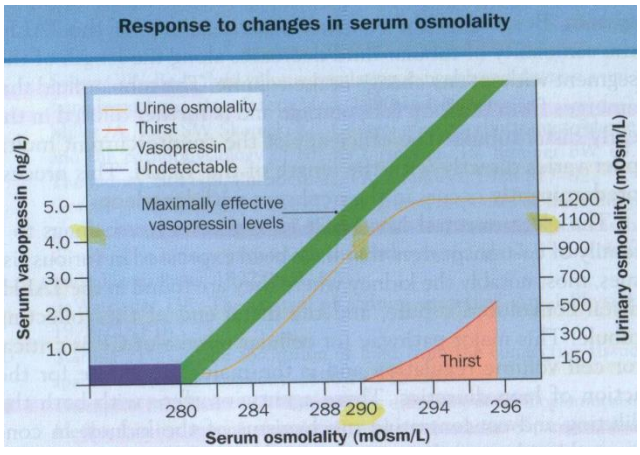
■ ***Regulation Mechanisms of Fluid and Electrolytes:***

- ✓ Regulation of **osmolality** and **volume** is achieved through:
  - Osmoreceptor-Thirst
  - Osmoreceptor-antidiuretic hormone system (vasopressin)
  - ***Volume is more important than osmolality***
- ✓ The regulation of **volume** also occurs through neurological and renal mechanisms
  - The stretch receptors (baroreceptors)
  - The Renin-Angiotension-Aldosterone System
  - The Natriuretic peptides
  - Kinins & Prostaglandins



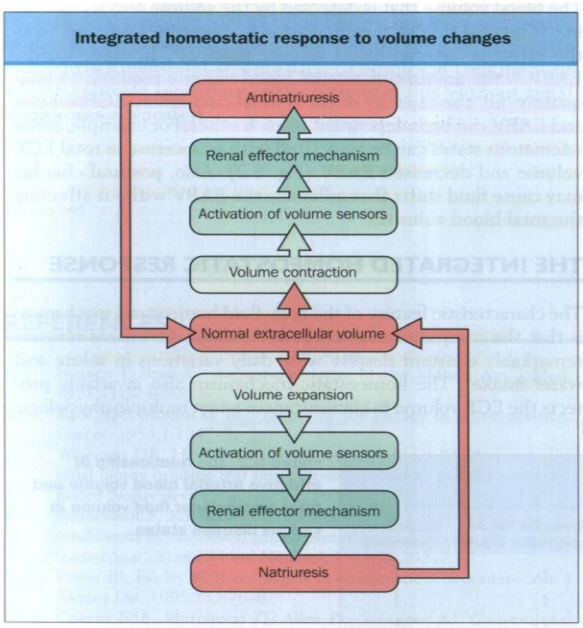


Figure 8.3 A general overview of the integrated homeostatic response system regulating extracellular fluid volume during volume contraction and expansion.

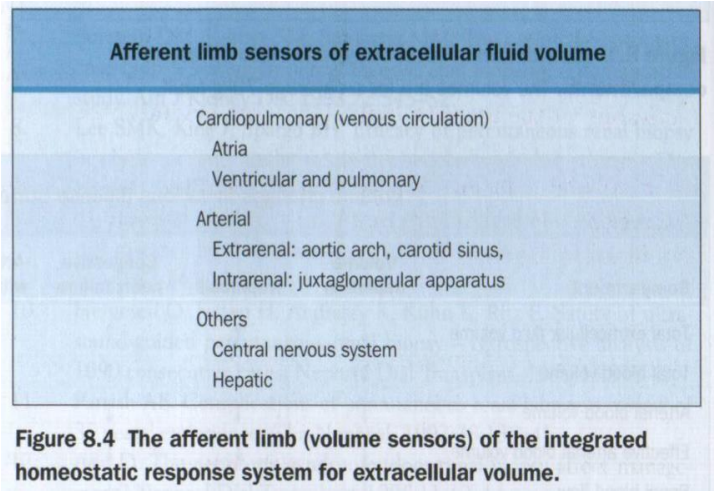
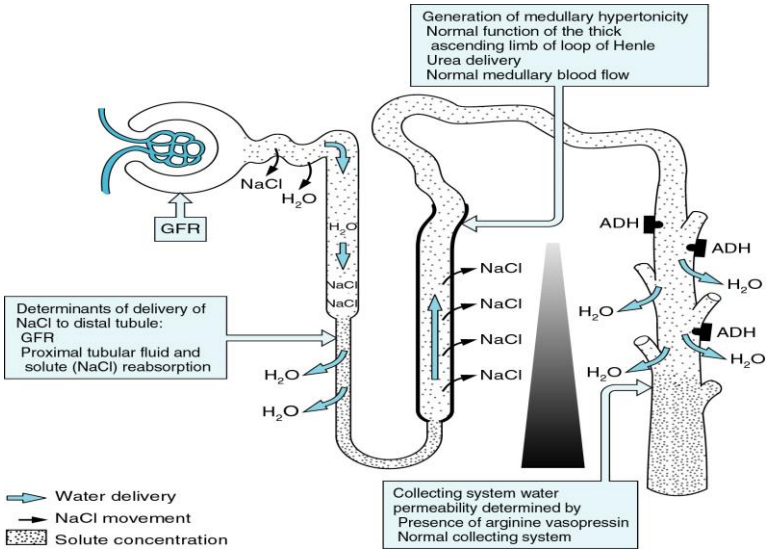
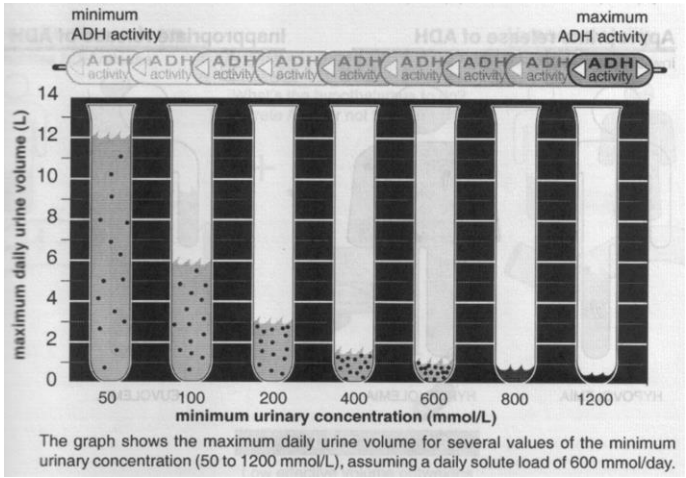


