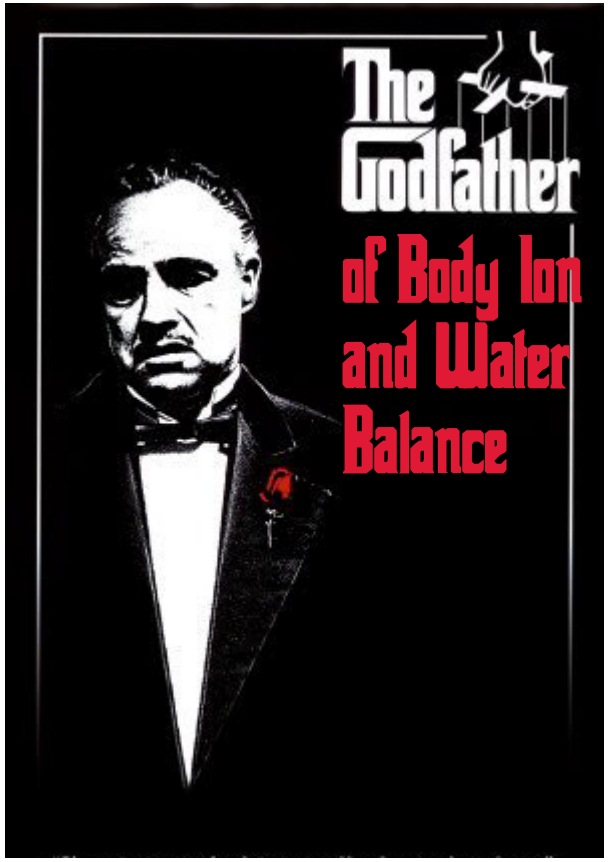
Quantitative Nephrology III: The Edelman Equation

7/30/2020

$$Na'_s = 1.11 \frac{(Na_e + K_e)}{T.B.W.} - 25.6$$

Quantitative Nephrology III: The Edelman Equation

A Bit of History: Isidore (Izzy) S Edelman, MD



Quantitative Nephrology III: The Edelman Equation

Lecture Objectives

1. Derive the simplified Edelman equation from fundamental physiologic principles.
2. Compare the derived (i.e., theoretical) equation to the empirical relationship described in Edelman's classic paper:

   Edelman IS, Leibman J, O'Meara MP, Birkenfeld LW. Interrelations between serum sodium concentration, serum osmolarity and total exchangeable sodium, total exchangeable potassium and total body water. *J Clin Invest*. 1958;37(9):1236–56. PMID: 13575523.

3. Perform computations using the simplified Edelman equation.

Quantitative Nephrology III: The Edelman Equation

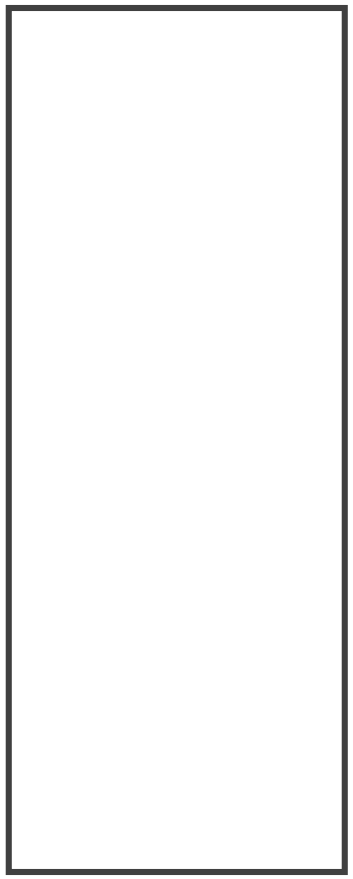
A general fluid compartment: Basic structure

Fluid compartment

Quantitative Nephrology III: The Edelman Equation

A general fluid compartment: Basic structure

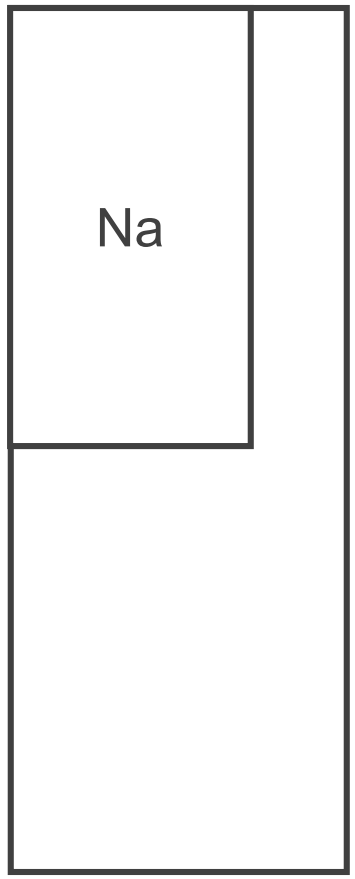
- Water



Quantitative Nephrology III: The Edelman Equation

A general fluid compartment: Basic structure

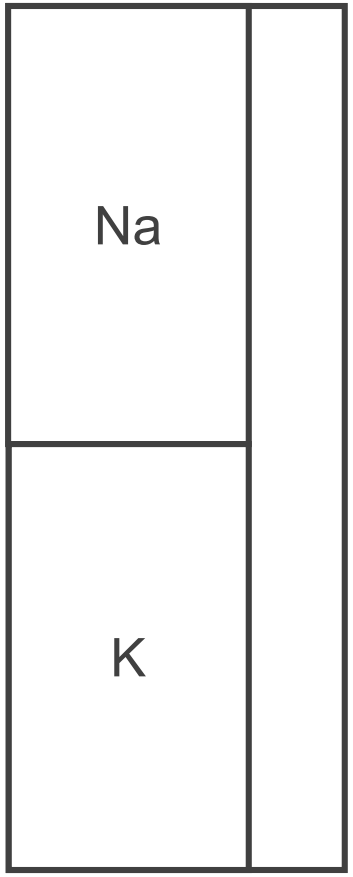
- Water
- Sodium (Na) ions



Quantitative Nephrology III: The Edelman Equation

A general fluid compartment: Basic structure

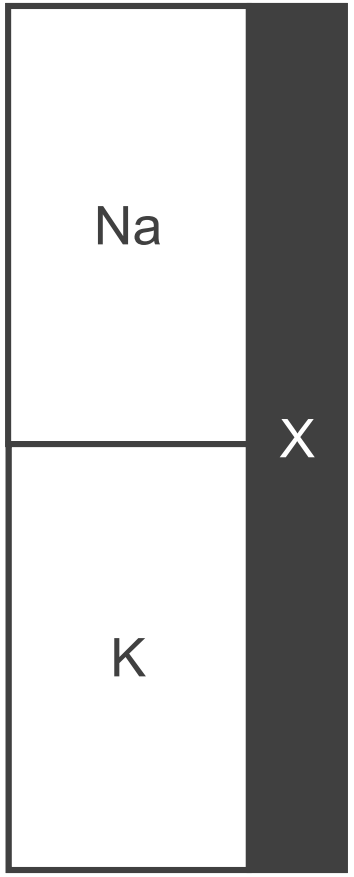
- Water
- Sodium (Na) ions
- Potassium (K) ions



Quantitative Nephrology III: The Edelman Equation

A general fluid compartment: Basic structure

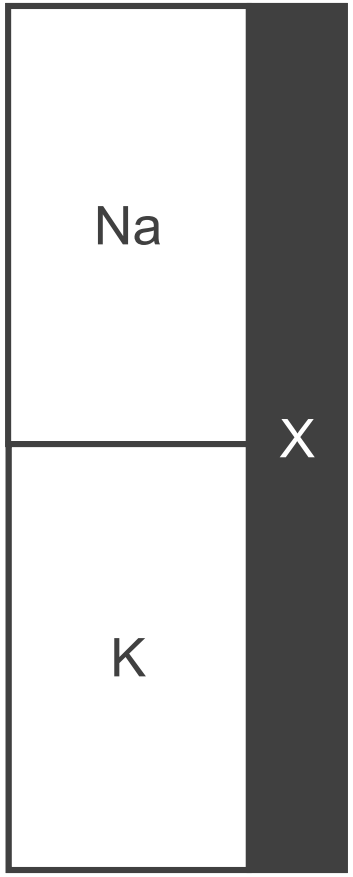
- Water
- Sodium (Na) ions
- Potassium (K) ions
- Generic anions (X)



Quantitative Nephrology III: The Edelman Equation

A general fluid compartment: Translation into math

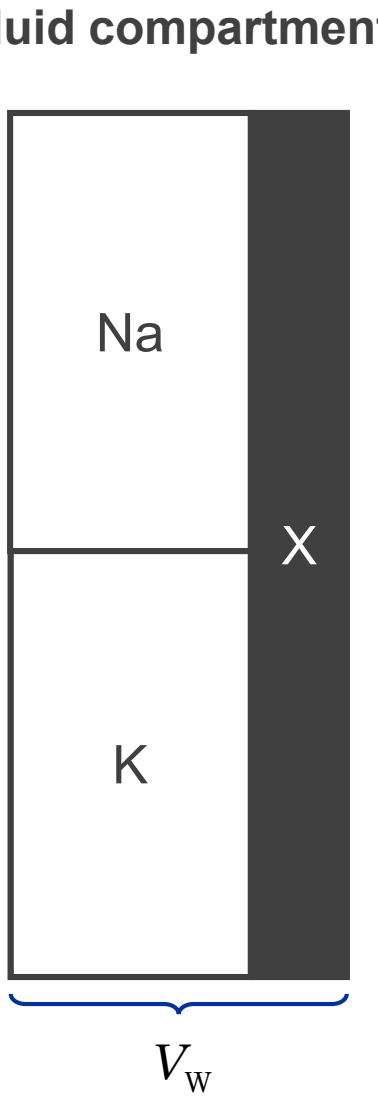
Fluid compartment



Quantitative Nephrology III: The Edelman Equation

A general fluid compartment: Translation into math

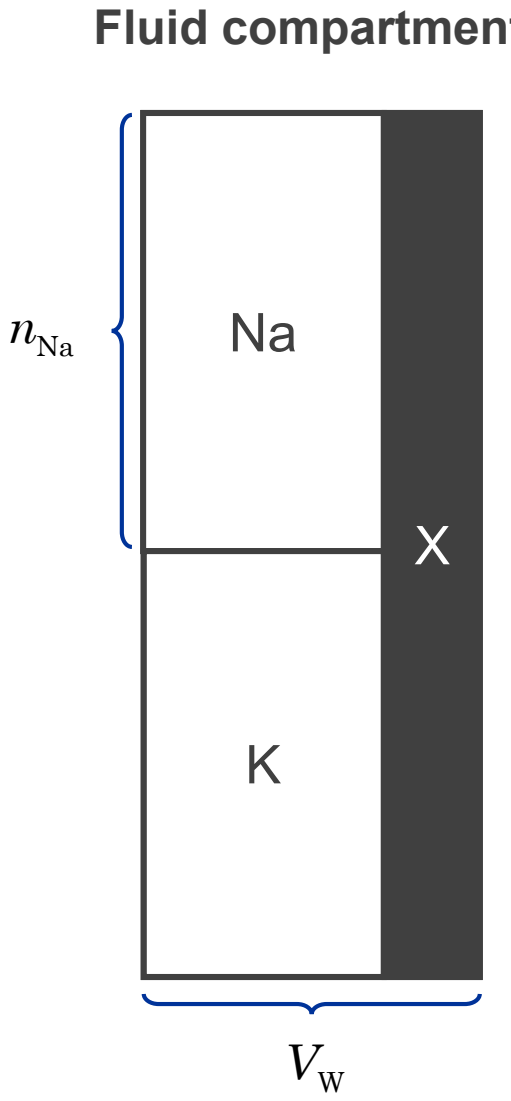
- Water *volume*



Quantitative Nephrology III: The Edelman Equation

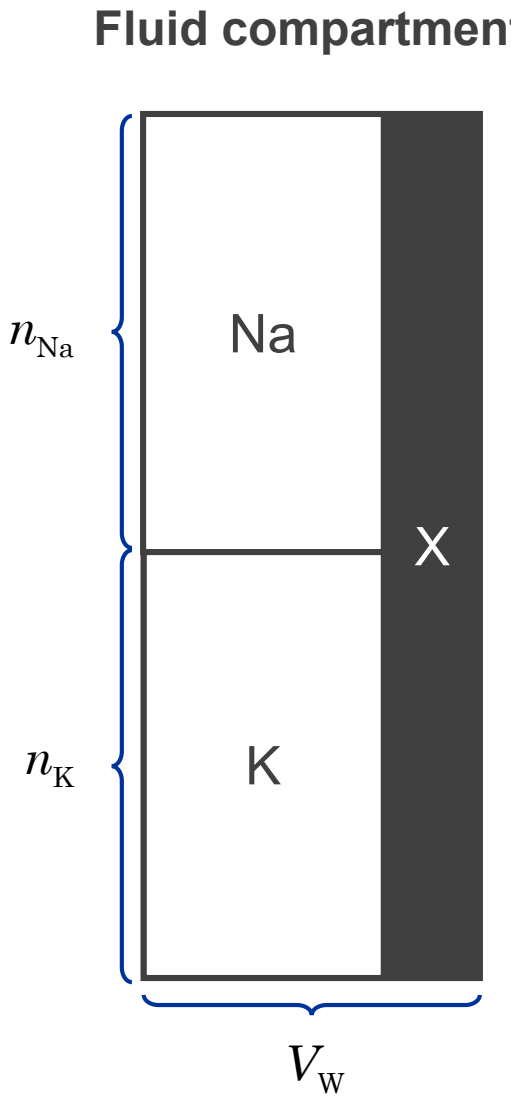
A general fluid compartment: Translation into math

- Water *volume*
- Sodium (Na) ion *amount*



A general fluid compartment: Translation into math

- Water *volume*
- Sodium (Na) ion *amount*
- Potassium (K) ion *amount*



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A general fluid compartment: Translation into math

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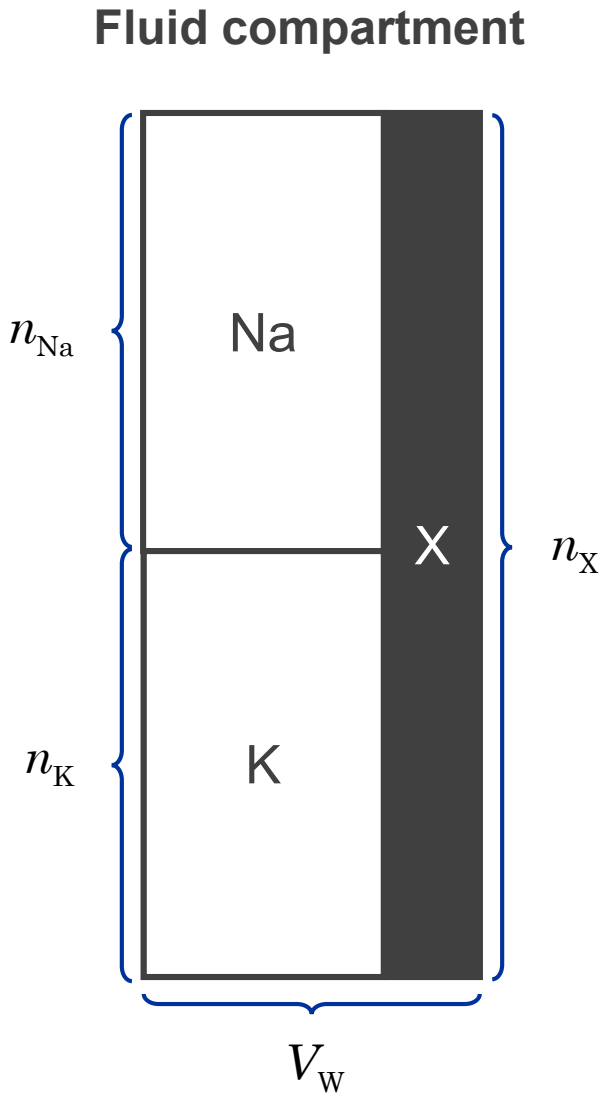

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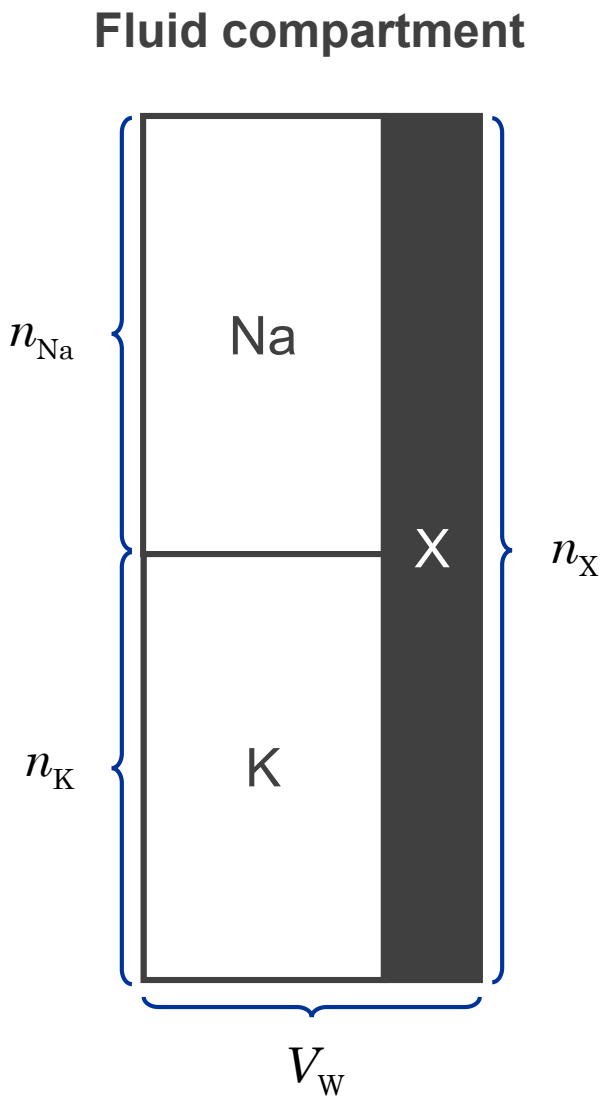

What is the relationship between n_X, n_{Na}, and n_K?

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A general fluid compartment: Translation into math

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- Sodium (Na) ion *amount*
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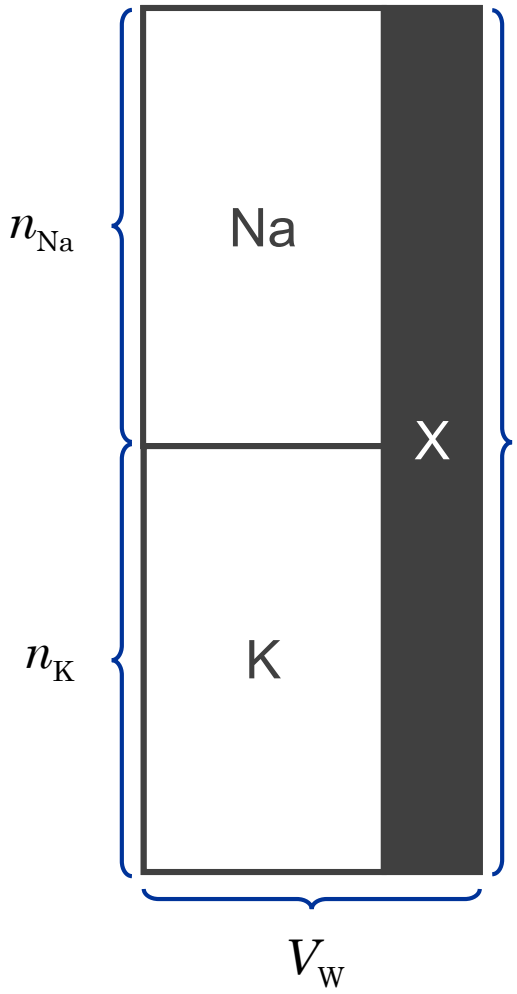
Fluid compartment

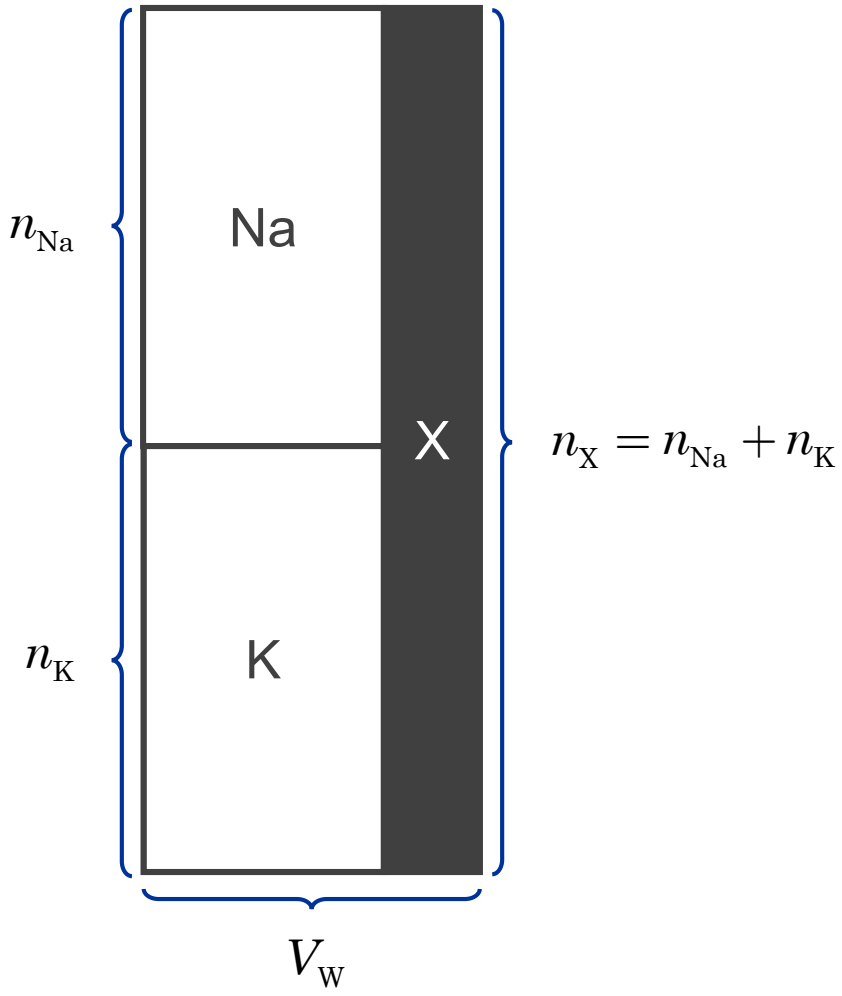


What is the relationship between n_X, n_{Na}, and n_K?

$$n_X = n_{Na} + n_K$$

A general fluid compartment: Concentration definitions

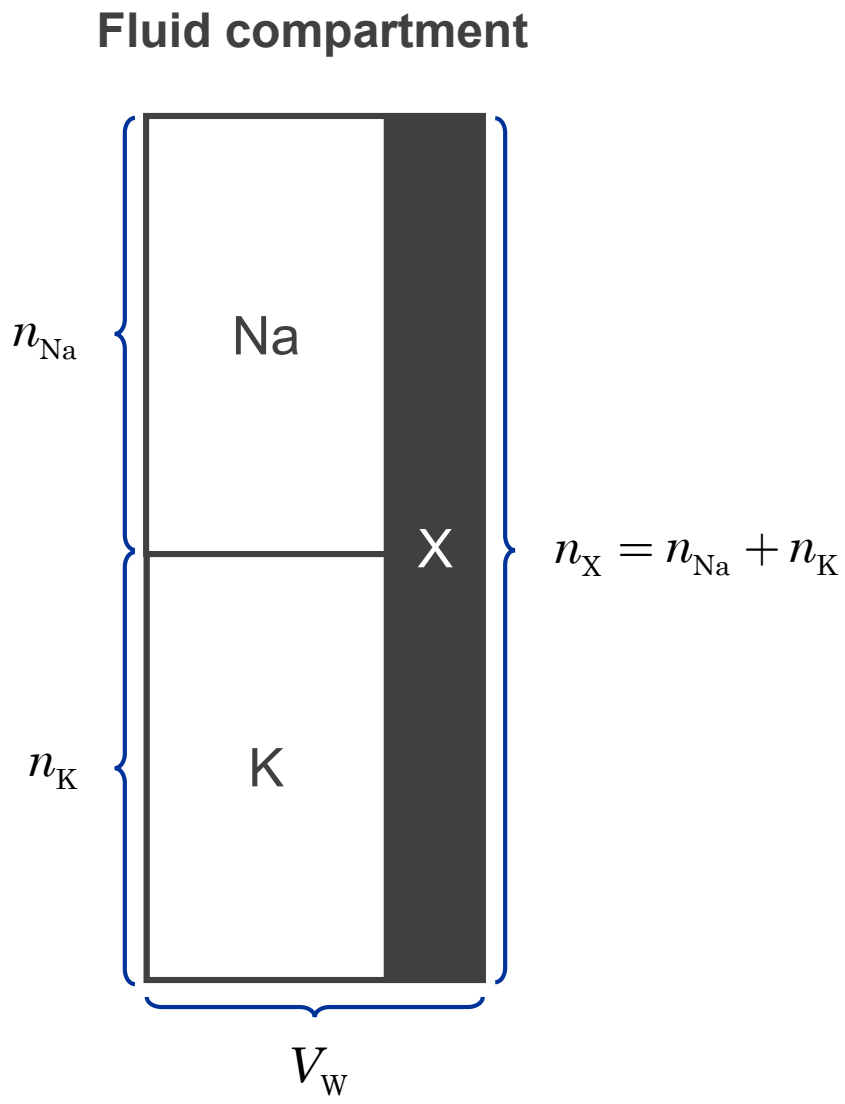
Fluid compartment



$$n_X = n_{Na} + n_K$$

A general fluid compartment: Concentration definitions

What is the definition of $[\mathrm{Na}]$?

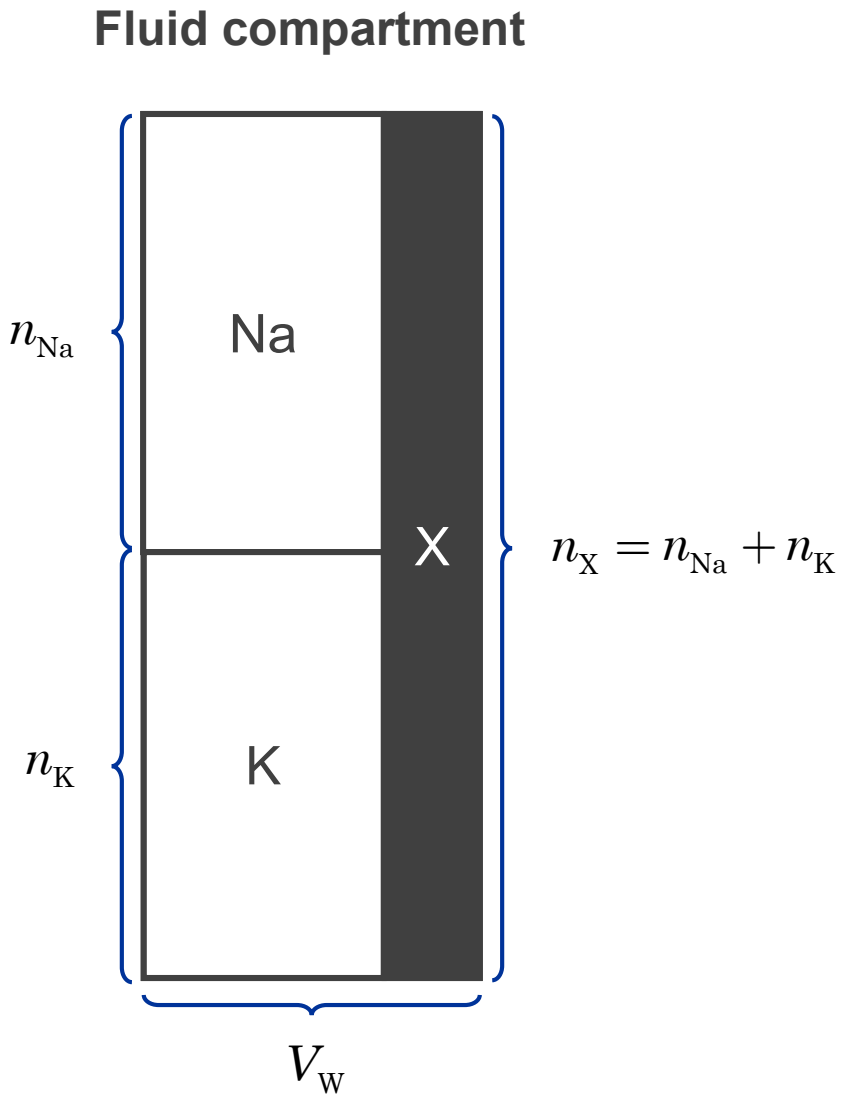


Quantitative Nephrology III: The Edelman Equation

A general fluid compartment: Concentration definitions

What is the definition of $[\mathrm{Na}]$?

$$[\mathrm{Na}] = \frac{n_{\mathrm{Na}}}{V_{\mathrm{W}}}$$



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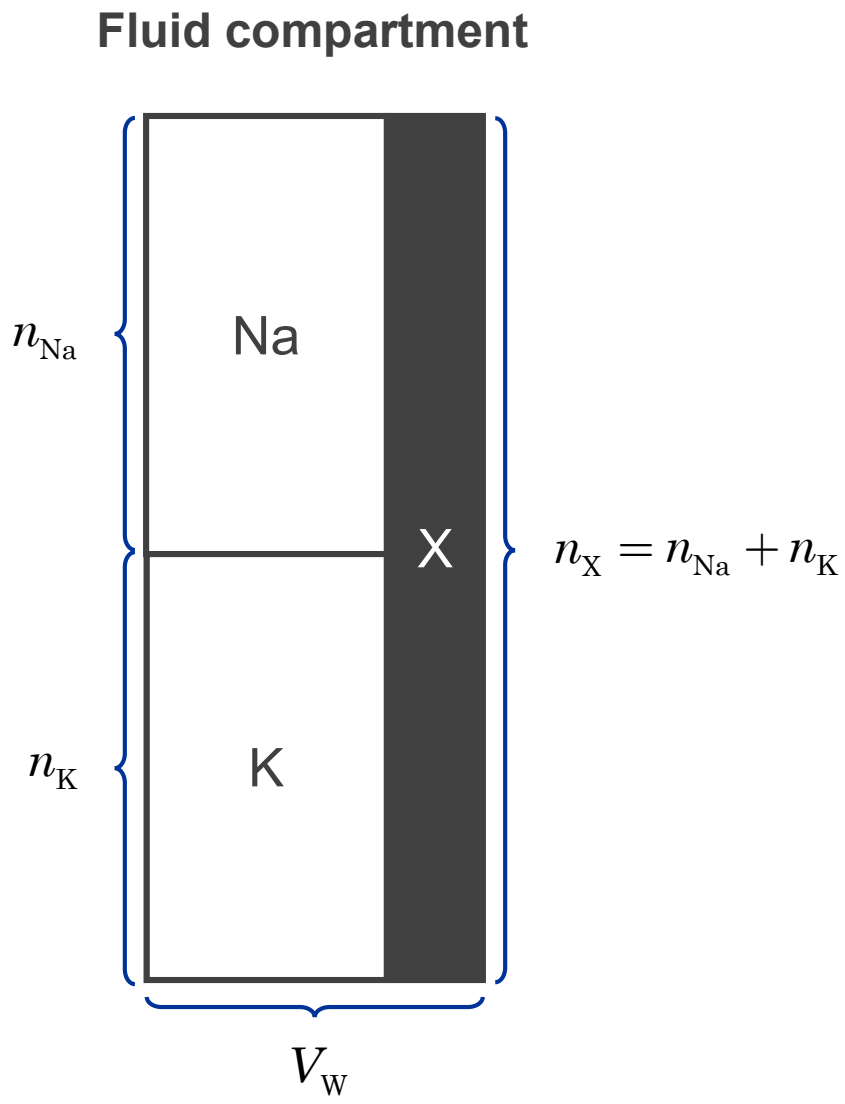

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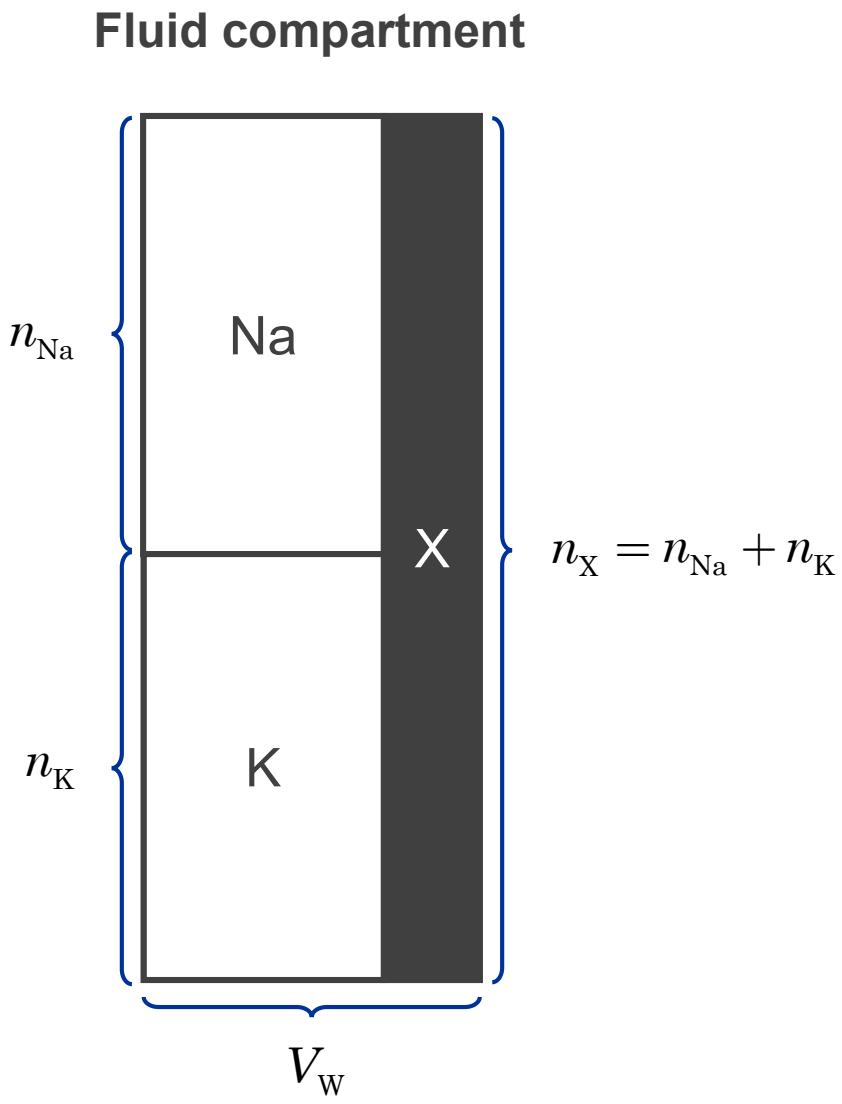

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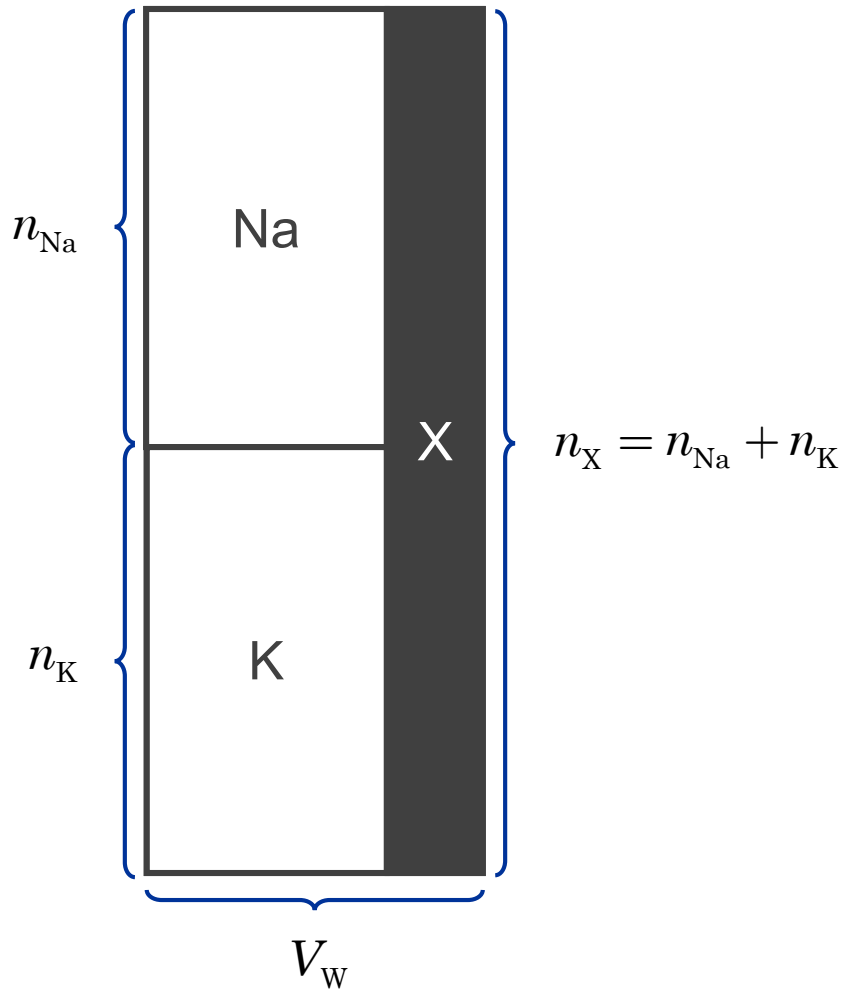

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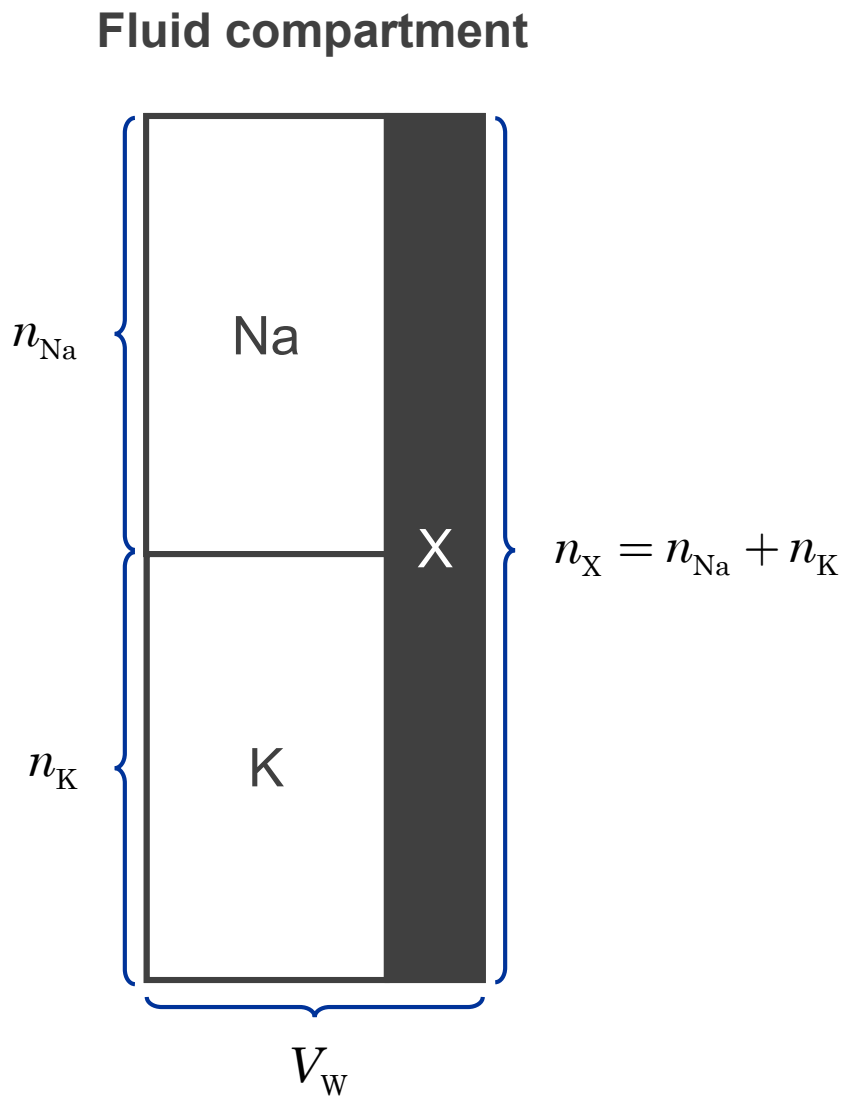

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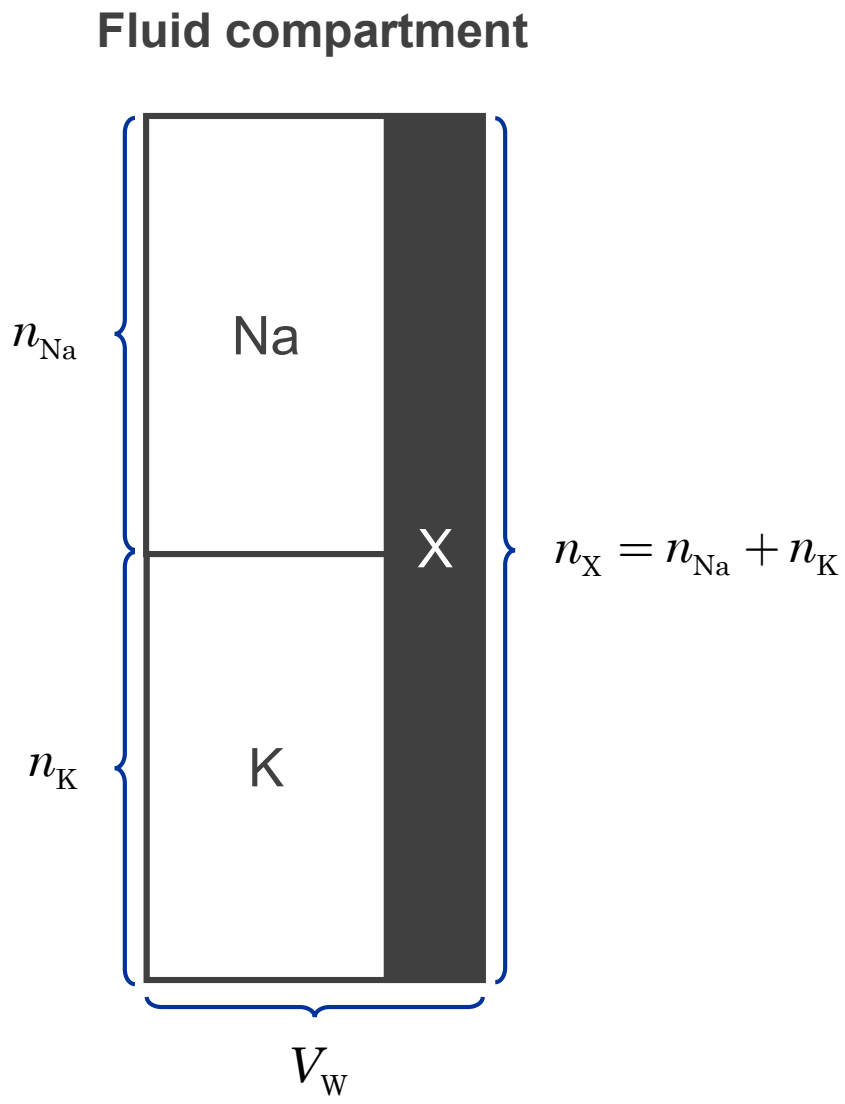

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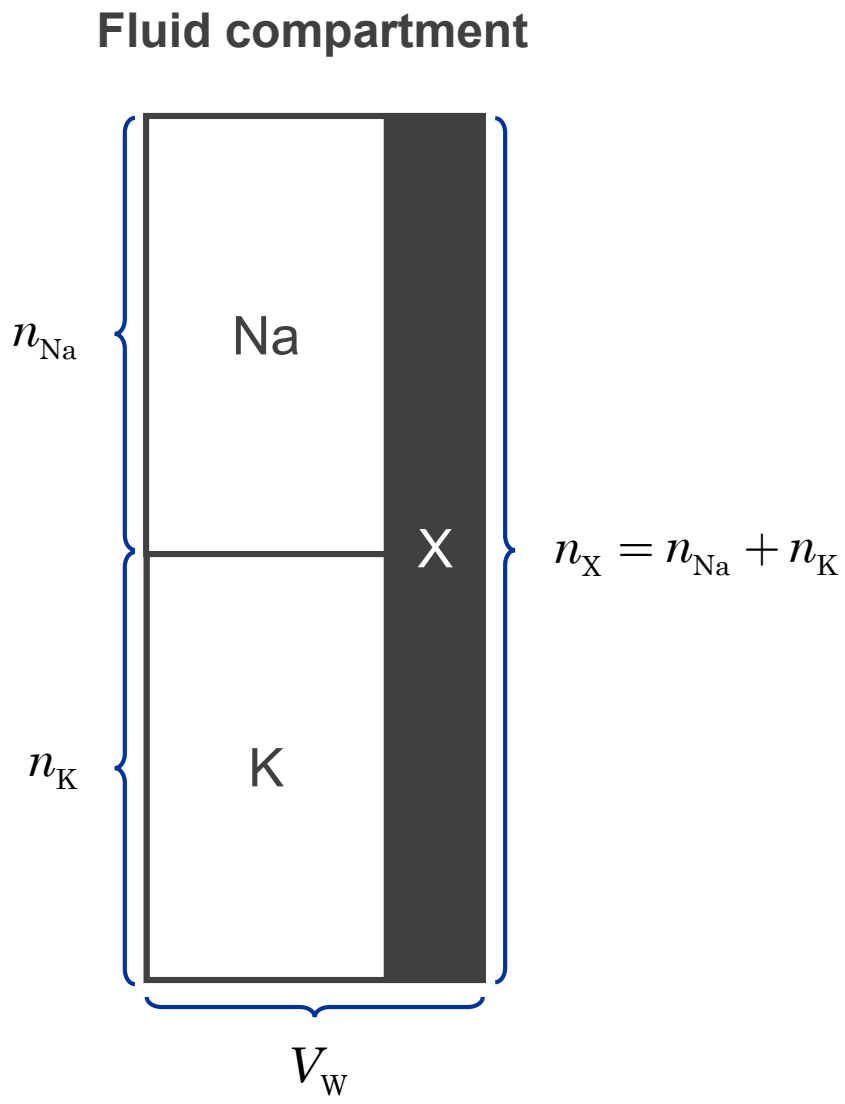
Remember: There must be equal numbers of cations and anions in order to maintain **electroneutrality**!



