Disorders of water and electrolyte balance

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Average daily water intake and output of a normal adult

Intake of water	mL	Output of water	mL
Water drunk	1500	Urine volume	1500
Water in food	750	Water content of faeces	50
Water from metabolism of food	250	Losses in expired air and insensible perspiration	950
Total intake	2500	Total output	2500

Approximate contributions to plasma osmolality

	Osmolality (mmol/kg)	Per cent total
Sodium and anions	270	92
Potassium and anions	7	8
Calcium (ionized) and anions	3+	
Magnesium and anions	1+	
Urea	5	
Glucose	5	
Protein	Approximately 1	
Total	Approximately 292	

Distribution of water in the body

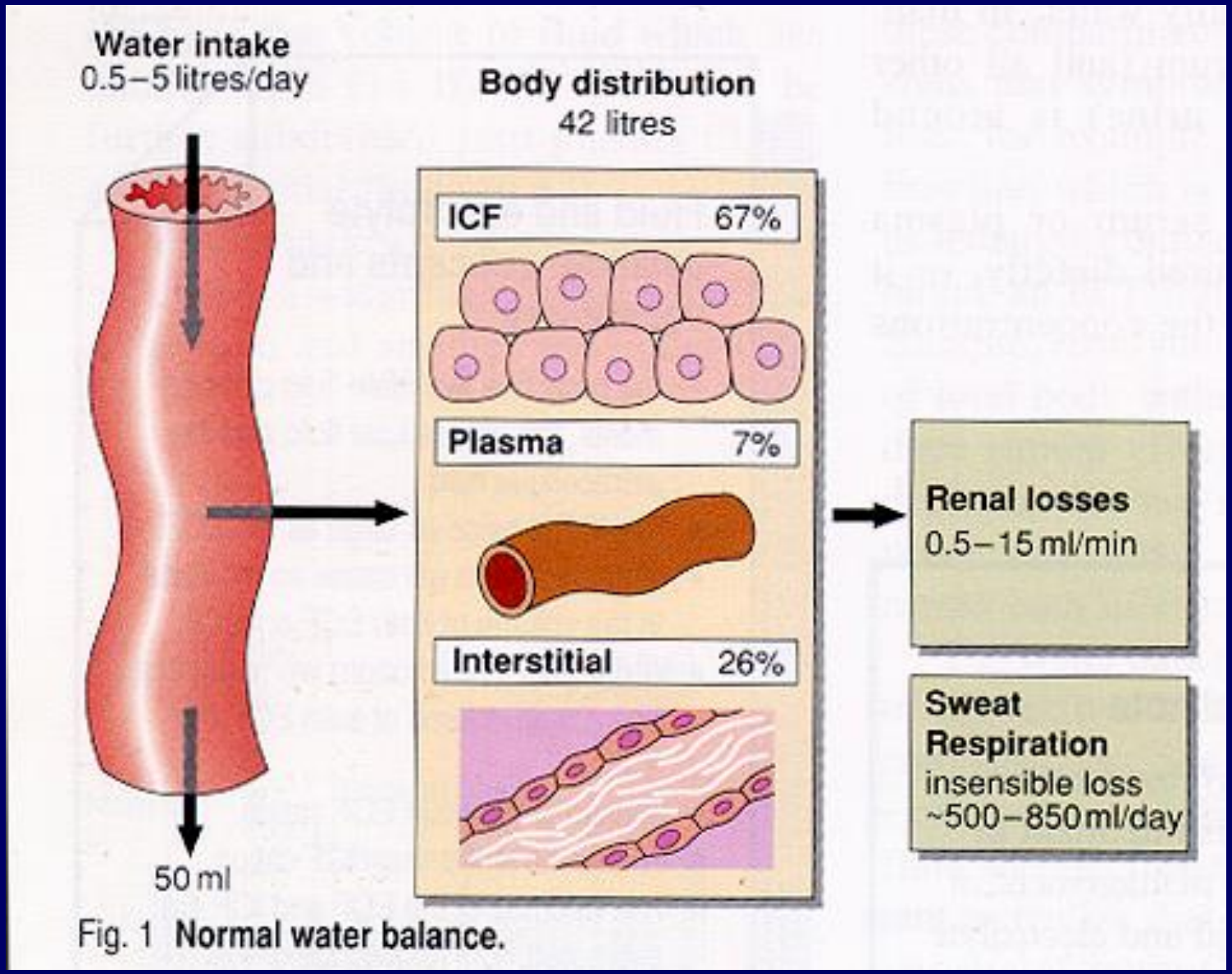


Fig. 1 Normal water balance.

Electrolytes – Electrical Neutrality

Component (Cations)	Plasma (mmol/L)	Component (Anions)	Plasma (mmol/L)
Na^+	142	Cl^-	103
K^+	5	HCO_3^-	24
Ca^{2+}	2	$Protein^-$	15
Mg^{2+}	1	$Organic\ acids^-$	3
		HPO_4^{---}	2
		SO_4^{--}	1
		Total Anions	1
Total cations	149		149

Adapted from C.A. Burtis, ed., *et. al.* Tietz Fundamentals of Clinical Chemistry. 5th ed. Philadelphia: WB Saunders Company, 2001, pg 725.