Figure 8.4 The afferent limb (volume sensors) of the integrated homeostatic response system for extracellular volume.



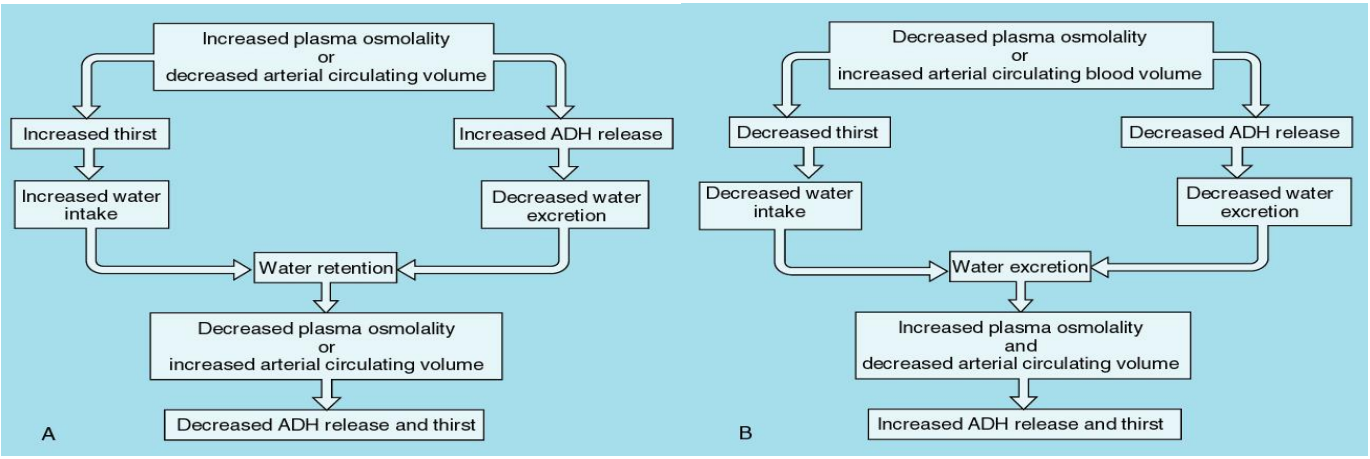


The graph shows the maximum daily urine volume for several values of the minimum urinary concentration (50 to 1200 mmol/L), assuming a daily solute load of 600 mmol/day.

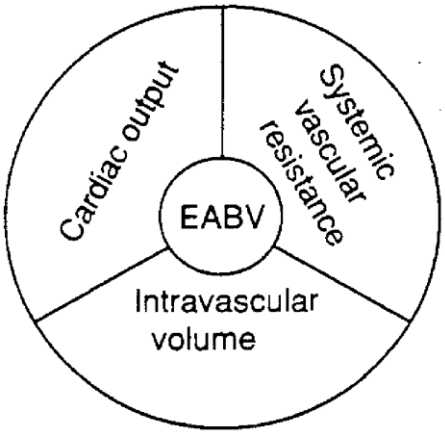
- ***Urine Output & Daily Solute Load*** →

- ***The Linear Relationship Between Urine Specific Gravity and Uosm (Plasma SG ~ 1.008)***

Urine SG	*Urine Osmolality (mOsm/Kg H_2O)*
1.010	300 – 400
1.020	700 – 800
1.030	1000 – 1200