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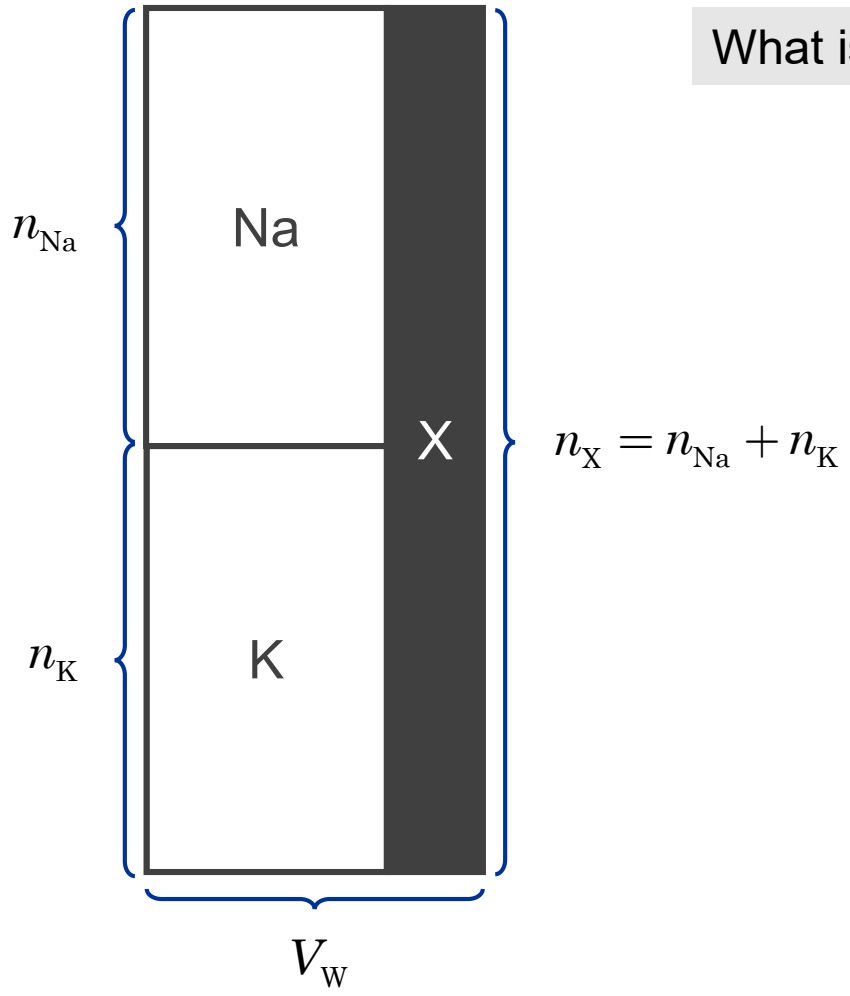
Fluid compartment



$$n_{\mathrm{X}} = n_{\mathrm{Na}} + n_{\mathrm{K}}$$

What is the definition of $[\mathrm{osm}]$?

Quantitative Nephrology III: The Edelman Equation

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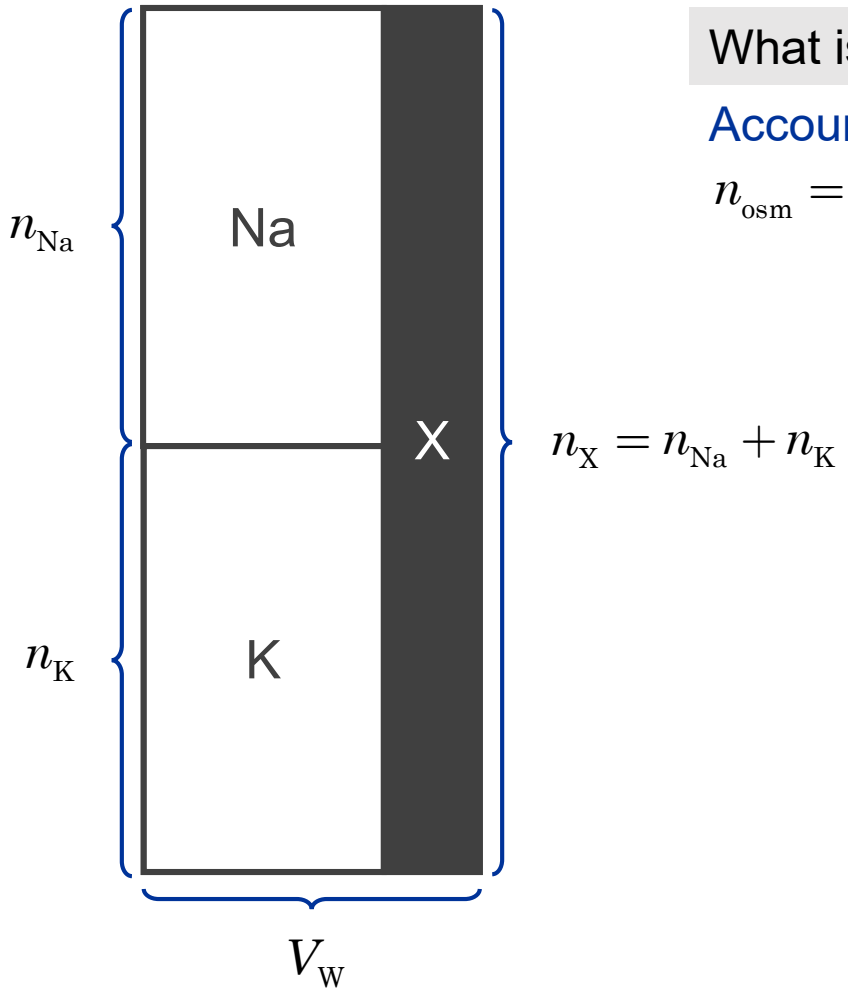

$$n_{\mathrm{X}} = n_{\mathrm{Na}} + n_{\mathrm{K}}$$

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Account for all particles:

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A general fluid compartment: Concentration definitions

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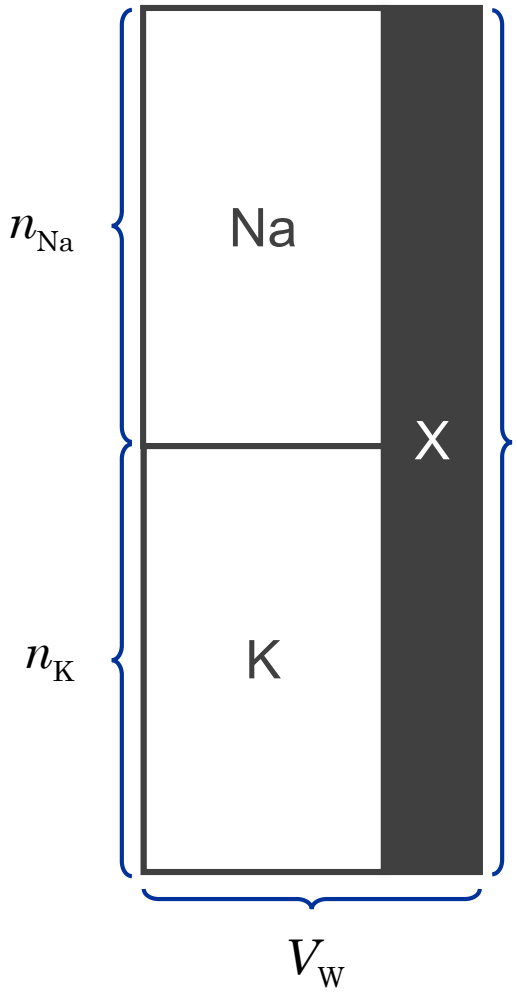

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$$\begin{aligned} n_{\mathrm{osm}} &= n_{\mathrm{Na}} + n_{\mathrm{K}} + n_{\mathrm{X}} \\ &= n_{\mathrm{Na}} + n_{\mathrm{K}} + \{n_{\mathrm{Na}} + n_{\mathrm{K}}\} \end{aligned}$$

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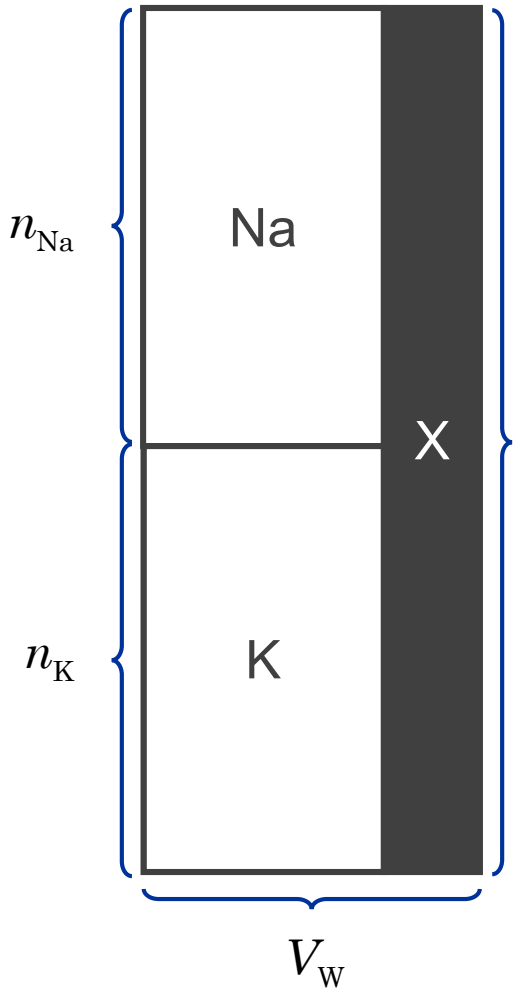

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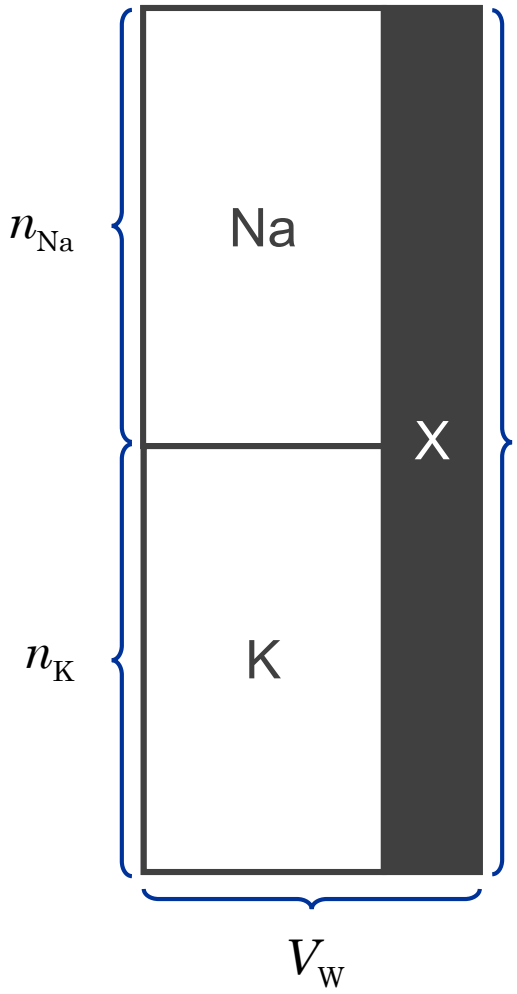

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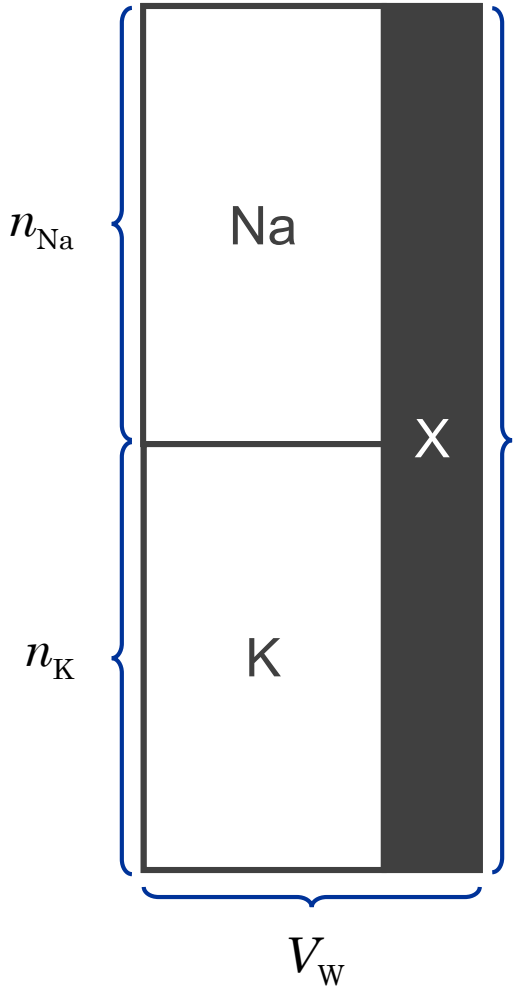

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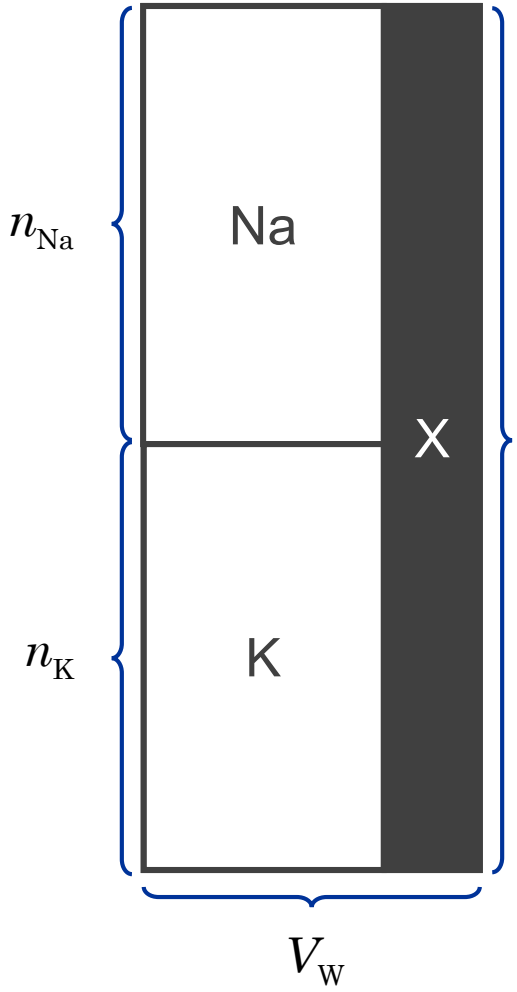

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Complete the definition:

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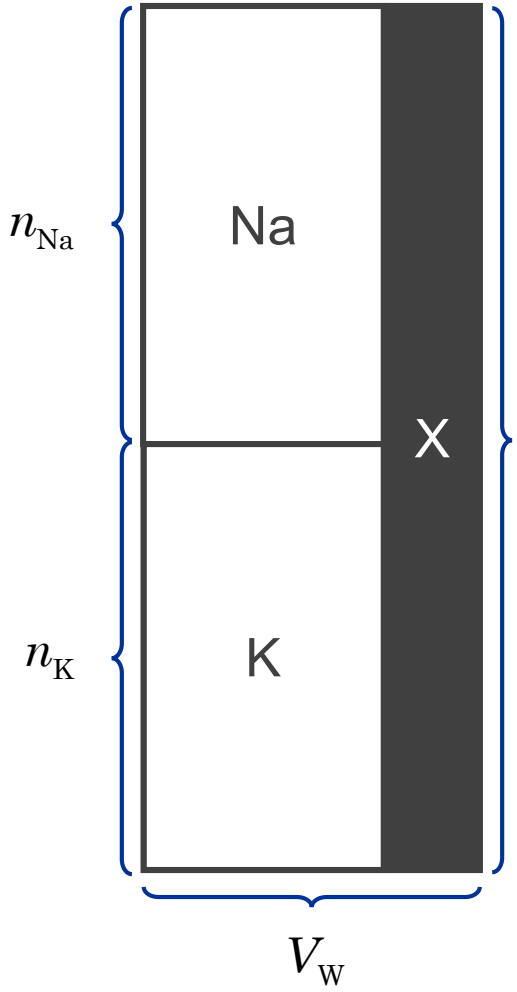

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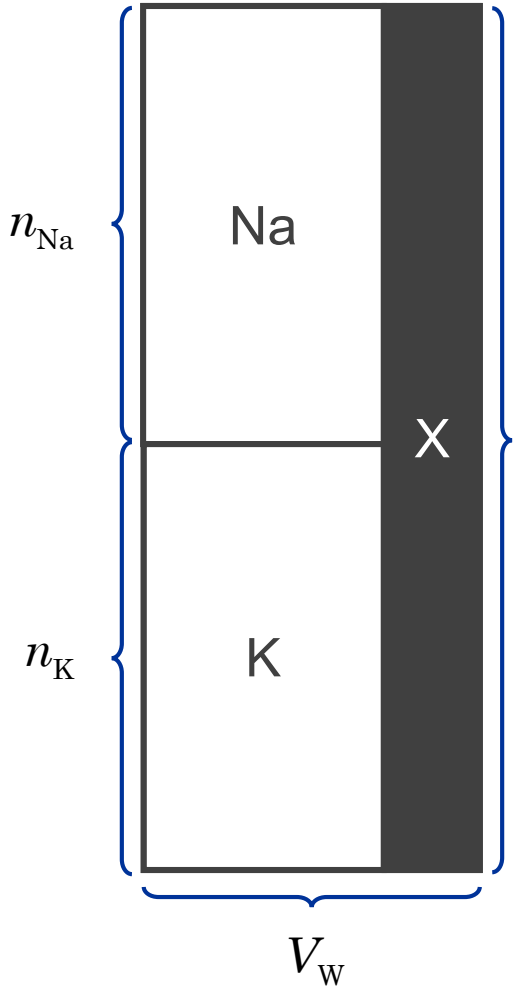


$$n_{\mathrm{X}} = n_{\mathrm{Na}} + n_{\mathrm{K}}$$

What is the definition of $[\mathrm{osm}]$?

Account for all particles:

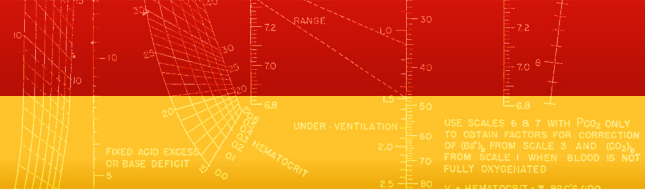
$$\begin{aligned} n_{\mathrm{osm}} &= n_{\mathrm{Na}} + n_{\mathrm{K}} + n_{\mathrm{X}} \\ &= n_{\mathrm{Na}} + n_{\mathrm{K}} + \{n_{\mathrm{Na}} + n_{\mathrm{K}}\} \\ &= 2\{n_{\mathrm{Na}} + n_{\mathrm{K}}\} \end{aligned}$$

Complete the definition:

$$[\mathrm{osm}] = \frac{n_{\mathrm{osm}}}{V_{\mathrm{W}}} = \frac{2\{n_{\mathrm{Na}} + n_{\mathrm{K}}\}}{V_{\mathrm{W}}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: ICF and ECF



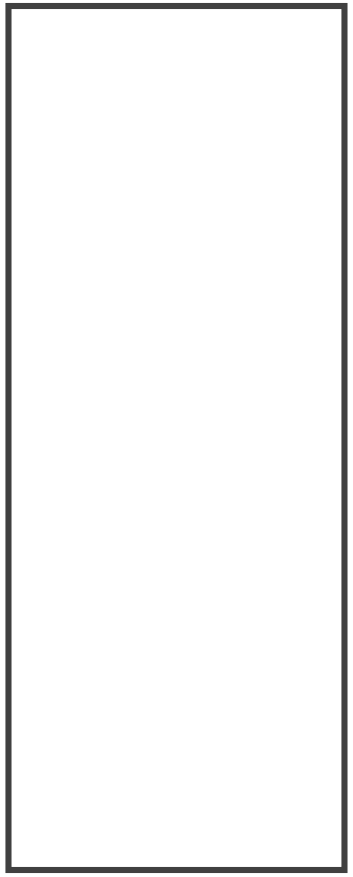
Intracellular fluid (ICF)

Extracellular fluid (ECF)

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: ICF and ECF

Intracellular fluid (ICF)

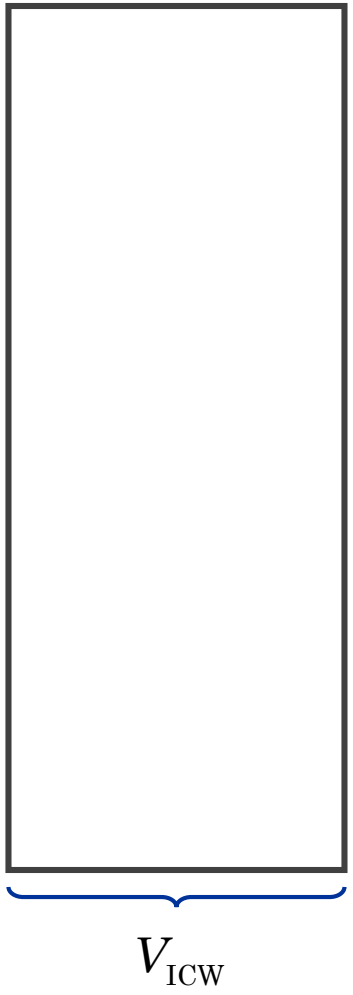


Extracellular fluid (ECF)

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: ICF and ECF

Intracellular fluid (ICF)



Extracellular fluid (ECF)

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: ICF and ECF

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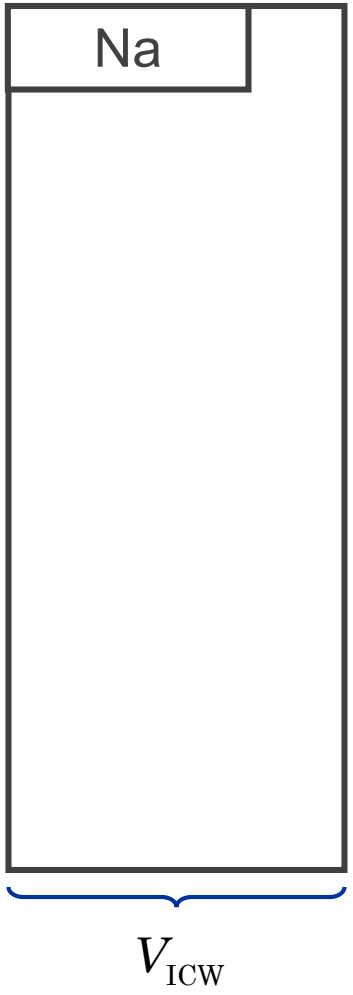

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Quantitative Nephrology III: The Edelman Equation

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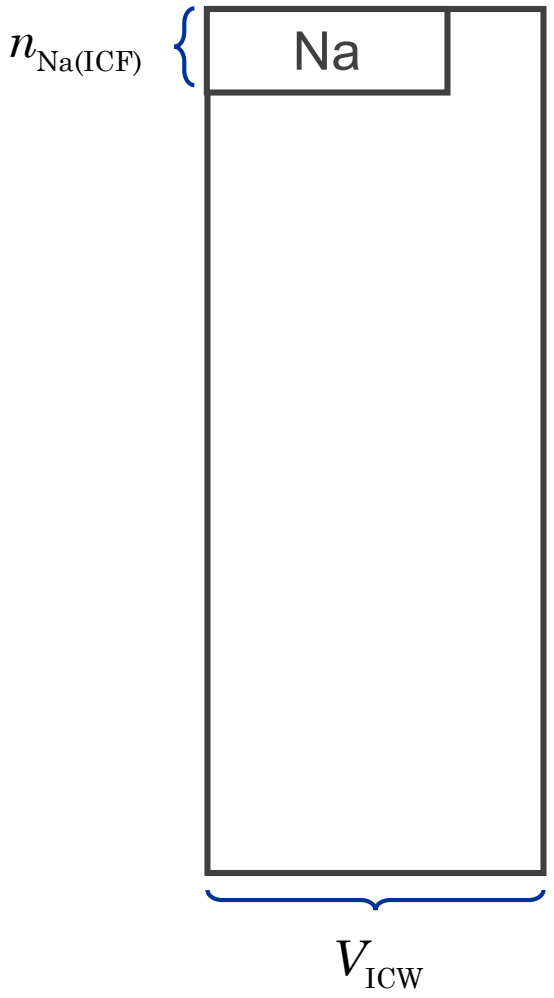

Extracellular fluid (ECF)

Quantitative Nephrology III: The Edelman Equation

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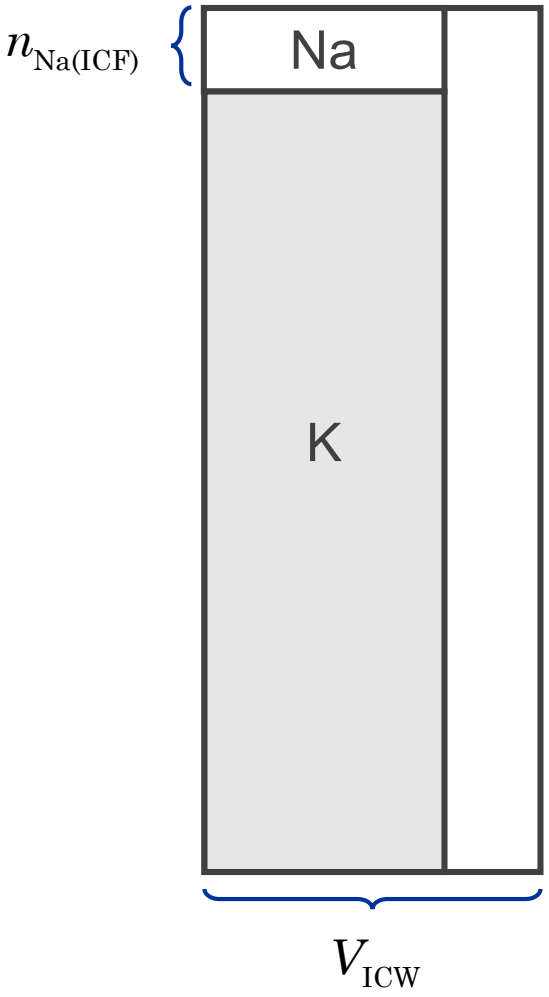

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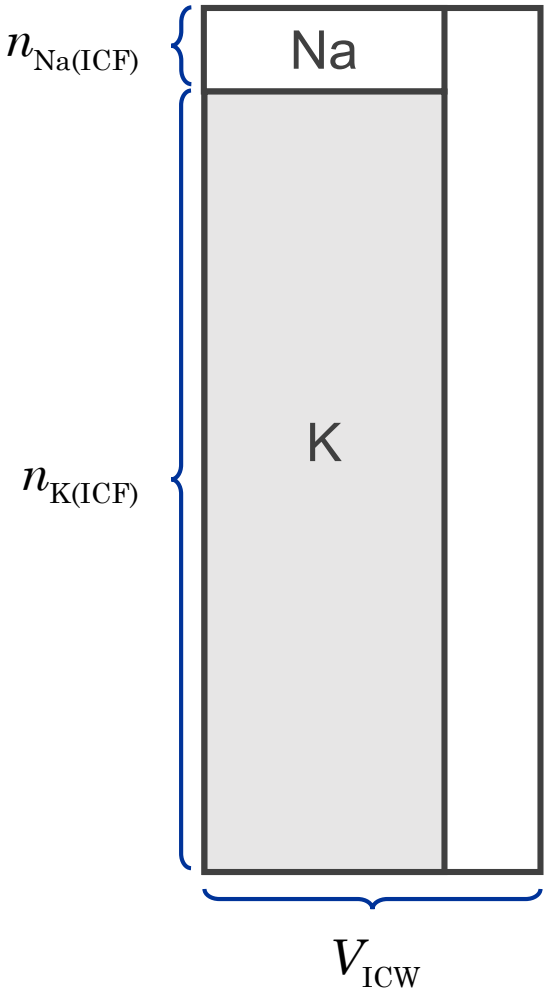

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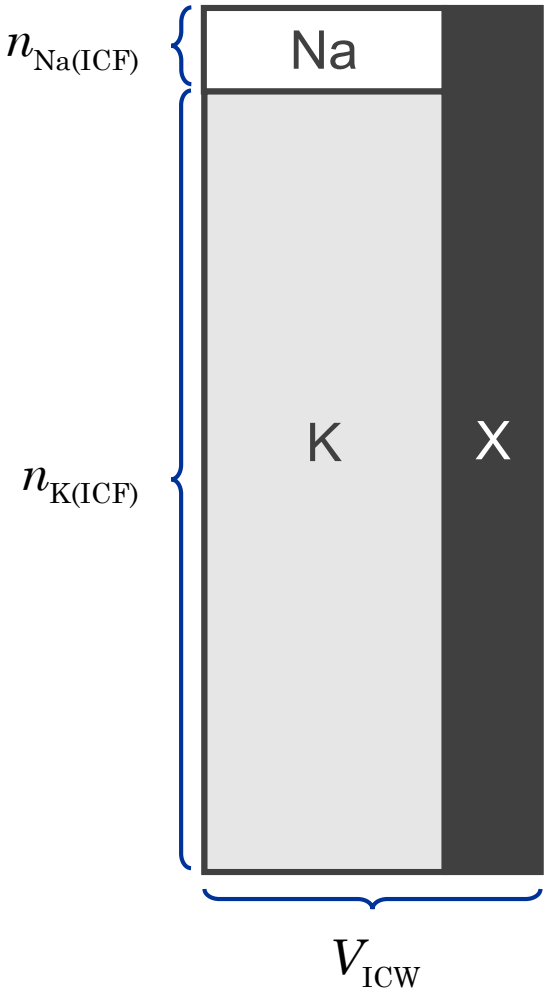

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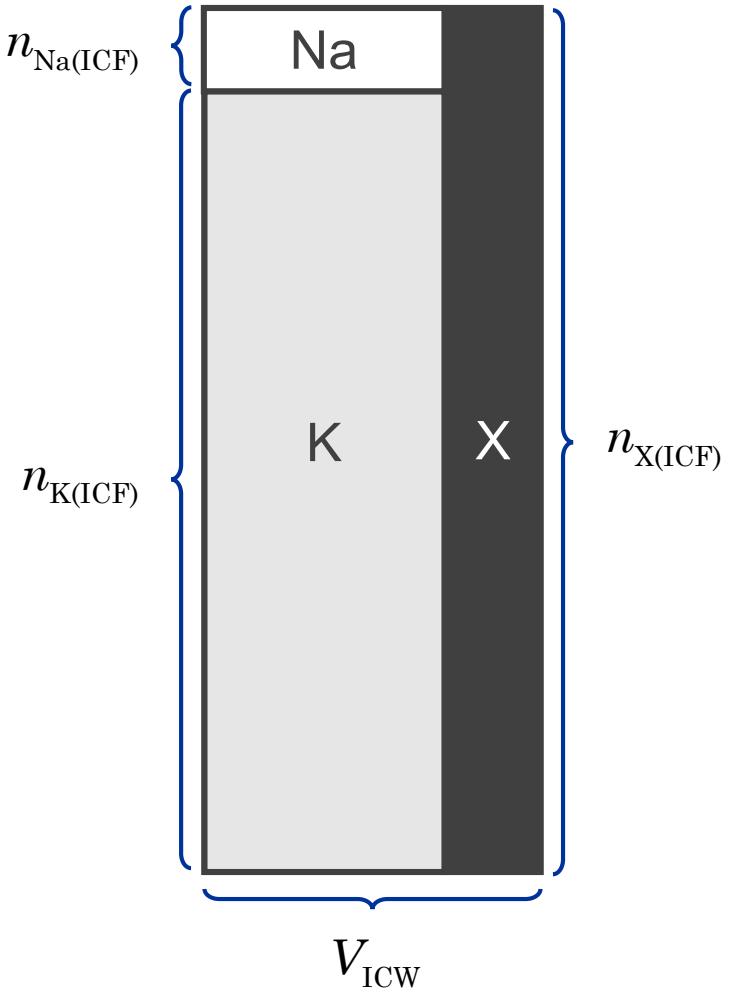

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Quantitative Nephrology III: The Edelman Equation

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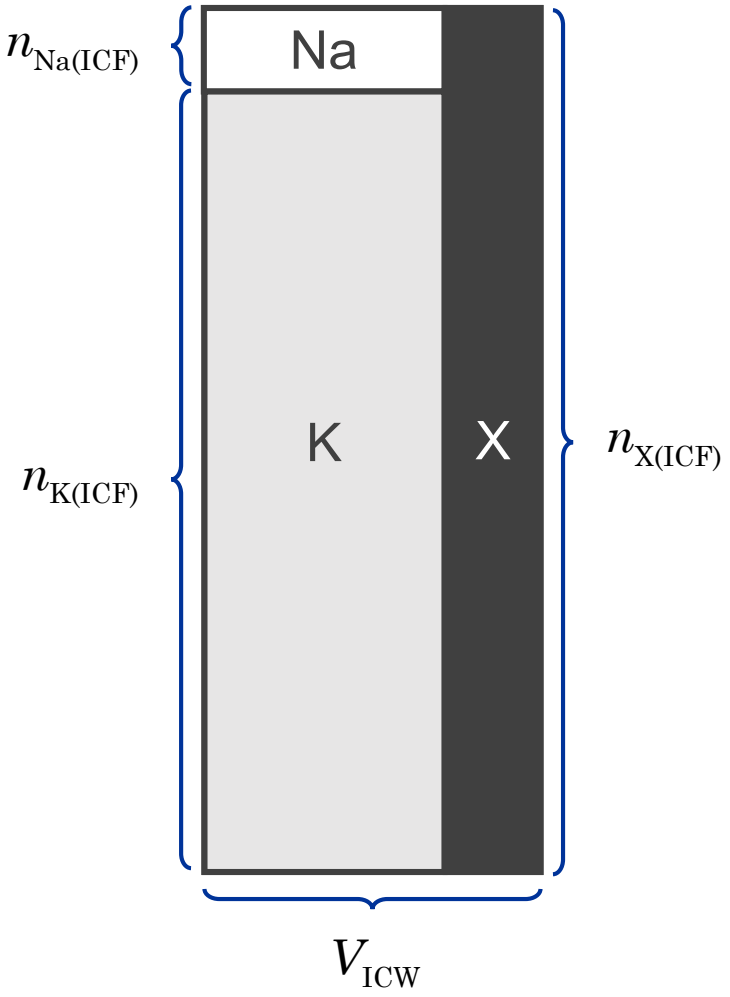

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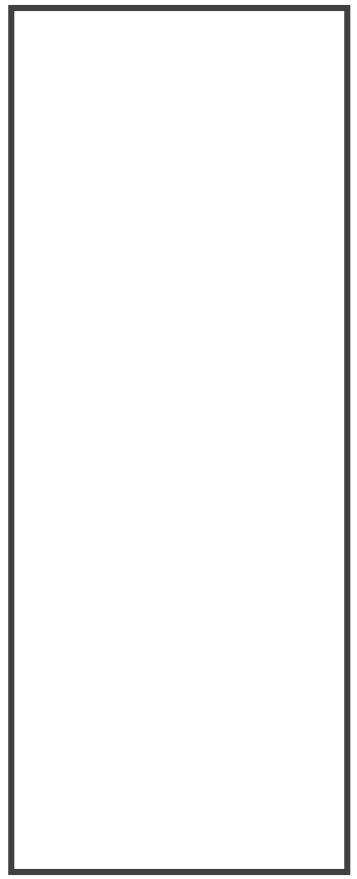

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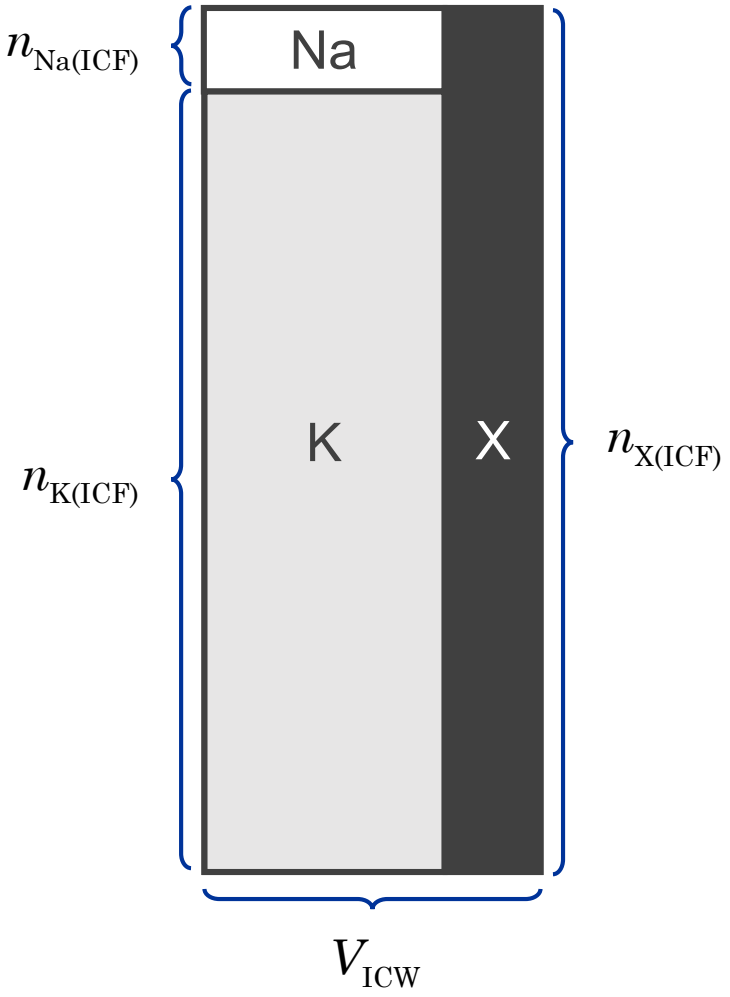

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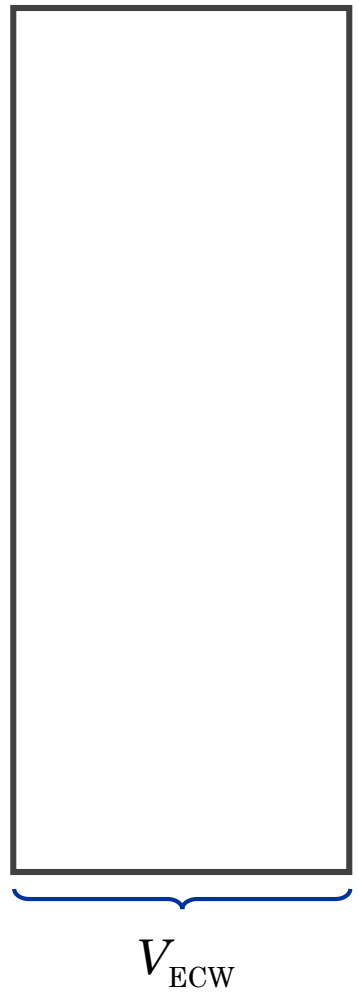

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Specific fluid compartments: ICF and ECF