Change in [Electrolyte] Can Occur By…

1.) Increase/Decrease in amount of electrolyte

2.) Increase/Decrease in amount of water

Remember

$$\text{Concentration} = \frac{\text{amount of solute}}{\text{volume of solution}}$$

Paradox of intracellular components

Human body: approx. 70kg - 10^{15} living cells

Intracellular components:
water, protein, nucleic acids
Organic small molecules
macro- and microelements
All in structure!
Release into the extracellular space
in health and in diseases conditions

Electrolyte paradox

Intracellular electrolytes:
K, Ca, Mg, Zn, Fe ... Trace elements

Mostly protein bound!

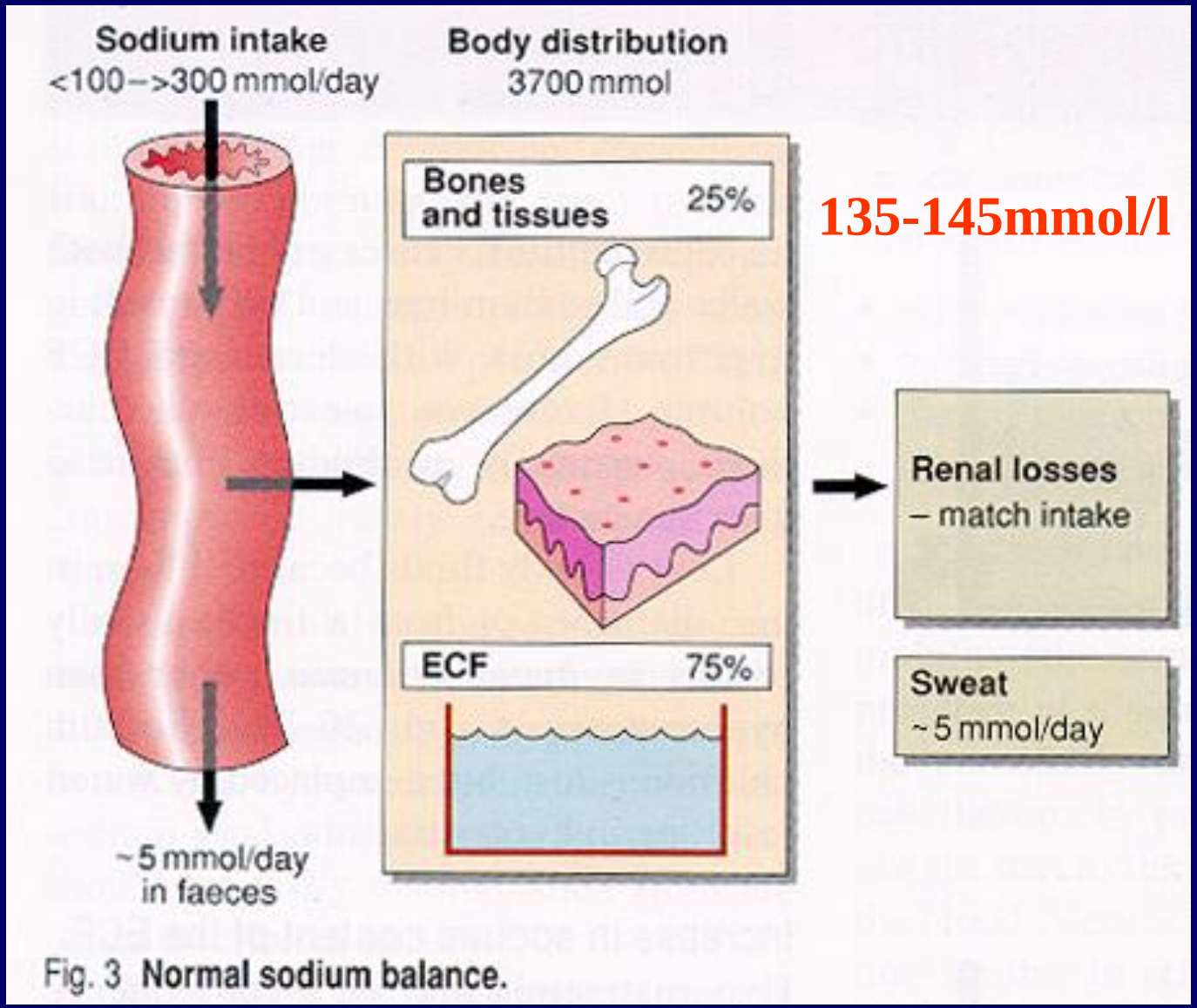
Extracellular space concentrations do not mirror intracellular load!

Methodological palette

- **Water – electrolyte balance tested together!**
- **Sodium: ~ 150g Potassium: ~ 200g**
- **Sodium – potassium: inverse distribution**
- **Sodium - water changes parallel, strict regulation, negligible part is interchangable**