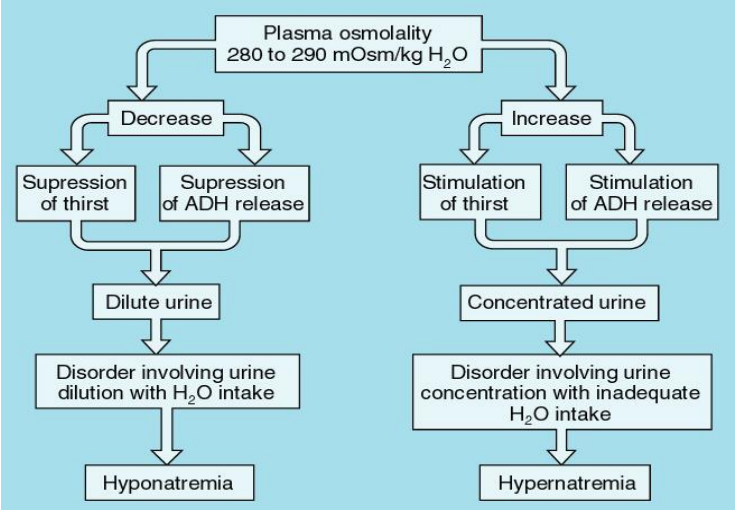
- ***Effective Arterial Blood Volume (EABV):***
  - Although the absolute volume of the intravascular space is an important component of circulatory "fullness", ***the adequacy of the circulation*** (more commonly called **the effective arterial blood volume or EABV**) also is determined by cardiac output and systemic vascular resistance
  - ↓ **EABV:**
    - ↑ CO
    - ↑ SVR
    - ↑ Renal Na retention
  - ↑ **EABV:**
    - ↓ CO
    - ↓ SVR
    - ↓ Renal Na retention
  - **EABV is the amount of arterial blood volume required to adequately 'fill' the capacity of the arterial circulation**



  - ECF volume and EABV can be independent of each other
    - Edematous states: increase in total ECF volume and decreased EABV
    - Postural changes may cause shifts that influence the EABV without affecting the total blood volume
- ***Clinical features of Hypovolemia & Hypervolemia***

	Hypovolemia	Hypervolemia
Symptoms	Thirst	Ankle swelling
	Dizziness on standing	Abdominal swelling
	Weakness	Breathlessness
Signs	Low JVP	Raised JVP
	Postural hypotension	Peripheral edema
	Tachycardia	Pulmonary crepitations
	Dry mouth	Pleural effusion

	Reduced skin turgor	Ascites
	Reduced urine output	Hypertension (sometimes)
	Weight loss	Weight gain
	Confusion, stupor	



- ***Sodium and Water:***
  - ECF volume= ***absolute*** amounts of Sodium and water
  - Plasma [Na^+] = ***ratio*** between the amounts of Sodium and water (Concentration)
  - Hyponatremia = Water Excess
  - Hypernatremia = Water Deficit
  - Hypervolemia = Sodium Excess ("Edema")
  - Hypovolemia = Sodium Deficit ("Dehydration")

	Hyponatremia (Water Excess)	***Hypernatremia (Water Deficit)***
Hypovolemia (Dehydration) (Sodium Deficit)	Hemorrhagic Shock with good oral water intake	Diarrhea in Children and Seniors
Hypervolemia (Edema) (Sodium Excess)	Advanced Congestive Heart Failure	Hemodialysis Patient after 3% Saline infusion

- ***Tonicity***

- To compare the osmolality of a solution to that of another solution (body fluid compartments)
- Used to compare the osmolality of intravenous solutions to that of the serum:
  - *ISOTONIC*
  - *HYPOTONIC*
  - *HYPERTONIC*

Hypotonic	***Isotonic***	***Hypertonic***
Solutions have more water than solutes comparing to ECF	Solutions have the same solute concentration as the ECF	Solutions have more solutes than water comparing to ECF
Water will move from ECF into ICF	It will remain in the ECF	Water will move from ICF to ECF
Distilled Water 0.45% NaCl (1/2) 0.33% NaCl (1/3)	NS (0.9% NaCl) Ringers Lactate 2/3 DW-1/3 NS 5% Dextrose in Water (D5W)	3% NaCl 10%-50% Dextrose D5W-1/2 NS D5NS Amino acid solution

- ***Intravenous Solutions: Crystalloids*** **vs** ***Colloids***
  - *Crystalloids* are intravenous solutions that contain solutes that readily cross the capillary membrane
    - Dextrose and electrolyte solutions
  - *Colloids* are intravenous solutions that DO NOT readily cross the capillary membrane
    - Blood, albumin, plasma

Solution	*Gluc*	*Na^+*	*K^+*	*Ca^{+2}*	*Cl^-*	*Lact*	*mOsm/L*
D_5W	50	0	0	0	0	0	253
$D_{10}W$	100	0	0	0	0	0	506
NS	0	154	0	0	154	0	308
½ NS	0	77	0	0	77	0	154
D_5 NS	50	154	0	0	154	0	561
D_5 ½ NS	50	77	0	0	77	0	407
2/3-1/3	33	50	0	0	50	0	285
Ringer's Lactate	0	130	4	3	109	28	274

D5W: 5 g dextrose/100 mL (50 g/L)