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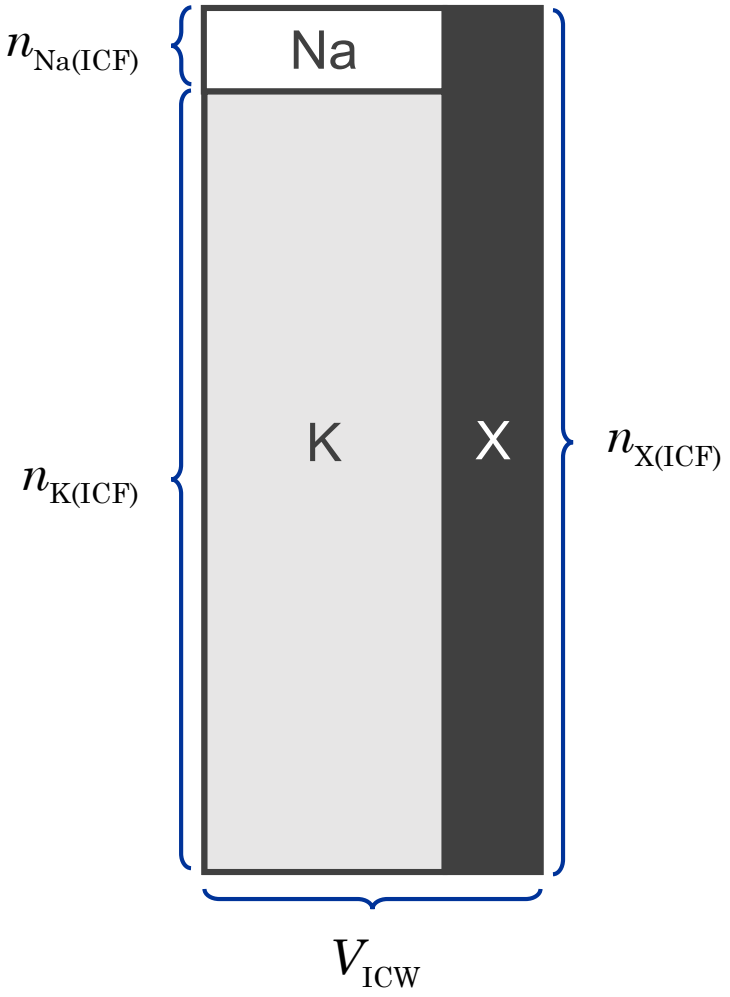

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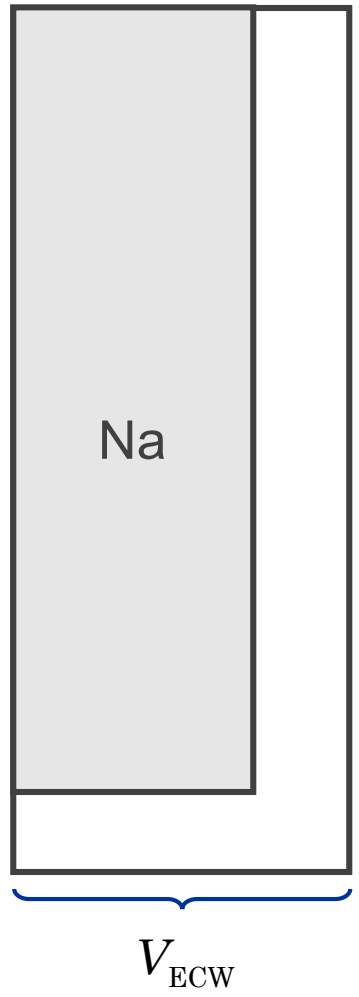

Quantitative Nephrology III: The Edelman Equation

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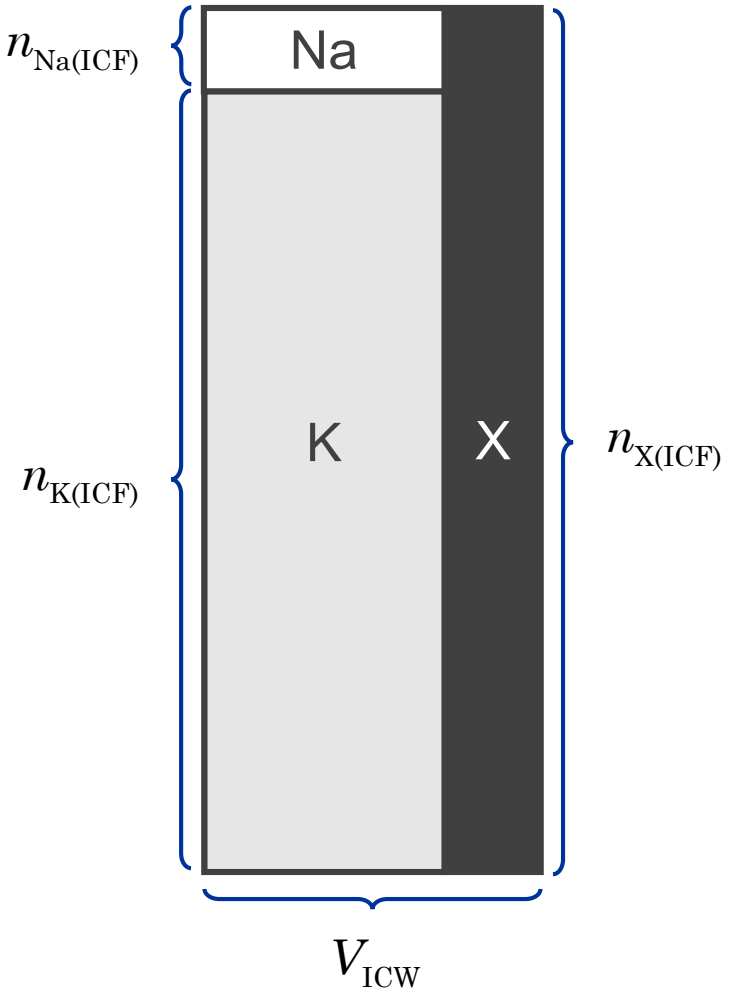

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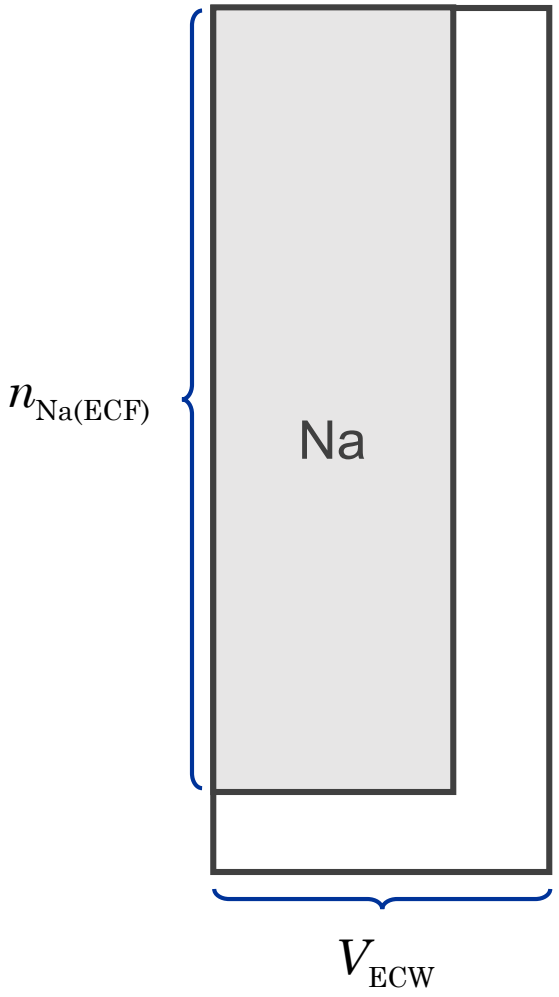

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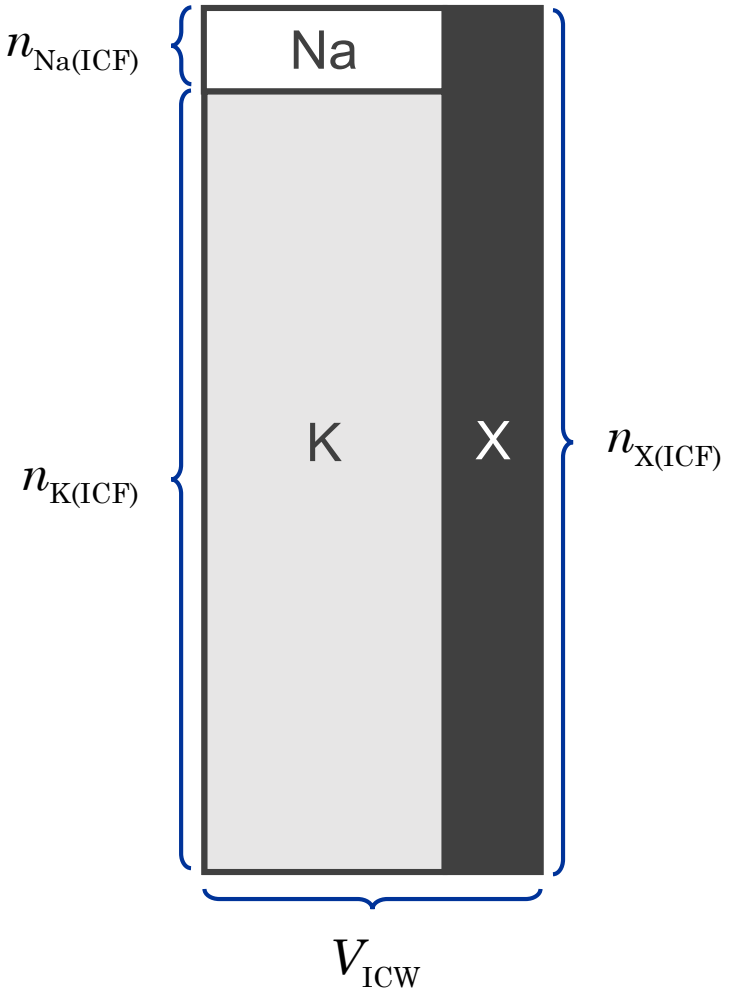

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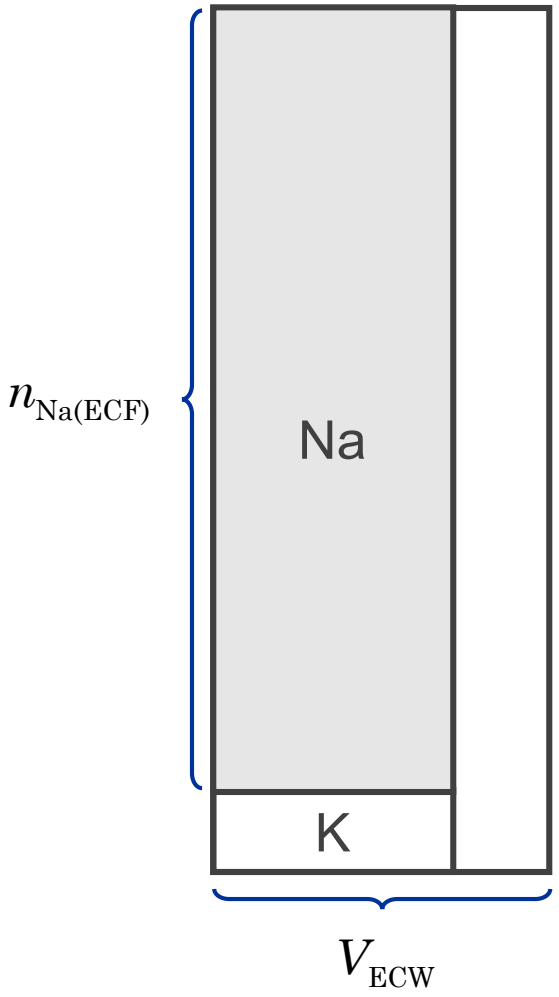

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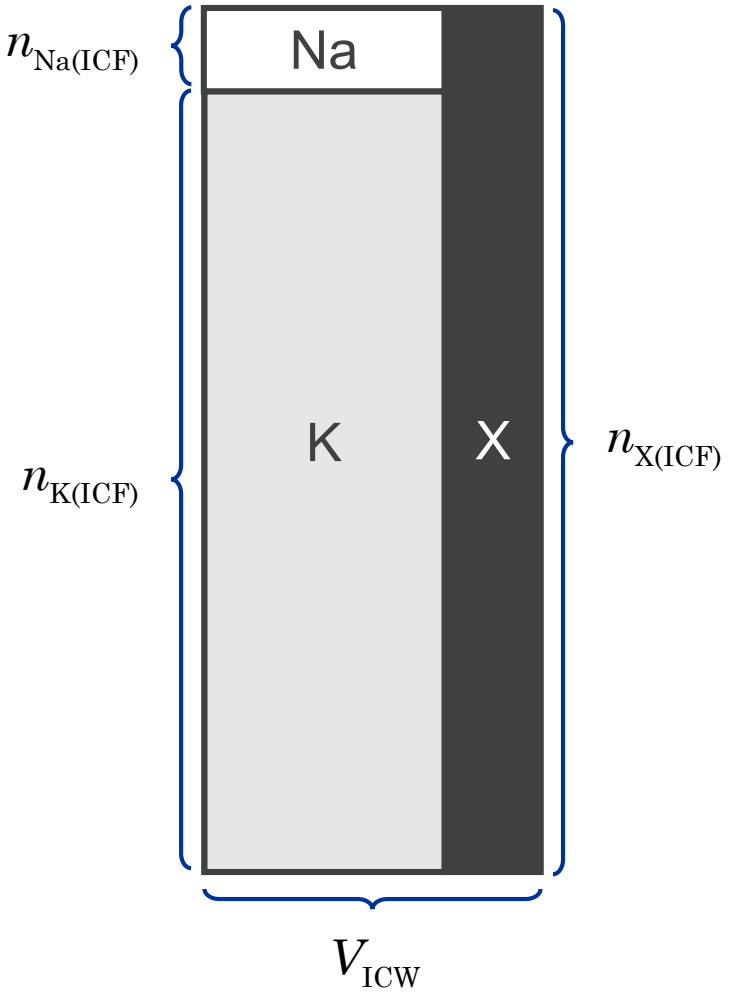

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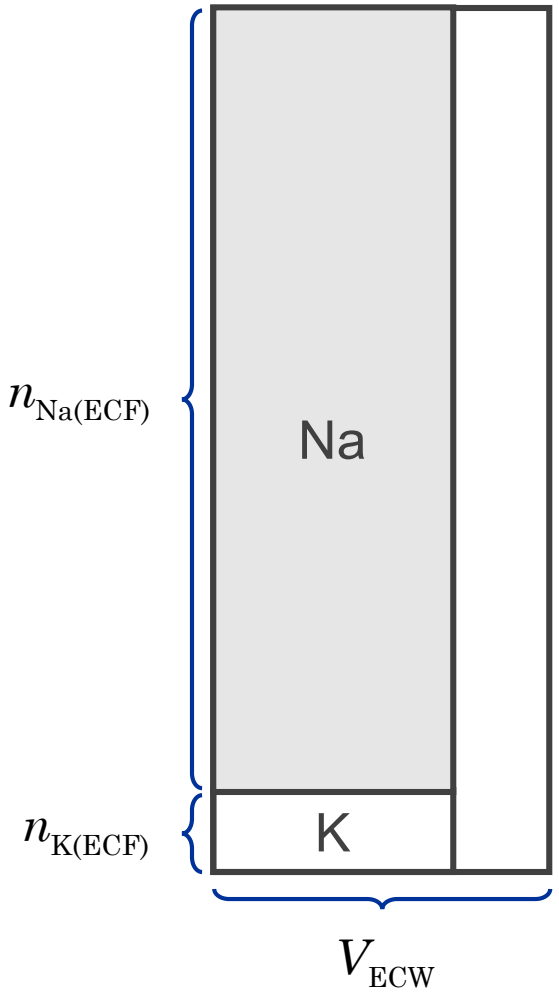

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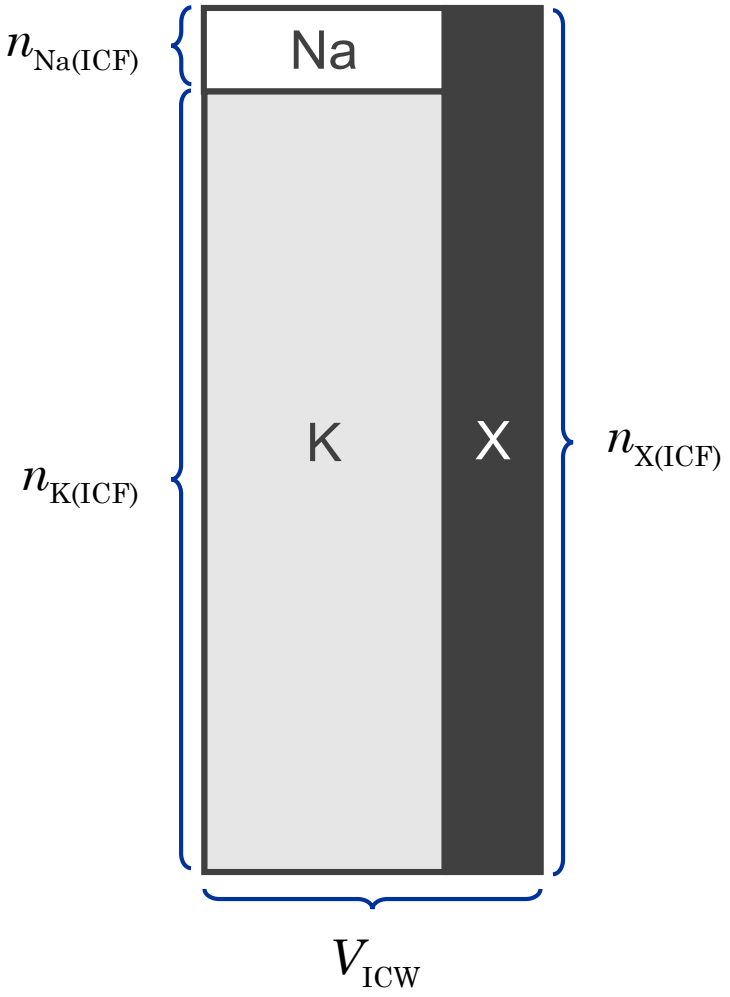

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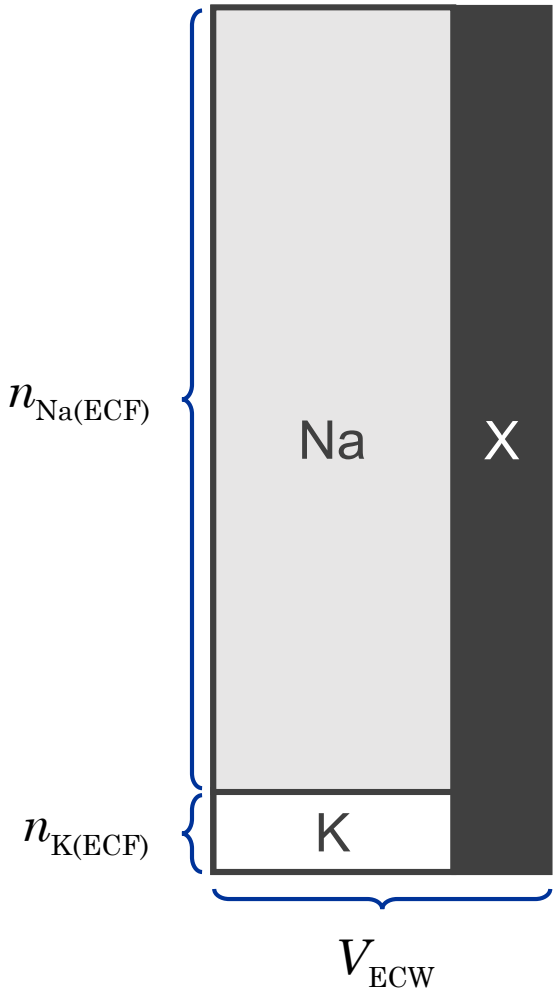

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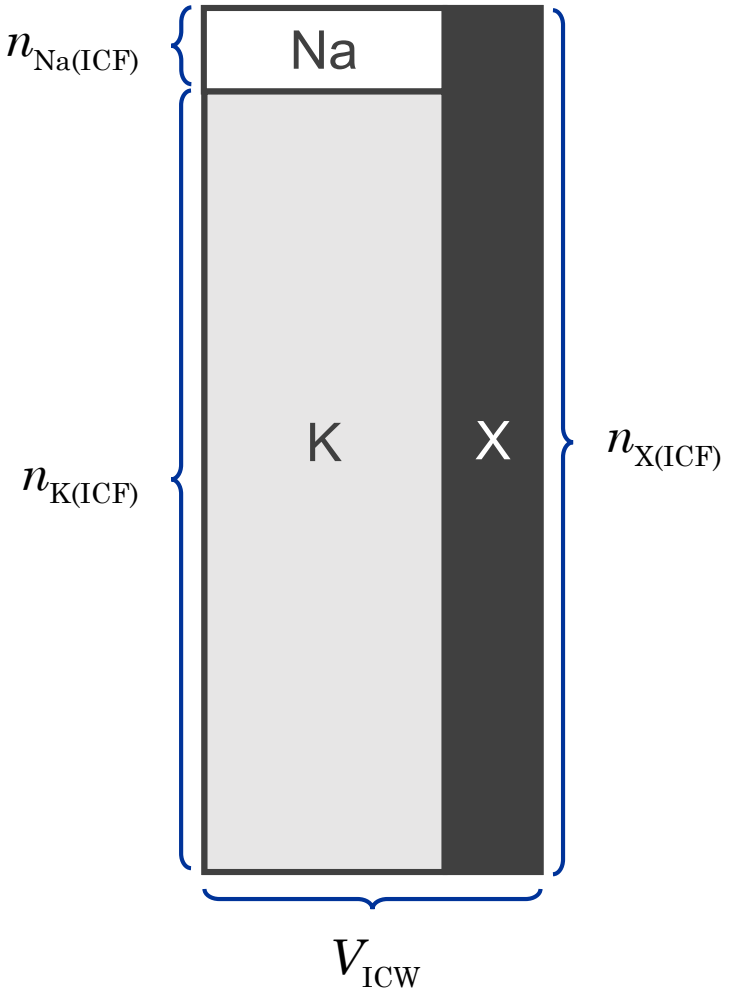

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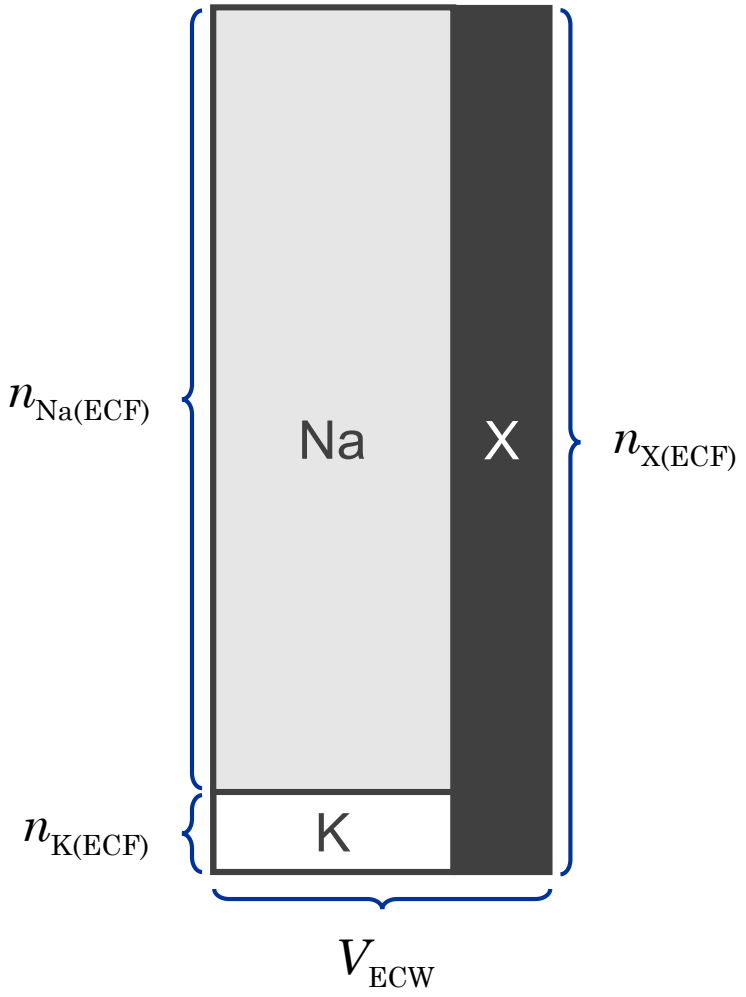

Quantitative Nephrology III: The Edelman Equation

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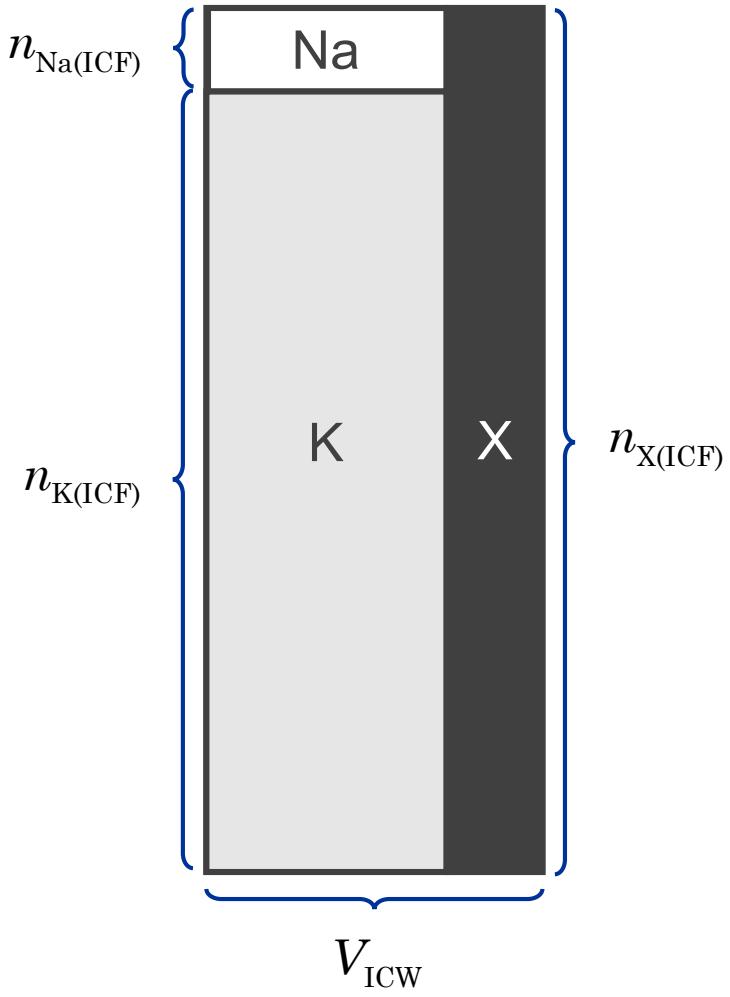
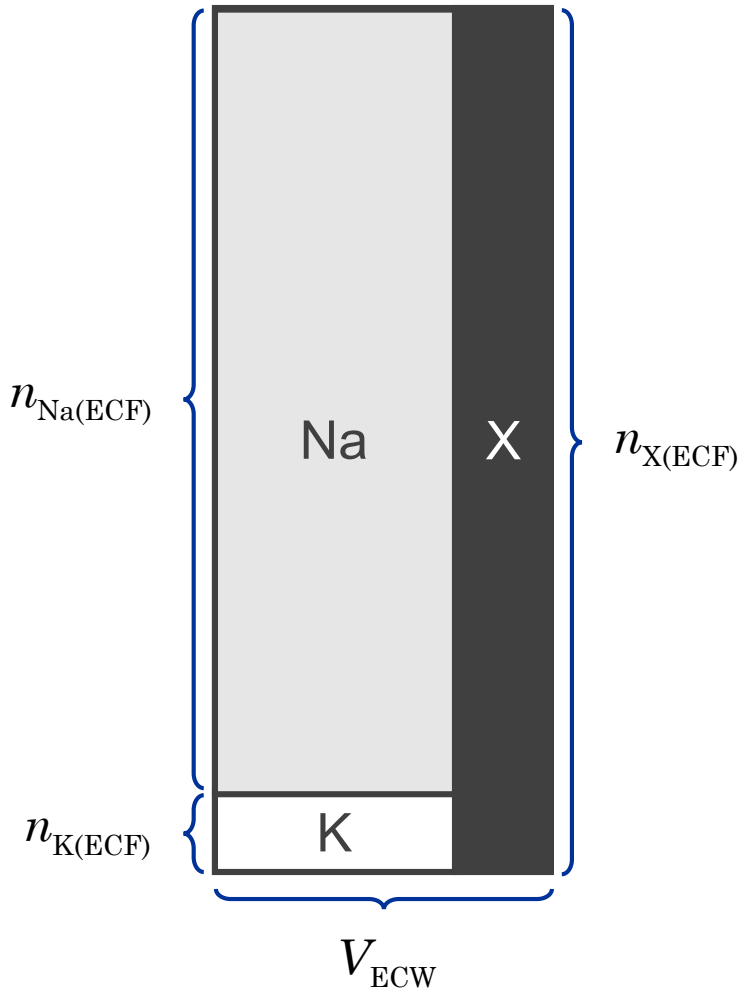


Extracellular fluid (ECF)



Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: ICF and ECF

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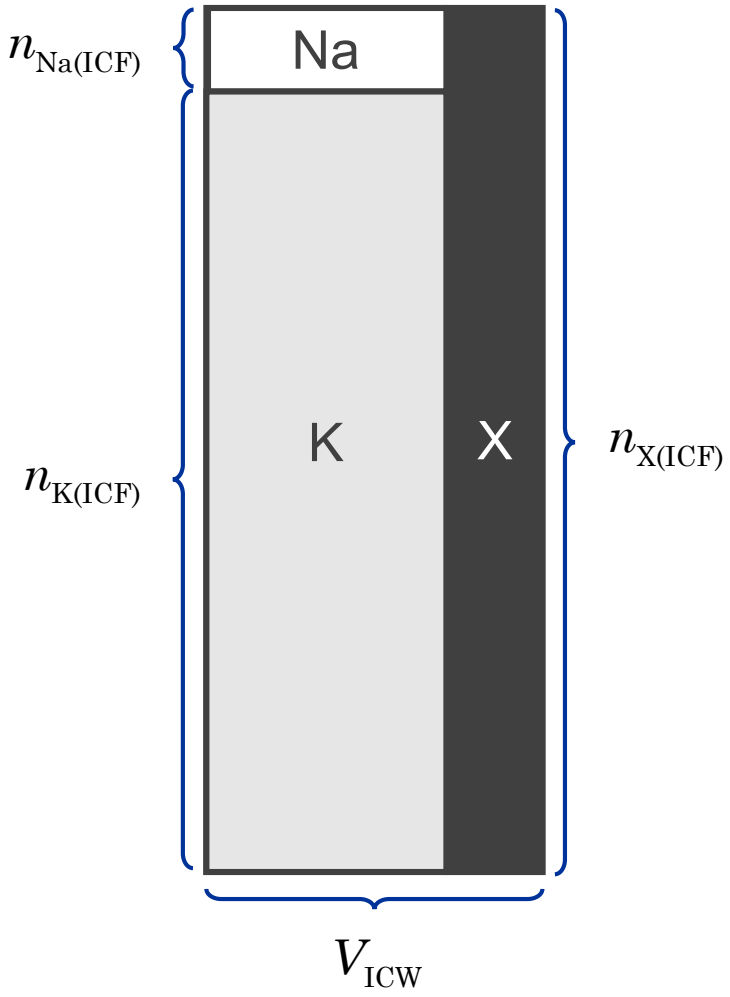
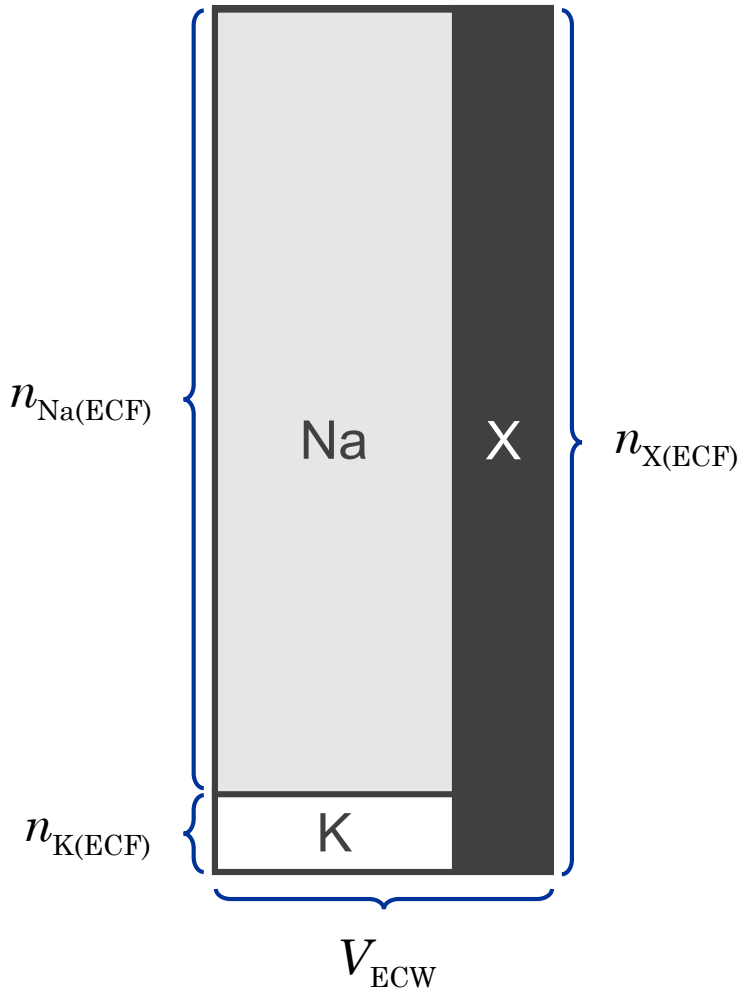


$$[Na]_{ICF} = \frac{n_{Na(ICF)}}{V_{ICW}}$$

$$[K]_{ICF} = \frac{n_{K(ICF)}}{V_{ICW}}$$

$$[X]_{ICF} = \frac{n_{X(ICF)}}{V_{ICW}}$$

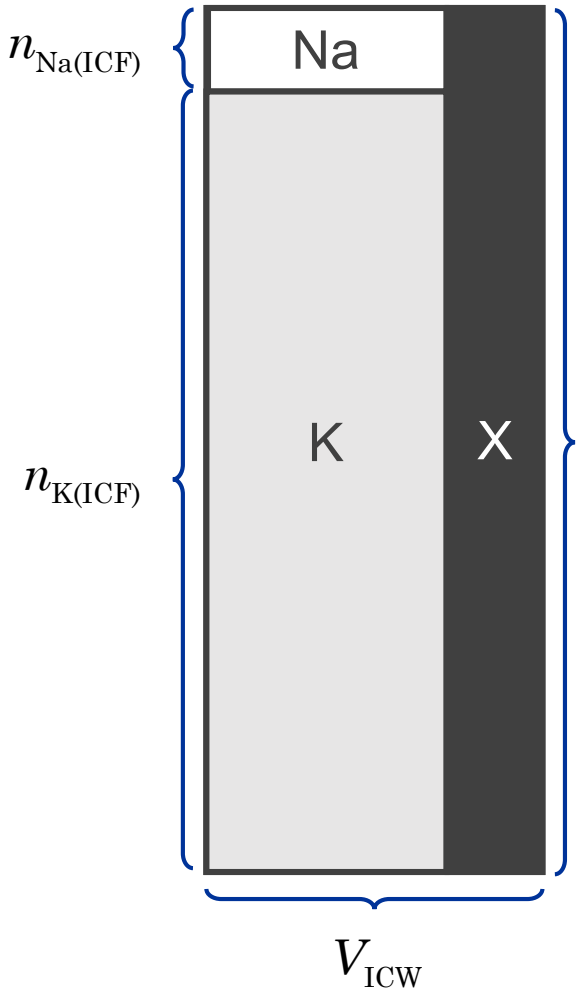
Extracellular fluid (ECF)



Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: ICF and ECF

Intracellular fluid (ICF)



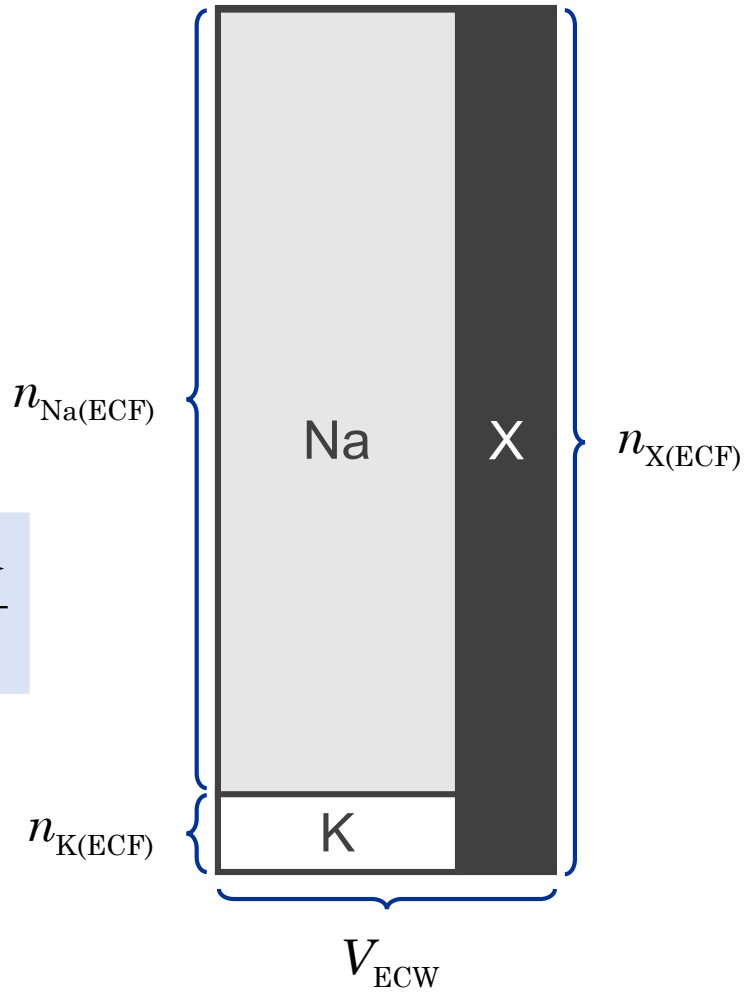
$$[Na]_{ICF} = \frac{n_{Na(ICF)}}{V_{ICW}}$$

$$[K]_{ICF} = \frac{n_{K(ICF)}}{V_{ICW}}$$

$$[X]_{ICF} = \frac{n_{X(ICF)}}{V_{ICW}}$$

$$[osm]_{ICF} = \frac{2\left\{n_{Na(ICF)} + n_{K(ICF)}\right\}}{V_{ICW}}$$

Extracellular fluid (ECF)



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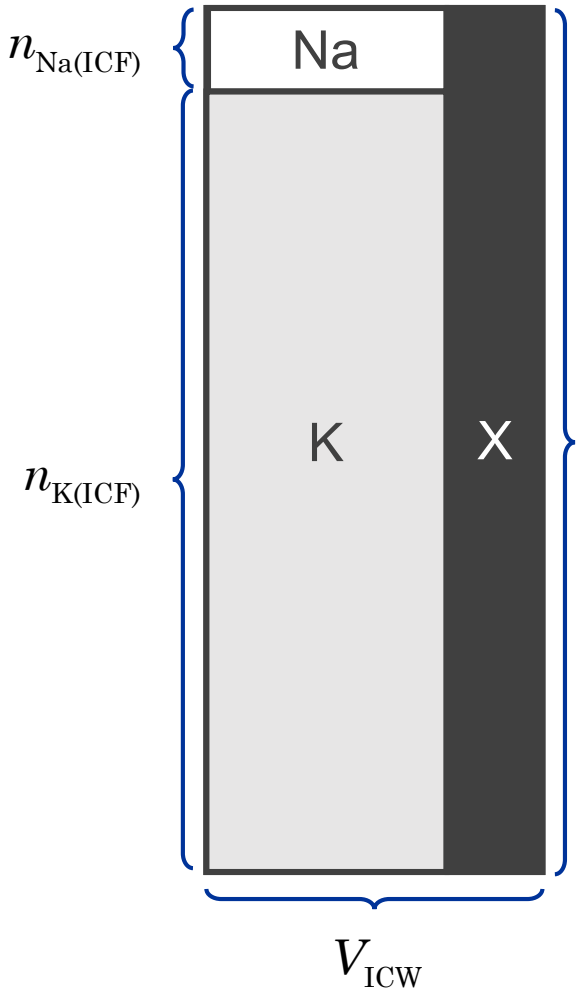

$$[Na]_{ICF} = \frac{n_{Na(ICF)}}{V_{ICW}}$$

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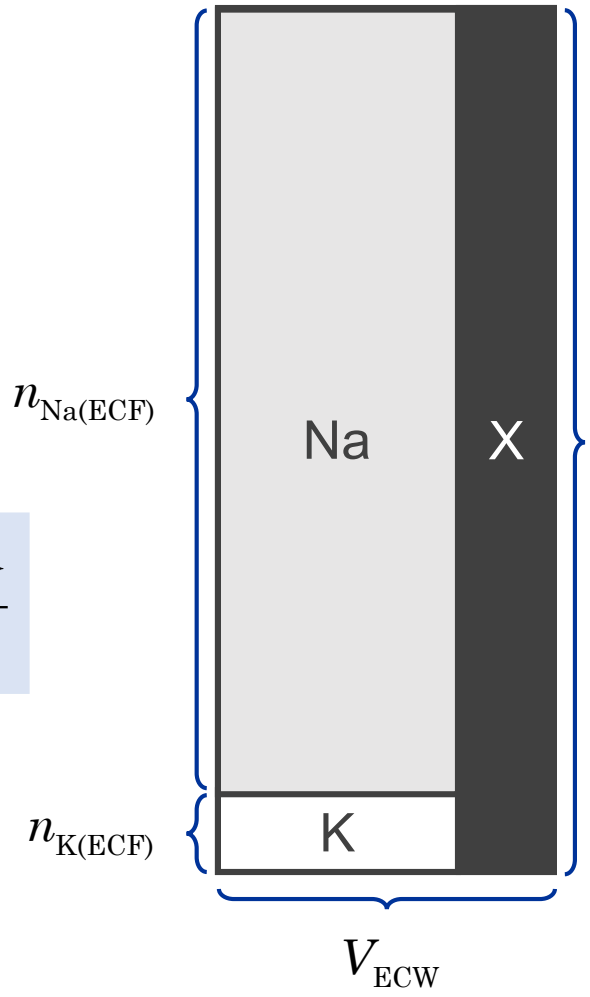
$$[osm]_{ICF} = \frac{2\left\{n_{Na(ICF)} + n_{K(ICF)}\right\}}{V_{ICW}}$$

Extracellular fluid (ECF)



$$[Na]_{ECF} = \frac{n_{Na(ECF)}}{V_{ECW}}$$

$$[K]_{ECF} = \frac{n_{K(ECF)}}{V_{ECW}}$$

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Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: ICF and ECF