Hyponatraemia Hypernatraemia Osmolality

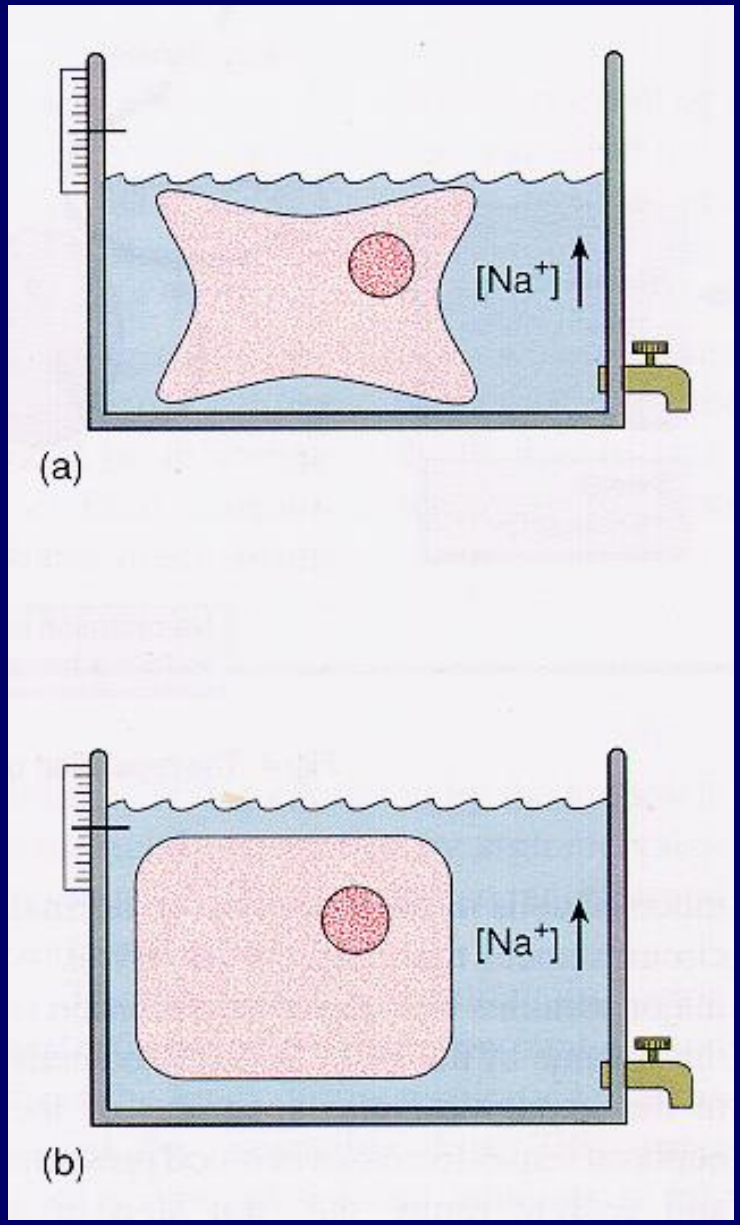
Sodium balance



135-145mmol/l

Fig. 3 Normal sodium balance.

Hypernatraemia



Loss of water (dehydration)