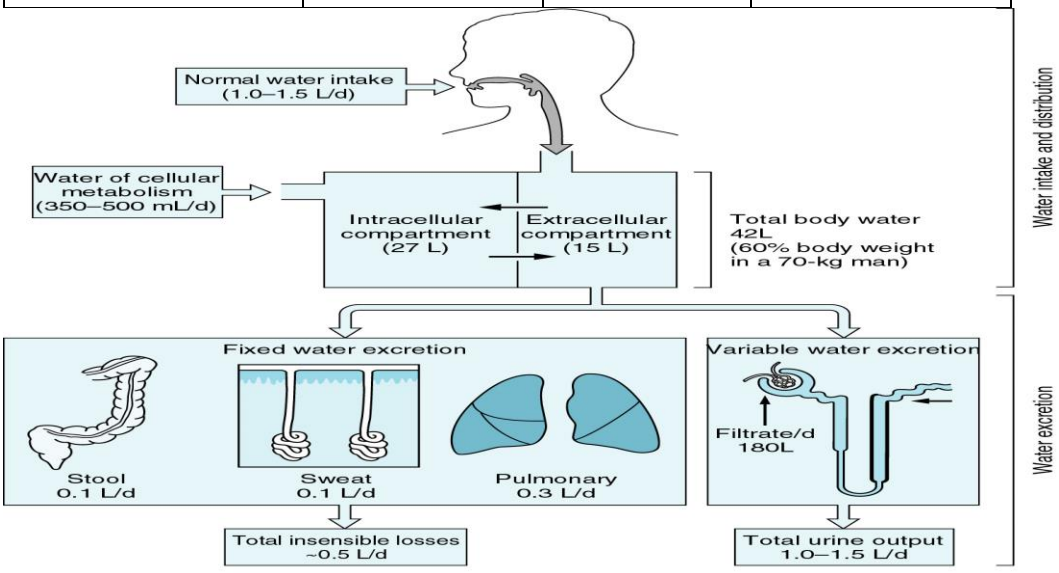
D10W: 10 g dextrose/100 mL (100 g/L)

NS (0.9% NS): 0.9 g NaCl/100 mL (9 g/L)

½ NS (0.45% NS): 0.45 g NaCl/100 mL (4.5 g/L)

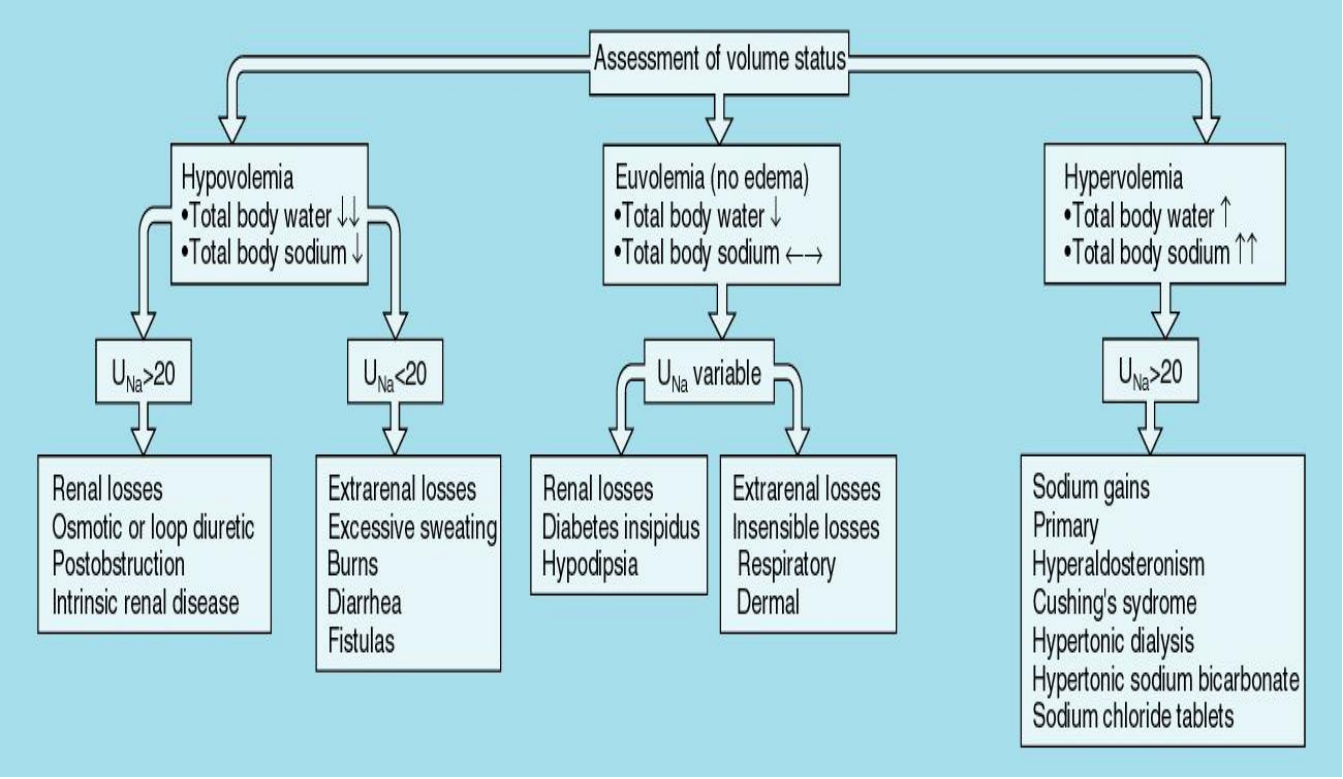
2/3-1/3: 2/3 D5W (33 g/L) + 1/3 NS (0.33 g NaCl/100mL or 3.3 g NaCl/L)