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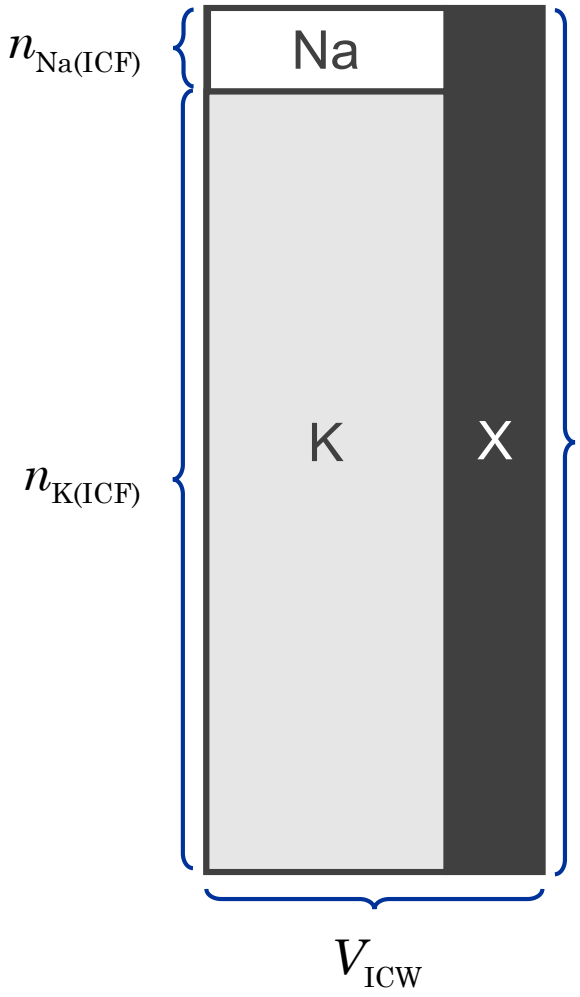

$$[Na]_{ICF} = \frac{n_{Na(ICF)}}{V_{ICW}}$$

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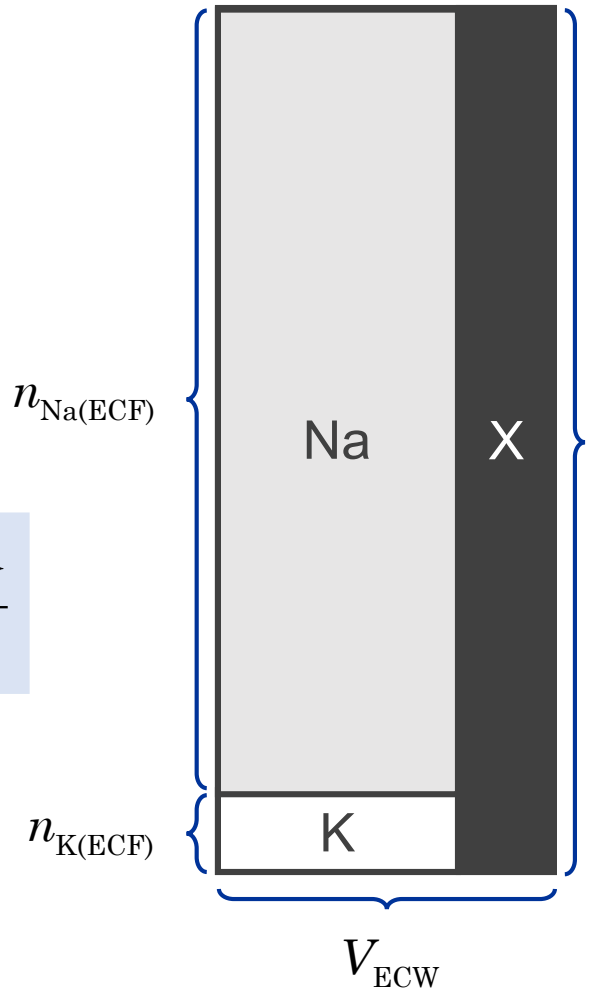
Extracellular fluid (ECF)



$$[Na]_{ECF} = \frac{n_{Na(ECF)}}{V_{ECW}}$$

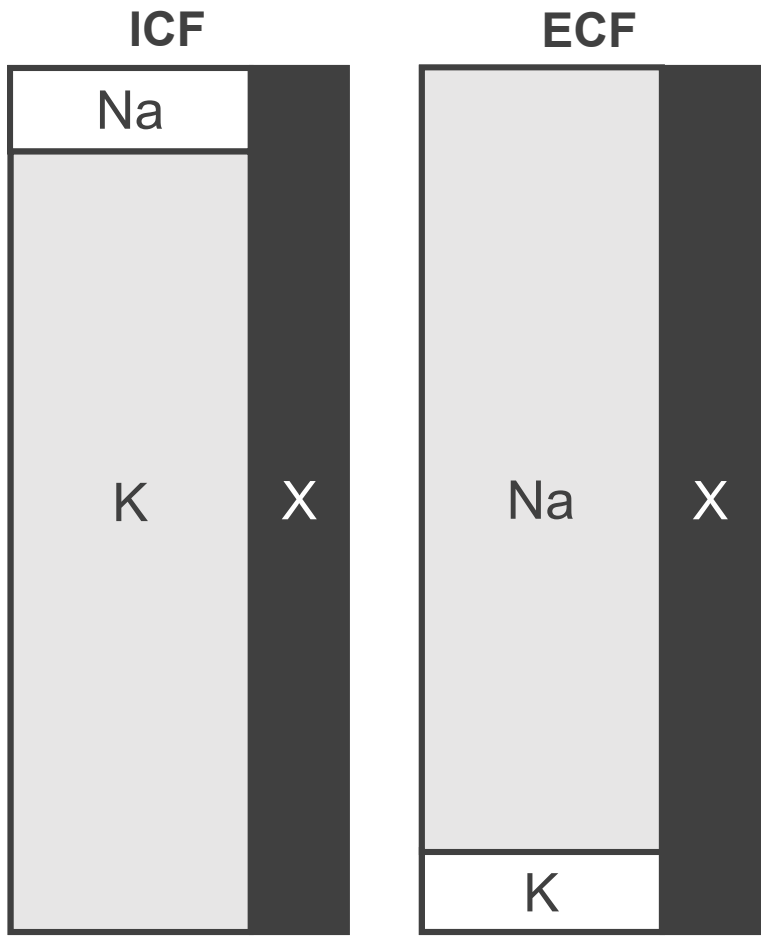
$$[K]_{ECF} = \frac{n_{K(ECF)}}{V_{ECW}}$$

$$[X]_{ECF} = \frac{n_{X(ECF)}}{V_{ECW}}$$

$$[osm]_{ECF} = \frac{2\left\{n_{Na(ECF)} + n_{K(ECF)}\right\}}{V_{ECW}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



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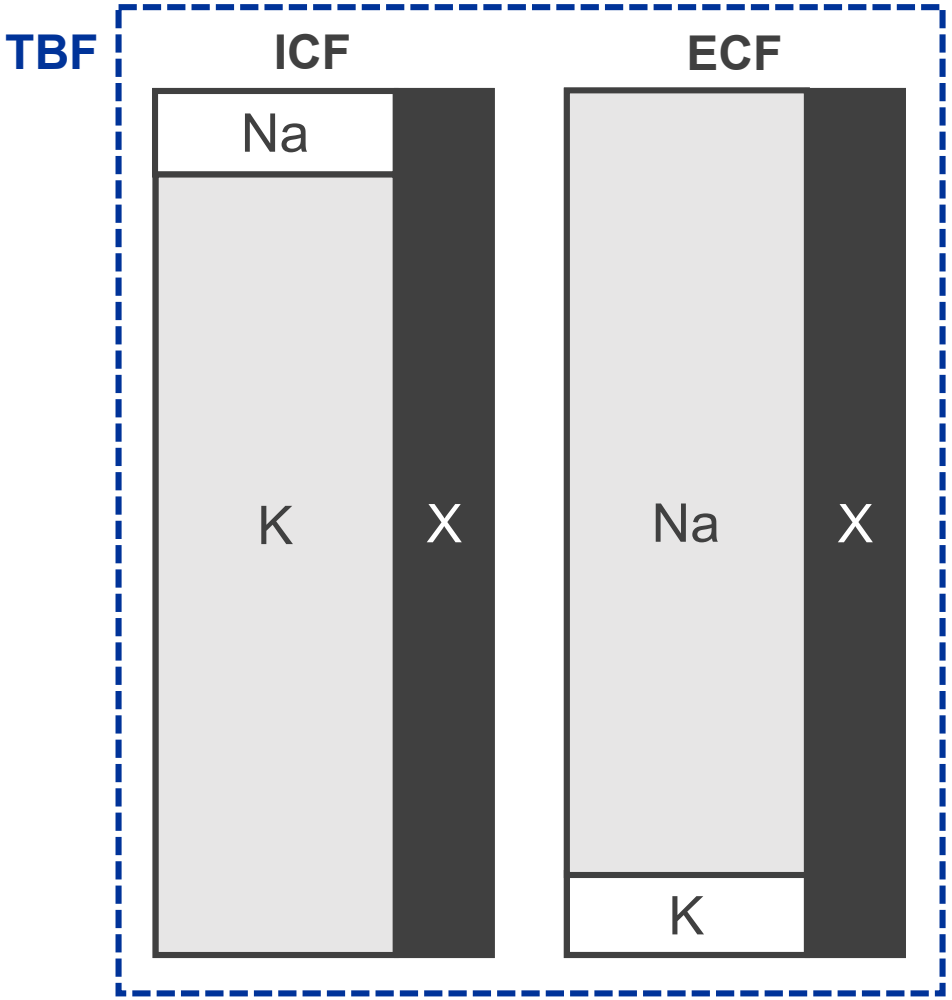

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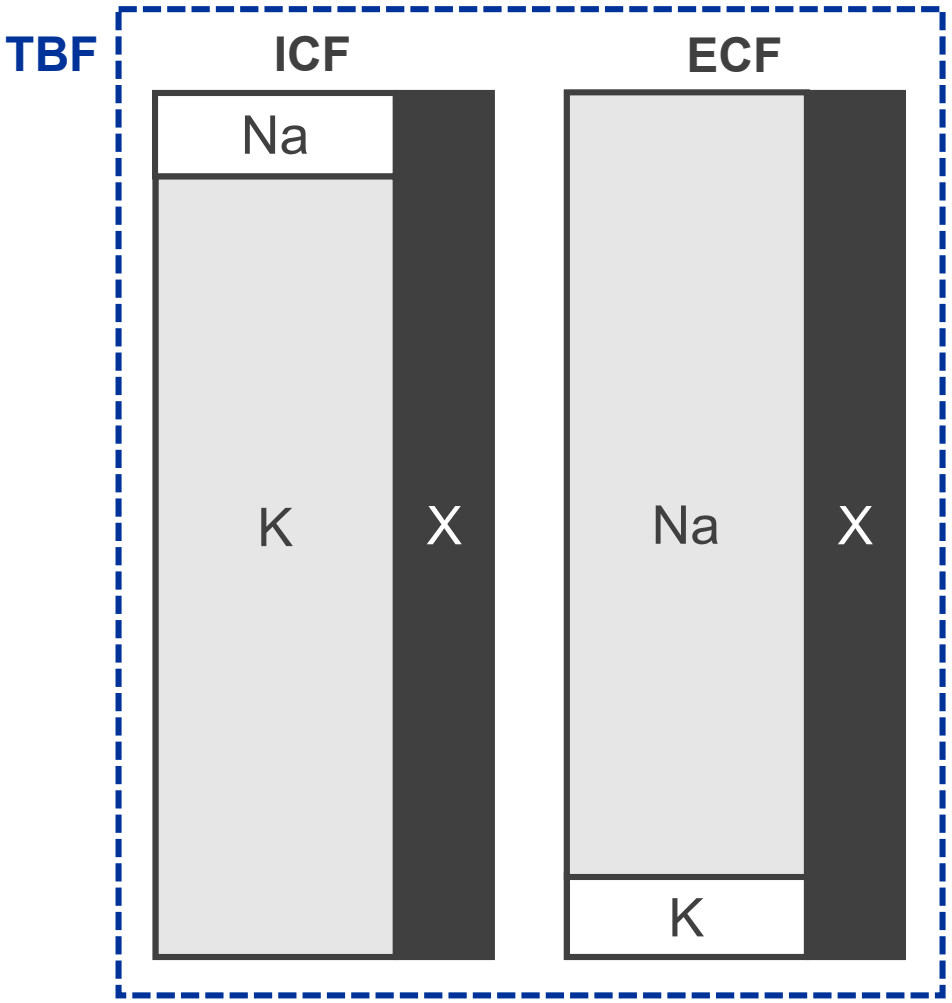
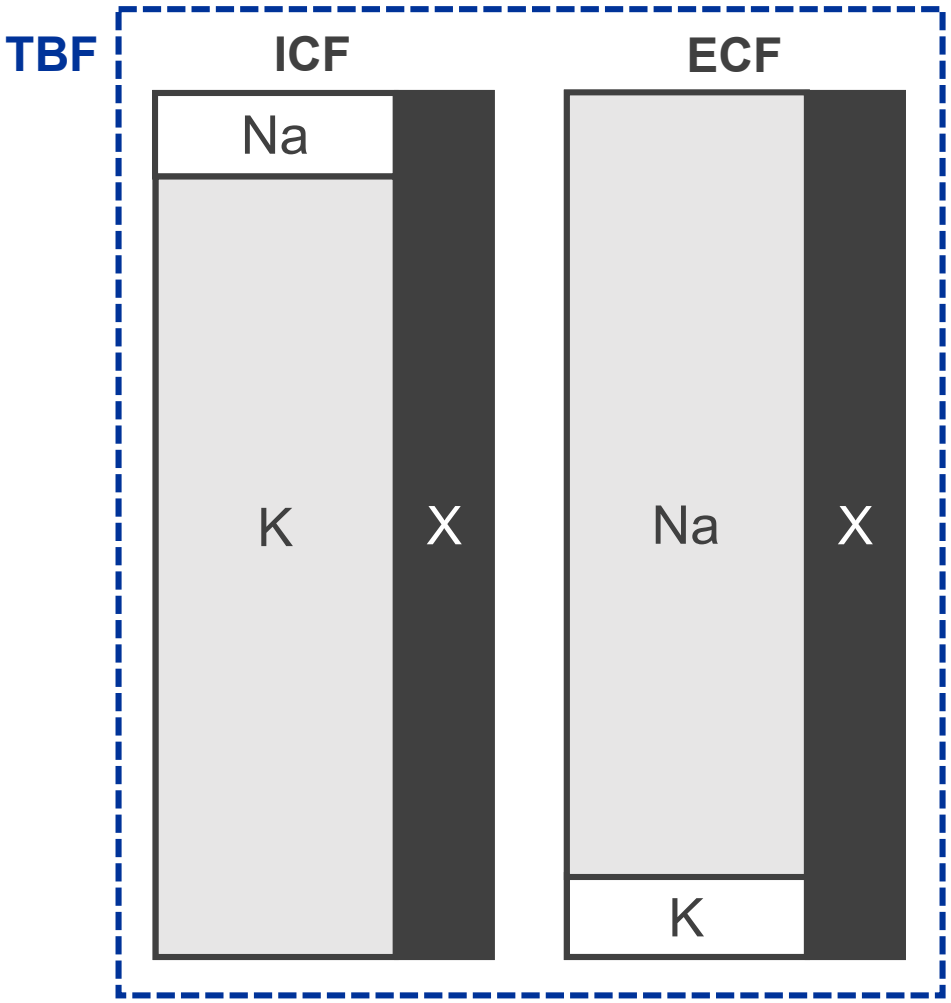


$$V_{TBW} = V_{ICW} + V_{ECW}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF

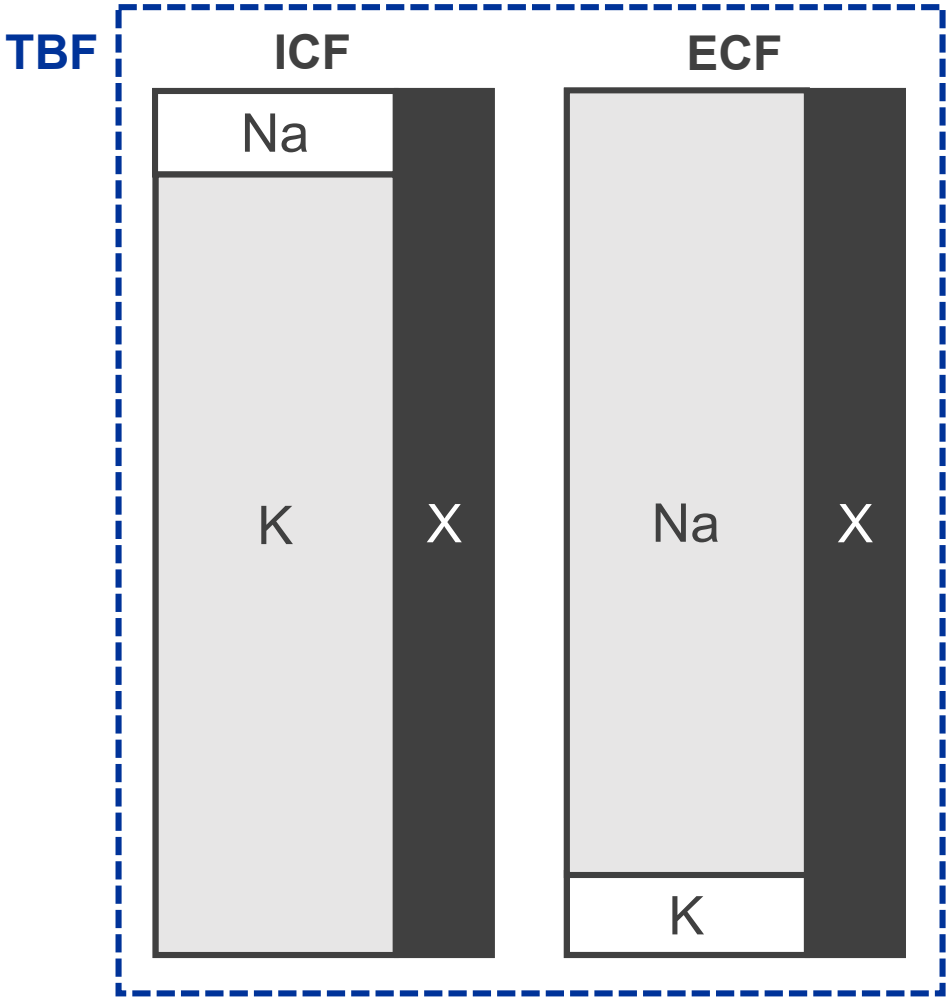


$$n_{\mathrm{Na(TBF)}}$$

$$V_{\mathrm{TBW}} = V_{\mathrm{ICW}} + V_{\mathrm{ECW}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



$$n_{\mathrm{Na(TBF)}} = n_{\mathrm{Na(ICF)}} + n_{\mathrm{Na(ECF)}}$$

$$V_{\mathrm{TBW}} = V_{\mathrm{ICW}} + V_{\mathrm{ECW}}$$

Quantitative Nephrology III: The Edelman Equation

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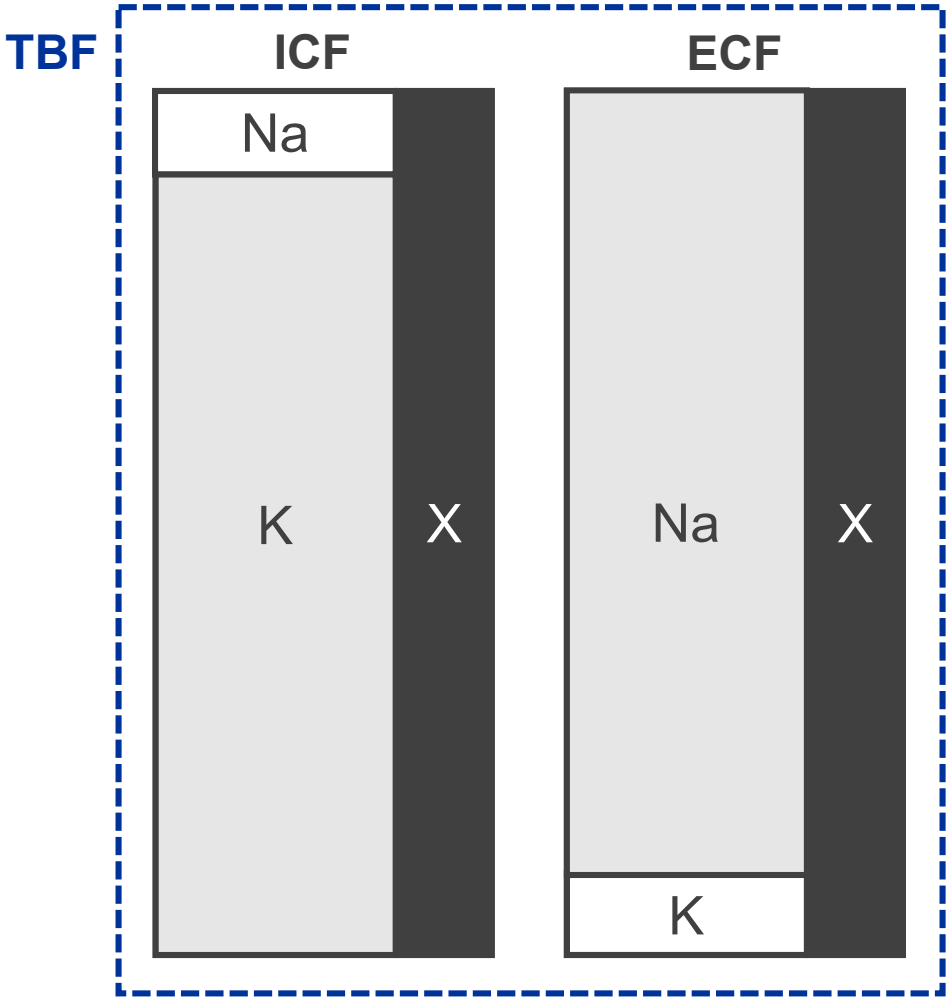


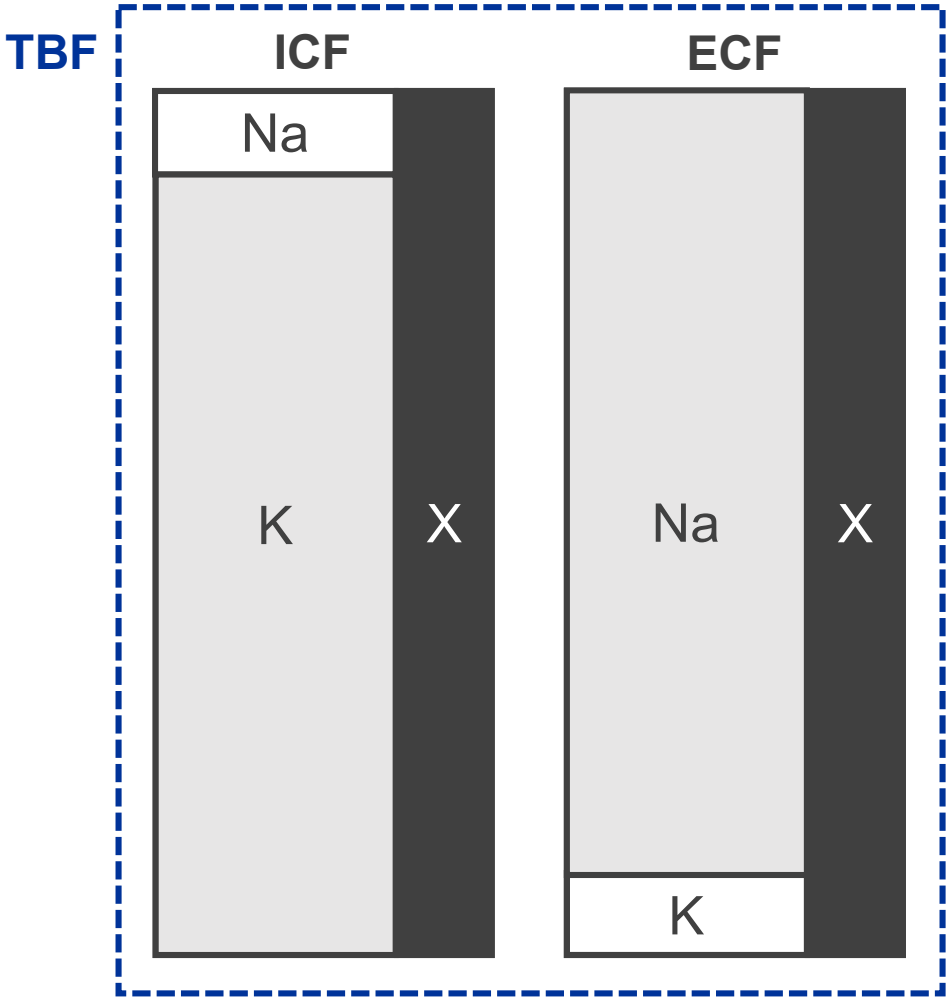
$$V_{TBW} = V_{ICW} + V_{ECW}$$

$$n_{Na(TBF)} = n_{Na(ICF)} + n_{Na(ECF)}$$

$$n_{K(TBF)}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



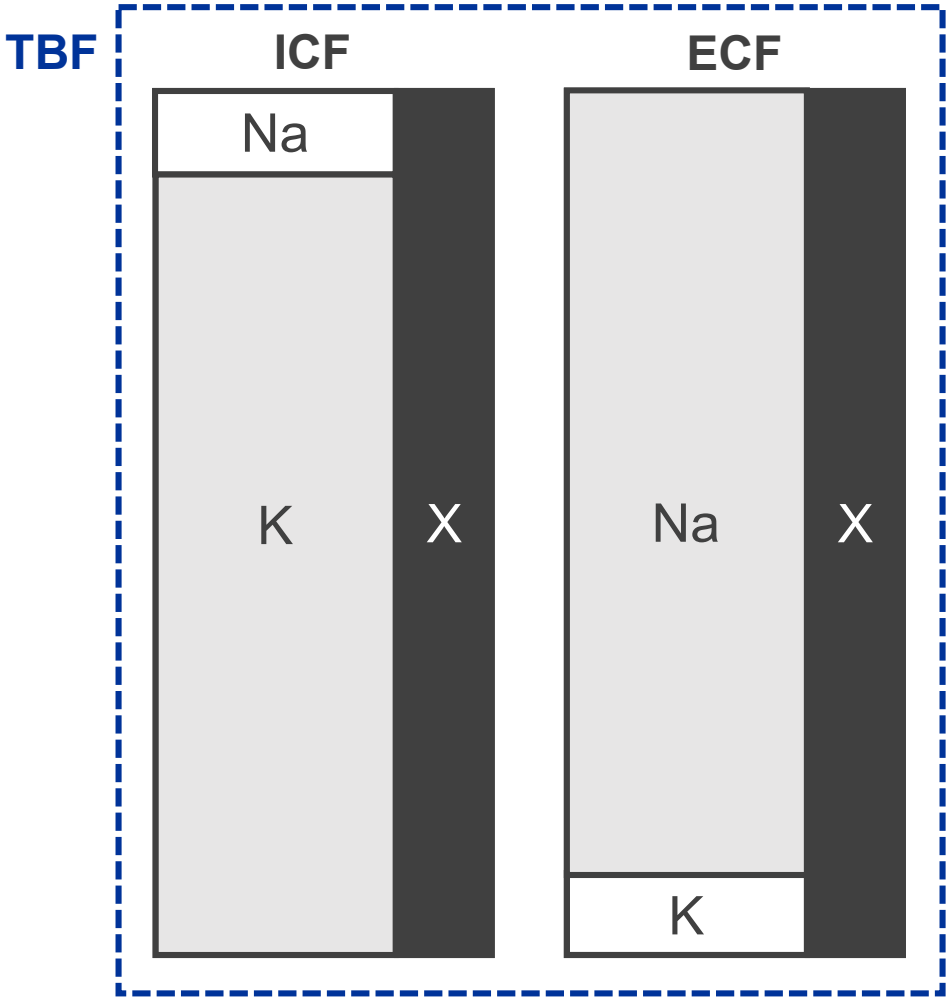
$$V_{TBW} = V_{ICW} + V_{ECW}$$

$$n_{Na(TBF)} = n_{Na(ICF)} + n_{Na(ECF)}$$

$$n_{K(TBF)} = n_{K(ICF)} + n_{K(ECF)}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



$$V_{TBW} = V_{ICW} + V_{ECW}$$

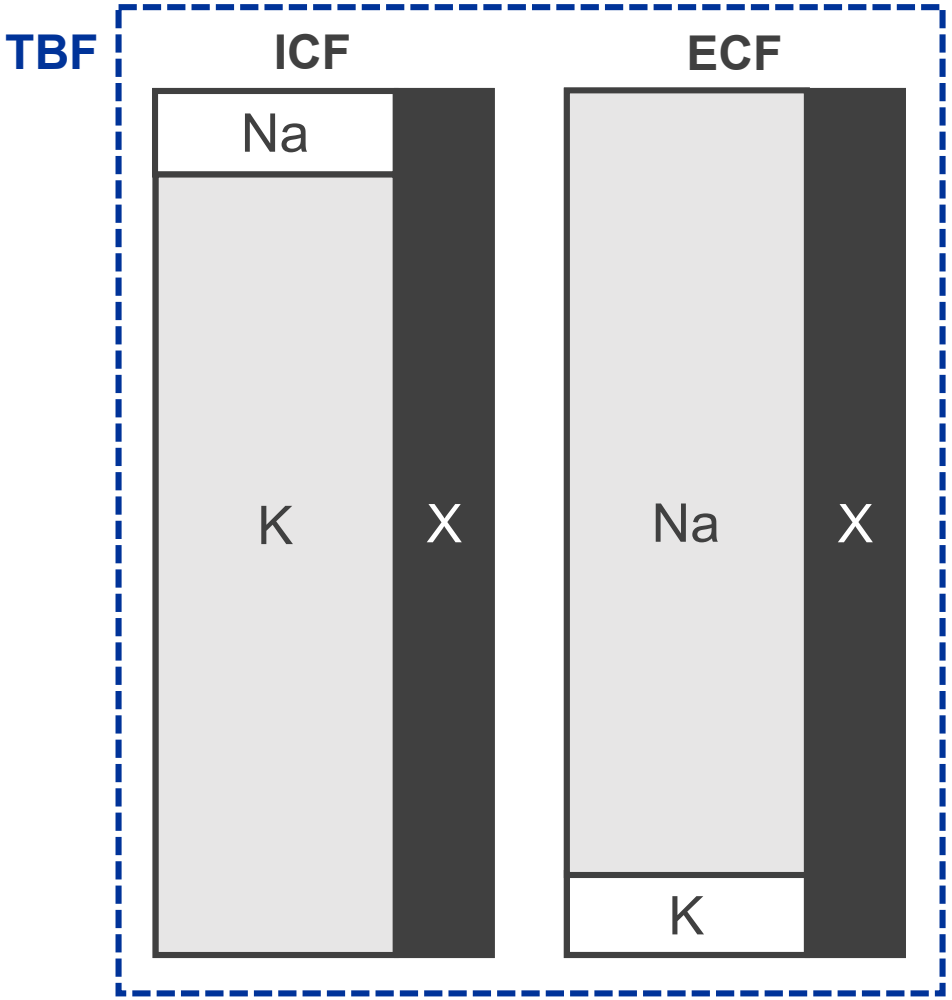
$$n_{Na(TBF)} = n_{Na(ICF)} + n_{Na(ECF)}$$

$$n_{K(TBF)} = n_{K(ICF)} + n_{K(ECF)}$$

$$n_{X(TBF)}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



$$n_{\mathrm{Na(TBF)}} = n_{\mathrm{Na(ICF)}} + n_{\mathrm{Na(ECF)}}$$

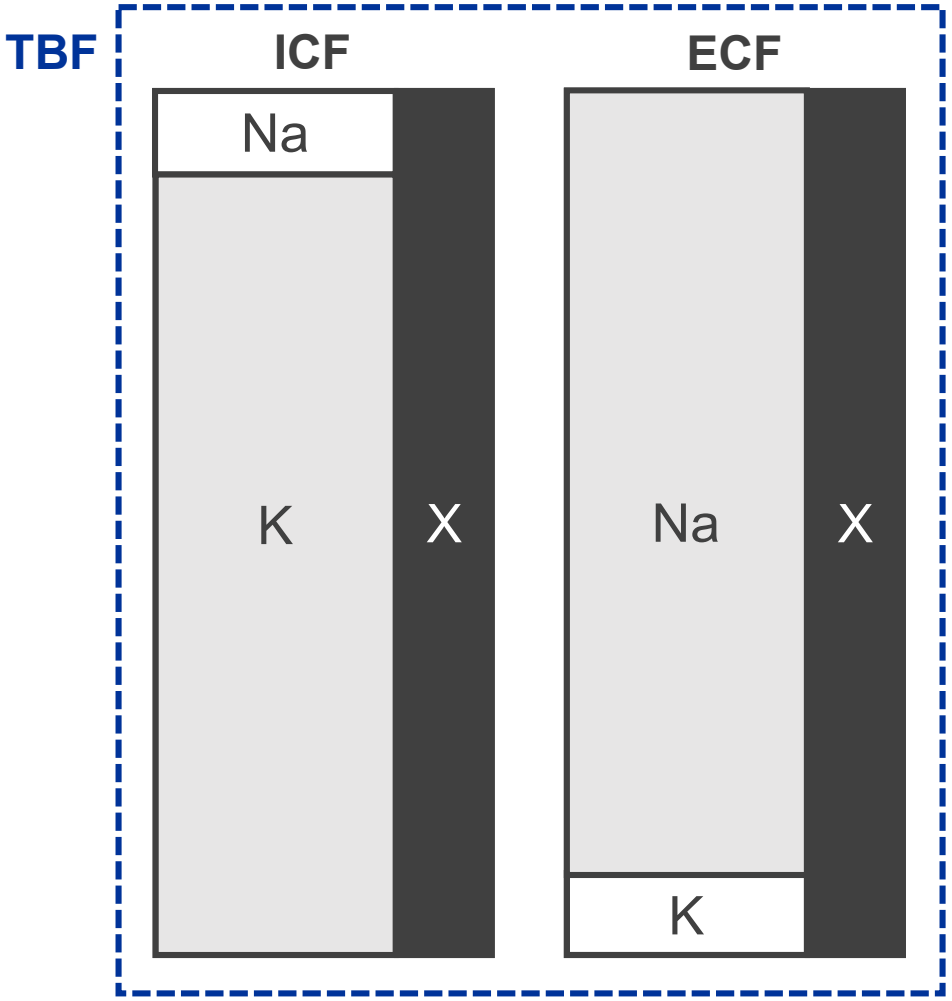
$$n_{\mathrm{K(TBF)}} = n_{\mathrm{K(ICF)}} + n_{\mathrm{K(ECF)}}$$

$$n_{\mathrm{X(TBF)}} = n_{\mathrm{X(ICF)}} + n_{\mathrm{X(ECF)}}$$

$$V_{\mathrm{TBW}} = V_{\mathrm{ICW}} + V_{\mathrm{ECW}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



$$V_{TBW} = V_{ICW} + V_{ECW}$$

$$n_{Na(TBF)} = n_{Na(ICF)} + n_{Na(ECF)}$$

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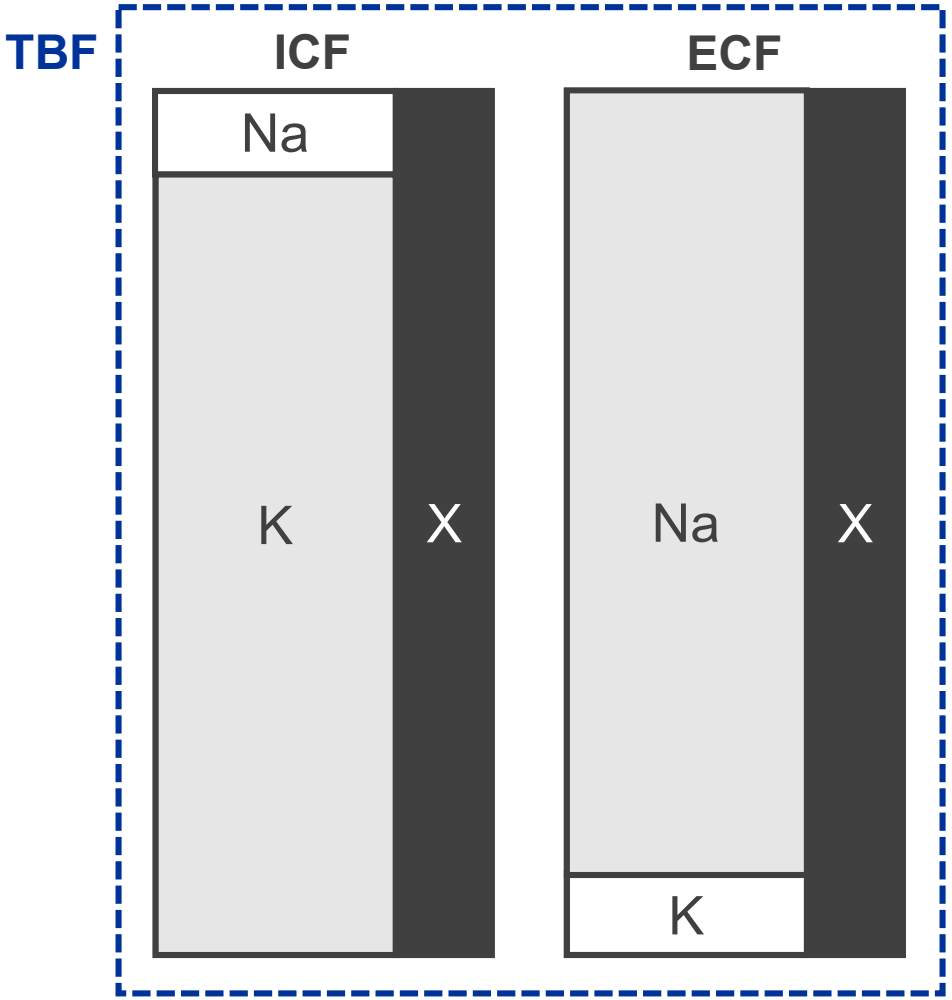
$$n_{X(TBF)} = n_{X(ICF)} + n_{X(ECF)}$$

$$= \left\{n_{Na(ICF)} + n_{K(ICF)}\right\} + \left\{n_{Na(ECF)} + n_{K(ECF)}\right\}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



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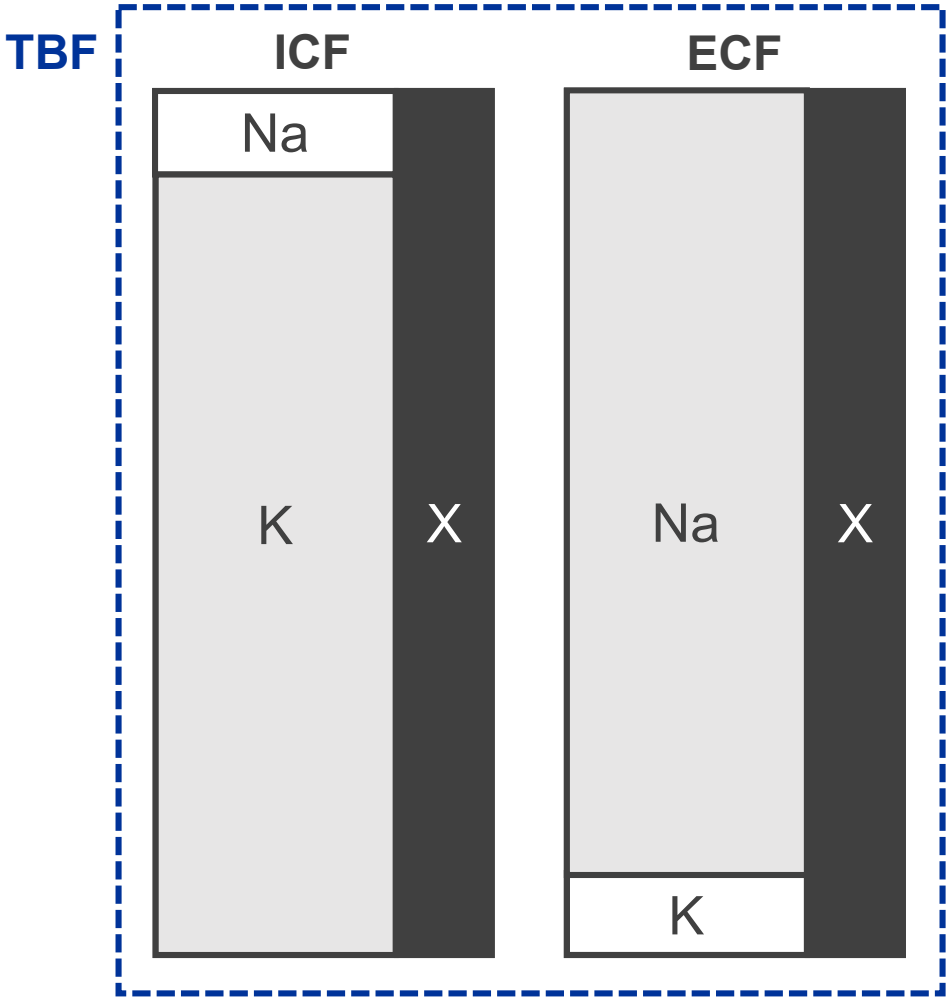
Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



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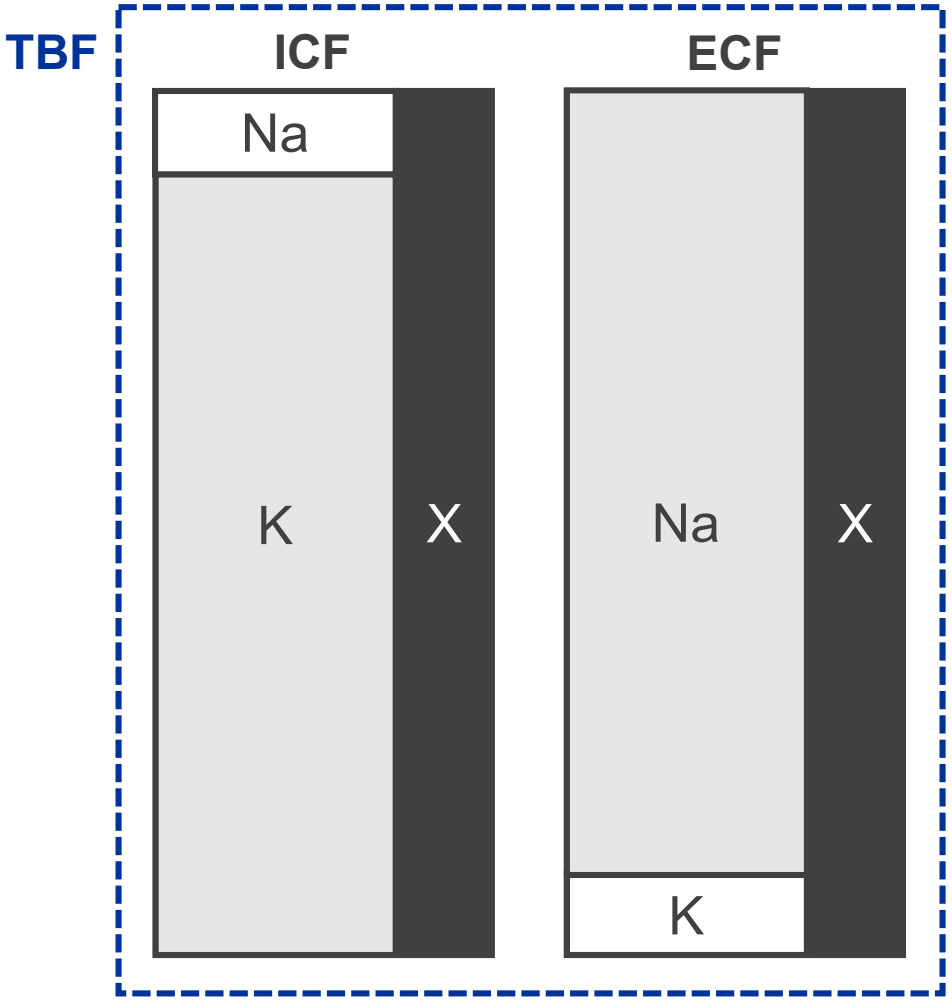
Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