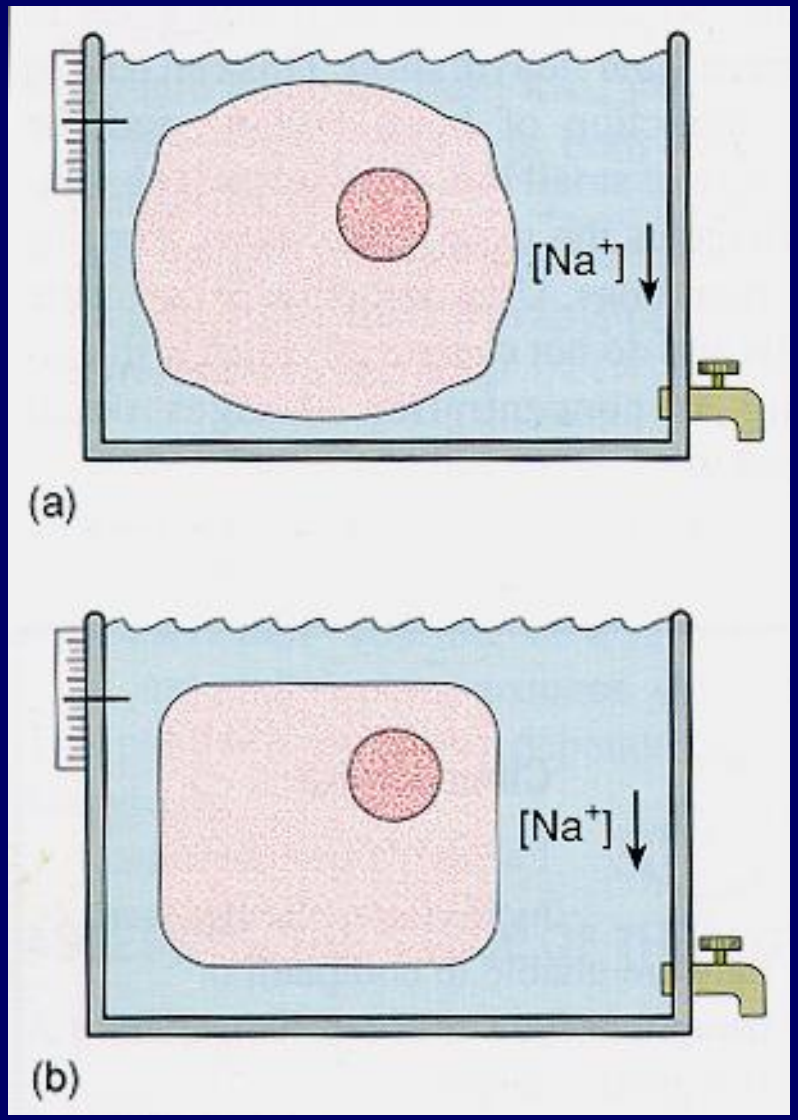
Diabetes insipidus

Serum/urine osmolality

Excess sodium intake

Hyperaldosteronism

Hyponatraemia 1



Water retention

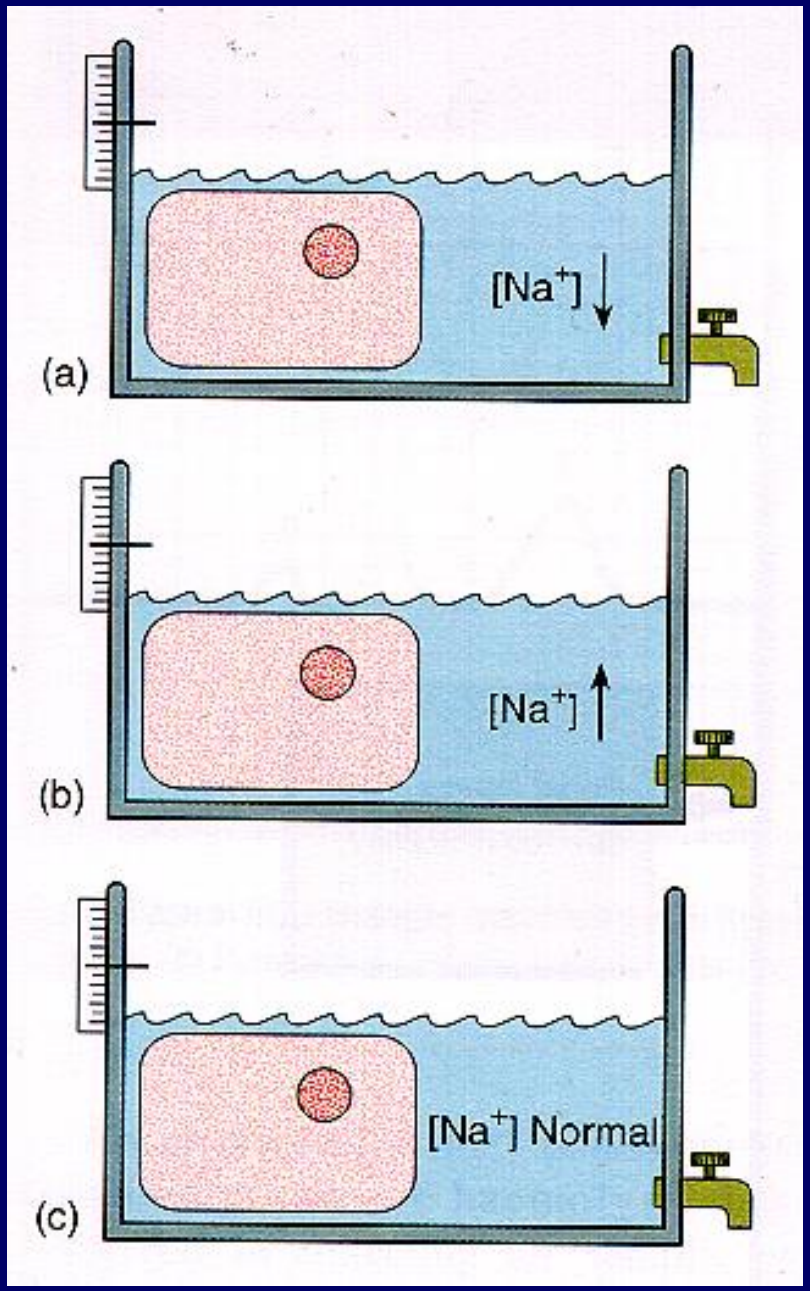
Total sodium normal

Serum/urine osmolality

Sodium loss, insufficient intake (rare)

(gastrointestinal, kidney)

Hyponatraemia 2



Water loss

ECF Na low

Water loss

ECF Na high

Water loss

ECF Na normal

Pseudo-hyponatraemia

- **Plasma water volume decreases:**
  Multiple myelome
  Lipemic serum

- **Method dependent: flame photometry**
  ion selective electrode

Potassium balance

- Major intracellular cation
- Easily released and reuptaken again (acidosis, catabolism, insulin dependence)

  3.7 – 5.2 mmol/l
- Not well regulated
- Daily intake is important!
- Hyper- hypokalaemia may be lethal!
- Measurement of whole body potassium

Functional K test

- Intravenous load test
- 4h slow infusion, known amount of K
- Urine collection: excreted K/4h
- Calculation: balance, deficit, excess

Calcium homeostasis

- Ca 1000g in adults
- 99% in bones (extracellular, Mg, P as well)
- Plasma/intracellular concentration:

  total Ca 10^{-3} mol/l water
- Intracellular concentration:

  „ionized” Ca 10^{-7} mol/l water
- Ionized Ca - muscle contraction, blood coagulation, enzyme activation, signaling, regulation of absorption/excertion

Interpretation of plasma Ca levels (2.10-2.60 mmol/l as total)

Fractions of plasma Ca	% of plasma total Ca
Ionized calcium (Ca^{2+})	50-65
Protein (albumin) bound Ca	30-45
Ca complexes	5-10

Plasma total Ca is depending on albumin concentration

Ionized Ca concentration depends on blood H^+ (respiratory alkalosis - tetany)

Magnesium metabolism

- 24 g in adults, mostly intracellularly
- Plasma: 0.7-1.1 mmol/l (30% protein bound)
- Deficieny: rare, slow development

Functional test (oral)