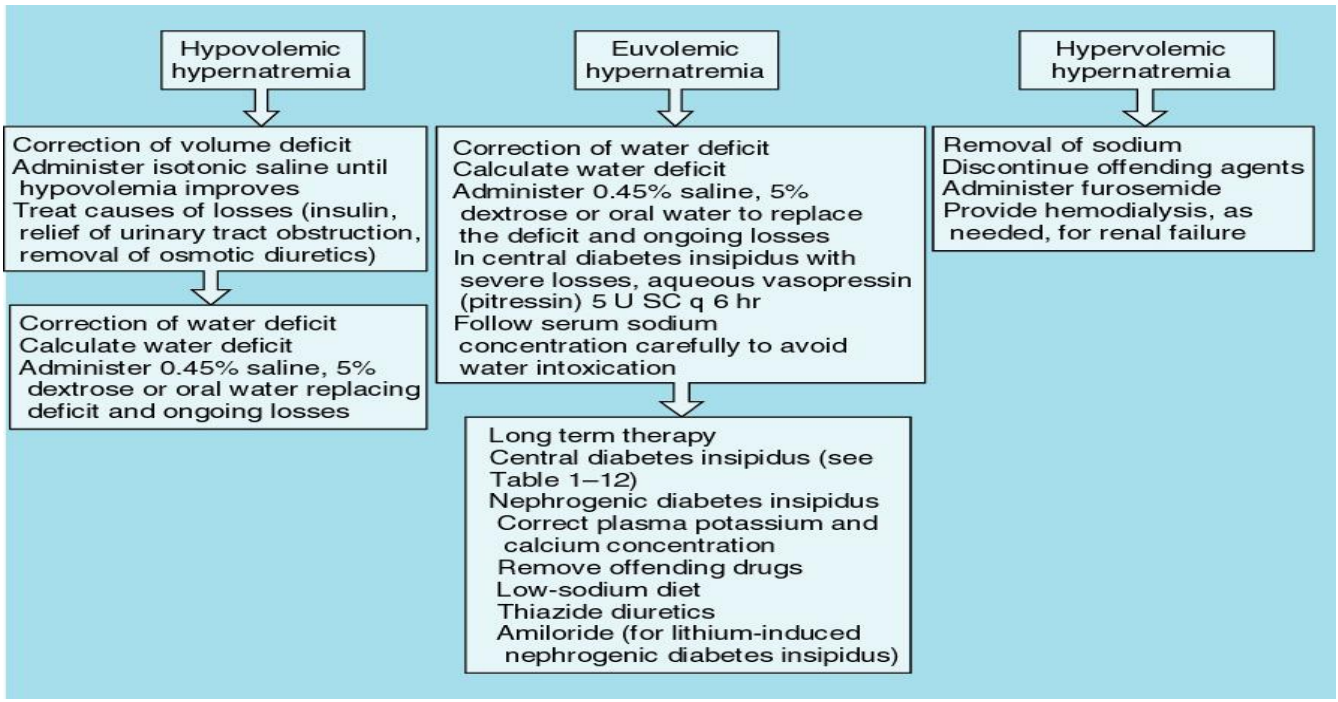
Parental Fluid	***ECF (1/3 TBW)***		***ICF (2/3 TBW)***
	IV (1/4 ECF)	***ISF (3/4 ECF)***	
1000 ml D_5W	80 ml	250 ml	670 ml
1000 ml NS	250 ml	750 ml	---
Colloids (PRBC)	300 ml	---	---
1000 ml ½ NS:			
(500 ml NS)	125 ml	375 ml	---
(500ml water)	40 ml	125 ml	335 ml
Total	165 ml	500 ml	335 ml
1000 ml D_5½NS	165 ml	500 ml	335 ml
1000 ml $D_{10}W$	80 ml	250 ml	670 ml
1000 ml D_5NS	250 ml	750 ml	---



- ***Basal Requirements:***
  - Basal Water:
    - 1st 10 kg: 4 ml/kg/h +
    - 2nd 10 kg: 2 ml/kg/h +
    - > 20 kg: 1 ml/kg/h
  - Insensible water loss:
    - Stool, breath, sweat: 800 ml/d
    - Increases by 100-150 ml/d for each degree above 37 C
  - Electrolytes:
    - Na: 50-150 mmol/d (NaCl)
    - Cl: 50-150 mmol/d (NaCl)
    - K: 20-60 mmol/d (KCl)
  - Carbohydrates:
    - Dextrose: 100-150 g/d
  - IV Dextrose minimizes protein catabolism and prevents ketoacidosis