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$$= \{n_{Na(ICF)} + n_{Na(ECF)}\} + \{n_{K(ICF)} + n_{K(ECF)}\}$$

$$n_{X(TBF)} = n_{Na(TBF)} + n_{K(TBF)}$$

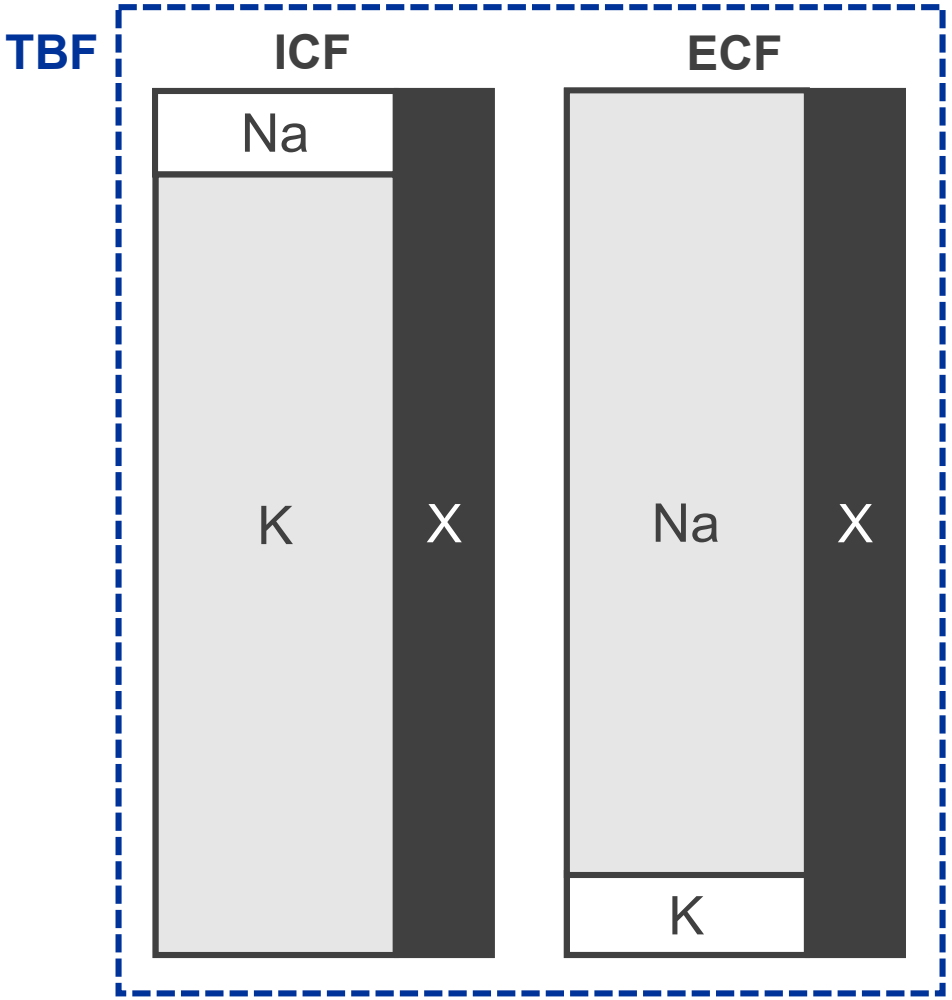
$$[Na]_{TBF} = \frac{n_{Na(TBF)}}{V_{TBW}} = \frac{n_{Na(ICF)} + n_{Na(ECF)}}{V_{ICW} + V_{ECW}}$$

$$[K]_{TBF} = \frac{n_{K(TBF)}}{V_{TBW}} = \frac{n_{K(ICF)} + n_{K(ECF)}}{V_{ICW} + V_{ECW}}$$

$$[X]_{TBF} = \frac{n_{X(TBF)}}{V_{TBW}} = \frac{n_{Na(TBF)} + n_{K(TBF)}}{V_{ICW} + V_{ECW}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Total-body fluid (TBF) = ICF + ECF



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$$= \{n_{Na(ICF)} + n_{Na(ECF)}\} + \{n_{K(ICF)} + n_{K(ECF)}\}$$

$$n_{X(TBF)} = n_{Na(TBF)} + n_{K(TBF)}$$

$$[Na]_{TBF} = \frac{n_{Na(TBF)}}{V_{TBW}} = \frac{n_{Na(ICF)} + n_{Na(ECF)}}{V_{ICW} + V_{ECW}}$$

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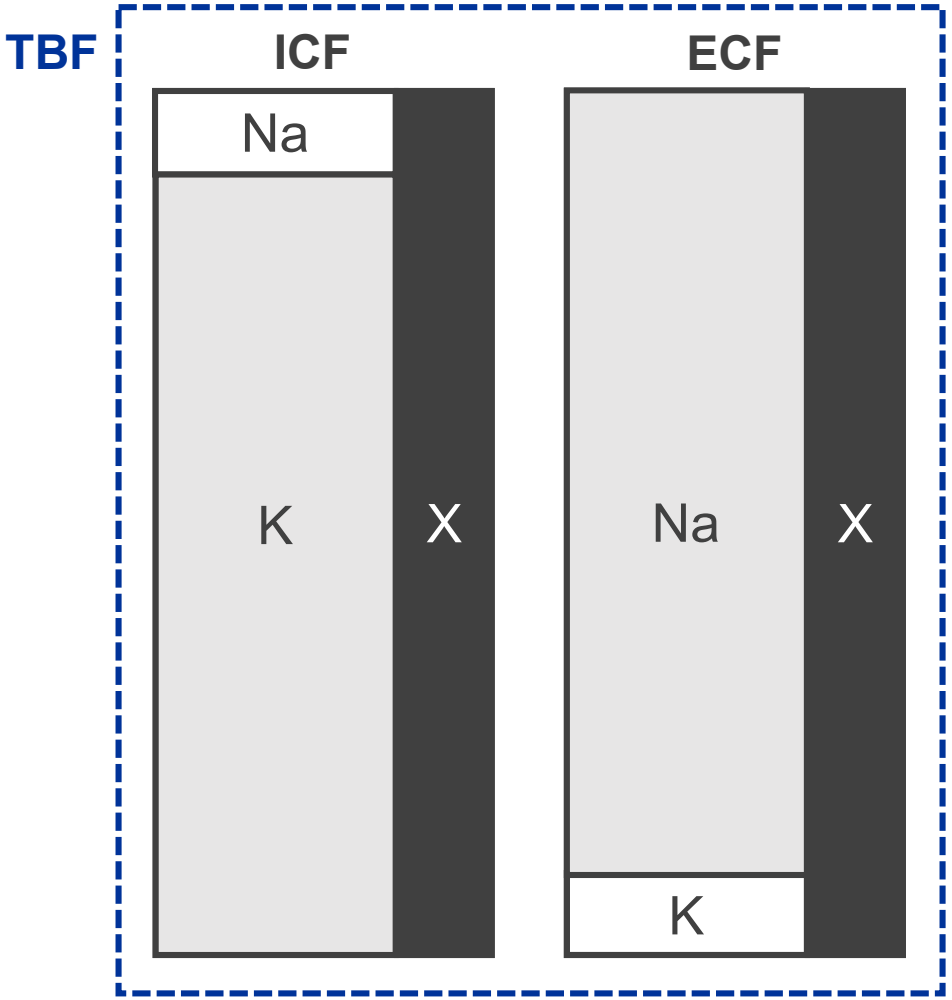
$$[X]_{TBF} = \frac{n_{X(TBF)}}{V_{TBW}} = \frac{n_{Na(TBF)} + n_{K(TBF)}}{V_{ICW} + V_{ECW}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF



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Quantitative Nephrology III: The Edelman Equation

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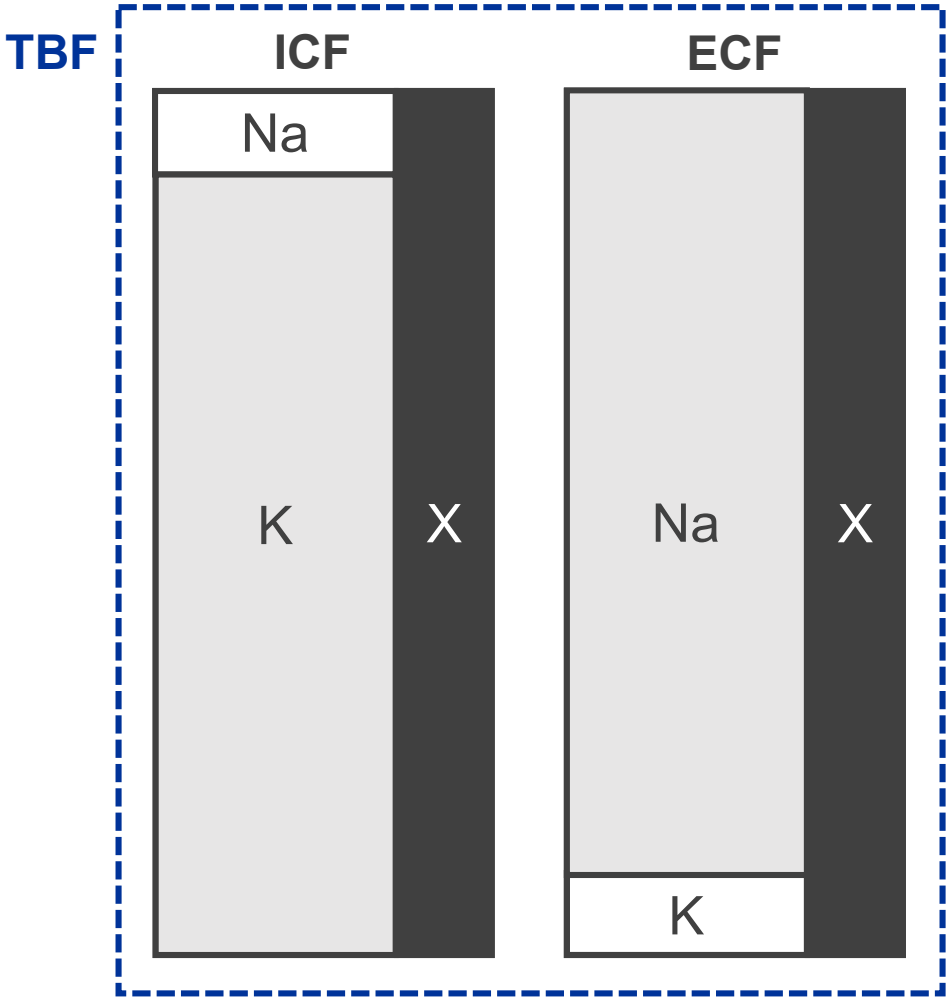

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$$= \left\{n_{Na(ICF)} + n_{K(ICF)}\right\} + \left\{n_{Na(ECF)} + n_{K(ECF)}\right\}$$

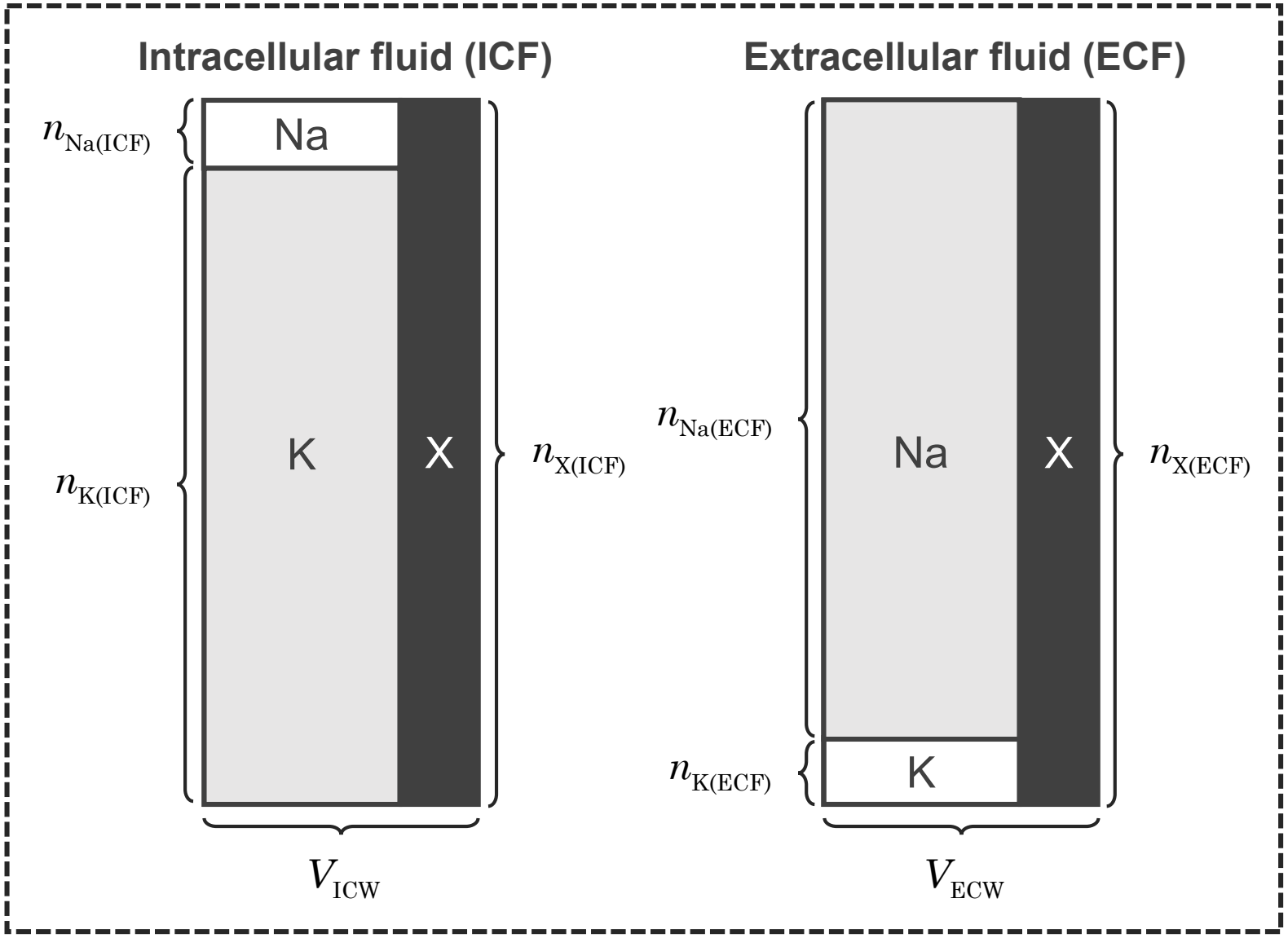
$$= \left\{n_{Na(ICF)} + n_{Na(ECF)}\right\} + \left\{n_{K(ICF)} + n_{K(ECF)}\right\}$$

$$n_{X(TBF)} = n_{Na(TBF)} + n_{K(TBF)}$$

$$[osm]_{TBF} = \frac{2\left\{n_{Na(TBF)} + n_{K(TBF)}\right\}}{V_{TBW}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: SUMMARY



Total-body fluid (TBF)

$$V_{TBW} = V_{ICW} + V_{ECW}$$

$$n_{Na(TBF)} = n_{Na(ICF)} + n_{Na(ECF)}$$

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$$n_{X(TBF)} = n_{X(ICF)} + n_{X(ECF)}$$

$$n_{X(TBF)} = n_{Na(TBF)} + n_{K(TBF)}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: SUMMARY

Intracellular fluid (ICF)

$$[\mathrm{Na}]_{\mathrm{ICF}} = \frac{n_{\mathrm{Na(ICF)}}}{V_{\mathrm{ICW}}}$$

$$[\mathrm{K}]_{\mathrm{ICF}} = \frac{n_{\mathrm{K(ICF)}}}{V_{\mathrm{ICW}}}$$

$$[\mathrm{X}]_{\mathrm{ICF}} = \frac{n_{\mathrm{X(ICF)}}}{V_{\mathrm{ICW}}}$$

$$[\mathrm{osm}]_{\mathrm{ICF}} = \frac{2\left\{n_{\mathrm{Na(ICF)}} + n_{\mathrm{K(ICF)}}\right\}}{V_{\mathrm{ICW}}}$$

Extracellular fluid (ECF)

$$[\mathrm{Na}]_{\mathrm{ECF}} = \frac{n_{\mathrm{Na(ECF)}}}{V_{\mathrm{ECW}}}$$

$$[\mathrm{K}]_{\mathrm{ECF}} = \frac{n_{\mathrm{K(ECF)}}}{V_{\mathrm{ECW}}}$$

$$[\mathrm{X}]_{\mathrm{ECF}} = \frac{n_{\mathrm{X(ECF)}}}{V_{\mathrm{ECW}}}$$

$$[\mathrm{osm}]_{\mathrm{ECF}} = \frac{2\left\{n_{\mathrm{Na(ECF)}} + n_{\mathrm{K(ECF)}}\right\}}{V_{\mathrm{ECW}}}$$

Total-body fluid (TBF)

$$[\mathrm{Na}]_{\mathrm{TBF}} = \frac{n_{\mathrm{Na(TBF)}}}{V_{\mathrm{TBW}}} = \frac{n_{\mathrm{Na(ICF)}} + n_{\mathrm{Na(ECF)}}}{V_{\mathrm{ICW}} + V_{\mathrm{ECW}}}$$

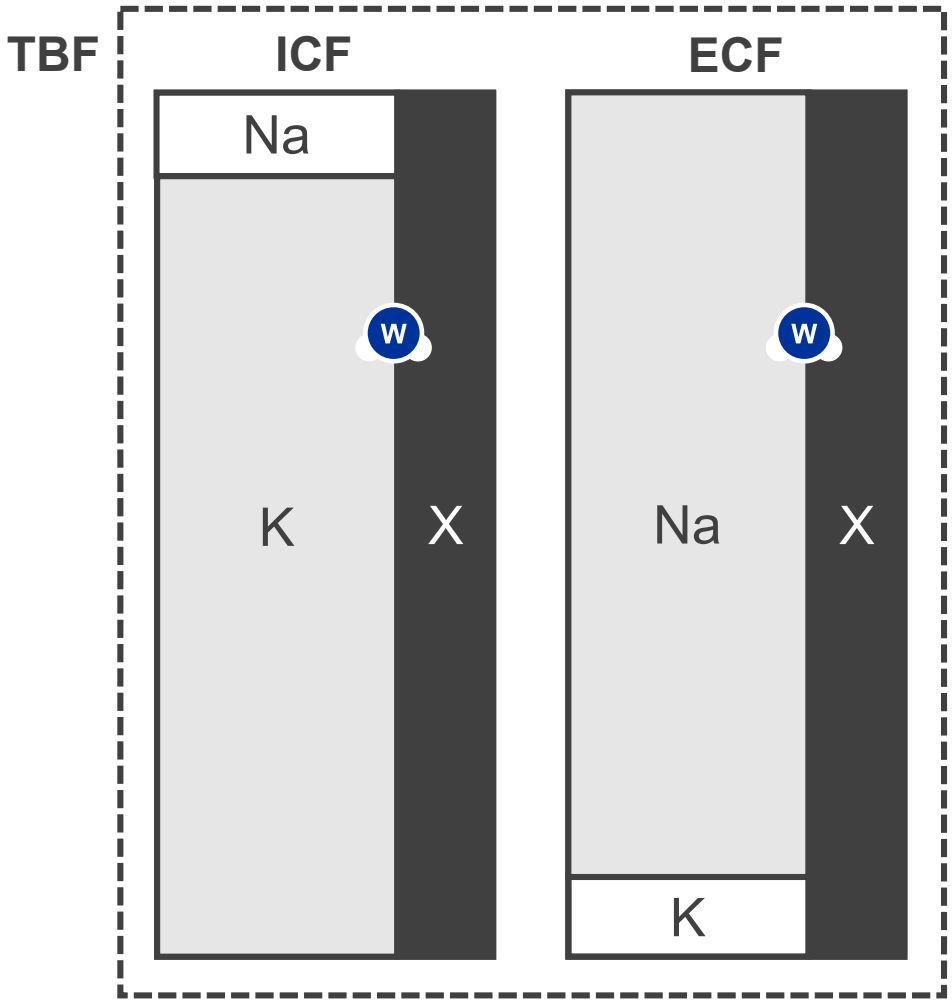
$$[\mathrm{K}]_{\mathrm{TBF}} = \frac{n_{\mathrm{K(TBF)}}}{V_{\mathrm{TBW}}} = \frac{n_{\mathrm{K(ICF)}} + n_{\mathrm{K(ECF)}}}{V_{\mathrm{ICW}} + V_{\mathrm{ECW}}}$$

$$[\mathrm{X}]_{\mathrm{TBF}} = \frac{n_{\mathrm{X(TBF)}}}{V_{\mathrm{TBW}}} = \frac{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}}{V_{\mathrm{ICW}} + V_{\mathrm{ECW}}}$$

$$[\mathrm{osm}]_{\mathrm{TBF}} = \frac{2\left\{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}\right\}}{V_{\mathrm{TBW}}}$$

Quantitative Nephrology III: The Edelman Equation

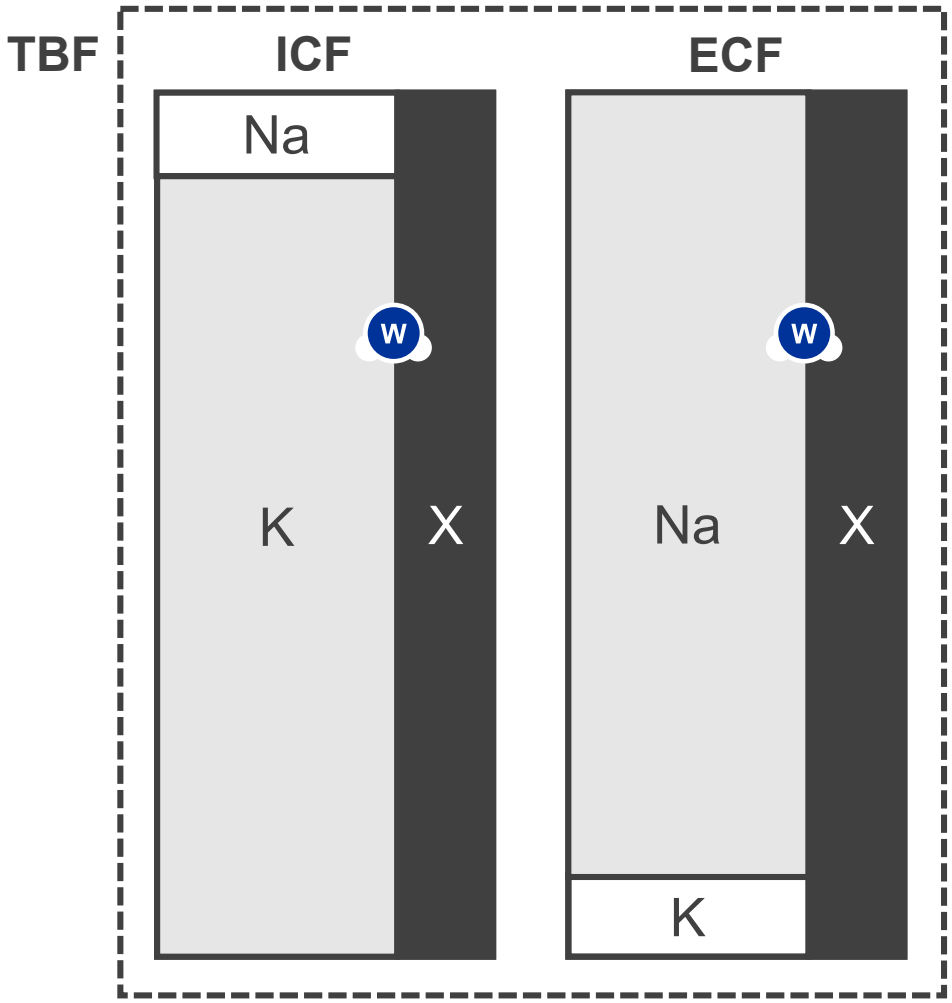
Specific fluid compartments: TBF = ICF + ECF



Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

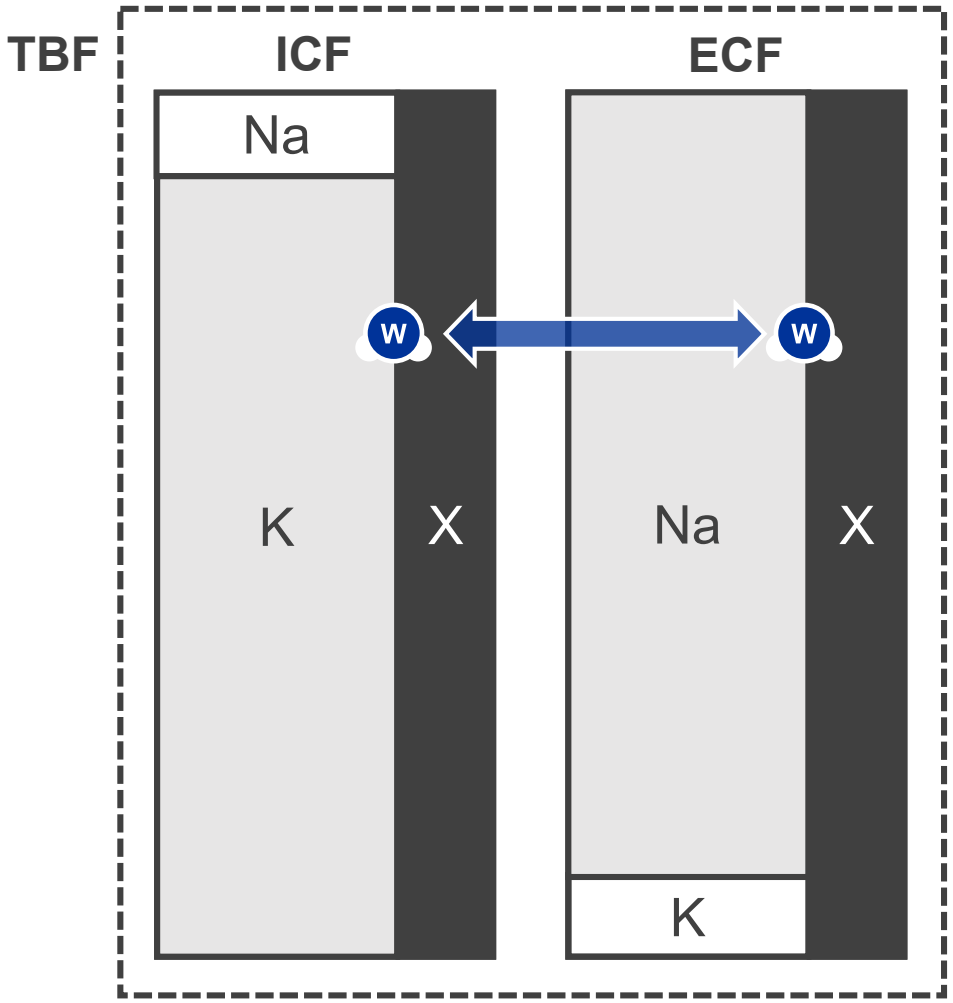


Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

Yes



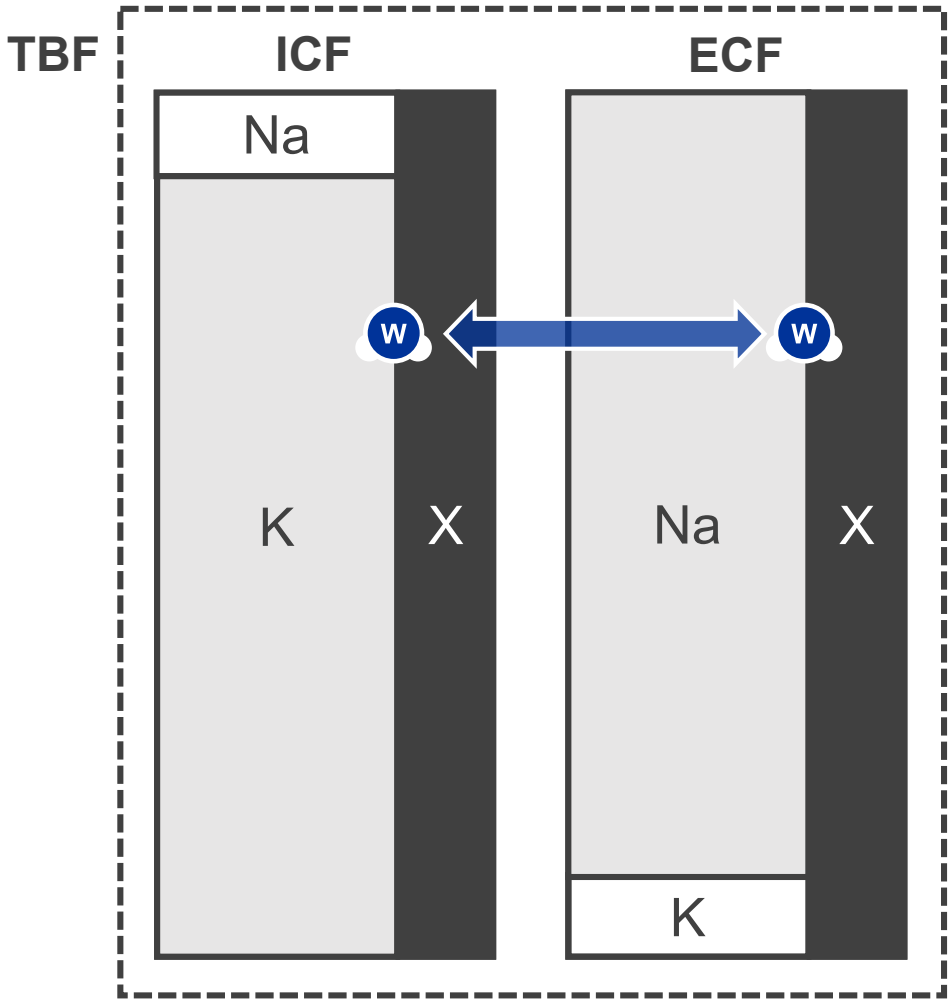
Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

Yes

What is the driving force for this movement?



Quantitative Nephrology III: The Edelman Equation

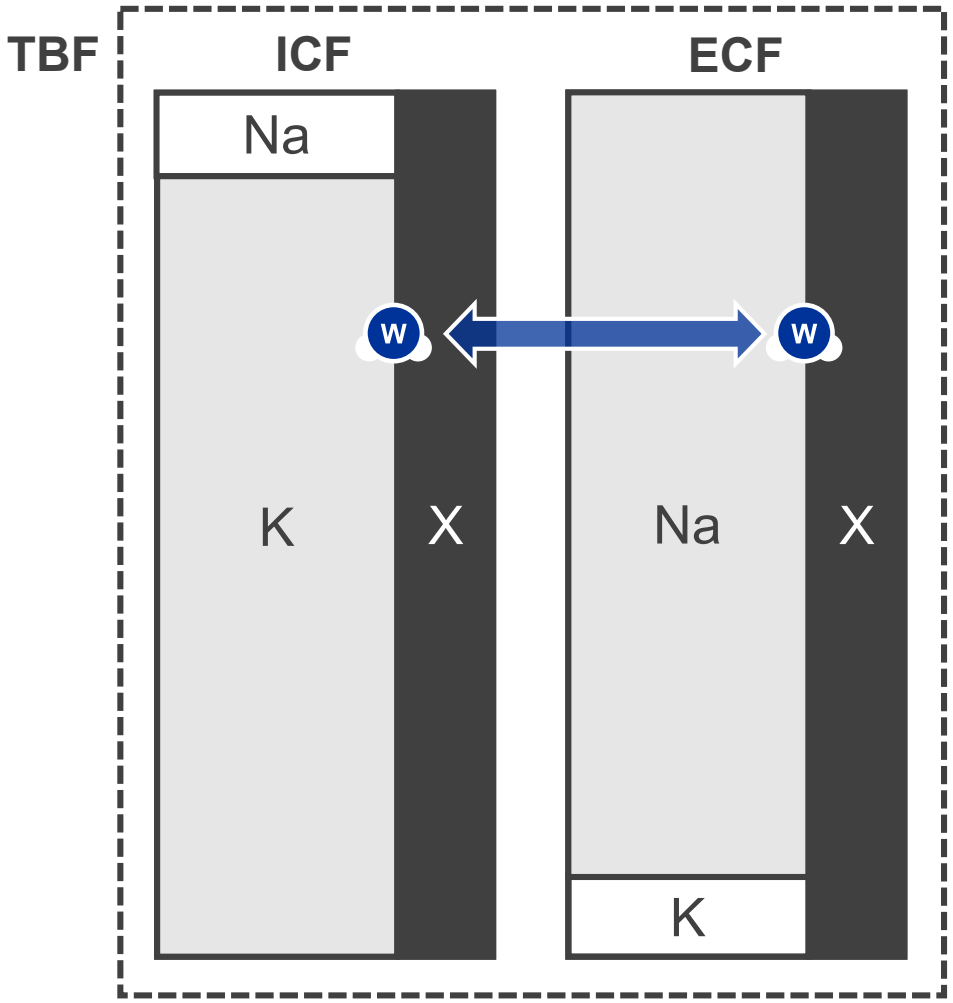
Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

Yes

What is the driving force for this movement?

Δ[osm]



Quantitative Nephrology III: The Edelman Equation

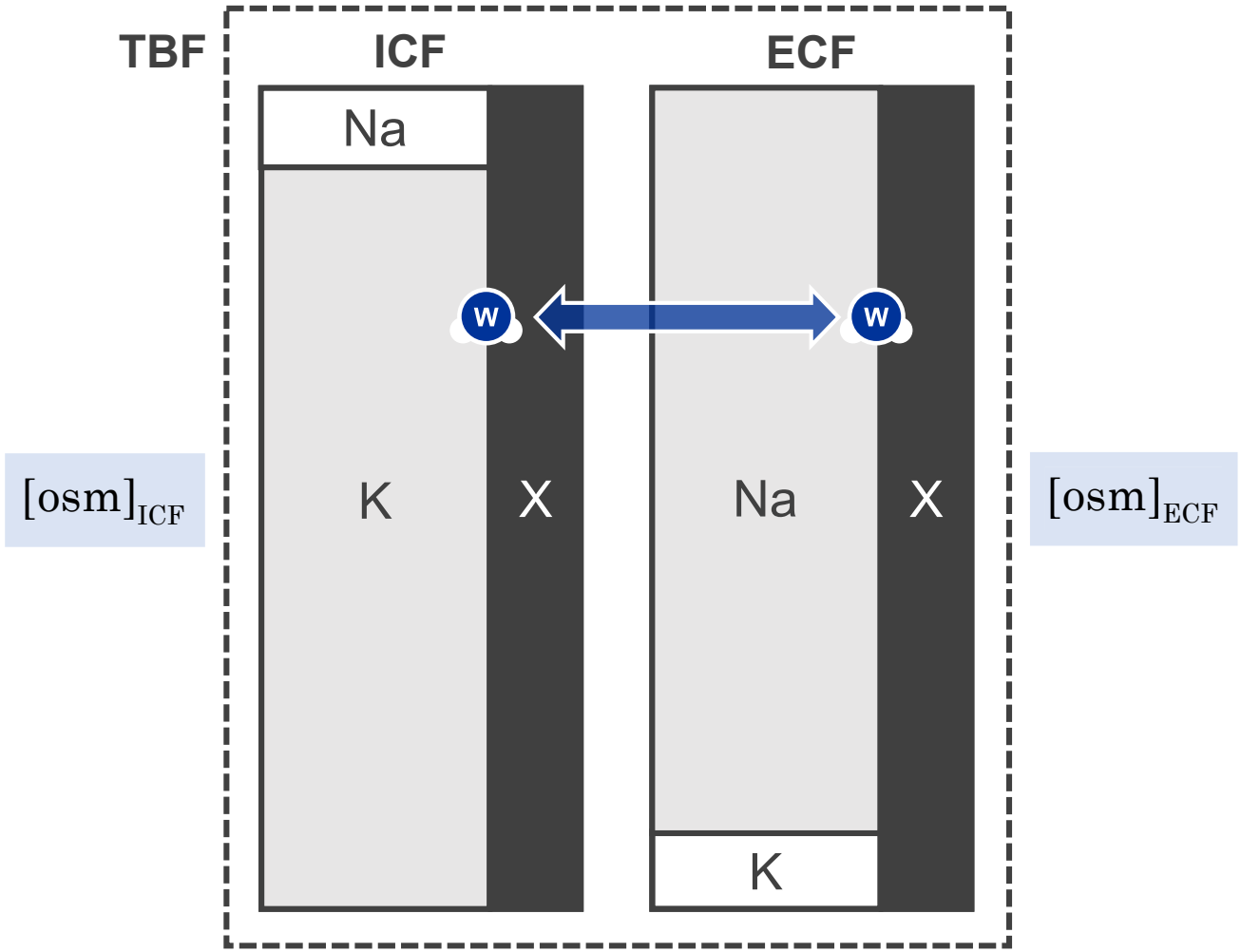
Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

Yes

What is the driving force for this movement?

Δ[osm]



Quantitative Nephrology III: The Edelman Equation

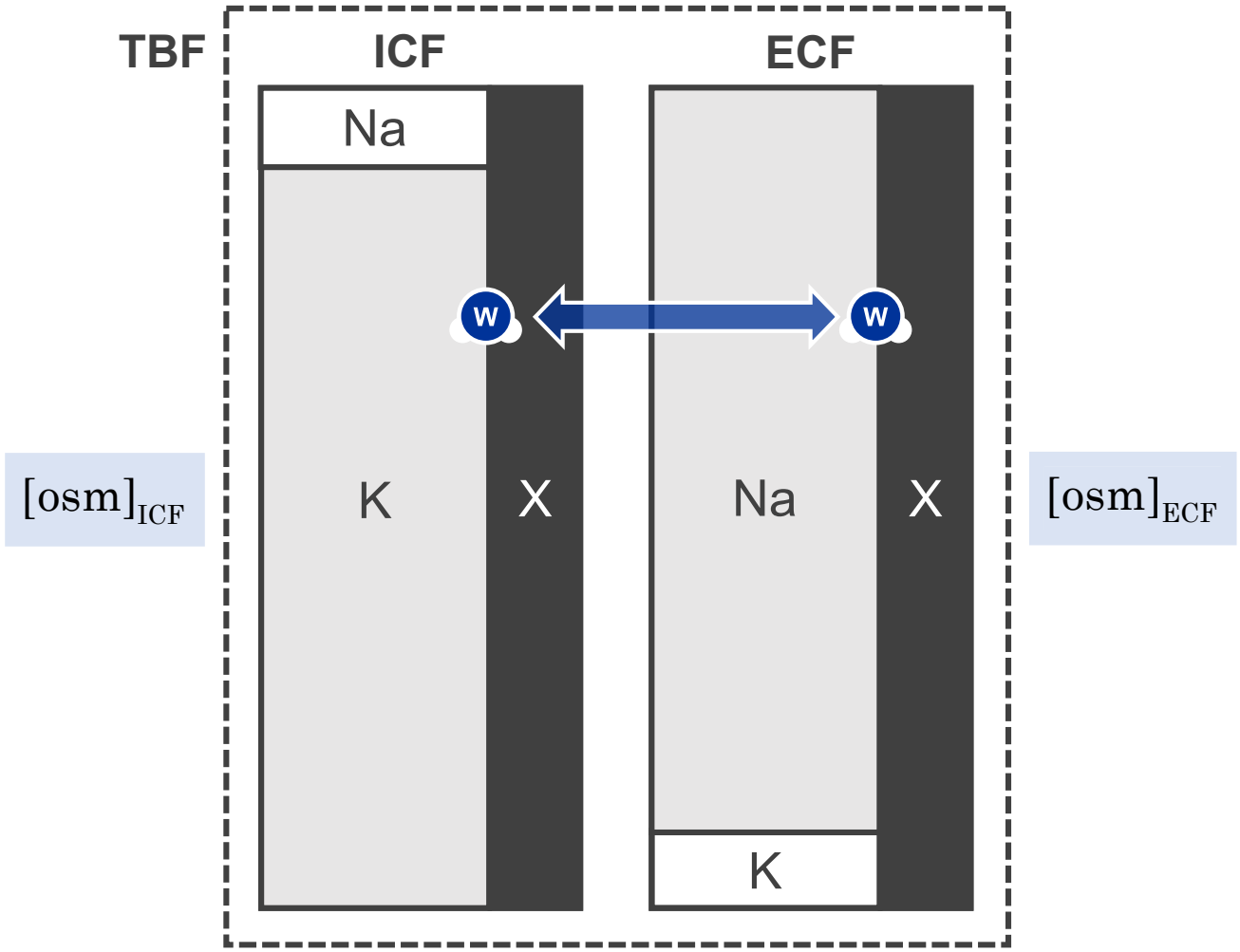
Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

Yes

What is the driving force for this movement?

Δ[osm]



$$\Delta[osm] = [osm]_{ECF} - [osm]_{ICF}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF

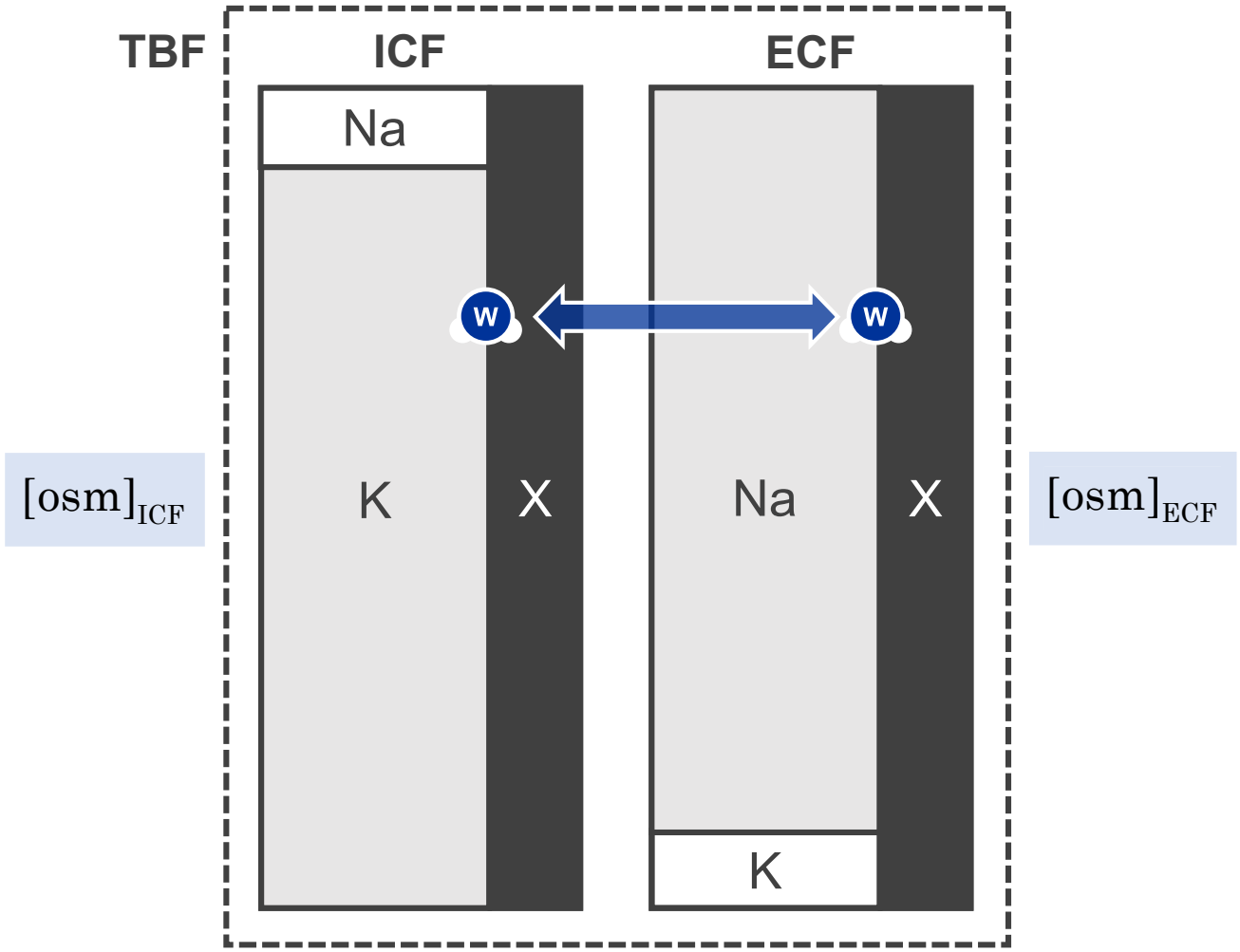
Is water allowed to move freely between fluid compartments?