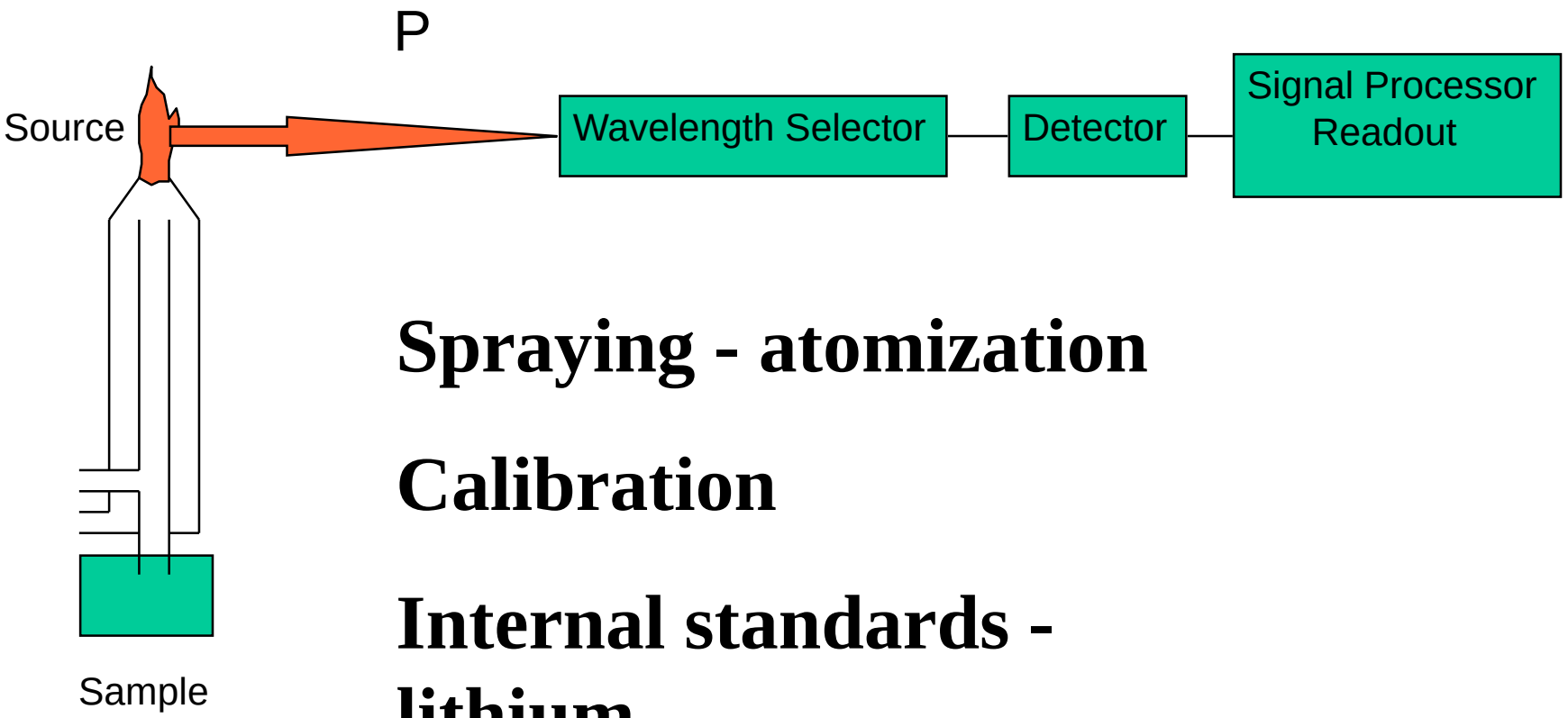
24h urinary Mg – basal excretion

24h urinary Mg – excretion after oral dose

Functional test (intravenous)

48h urinary Mg (>90% should be excreted)

