Total body water (TBW) = 0.6 body weight (BW)

2/3 of TBW is intracellular fluid volume (ICFV). ICFV = 0.4 BW

1/3 of TBW is extracellular fluid volume (ECFV). ECFV = 0.2 BW

3/4 of ECFV is interstitial fluid volume (ISFV). ISFV = 0.15 BW

1/4 of ECFV is plasma volume (PV). PV = 0.05 BW

ICFV osmolality **always** equals ECFV osmolality due to passive movement of H_20

Major cation in ICFV is K^+. Na^+ is major cation of ECFV since it is virtually restricted to ECFV.

Total body exchangeable Na^+ content (TBNa), therefore, determines the size of ECFV. Ingestion of Na^+ → ↑ TBNa → ↑ osmolality of ECFV since Na+ is restricted to ECFV. ↑ ECFV osmolality leads to ↑ thirst → ↑ H_20 intake and ↑ vasopressin → ↑ renal H_20 conservation. H_20 retention and intake continue until ECFV osmolality returns to normal → ↓ thirst and ↓ vasopressin. The net result then is retention of isotonic NaCl and expansion of ECFV with little or no change in ICFV. Isotonic volume depletion occurs when isotonic fluids are lost from the ECFV and would also lead to no change in ICFV since ECFV osmolality is unchanged. Vomiting of gastric contents or diarrhea (intestinal contents) are examples of losses of essentially isotonic fluids. This loss would → ↓TBNAand therefore ↓ ECFV, with no change in ECFV osmolality or in the size of the ICFV. The composition of ions in gastric and intestinal fluid differ from plasma. Gastric losses are rich in HCl and would, therefore, be associated with metabolic alkalosis in addition to the ↓ ECFV. Intestinal fluid is relatively rich in HCO_3^- and would result in normal anion gap metabolic acidosis in addition to ↓ ECFV.

NOTE: Changes in TBNa (↑ or ↓) are synonomous with changes in ECFV
↑ TBNa lead to ECFV expansion and ↓ TBNa to ECFV depletion

Plasma Na^+ concentration (mEq/L) per se tells you nothing about TBNa content or the size of the ECFV. Plasma Na^+ concentration is always determined by the ratio of TBNa to TBW

Low Na^+ concentration could be associated with low, normal, or expanded ECFV depending on the relative changes in TBNa, TBW, or both. The same would be true for ↑ Na concentration.

Retention of water, with no change in TBNa, would lead to ↑ TBW
2/3 of H_20 would go to ICFV and 1/3 to ECFV. Likewise, loss of H_20 with no change in TBNa would be loss of TBW with 2/3 of loss from ICFV and 1/3 from ECFV.

Contrast this with isotonic losses or gains which result in changes in ECFV, but not ICFV. Remember: PV is part of ECFV and it is PV which perfuses all tissues of the body. The major implication of this is that it would take a decrease of 6 liters of pure H_20 loss (2/3 of pure H_20 loss from ICFV, 1/3 from ECFV) to produce the same change in ECFV as would be produced by a 2 liter loss of isotonic fluid .

There is no readily available laboratory test that can be used to determine TBNa content and, therefore, ECFV. An estimate of the state of ECFV and ICFV are made by use of clinical criteria such as the history, physical examination, and urinary Na and H_20 excretion.

History:

a. Volume depletion (predominantly isotonic losses) vomiting, diarrhea, poor intake, urine losses such as from diuretic drugs. (TBW ↓ , ECFV ↓ , ICFV ~ unchanged

b. Volume loss (mainly H_20 loss). Lack of H_20 intake with continued obligate H_20 loss from urine and insensible losses. Impaired renal H_20 conservation (lack of vasopressin, tubule resistance to vasopressin, marked solute excretion leading to impaired H_20 conservation since ↑ solute excretion → ↑. Note: Since H_20 excretion TBW is ↓ and TBNa is basically unchanged, these settings will be associated with ↑ plasma osmolality and plasma Na concentration [↓ TBW, ↓ ICFV, ↓ ECFV].

c. Isotonic volume expansion: Occurs when intake of NaCl and H_20 exceed ability of kidney to excrete the increased NaCl and H_20 e. g. CHF, cirrhosis, nephrotic syndrome, renal failure. Note that in these settings one could have normal plasma Na^+ concentration if TBNa and TBW are similarly increased or ↓ plasma Na^+ concentration if TBW increases more than TBNa.

d. Hypotonic volume expansion: Retention of H_20 (intake > output) with no change in TBNa. 2/3 of retained H20 to ICFV and 1/3 to ECFV (↑ TBW, ↑ ICFV, ↑ ECFV). Plasma osmolality and Na^+ concentration is low.

e. Hypertonic volume expansion - this is rare. It would require ↑ TBNA with either normal or slightly decreased TBW, e. g. massive ingestion of Na^+ without

much H_20 intake. An iatrogenic cause is excessive administration of hypertonic $NaHCO_3$. [↑ ECFV, ↓ ICFV, TBW ~ unchanged]
The ↑ osmolality of ECFV due to ↑ TBNa without equivalent ↑ in H20 leads to H20 movement from ICFV to ECFV.

Physical Exam:

a. Signs of ECFV depletion (Na depletion, ↓ $TBNa^+$) ↑ heart rate, ↓ blood pressure, orthostatic ↑ in heart rate or ↓ in blood pressure, poor skin turgor, absence of edema

b. Volume expansion (↑ $TBNa^+$ content) Edema - edema is ↑ ISFV but you cannot ↑ ISFV without also ↑ ECFV since the two compartments readily and rapidly equilibrate across capillaries.

JVD = distended neck veins
Rales = ↑ fluid in lungs, cardiomegaly

Urine Na^+ and H_20 handling:
In normal subject isotonic losses lead to retention of Na^+ and H_20 by kidney. Thus, urine Na^+ excretion is low (fractional excretion of Na^+ is low, <1%) and urine is concentrated (high urine osmolality, maximally up to ~ 1200 mosm/kg H_20. The ≠ urine osmolality is due to H_20 reabsorption not to solute excretion. The main osmole in such concentrated urine is urea, not Na^+).

In pathophysiologic settings (CHF, cirrhosis, nephrotic syndrome) the kidney receives neural and humoral signals which lead to retention of NaCl and H_20 and, therefore, similar low Na excretion and concentrated urine. The net result is Na^+ and H_20 intake exceeds excretion leading to ↑ TBNa and ↑ TBW.

Balance:

Refers to the relationship between intake and output of a substance, such as H20 or solute. Neutral balance means intake = output. Positive balance means intake exceeds output. Negative balance means output exceeds intake. Intake is normally by oral ingestion. Output is typically from renal and stool output; however, other GI losses such as vomiting would also contribute to net output.