Yes

What is the driving force for this movement?

Δ[osm]

At equilibrium, what is the value of Δ[osm]?



$$\Delta[osm] = [osm]_{ECF} - [osm]_{ICF}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

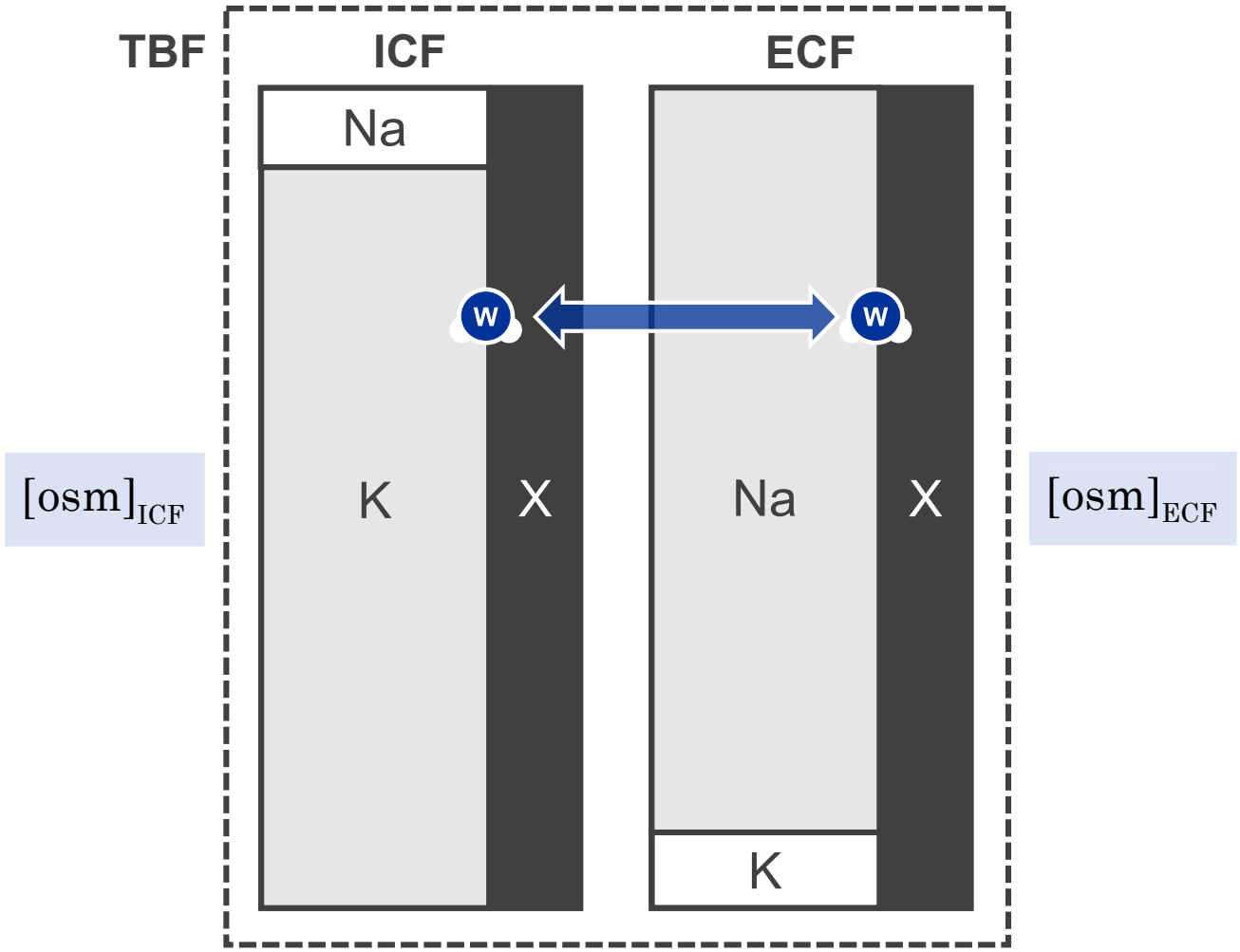
Yes

What is the driving force for this movement?

Δ[osm]

At equilibrium, what is the value of Δ[osm]?

0 (zero)



$$\Delta[osm] = [osm]_{ECF} - [osm]_{ICF}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

Yes

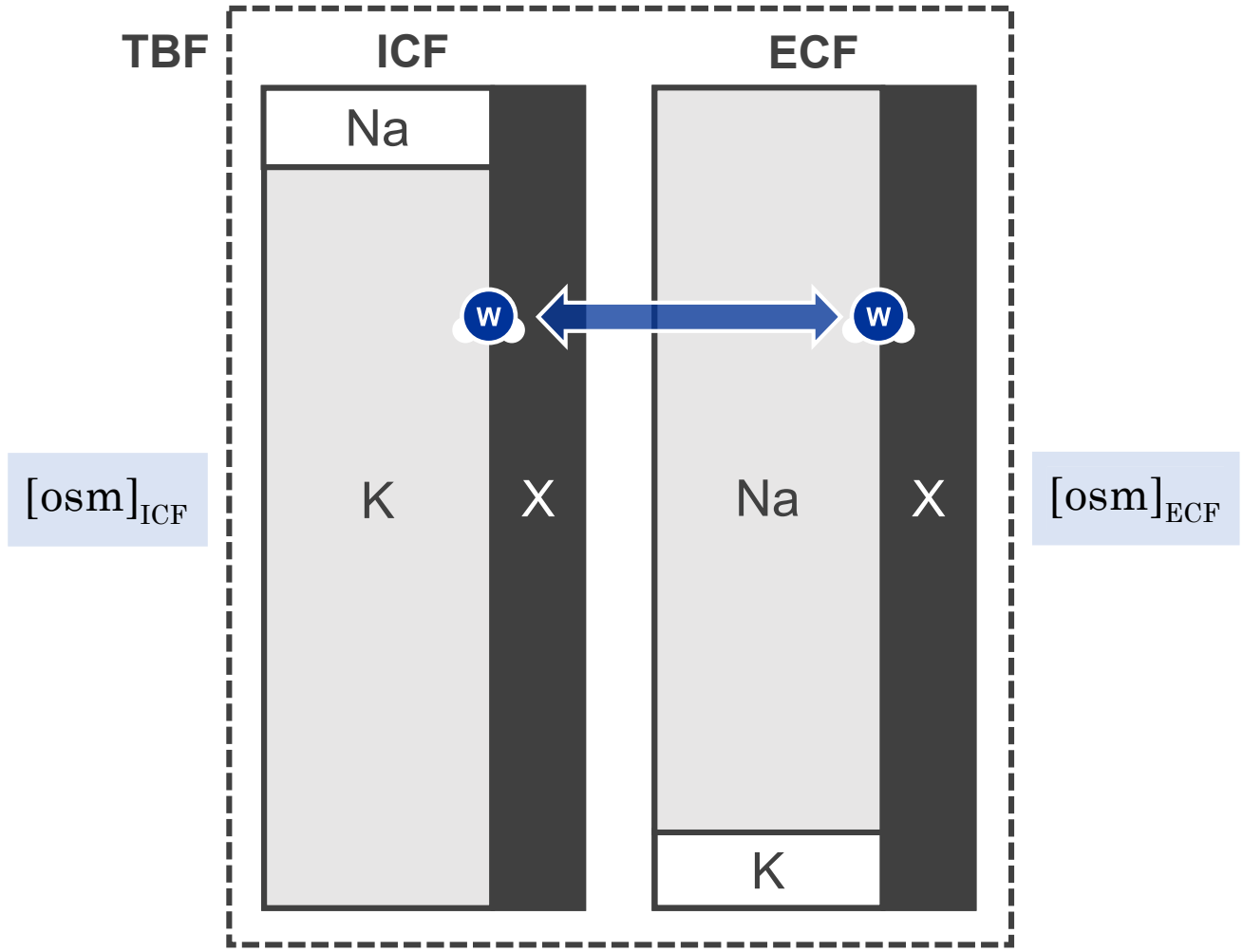
What is the driving force for this movement?

Δ[osm]

At equilibrium, what is the value of Δ[osm]?

0 (zero)

At equilibrium, what is the relationship between $[osm]_{ECF}$ and $[osm]_{ICF}$ and $[osm]_{TBF}$?



$$\Delta[osm] = [osm]_{ECF} - [osm]_{ICF}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: TBF = ICF + ECF

Is water allowed to move freely between fluid compartments?

Yes

What is the driving force for this movement?

Δ[osm]

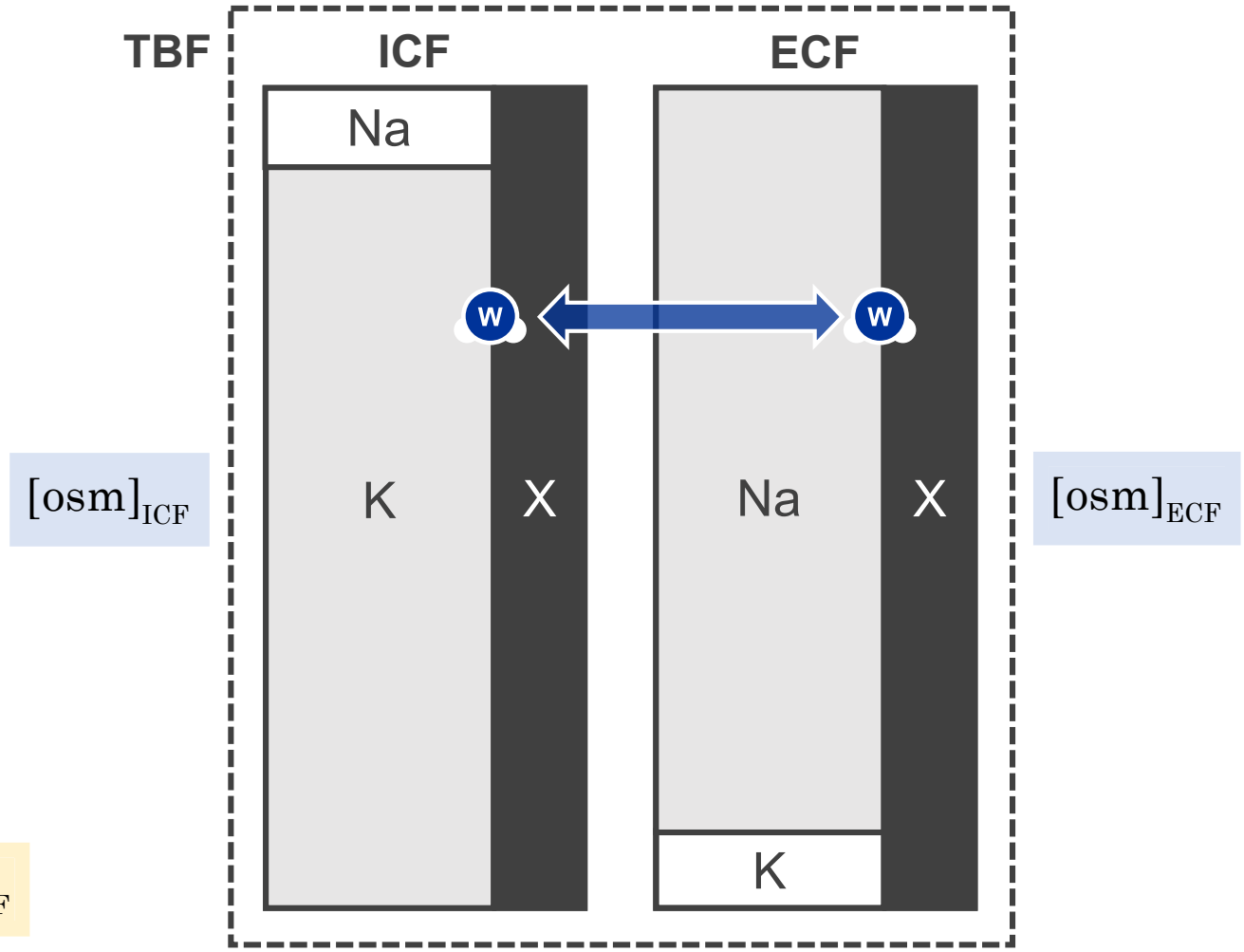
At equilibrium, what is the value of Δ[osm]?

0 (zero)

At equilibrium, what is the relationship between $[osm]_{ECF}$ and $[osm]_{ICF}$ and $[osm]_{TBF}$?

They are equal:

$$[osm]_{ECF} = [osm]_{ICF} = [osm]_{TBF}$$



$$\Delta[osm] = [osm]_{ECF} - [osm]_{ICF}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Updated SUMMARY

Intracellular fluid (ICF)

$$[\mathrm{Na}]_{\mathrm{ICF}} = \frac{n_{\mathrm{Na(ICF)}}}{V_{\mathrm{ICW}}}$$

$$[\mathrm{K}]_{\mathrm{ICF}} = \frac{n_{\mathrm{K(ICF)}}}{V_{\mathrm{ICW}}}$$

$$[\mathrm{X}]_{\mathrm{ICF}} = \frac{n_{\mathrm{X(ICF)}}}{V_{\mathrm{ICW}}}$$

$$[\mathrm{osm}]_{\mathrm{ICF}} = \frac{2\left\{n_{\mathrm{Na(ICF)}} + n_{\mathrm{K(ICF)}}\right\}}{V_{\mathrm{ICW}}}$$

Extracellular fluid (ECF)

$$[\mathrm{Na}]_{\mathrm{ECF}} = \frac{n_{\mathrm{Na(ECF)}}}{V_{\mathrm{ECW}}}$$

$$[\mathrm{K}]_{\mathrm{ECF}} = \frac{n_{\mathrm{K(ECF)}}}{V_{\mathrm{ECW}}}$$

$$[\mathrm{X}]_{\mathrm{ECF}} = \frac{n_{\mathrm{X(ECF)}}}{V_{\mathrm{ECW}}}$$

$$[\mathrm{osm}]_{\mathrm{ECF}} = \frac{2\left\{n_{\mathrm{Na(ECF)}} + n_{\mathrm{K(ECF)}}\right\}}{V_{\mathrm{ECW}}}$$

Total-body fluid (TBF)

$$[\mathrm{Na}]_{\mathrm{TBF}} = \frac{n_{\mathrm{Na(TBF)}}}{V_{\mathrm{TBW}}} = \frac{n_{\mathrm{Na(ICF)}} + n_{\mathrm{Na(ECF)}}}{V_{\mathrm{ICW}} + V_{\mathrm{ECW}}}$$

$$[\mathrm{K}]_{\mathrm{TBF}} = \frac{n_{\mathrm{K(TBF)}}}{V_{\mathrm{TBW}}} = \frac{n_{\mathrm{K(ICF)}} + n_{\mathrm{K(ECF)}}}{V_{\mathrm{ICW}} + V_{\mathrm{ECW}}}$$

$$[\mathrm{X}]_{\mathrm{TBF}} = \frac{n_{\mathrm{X(TBF)}}}{V_{\mathrm{TBW}}} = \frac{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}}{V_{\mathrm{ICW}} + V_{\mathrm{ECW}}}$$

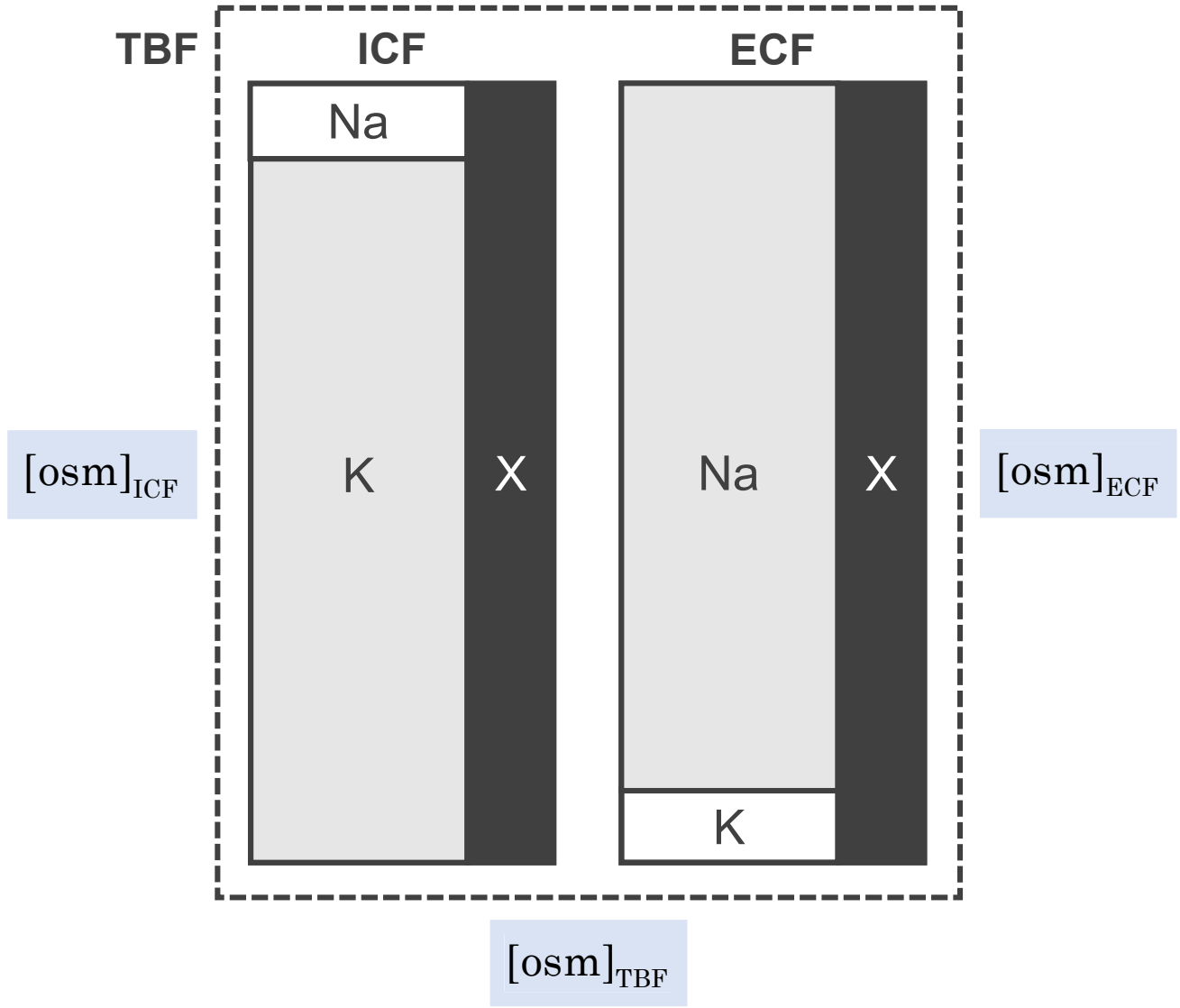
$$[\mathrm{osm}]_{\mathrm{TBF}} = \frac{2\left\{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}\right\}}{V_{\mathrm{TBW}}}$$

At equilibrium:

$$[\mathrm{osm}]_{\mathrm{ECF}} = [\mathrm{osm}]_{\mathrm{ICF}} = [\mathrm{osm}]_{\mathrm{TBF}}$$

Quantitative Nephrology III: The Edelman Equation

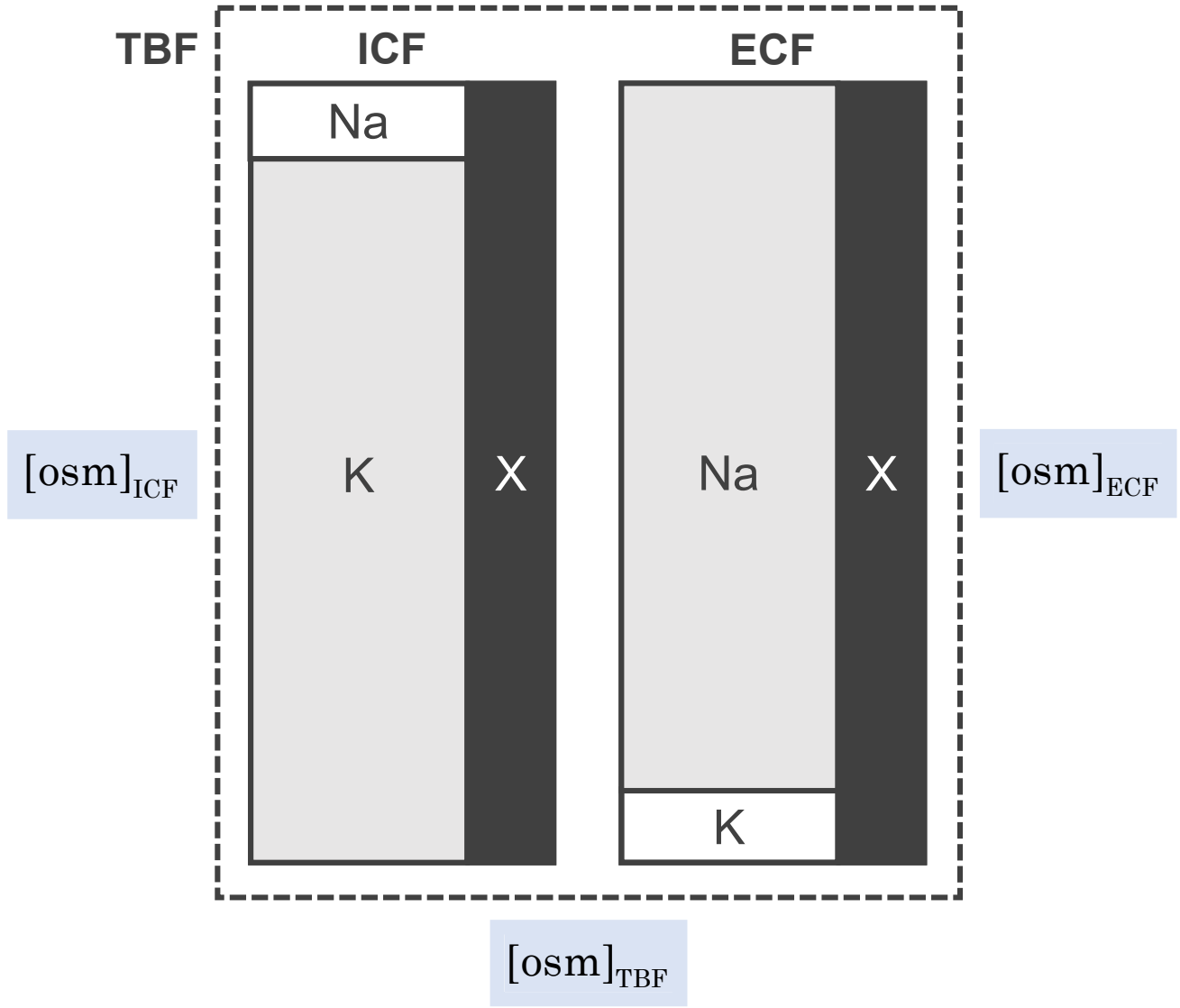
Specific fluid compartments: Approximation of $[osm]_{ECF}$ as $2[Na]_{ECF}$



Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Approximation of $[osm]_{ECF}$ as $2[Na]_{ECF}$

What is the major contributor to $[osm]_{ECF}$?

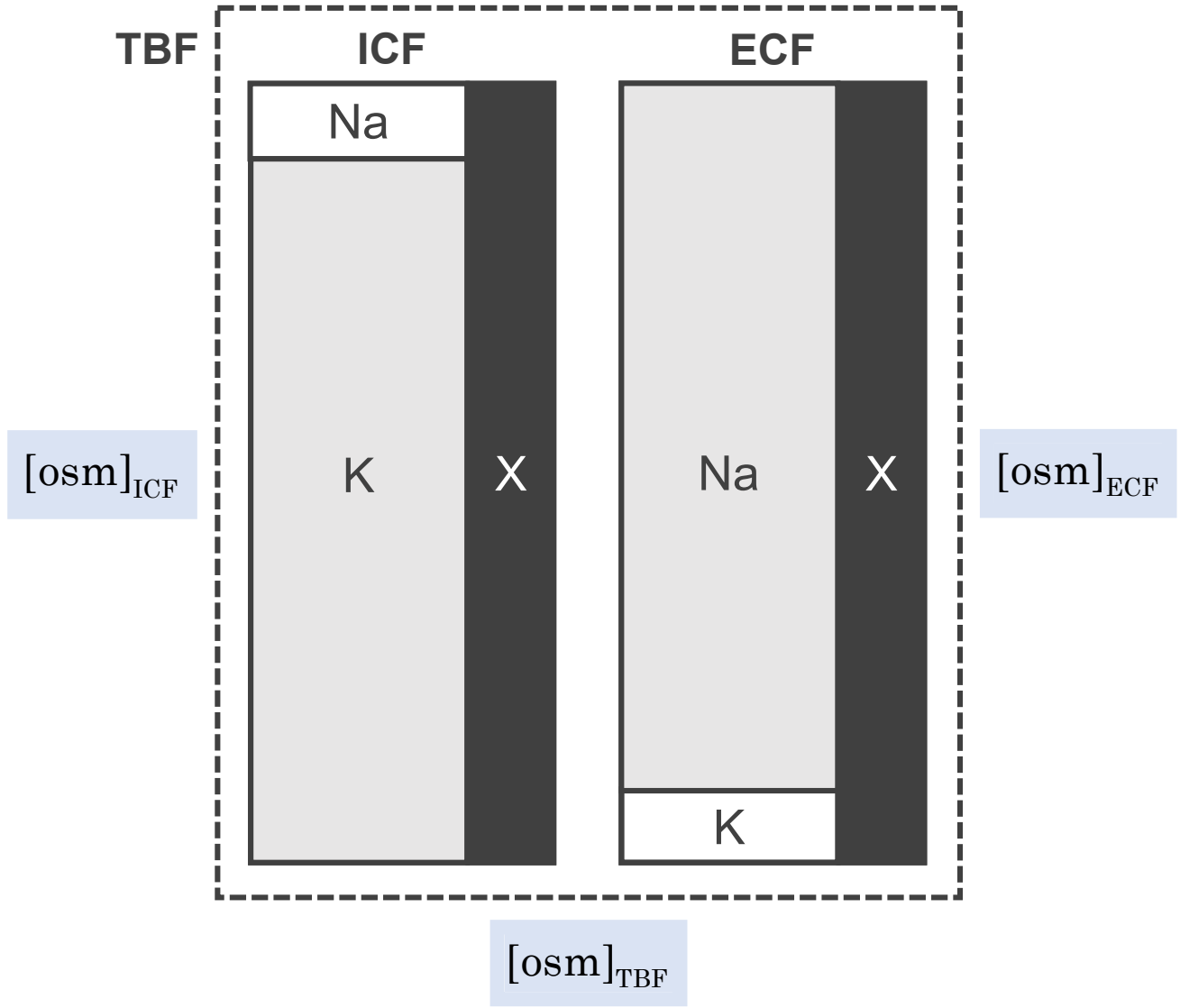


Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Approximation of $[osm]_{ECF}$ as $2[Na]_{ECF}$

What is the major contributor to $[osm]_{ECF}$?

Sodium salts (NaX)



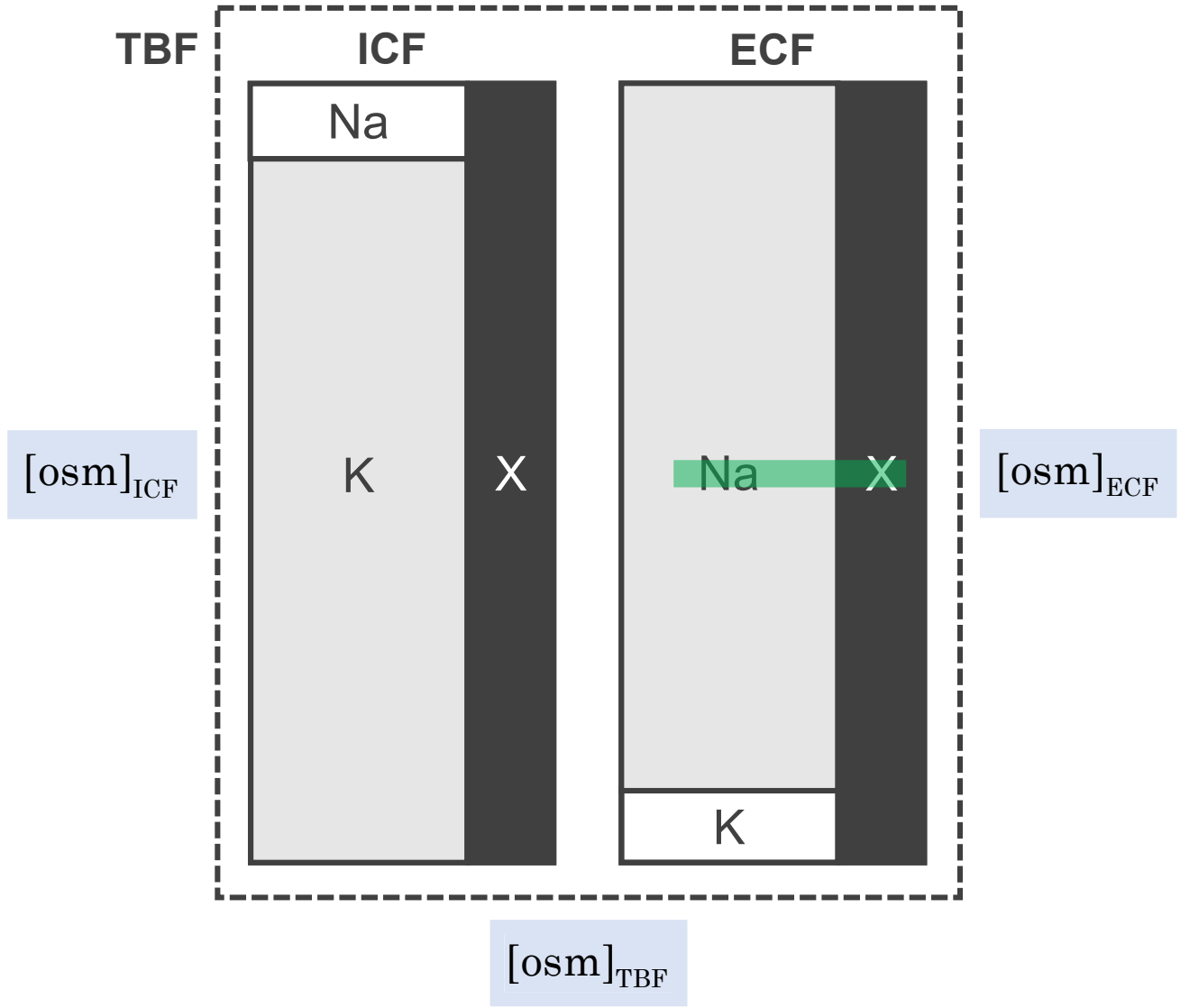
Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Approximation of $[osm]_{ECF}$ as $2[Na]_{ECF}$

What is the major contributor to $[osm]_{ECF}$?

Sodium salts (NaX)

Therefore, an approximate relationship is



Quantitative Nephrology III: The Edelman Equation

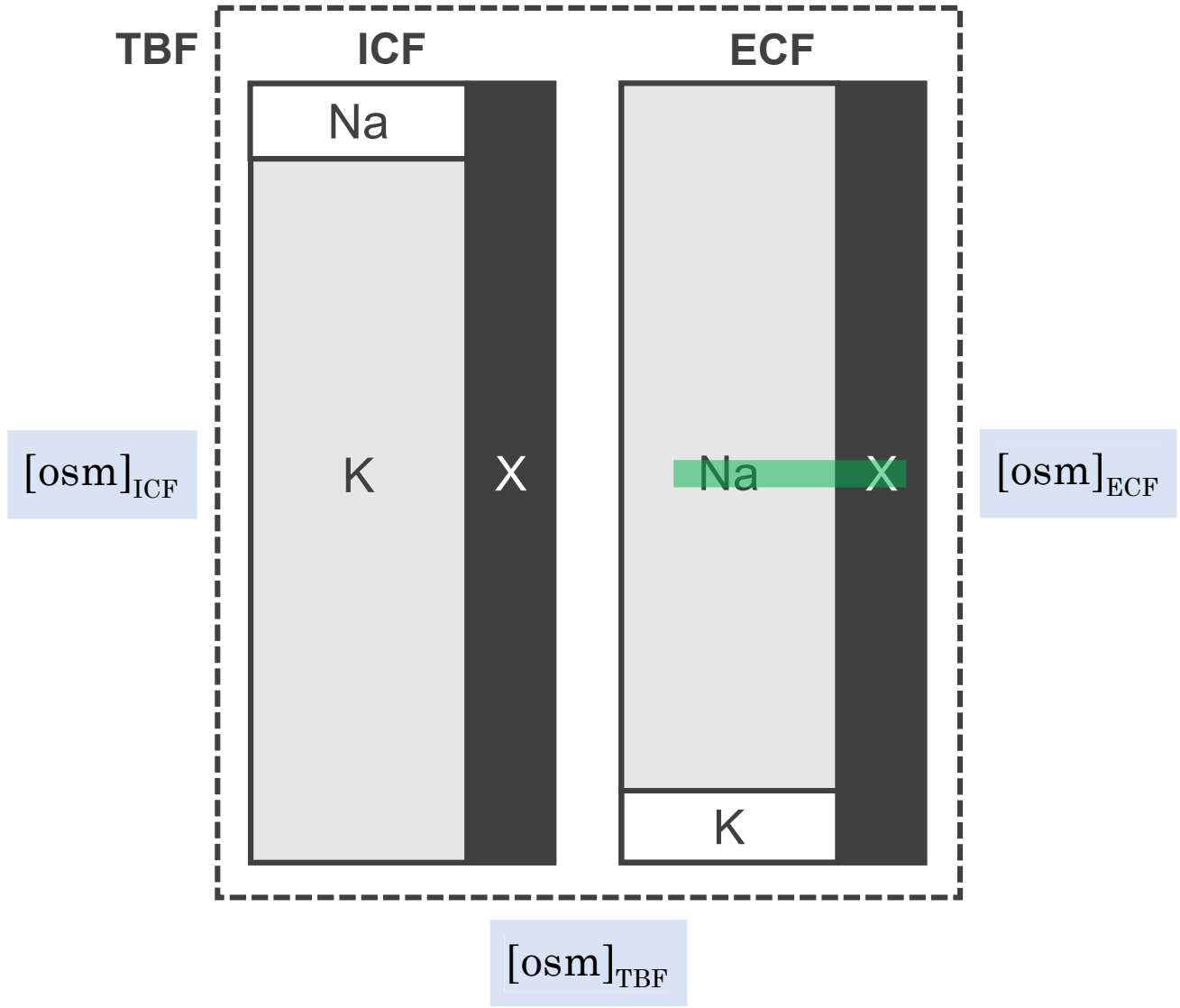
Specific fluid compartments: Approximation of $[osm]_{ECF}$ as $2[Na]_{ECF}$

What is the major contributor to $[osm]_{ECF}$?

Sodium salts (NaX)

Therefore, an approximate relationship is

$$[osm]_{ECF} \approx [NaX]_{ECF}$$



Quantitative Nephrology III: The Edelman Equation

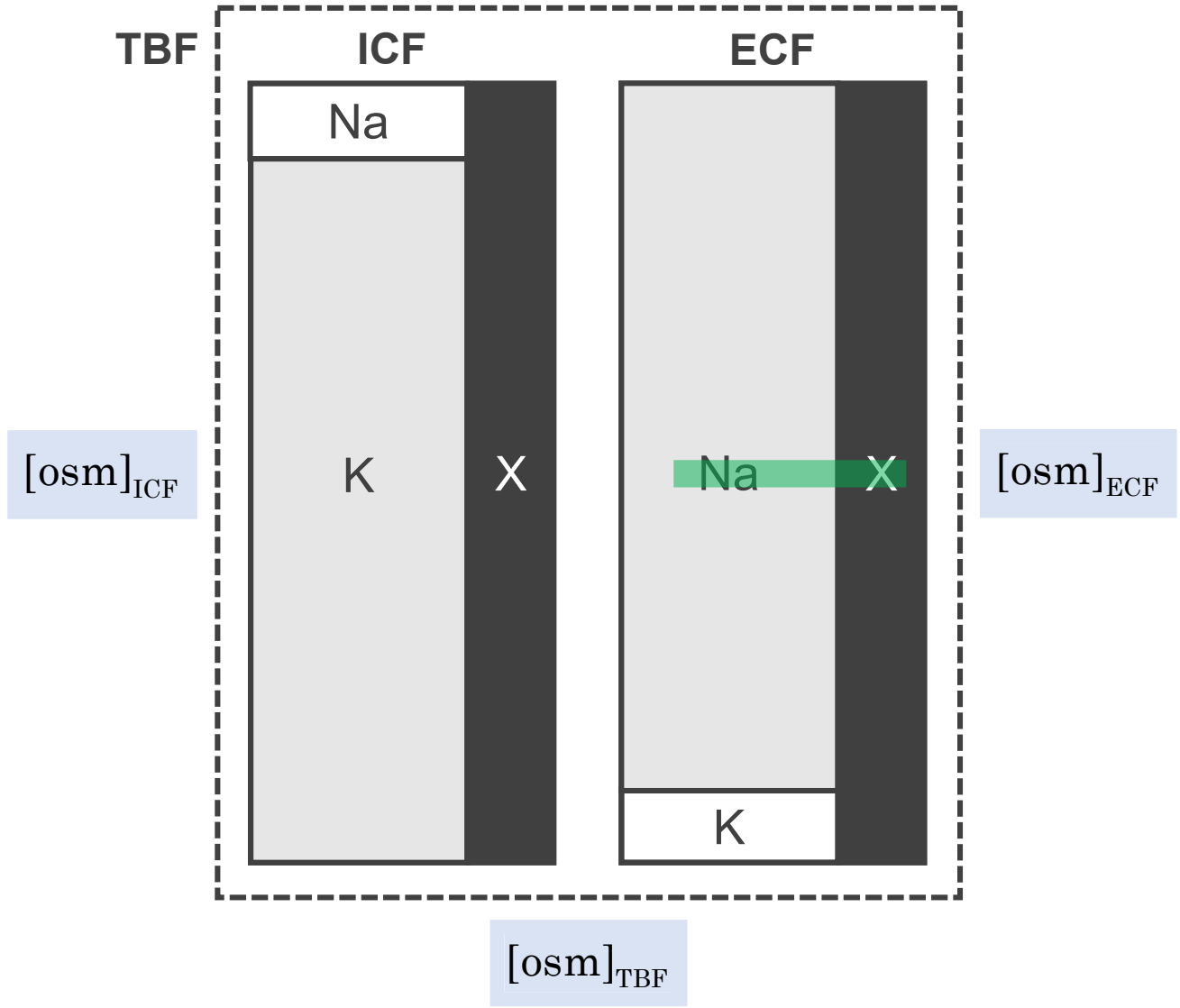
Specific fluid compartments: Approximation of $[osm]_{ECF}$ as $2[Na]_{ECF}$

What is the major contributor to $[osm]_{ECF}$?

Sodium salts (NaX)

Therefore, an approximate relationship is

$$[\text{osm}]_{\text{ECF}} \approx [\text{NaX}]_{\text{ECF}} \approx \frac{n_{\text{Na(ECF)}} + n_{\text{X(ECF)}}}{V_{\text{ECW}}}$$



Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Approximation of $[osm]_{ECF}$ as $2[Na]_{ECF}$

What is the major contributor to $[osm]_{ECF}$?