Measurement 1
Emission flame photometry

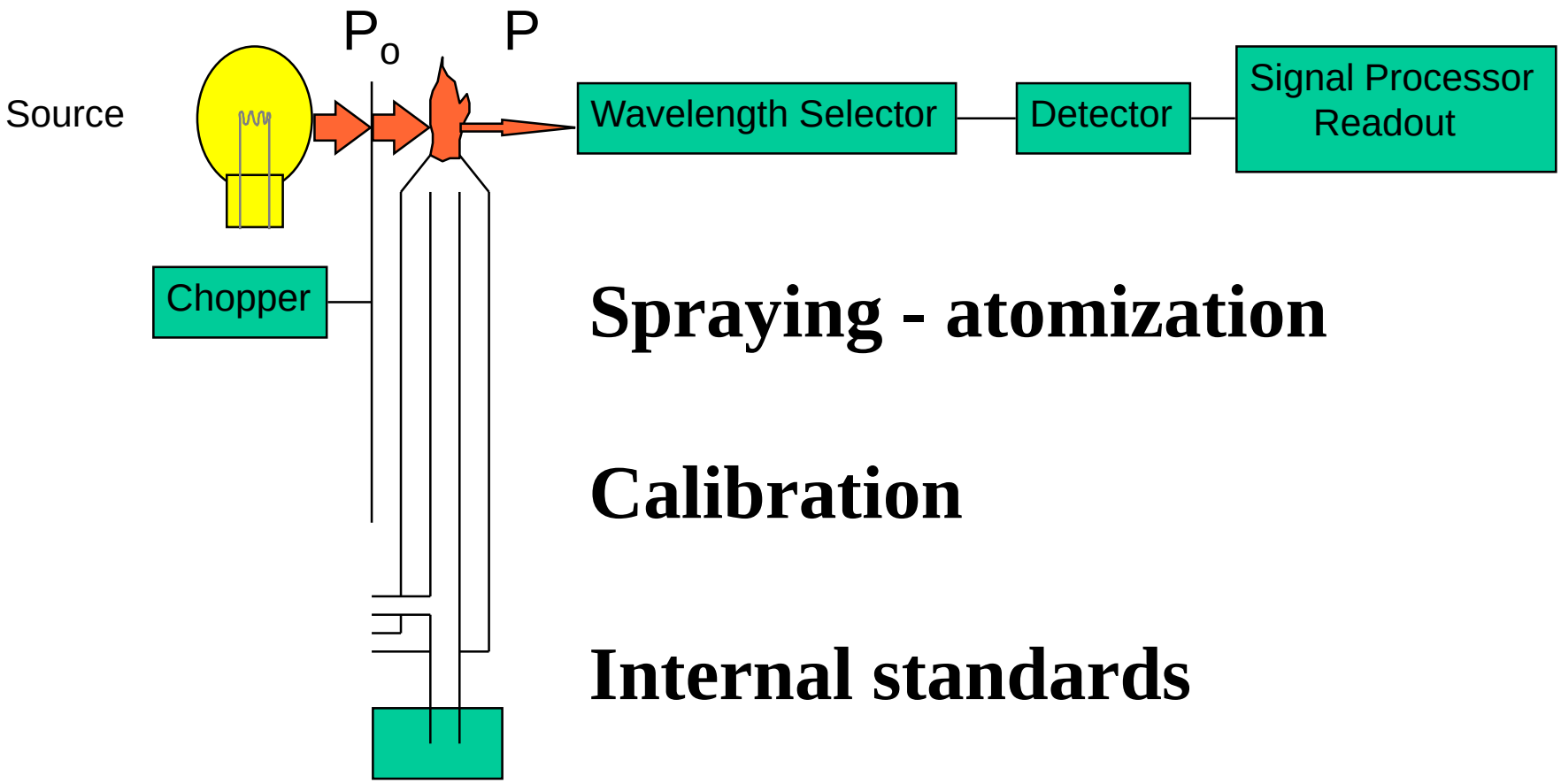


Spraying - atomization

Calibration

Internal standards - lithium

Measurement 2
Atomic absorption photometry



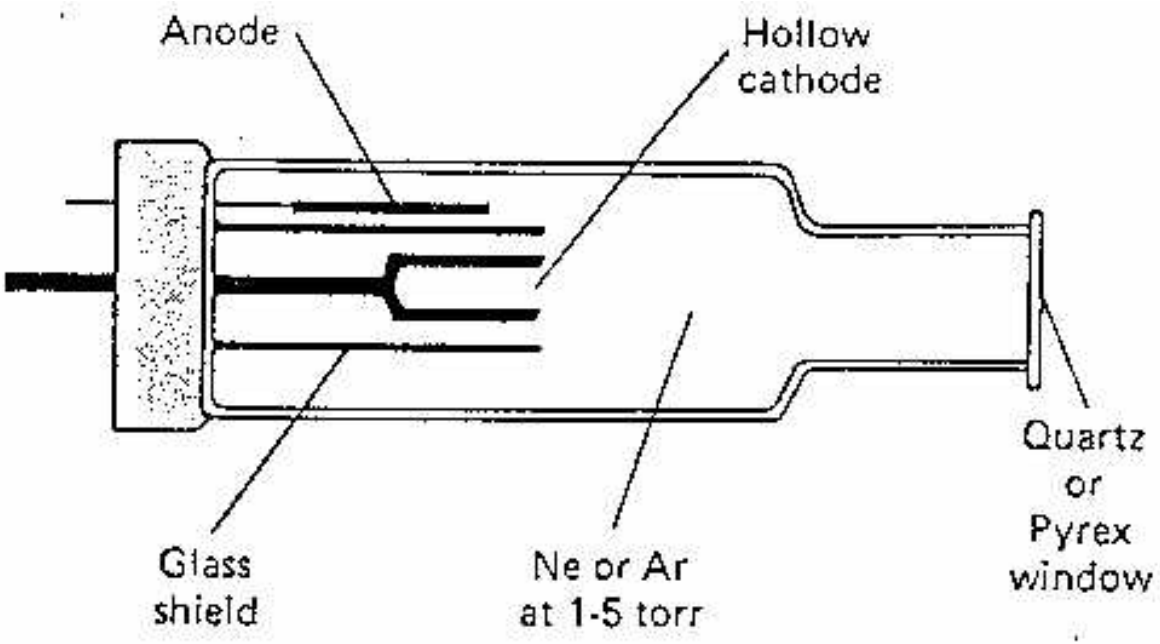
Spraying - atomization