- ***Hypernatremia:***

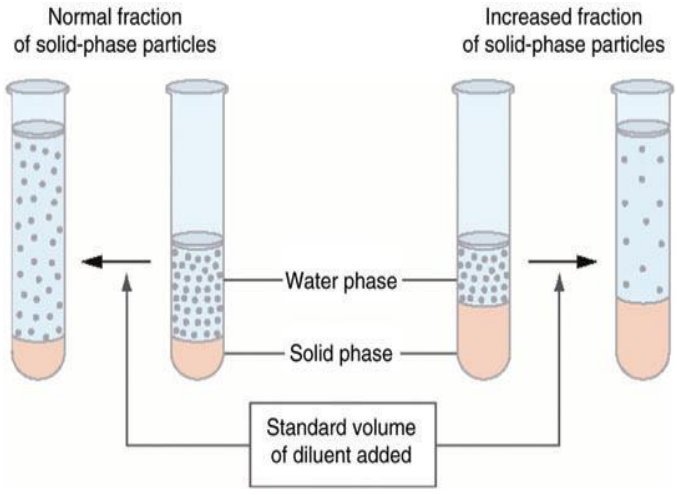




- ***Hypernatremia: Water Deficit Calculation***
  - Current Total Body Water = 0.6 x Current Body Weight
  - Current TBW x Current [Na^+] = Target TBW x Target [Na^+]
  - Target TBW – Current TBW = Water Deficit
  - Ongoing loss
  - IVF: type and rateReassessment