Sodium salts (NaX)

Therefore, an approximate relationship is

$$[osm]_{ECF} \approx [NaX]_{ECF}$$

$$\approx \frac{n_{Na(ECF)} + n_{X(ECF)}}{V_{ECW}}$$

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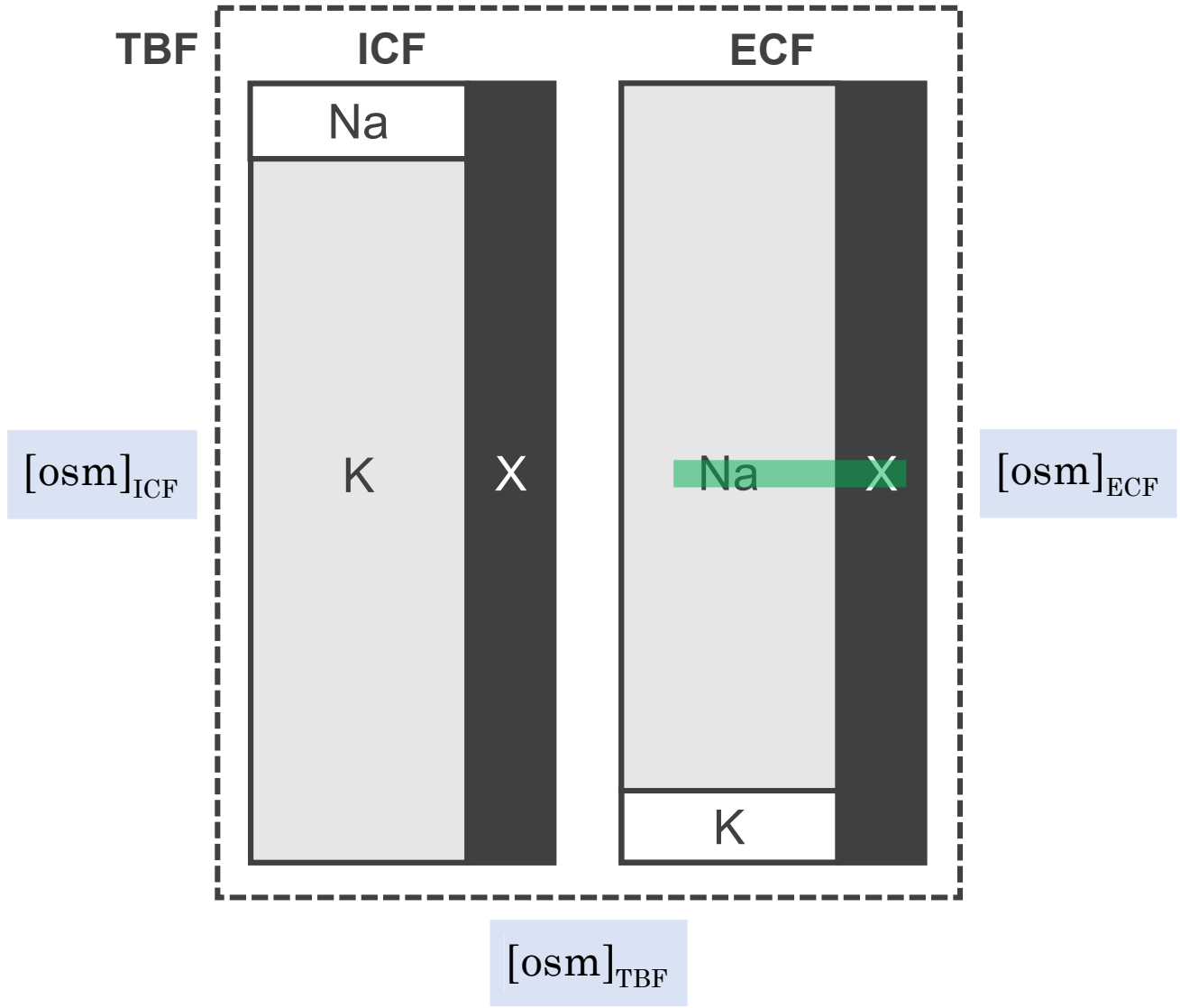

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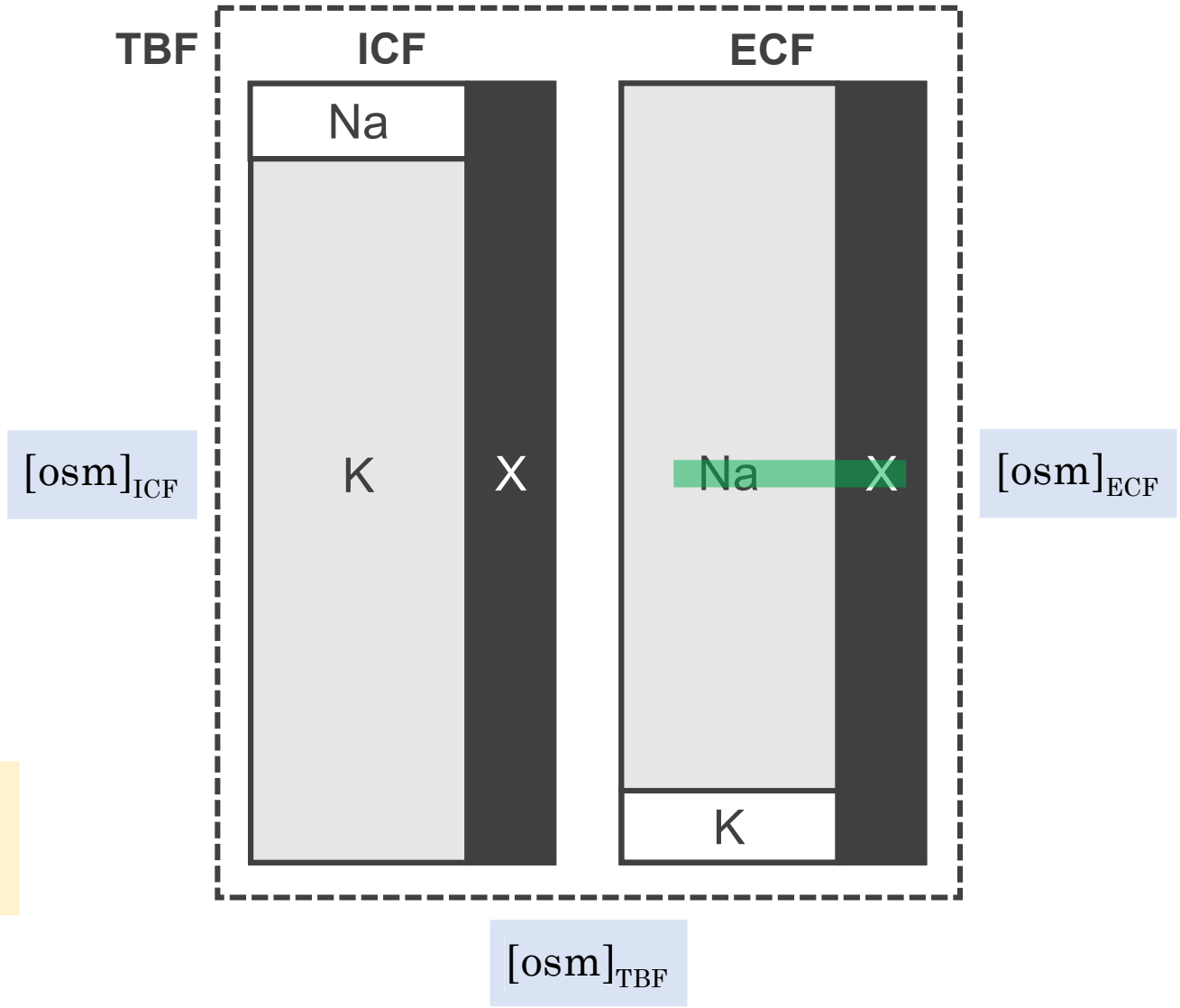
$$\approx \frac{n_{Na(ECF)} + n_{Na(ECF)}}{V_{ECW}}$$

$$[osm]_{ECF} \approx \frac{2n_{Na(ECF)}}{V_{ECW}} = 2[Na]_{ECF}$$



Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Relationship between $[Na]_{ECF}$ and total-body cation content

If we know that, at equilibrium, all compartment osmolarities are equal...

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Relationship between $[Na]_{ECF}$ and total-body cation content

If we know that, at equilibrium, all compartment osmolarities are equal...

$$[\text{osm}]_{\text{ECF}} = [\text{osm}]_{\text{ICF}} = [\text{osm}]_{\text{TBF}}$$

Quantitative Nephrology III: The Edelman Equation

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If we know that, at equilibrium, all compartment osmolarities are equal...

$$[osm]_{ECF} = [osm]_{ICF} = [osm]_{TBF}$$

and if we know that $[osm]_{ECF}$ is well approximated by $2[Na]_{ECF}$...

Quantitative Nephrology III: The Edelman Equation

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$$[\text{osm}]_{\text{ECF}} \approx 2[\text{Na}]_{\text{ECF}}$$

Quantitative Nephrology III: The Edelman Equation

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then what is the relationship between $[Na]_{ECF}$ and $[osm]_{ECF}$?

Quantitative Nephrology III: The Edelman Equation

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Quantitative Nephrology III: The Edelman Equation

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$$[osm]_{ECF} \approx 2[Na]_{ECF}$$

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Quantitative Nephrology III: The Edelman Equation

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$$[\text{osm}]_{\text{ECF}} \approx 2[\text{Na}]_{\text{ECF}}$$

$$[\text{osm}]_{\text{TBF}} \approx 2[\text{Na}]_{\text{ECF}}$$

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$$[\text{osm}]_{\text{TBF}} \approx 2[\text{Na}]_{\text{ECF}}$$

$$[\text{osm}]_{\text{TBF}} = \frac{2\left\{n_{\text{Na(TBF)}} + n_{\text{K(TBF)}}\right\}}{V_{\text{TBW}}}$$

Quantitative Nephrology III: The Edelman Equation

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$$[osm]_{TBF} = \frac{2\left\{n_{Na(TBF)} + n_{K(TBF)}\right\}}{V_{TBW}}$$

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$$[Na]_{ECF} = \frac{n_{Na(TBF)} + n_{K(TBF)}}{V_{TBW}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Relationship between $[Na]_{PW}$ and total-body cation content

If $[Na]_{ECF}$ is determined by the ratio of total-body cation content total-body water volume...

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Relationship between $[Na]_{PW}$ and total-body cation content

If $[Na]_{ECF}$ is determined by the ratio of total-body cation content total-body water volume...

$$[\mathrm{Na}]_{\mathrm{ECF}} = \frac{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}}{V_{\mathrm{TBW}}}$$

Quantitative Nephrology III: The Edelman Equation

Specific fluid compartments: Relationship between $[Na]_{PW}$ and total-body cation content

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and if we recognize that plasma water is a subset of ECF, meaning they have equal solute concentrations...

Quantitative Nephrology III: The Edelman Equation

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$$[\mathrm{Na}]_{\mathrm{ECF}} = [\mathrm{Na}]_{\mathrm{PW}}$$

Quantitative Nephrology III: The Edelman Equation

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Quantitative Nephrology III: The Edelman Equation

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$$[\mathrm{Na}]_{\mathrm{ECF}} = [\mathrm{Na}]_{\mathrm{PW}}$$

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$$[\mathrm{Na}]_{\mathrm{PW}} = \frac{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}}{V_{\mathrm{TBW}}}$$

Quantitative Nephrology III: The Edelman Equation

Classic Nephrology paper: Edelman IS et al. *J Clin Invest*. 1958;37(9):1236–56.

INTERRELATIONS BETWEEN SERUM SODIUM CONCENTRATION, SERUM OSMOLARITY AND TOTAL EXCHANGEABLE SODIUM, TOTAL EXCHANGEABLE POTASSIUM AND TOTAL BODY WATER [1]

By I. S. EDELMAN,[2] J. LEIBMAN,[3] M. P. O'MEARA,[4] AND L. W. BIRKENFELD [5]

(From the Department of Medicine, University of California School of Medicine, and the San Francisco Hospital, San Francisco, Calif.)

(Submitted for publication March 4, 1958; accepted May 2, 1958)

Although much is known about the effects of changes in electrolyte and water balance on serum sodium concentration, the quantitative relationships between body composition and the concentration of sodium in serum have not been established. Also, no definitive study has been made of the correspondence between serum sodium concentration and total serum osmolarity. It is necessary that these relationships be defined to permit classification and interpretation of abnormalities of serum sodium concentration in clinical states, as well as to extend present understanding of the effects of electrolyte equilibria and acid-base disturbances on serum sodium concentration.

heart failure (10). An integrated account of concomitant alterations in serum sodium concentration and body composition was first achieved by Deming and Gerbode (11), who observed that changes in serum sodium concentration paralleled net changes of sodium and potassium balance in relation to water balance in patients undergoing mitral valvulotomy. The influence of potassium balance on serum sodium concentration was confirmed by correlative studies in postoperative hyponatremia and by demonstration that administration of potassium can raise the serum sodium concentration in hyponatremic patients (4, 7, 12).

The dependence of serum sodium concentration

Edelman IS, Leibman J, O'Meara MP, Birkenfeld LW. Interrelations between serum sodium concentration, serum osmolarity and total exchangeable sodium, total exchangeable potassium and total body water. *J Clin Invest*. 1958;37(9):1236–56. PMID: 13575523.

Quantitative Nephrology III: The Edelman Equation

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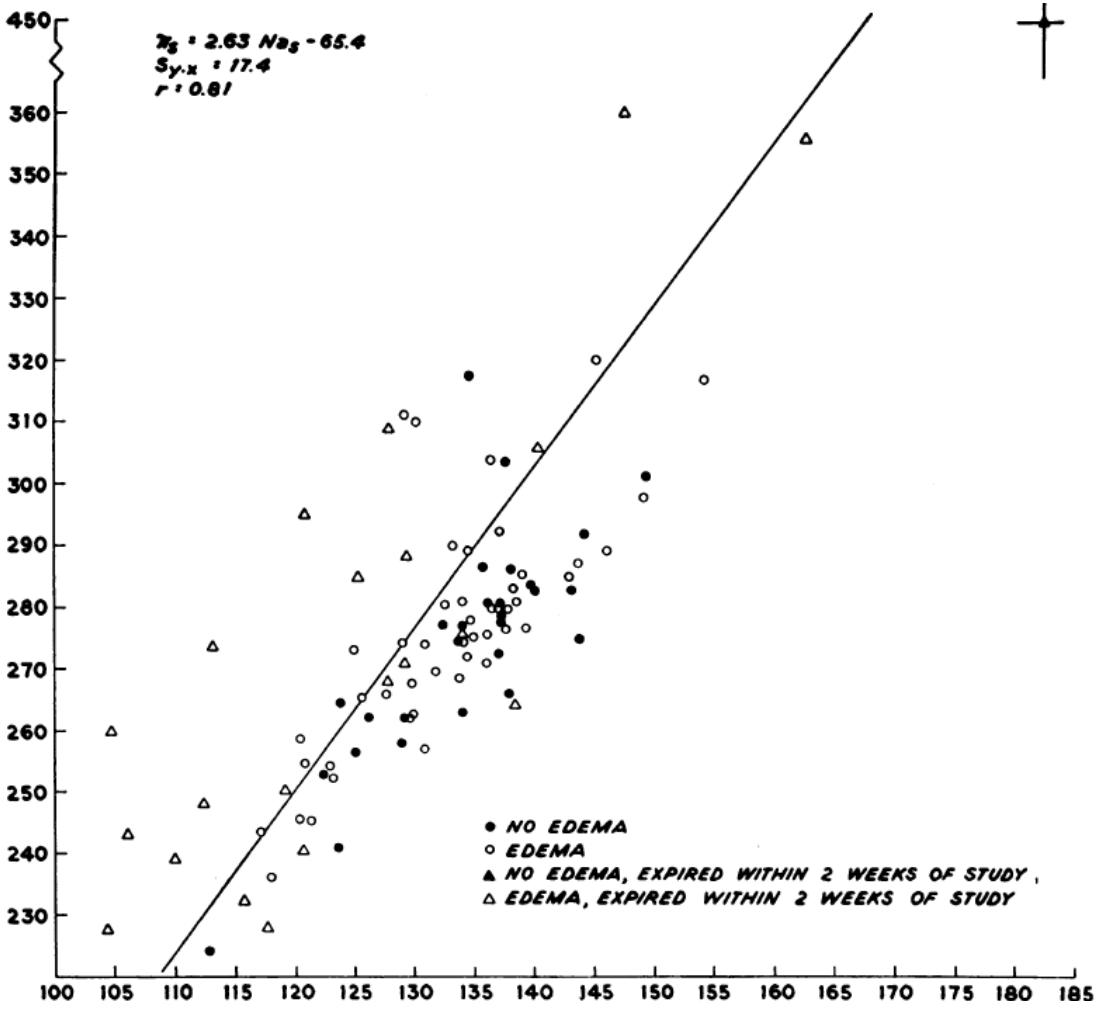

$[osm]_{PW}$

$[Na]_{PW}$

Quantitative Nephrology III: The Edelman Equation

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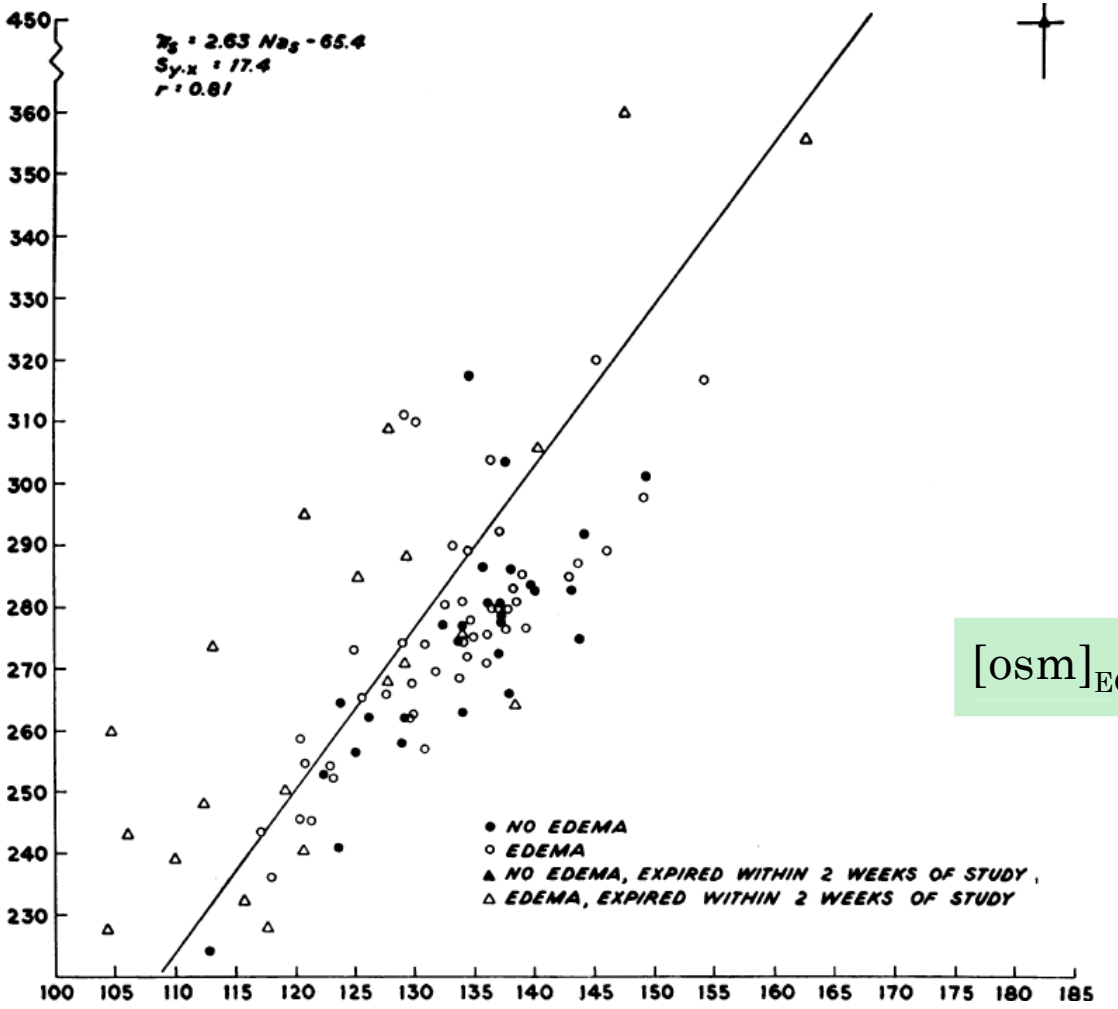

$[\text{osm}]_{\text{PW}}$

$[\text{Na}]_{\text{PW}}$

$[\text{osm}]_{\text{ECF}} \approx 2[\text{Na}]_{\text{ECF}}$

Quantitative Nephrology III: The Edelman Equation

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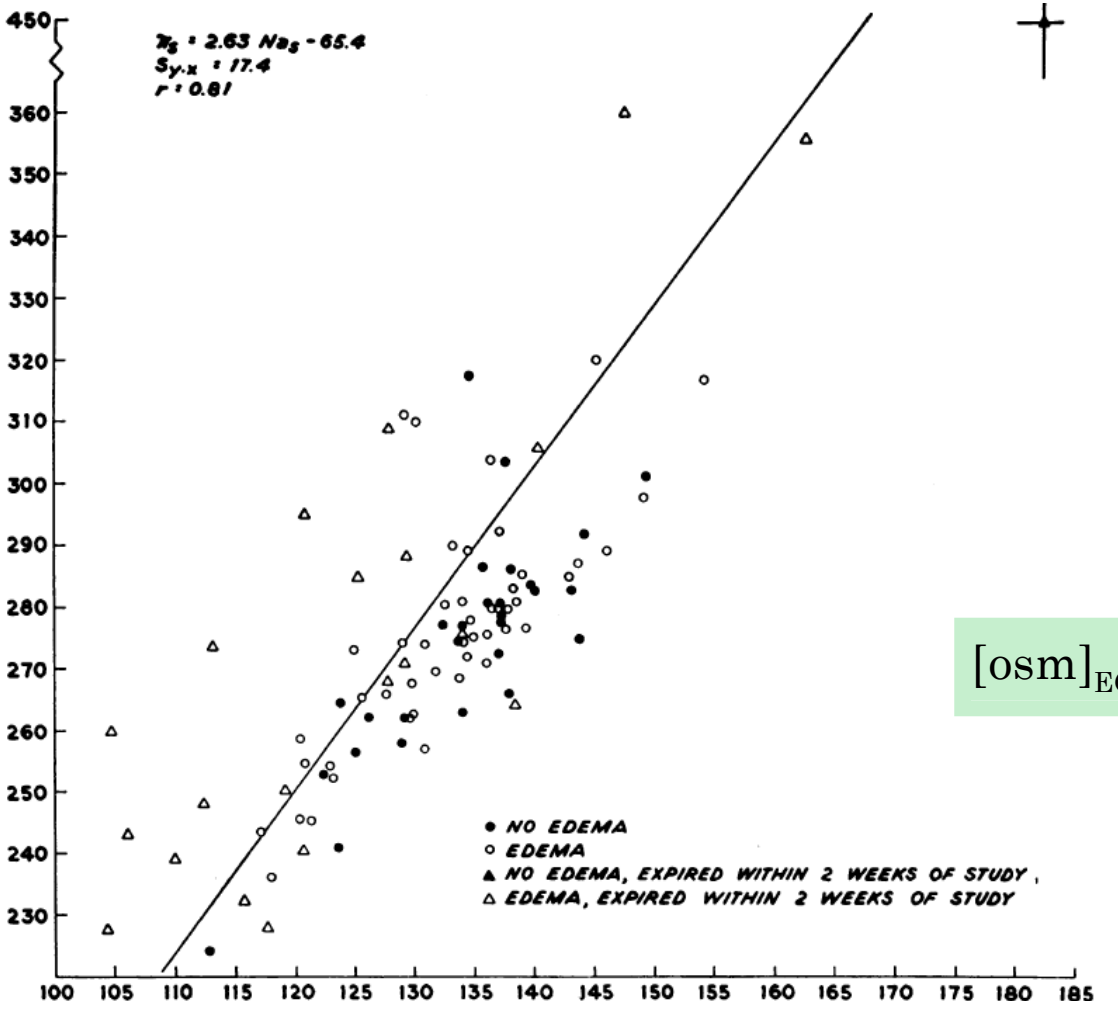

$[osm]_{PW}$

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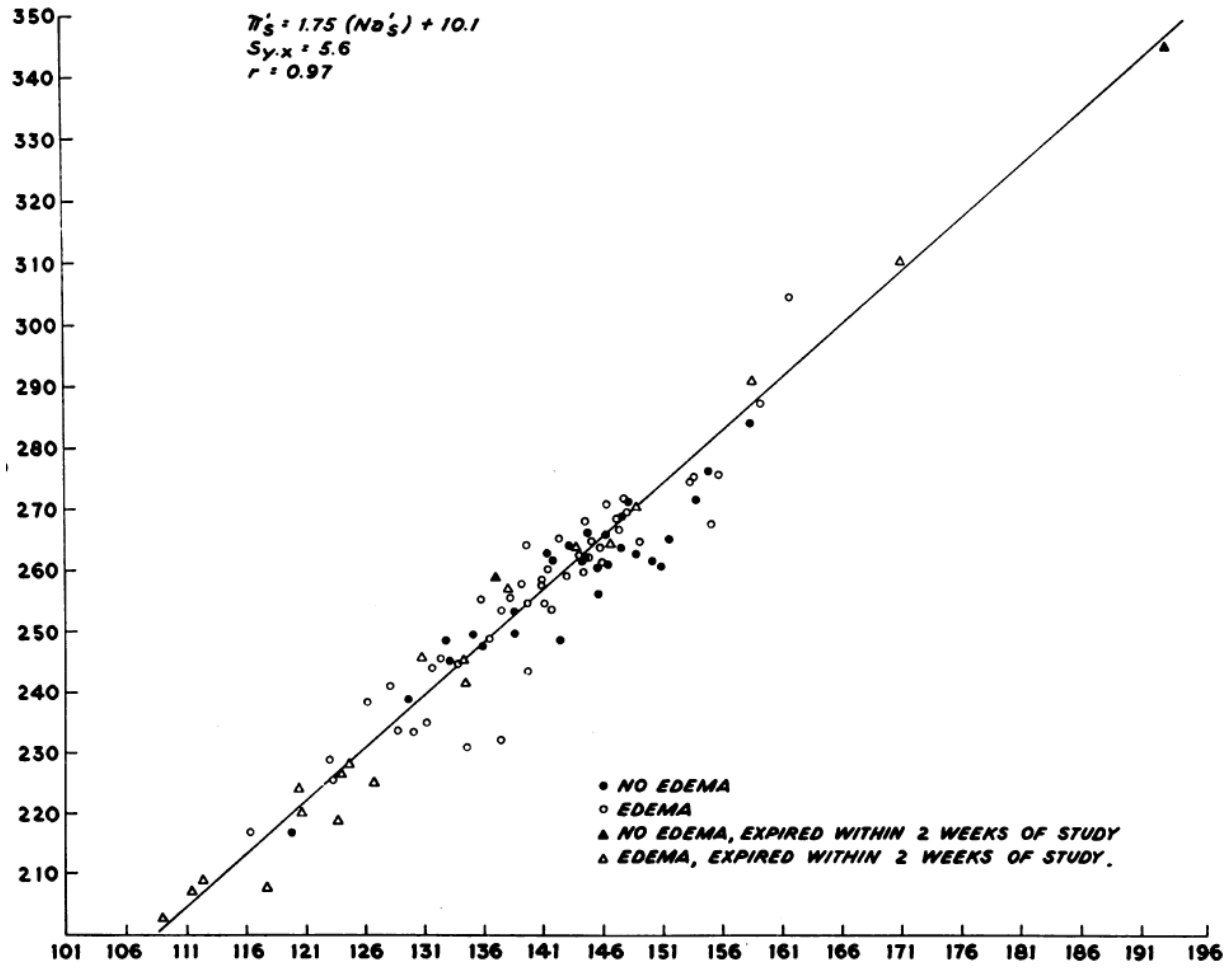
$[osm]_{ECF} \approx 2[Na]_{ECF}$

Quantitative Nephrology III: The Edelman Equation

Classic Nephrology paper: Edelman IS et al. *J Clin Invest*. 1958;37(9):1236–56.

corrected $[osm]_{PW}$



corrected $[Na]_{PW}$

Quantitative Nephrology III: The Edelman Equation

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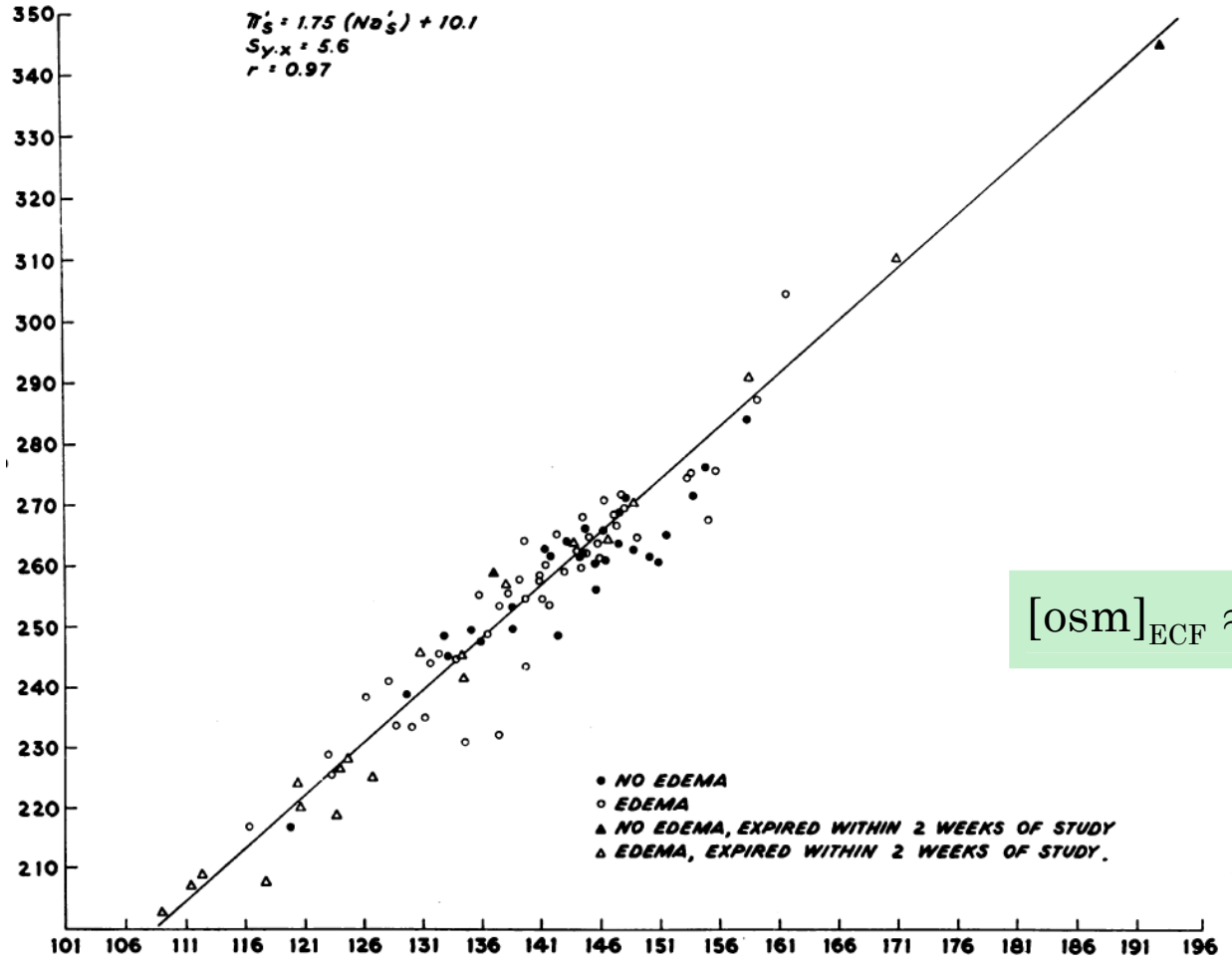
corrected $[\text{osm}]_{\text{PW}}$



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Quantitative Nephrology III: The Edelman Equation

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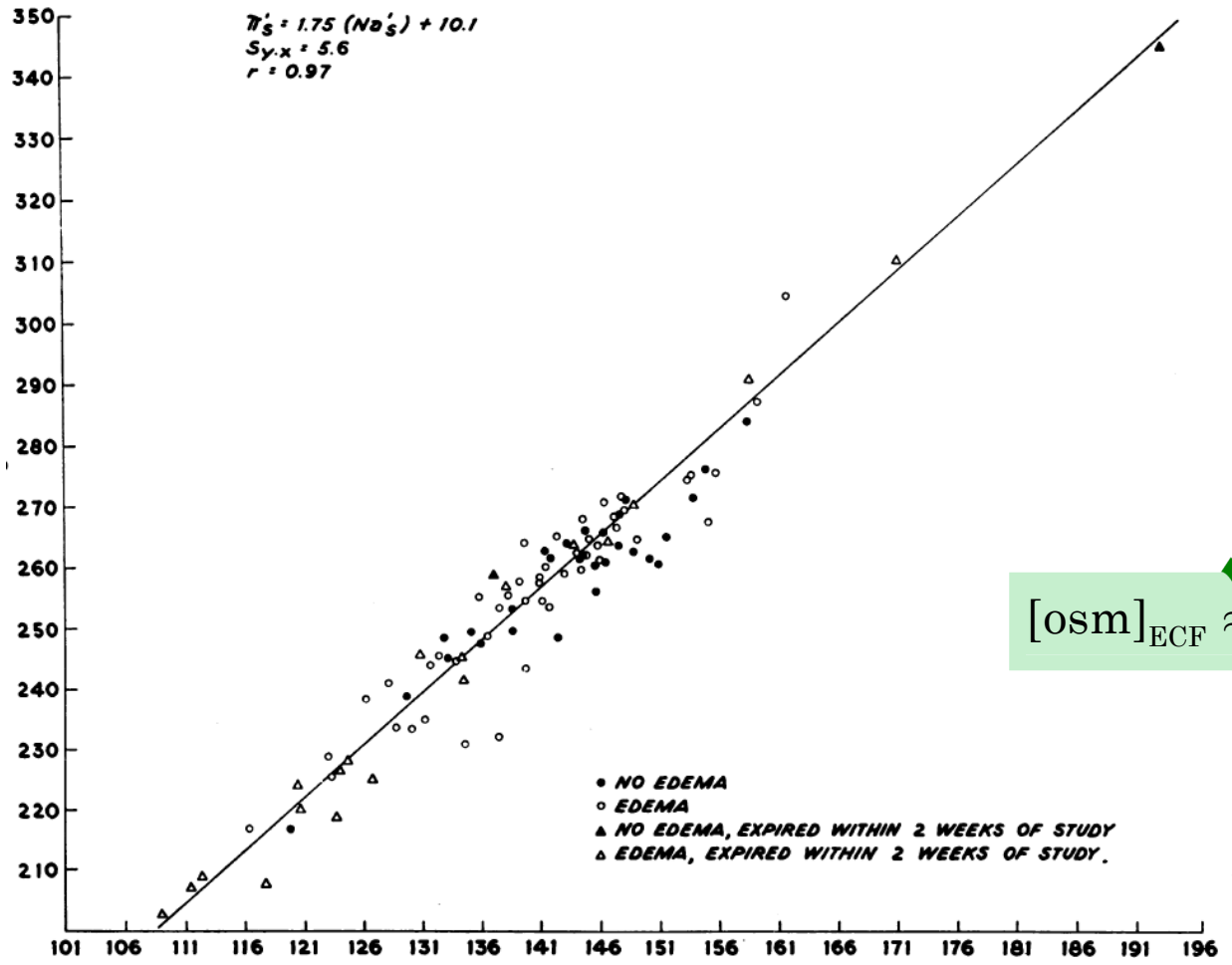

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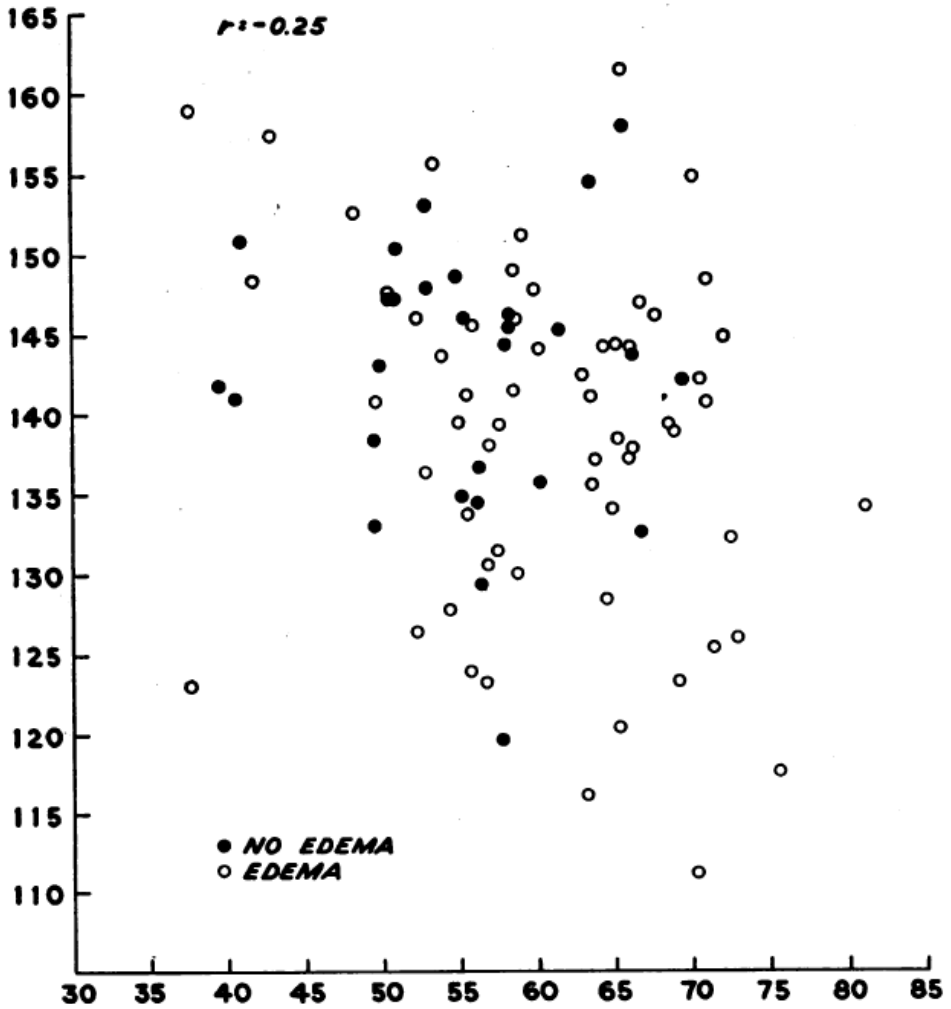

V_{TBW}

Quantitative Nephrology III: The Edelman Equation

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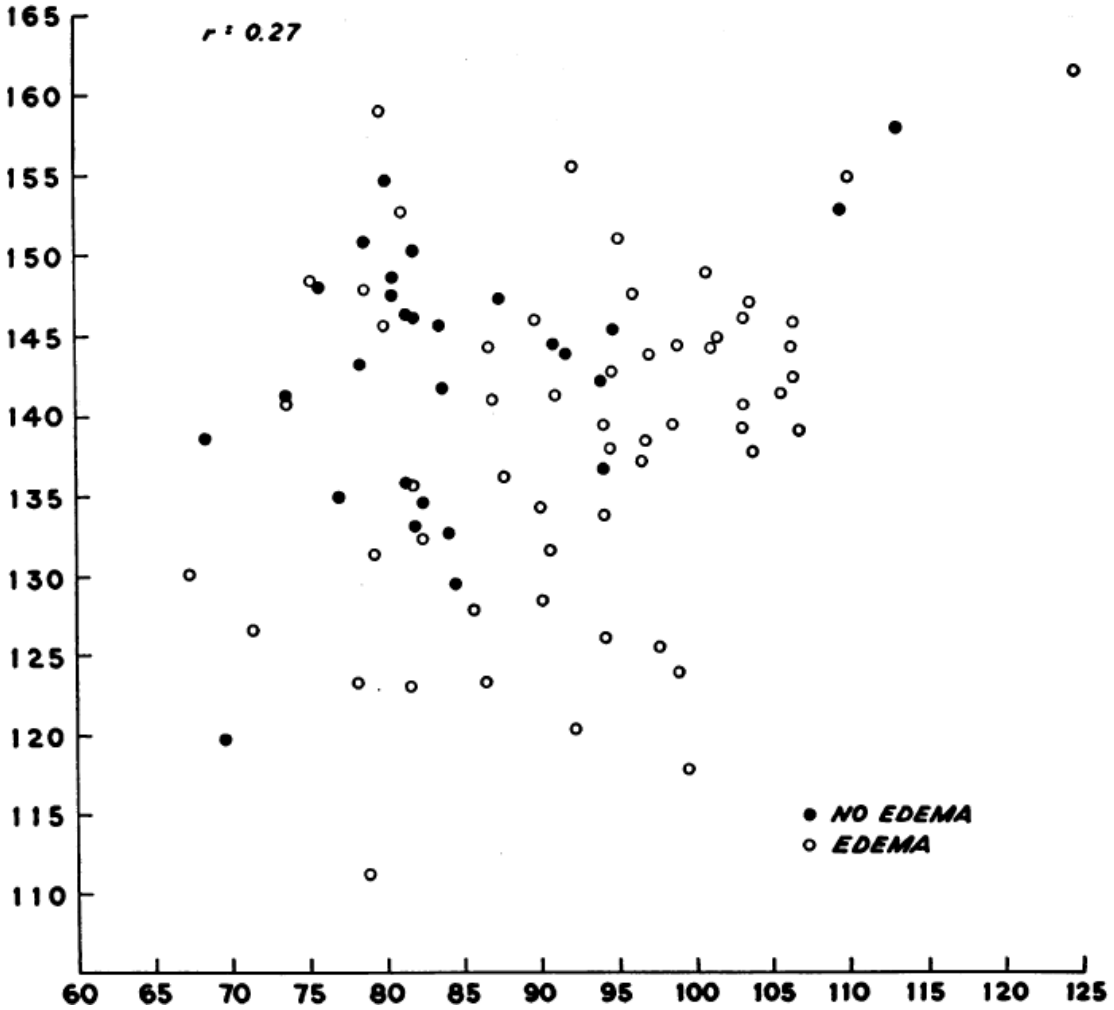
corrected $[Na]_{PW}$



$n_{Na(TBF)} / V_{TBW}$

Quantitative Nephrology III: The Edelman Equation

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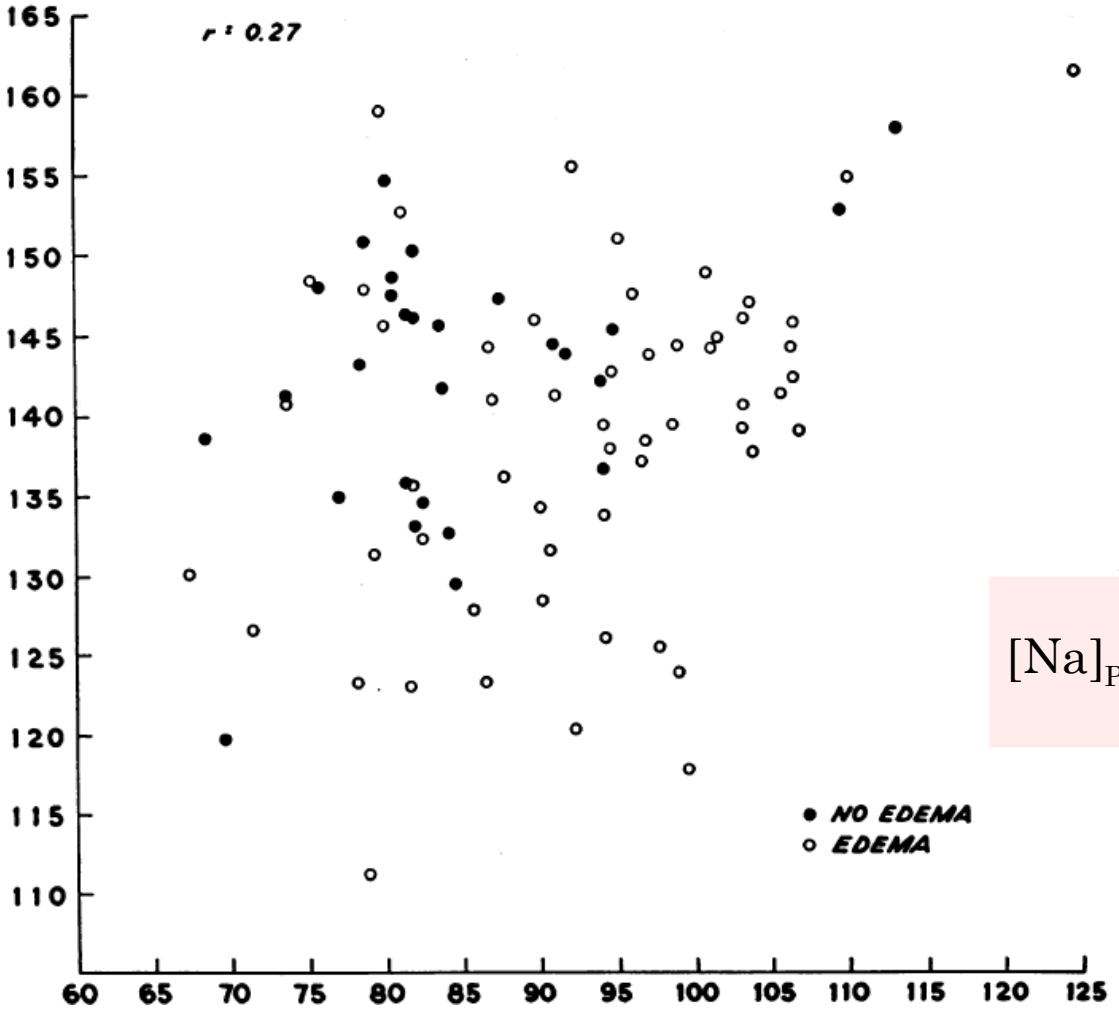
$\text{corrected } [\text{Na}]_{\text{PW}}$



$n_{\text{Na(TBF)}} / V_{\text{TBW}}$

$$[\text{Na}]_{\text{PW}} = \frac{n_{\text{Na(TBF)}}}{V_{\text{TBW}}}$$

Quantitative Nephrology III: The Edelman Equation

Classic Nephrology paper: Edelman IS et al. *J Clin Invest*. 1958;37(9):1236–56.