Calibration

Internal standards

Measurement 2
Atomic absorption photometry

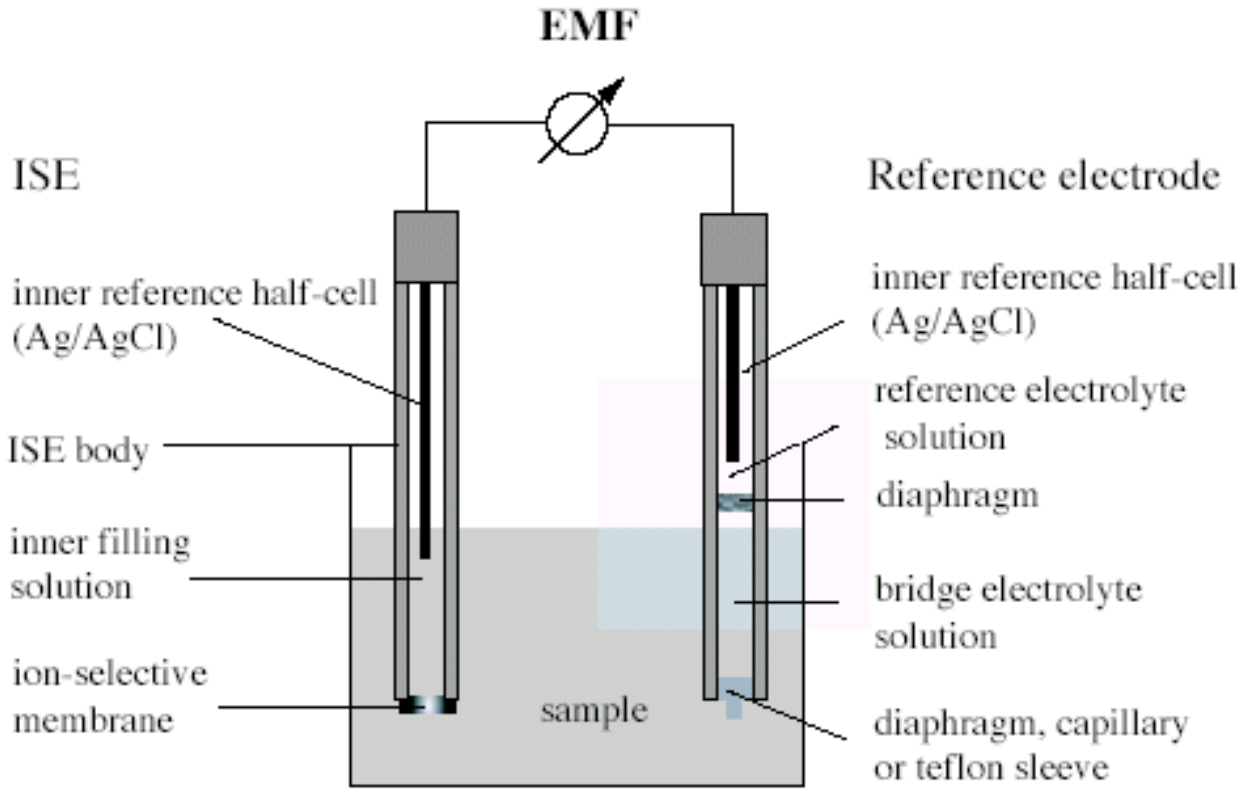
Hollow cathode lamp



Graphite furnace

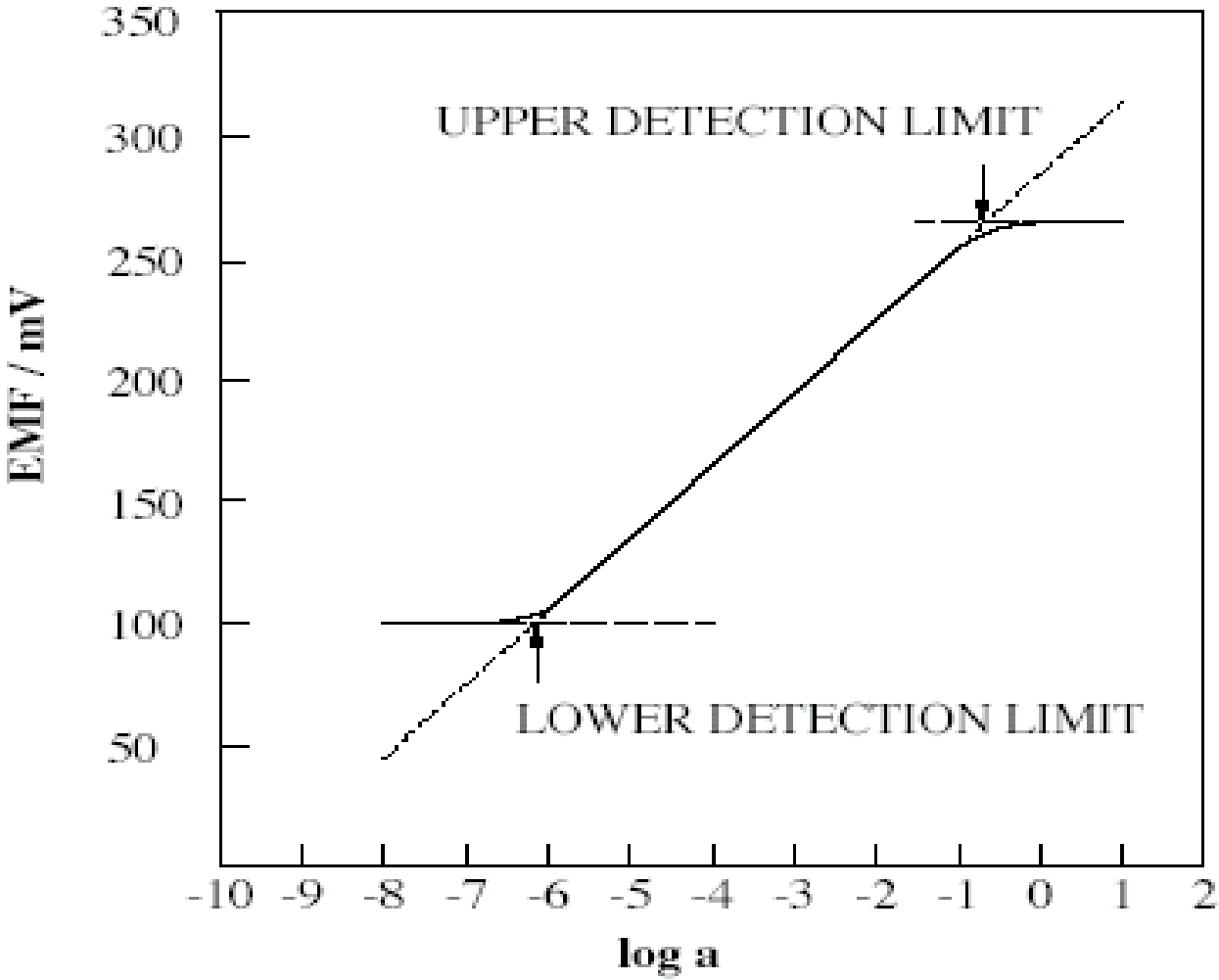
More sensitive

Measurement 3
Potentiometric principles