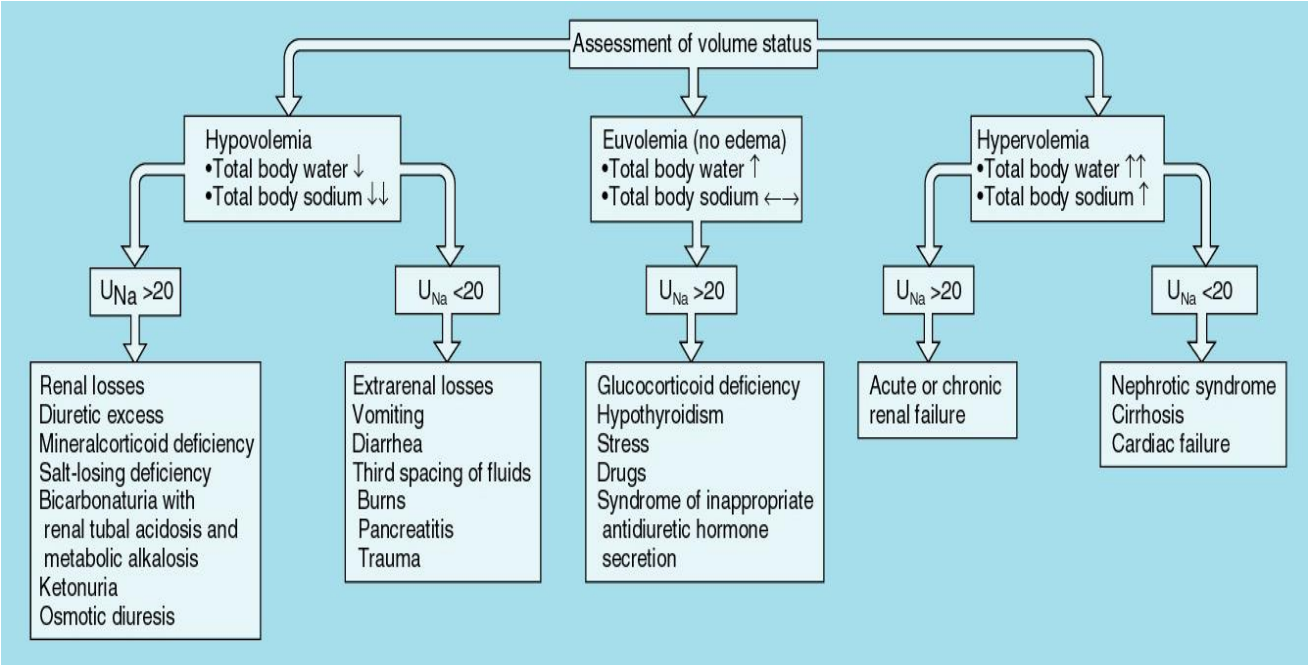
- ***Hyponatremia:***

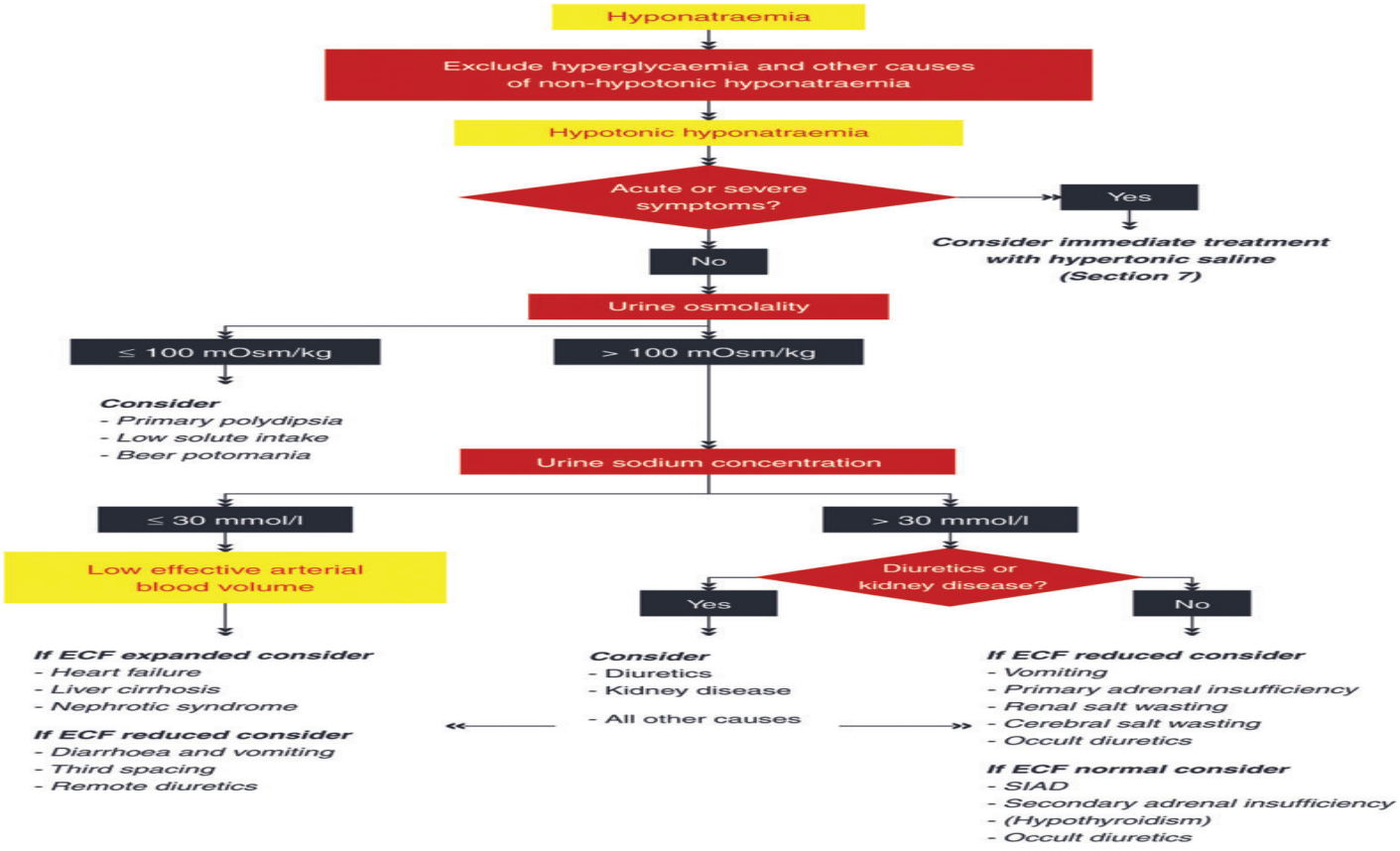
- ***Normotonic or Isotonic Hyponatremia***
  - *Factitious Hyponatremia*
  - *Pseudohyponatremia*
  - Results from laboratory artifact due to high concentrations of proteins or lipids
  - Flame photometric or Indirect potentiometry measurement of PNa^+
  - Normal Measured PNa^+ = 153 mmol/L of Plasma Water
  - Normal Plasma Water Phase = 93% of One liter of Plasma
  - Reported Plasma Na^+ = 153 x 0.93 = 142 mmol/L of Plasma



Hypertonic Hyponatremia

- *Translocational Hyponatremia/Dilutional hyponatremia (True hyponatremia)*
- Results from non-Na osmoles in serum (often glucose or mannitol) drawing Na-free H_2O from cells
- $[Na^+]$ declines by ~2.4 mEq/L for each 100 mg/dL [5.5 mmol/L] increase in serum glucose





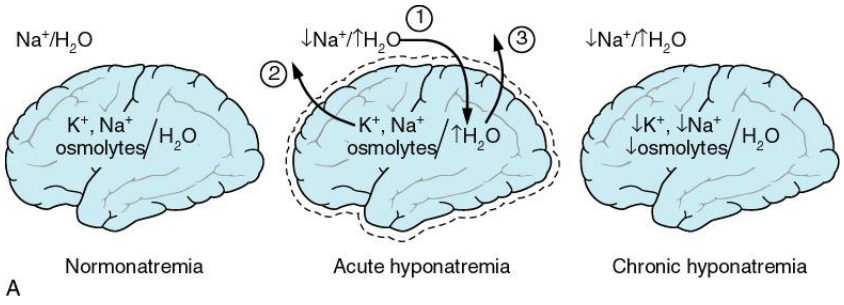
Classification of Symptoms of Hyponatremia

All symptoms that can be signs of cerebral edema should be considered as severe or moderate symptoms that can be caused by hyponatremia

- **Moderately Severe**
  - Nausea without vomiting
  - Confusion
  - Headache
- **Severe**
  - Vomiting
  - Cardiorespiratory distress
  - Abnormal and deep somnolence
  - Seizures
  - Coma (Glasgow Coma Scale ≤8)

Management of Hyponatremia:

- Symptoms & Signs
  - Volume Status
- Serum:
  - Osmolality
  - TSH, FT4, Cortisol
  - Albumin, Total Proteins
  - Uric Acid
- Urine:
  - Electrolytes (Na/K/Cl/Urea/Creatinine)
  - Osmolality
  - Urinalysis



- Rate of correction: 0.5 mmol/L/h ~ 10-12 mmol/L/d

Diagnostic Criteria for SIADH

Essential criteria

- Effective serum osmolality <275 mOsm/kg
- Urine osmolality >100 mOsm/kg
- Clinical euvolemia
- Urine sodium concentration >30 mmol/l with normal dietary salt and water intake
- Absence of adrenal, thyroid, pituitary or renal insufficiency
- No recent use of diuretic agents

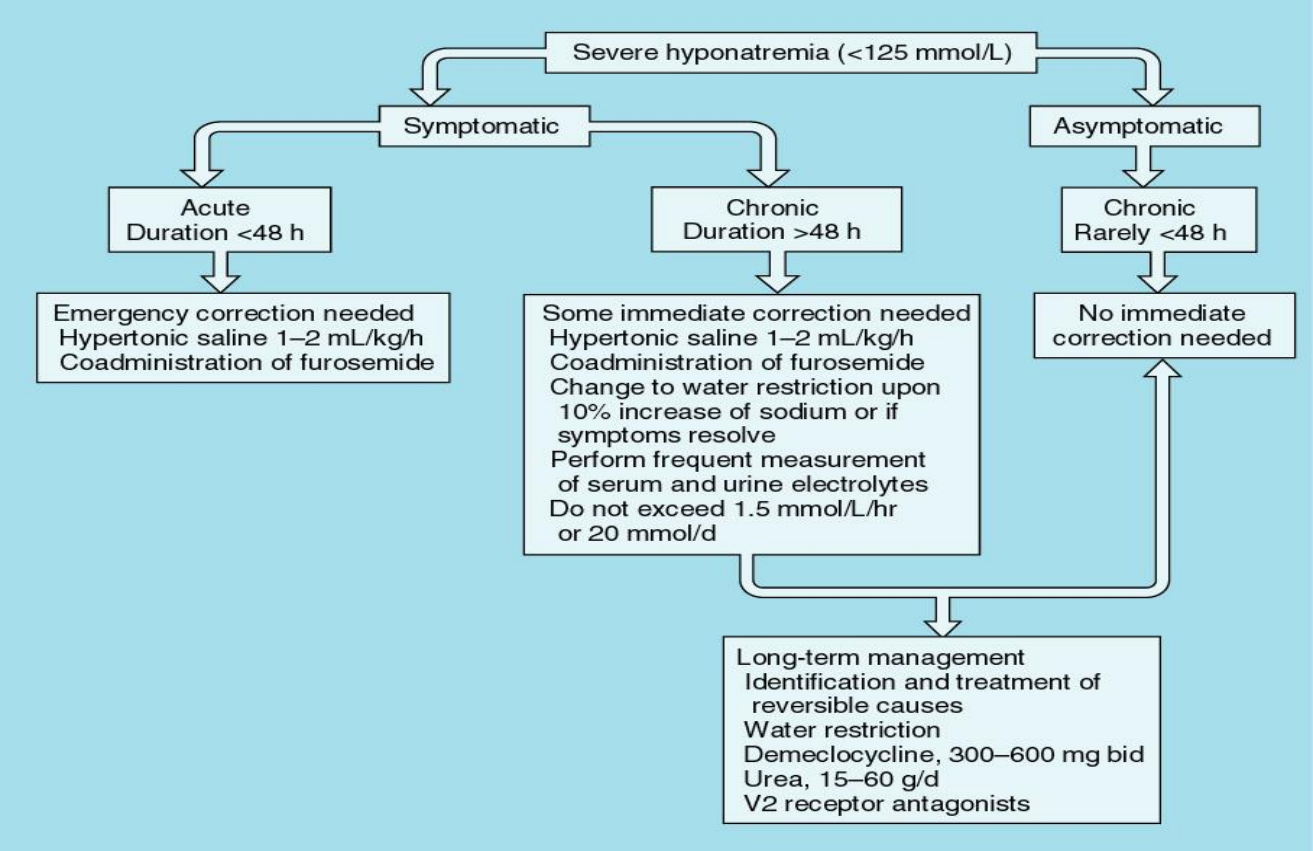
Supplemental criteria

- Serum uric acid <0.24 mmol/l (<4 mg/dl)
- Serum urea <3.6 mmol/l (<21.6 mg/dl)
- Failure to correct hyponatremia after 0.9% saline infusion
- Fractional sodium excretion >0.5%
- Fractional urea excretion >55%

- Fractional uric acid excretion >12%
- Correction of hyponatremia through fluid restriction

- **SIADH ("HIVE"):**

  - H: Hypoosmolar Hyponatremia (Posm <275 mOsm/Kg H_2O)
  - I: Inappropriate urine concentration (Uosm >100 mOsm/Kg H_2O)
  - V: Euvolemia, No diuretic use
  - E: Endocrine = normal Thyroid, adrenal and renal function
  - Hypouricemia (<238 mcmol/L) and low Urea (<3.5 mmol/L)



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