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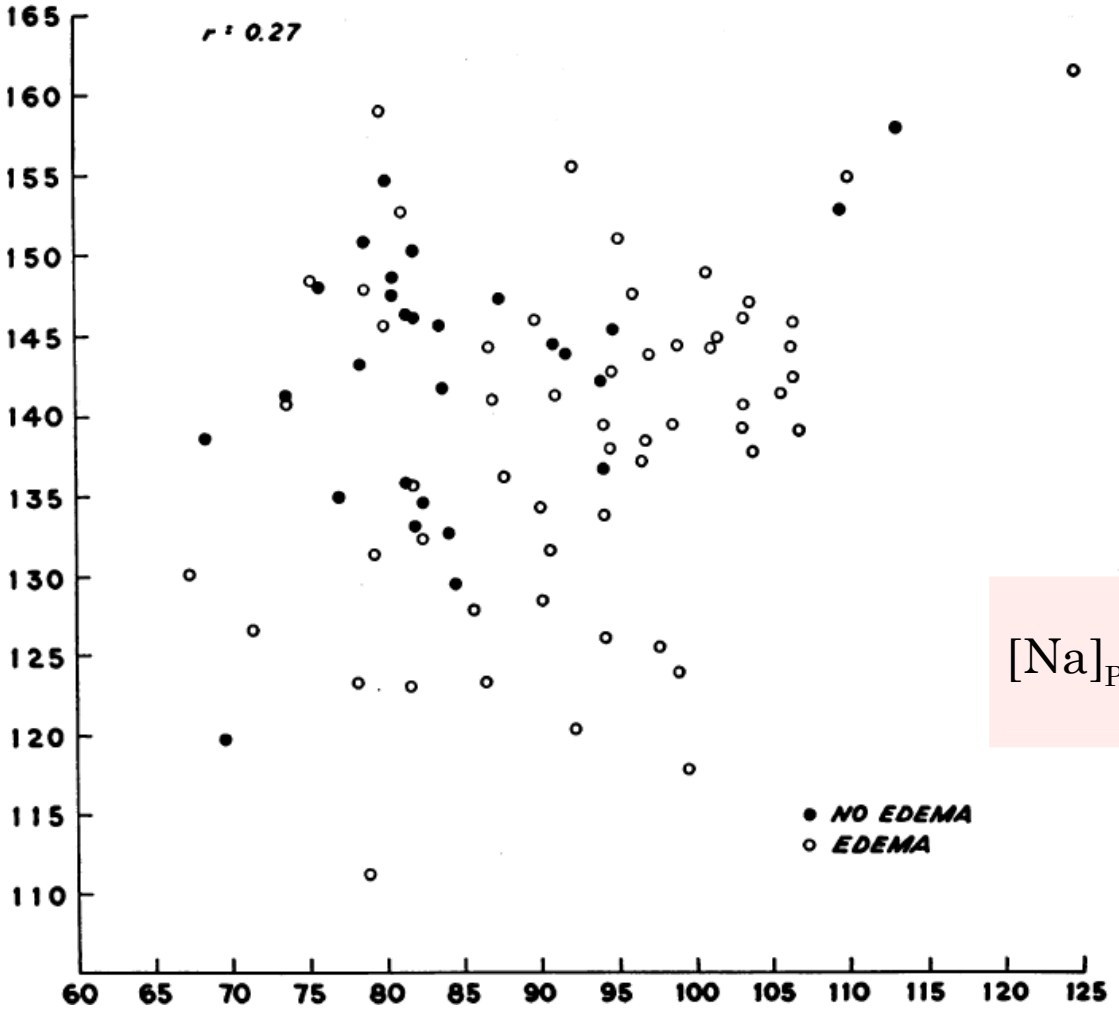

$n_{Na(TBF)}/V_{TBW}$

$$[Na]_{PW} \neq \frac{n_{Na(TBF)}}{V_{TBW}}$$

Quantitative Nephrology III: The Edelman Equation

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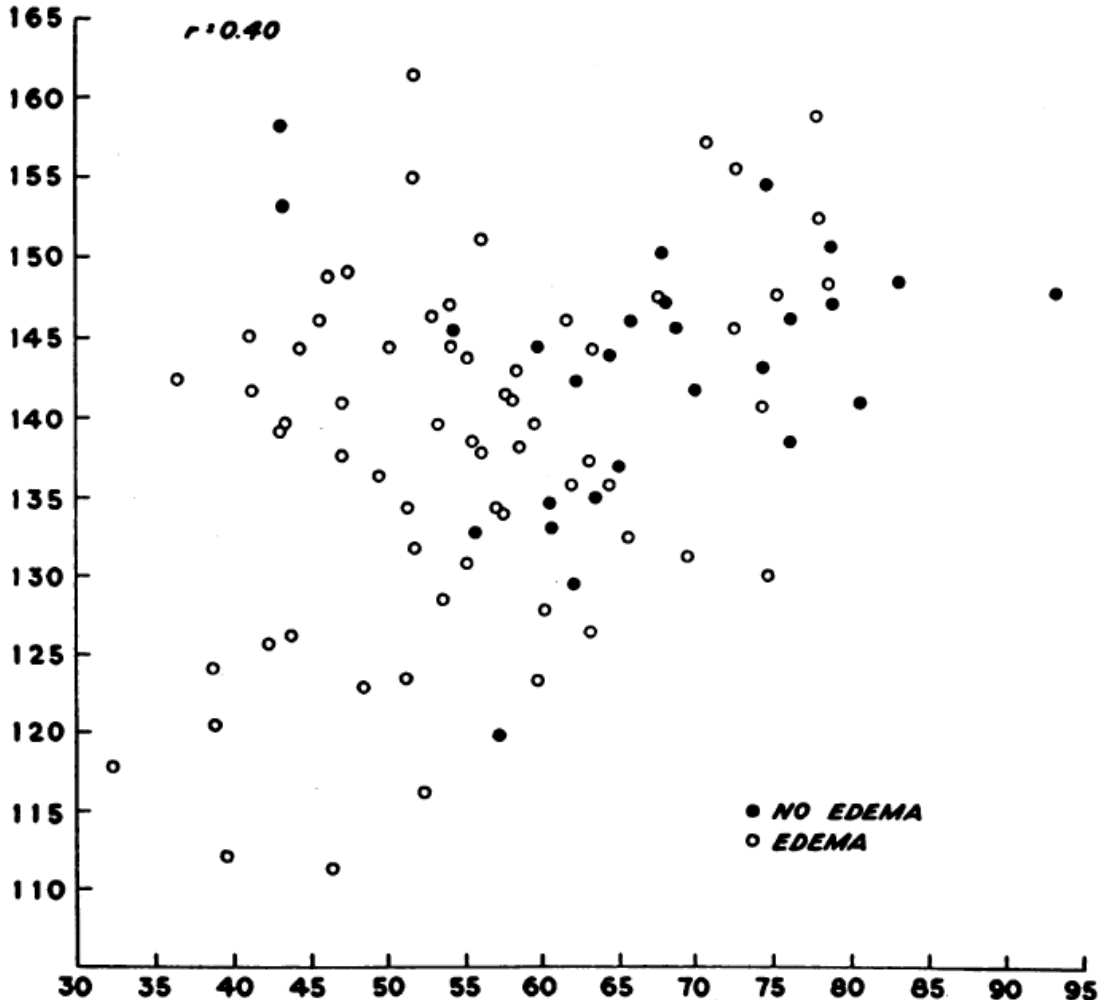
$\text{corrected } [Na]_{PW}$



$n_{K(TBF)} / V_{TBW}$

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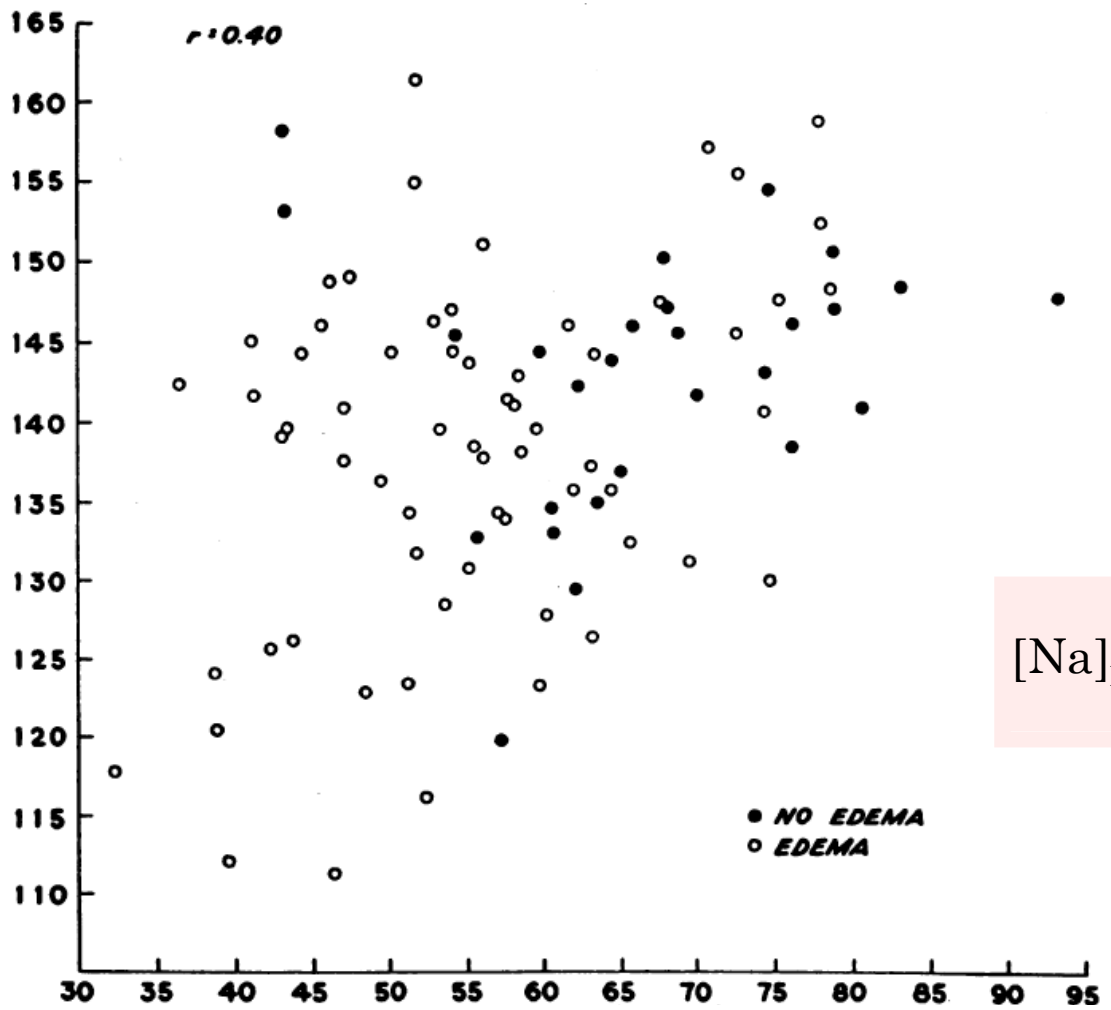
Classic Nephrology paper: Edelman IS et al. *J Clin Invest*. 1958;37(9):1236–56.

corrected $[Na]_{PW}$



$n_{K(TBF)}/V_{TBW}$

$$[Na]_{PW} = \frac{n_{K(TBF)}}{V_{TBW}}$$

Quantitative Nephrology III: The Edelman Equation

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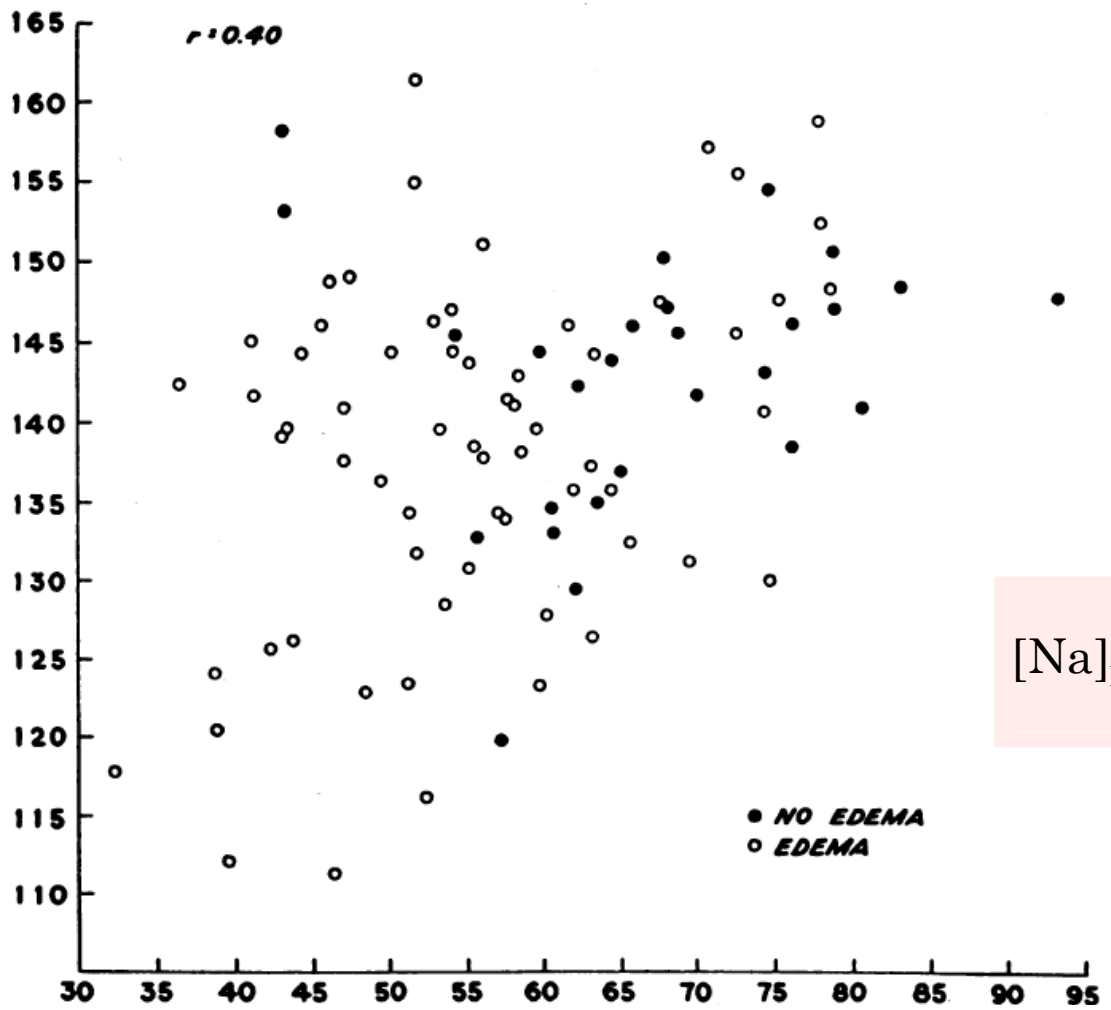

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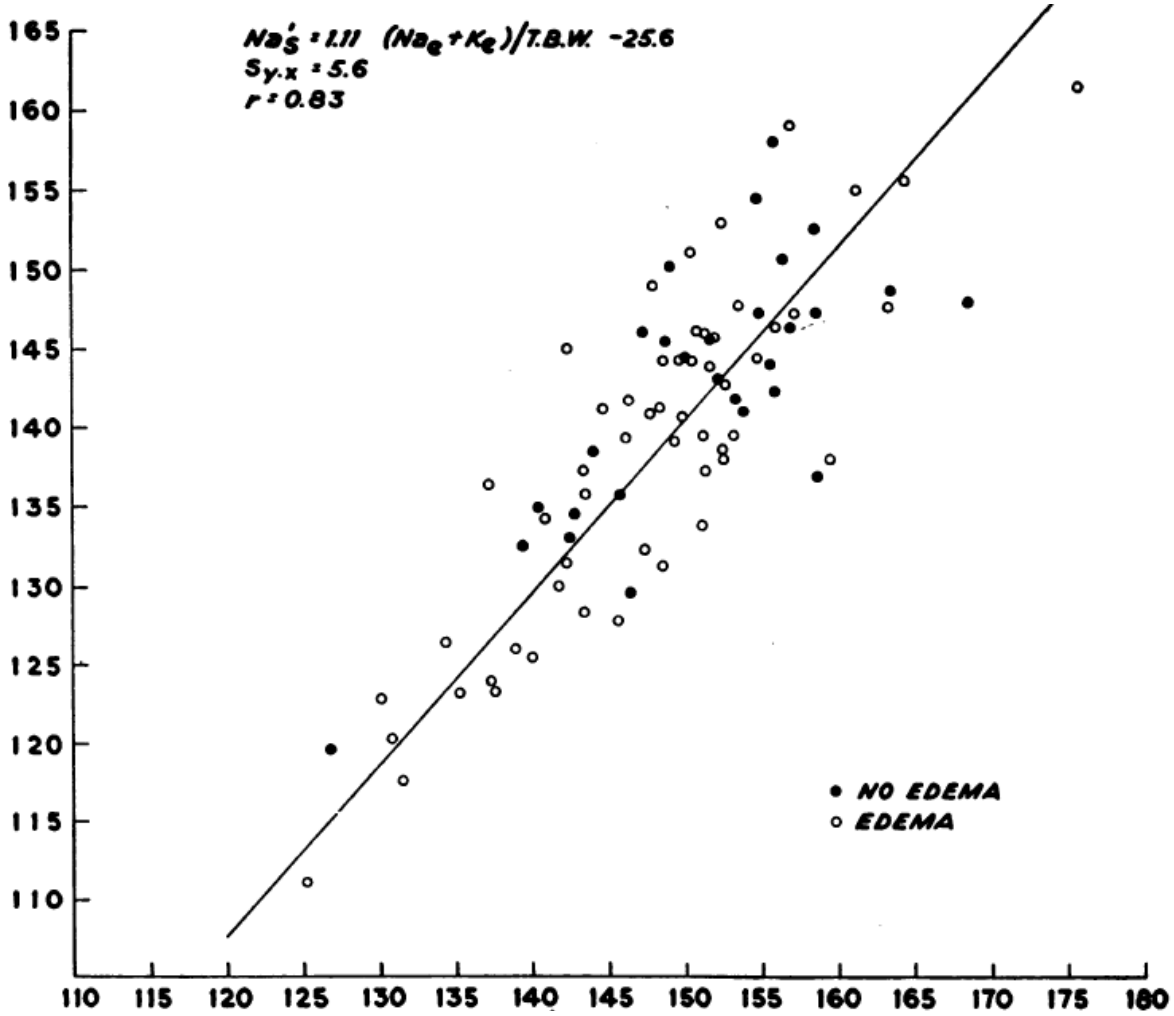
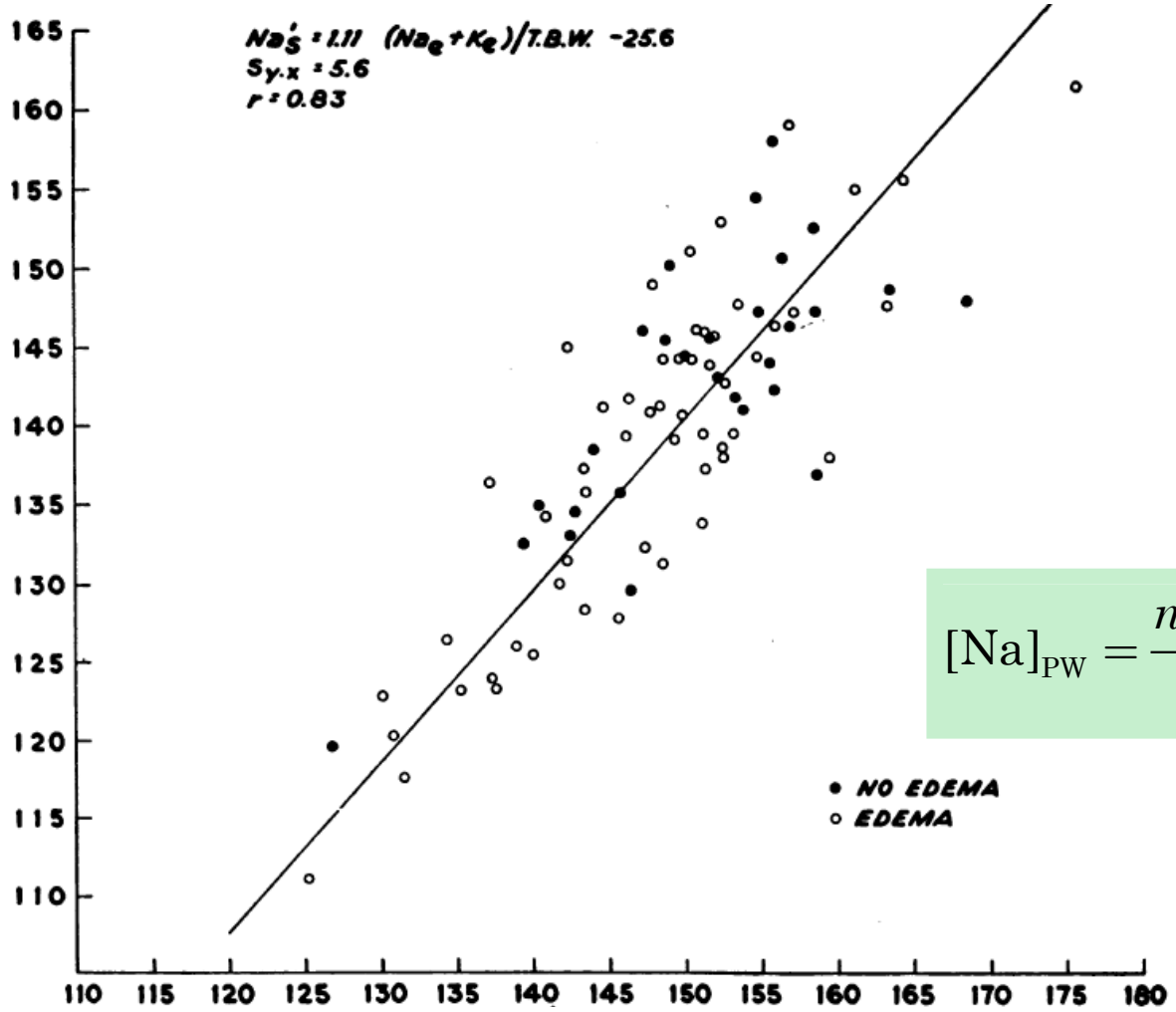


$$\left\{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}\right\} / V_{\mathrm{TBW}}$$

Quantitative Nephrology III: The Edelman Equation

Classic Nephrology paper: Edelman IS et al. *J Clin Invest*. 1958;37(9):1236–56.

corrected $[Na]_{PW}$



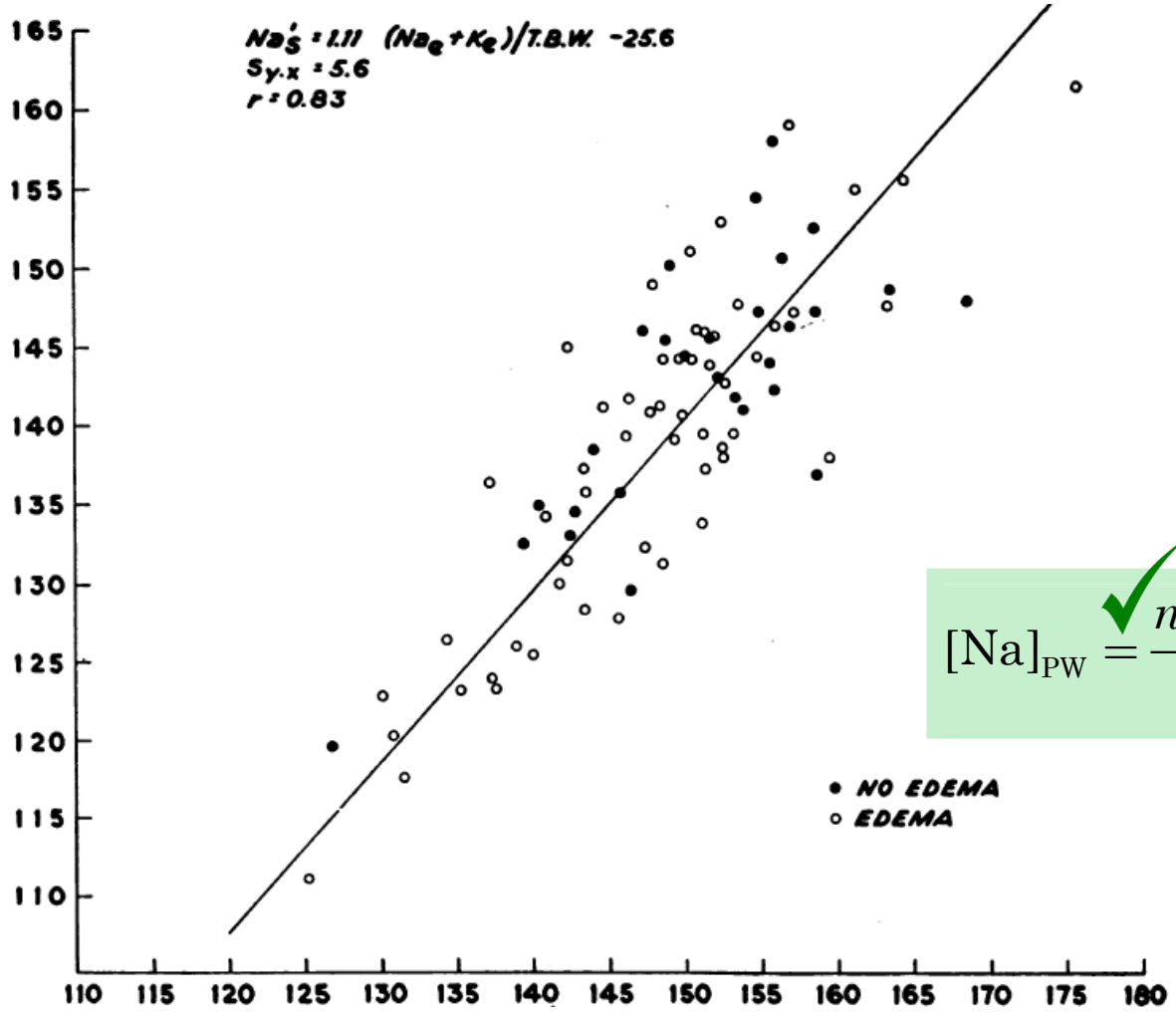
$$[Na]_{PW} = \frac{n_{Na(TBF)} + n_{K(TBF)}}{V_{TBW}}$$

$$\left\{n_{Na(TBF)} + n_{K(TBF)}\right\} / V_{TBW}$$

Quantitative Nephrology III: The Edelman Equation

Classic Nephrology paper: Edelman IS et al. *J Clin Invest*. 1958;37(9):1236–56.

corrected $[\mathrm{Na}]_{\mathrm{PW}}$



$$[\mathrm{Na}]_{\mathrm{PW}} = \frac{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}}{V_{\mathrm{TBW}}}$$

$$\left\{n_{\mathrm{Na(TBF)}} + n_{\mathrm{K(TBF)}}\right\} / V_{\mathrm{TBW}}$$

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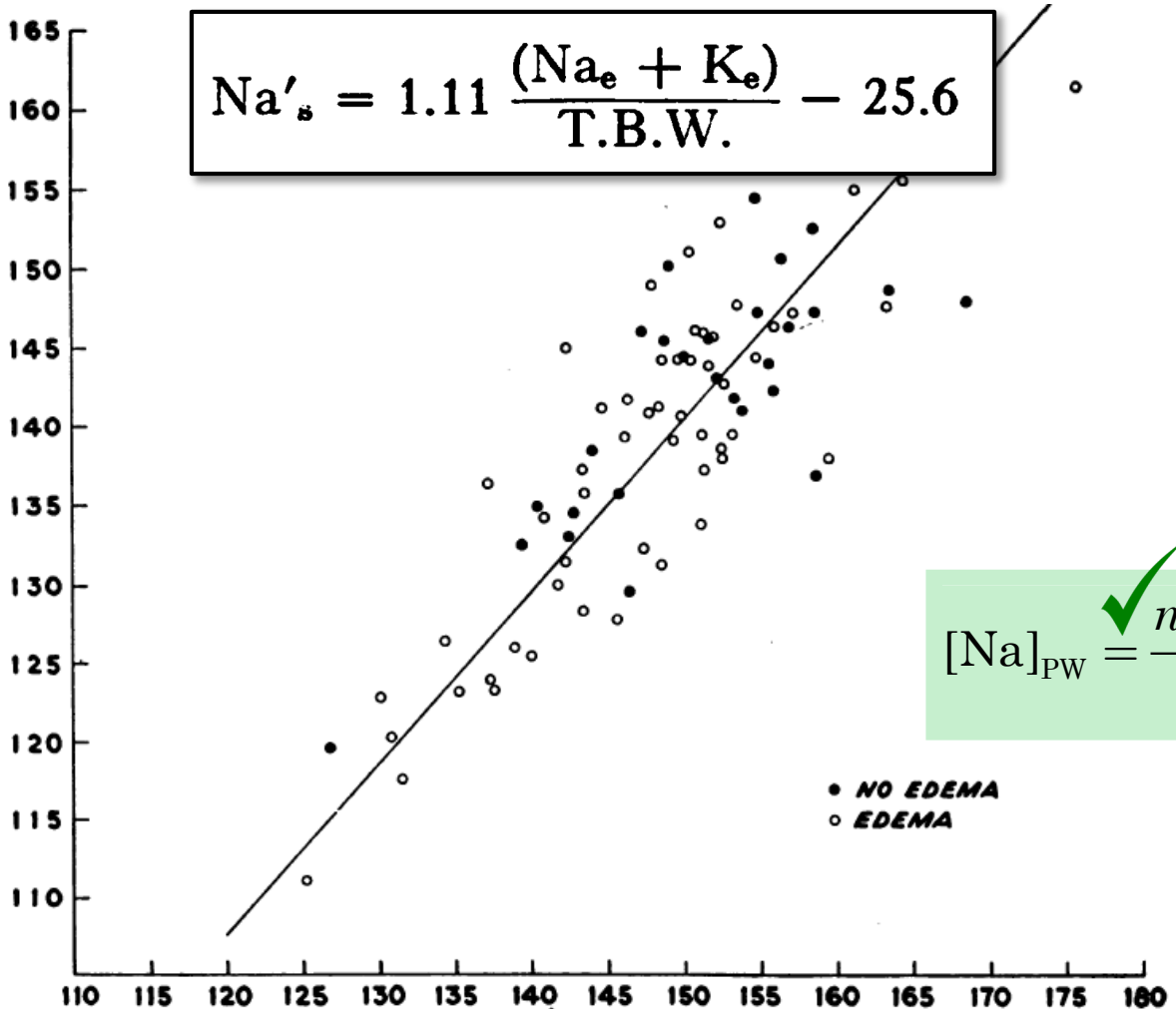
$$Na'_s = 1.11\,\frac{(Na_e + K_e)}{T.B.W.} - 25.6$$



corrected $[Na]_{PW}$

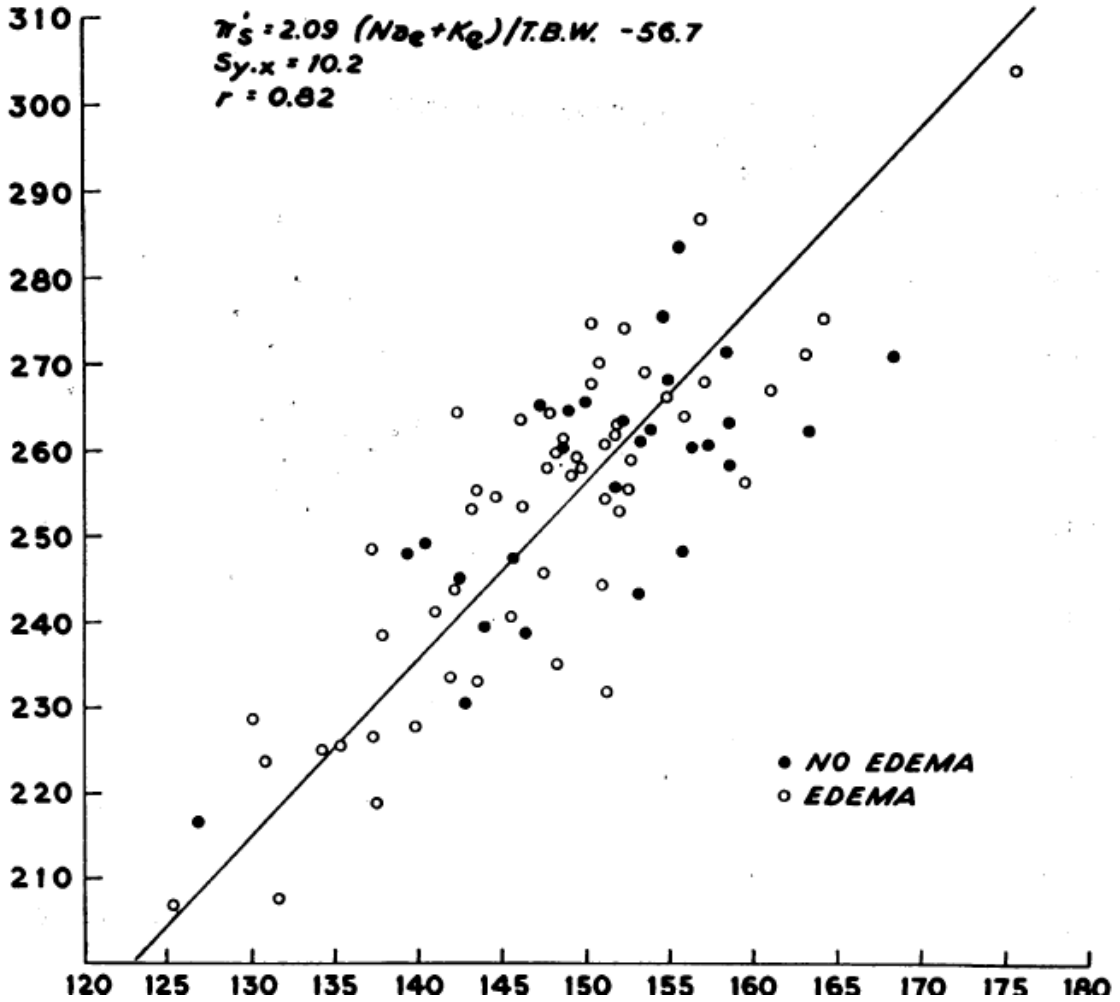
$$[Na]_{PW} = \frac{n_{Na(TBF)} + n_{K(TBF)}}{V_{TBW}}$$

$$\left\{n_{Na(TBF)} + n_{K(TBF)}\right\} / V_{TBW}$$

Quantitative Nephrology III: The Edelman Equation

Classic Nephrology paper: Edelman IS et al. *J Clin Invest*. 1958;37(9):1236–56.

corrected $[\text{osm}]_{\text{PW}}$



$$\left\{n_{\text{Na(TBF)}} + n_{\text{K(TBF)}}\right\} / V_{\text{TBW}}$$

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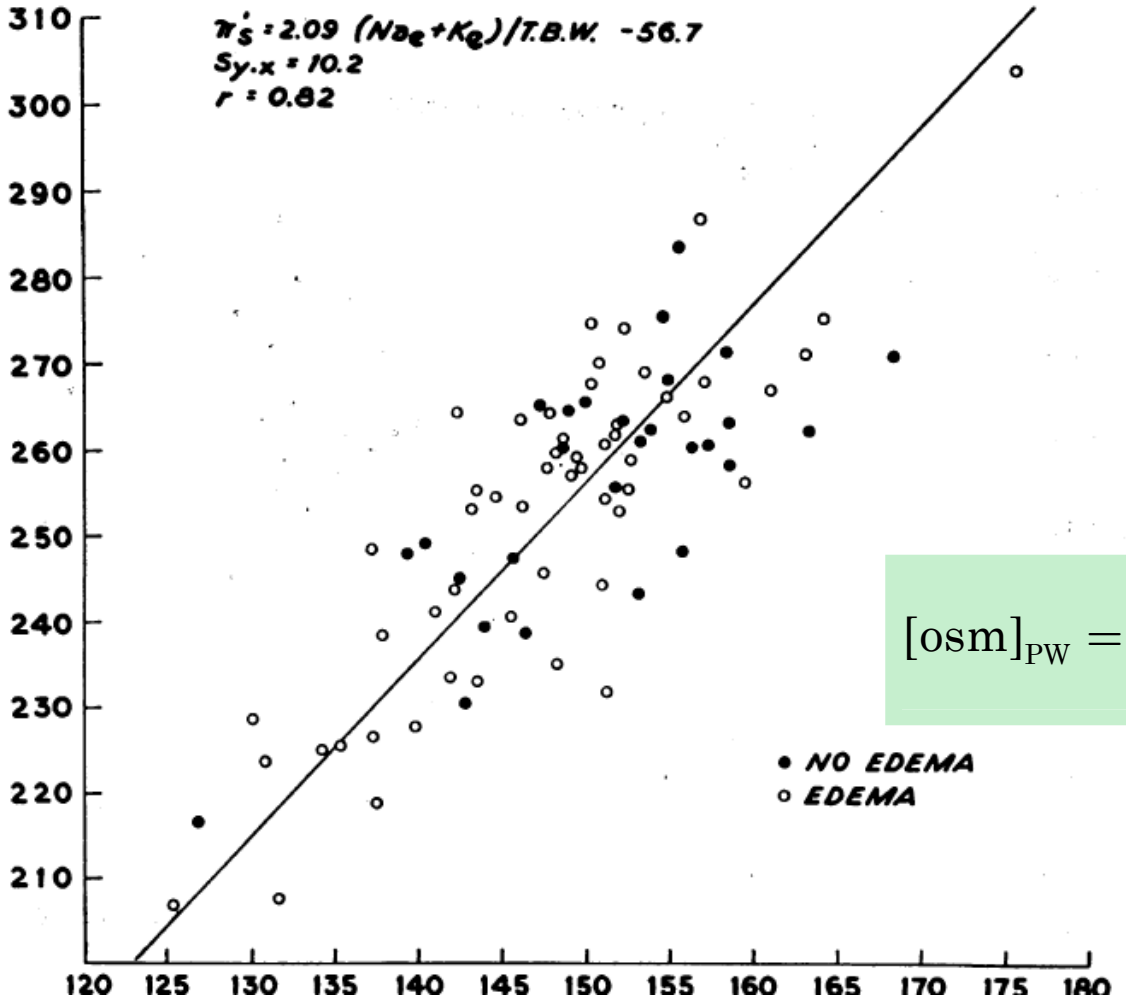

$$[\text{osm}]_{\text{PW}} = \frac{n_{\text{Na(TBF)}} + n_{\text{K(TBF)}}}{V_{\text{TBW}}}$$

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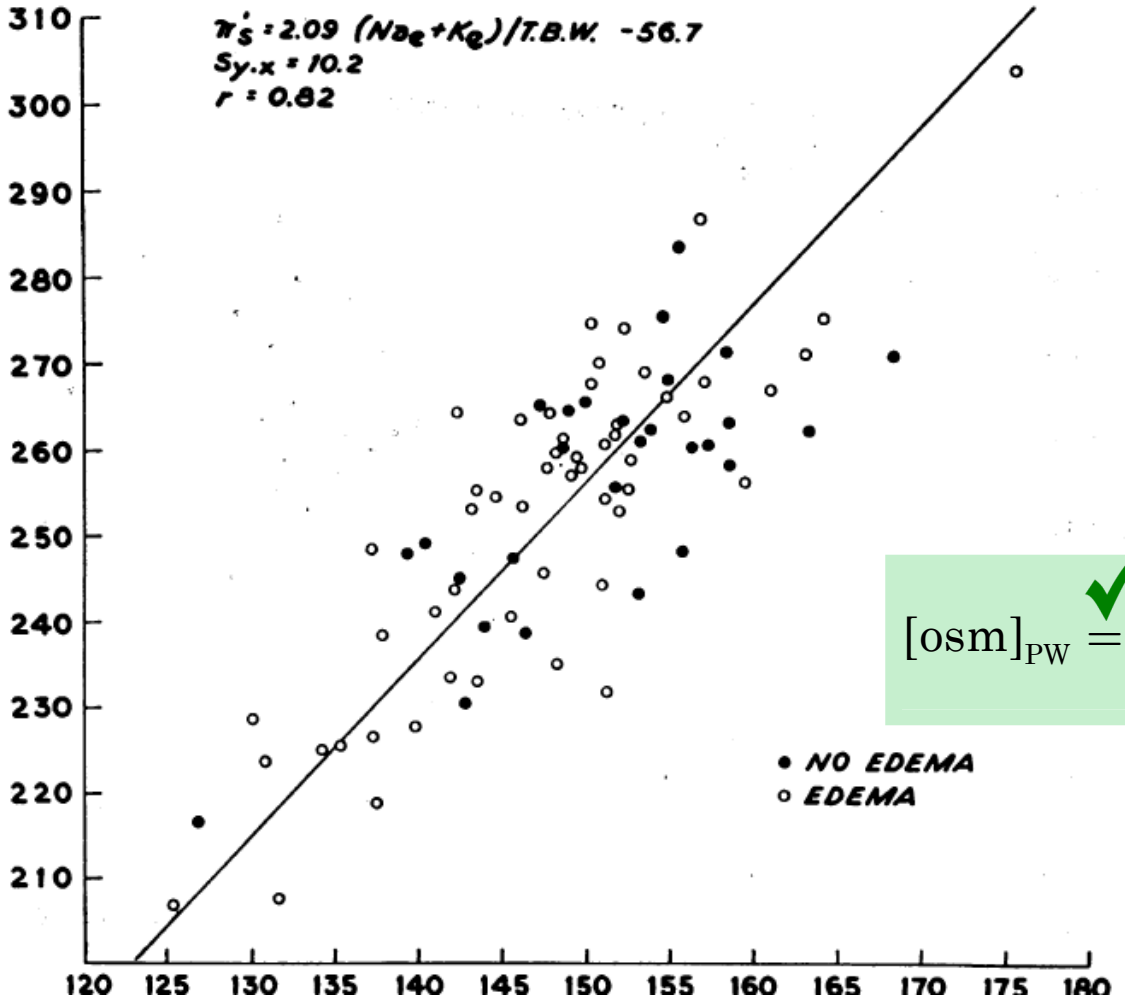

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