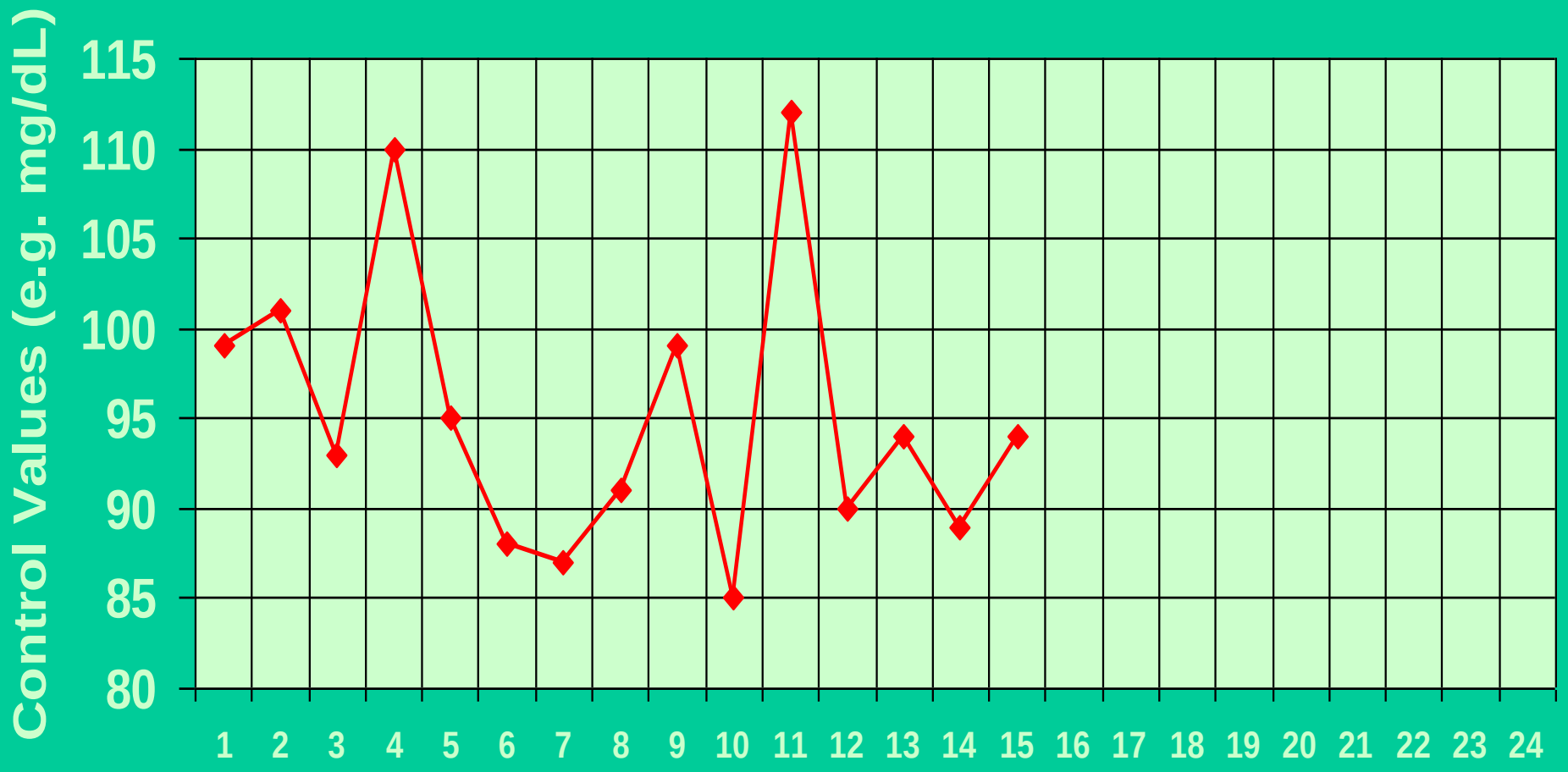


Ag | AgCl | KCl 3M || bridge electrolyte | sample || membrane || inner filling solution | AgCl | Ag

Measurement 3
Potentiometric principles



Quality control
Levey-Jennings chart



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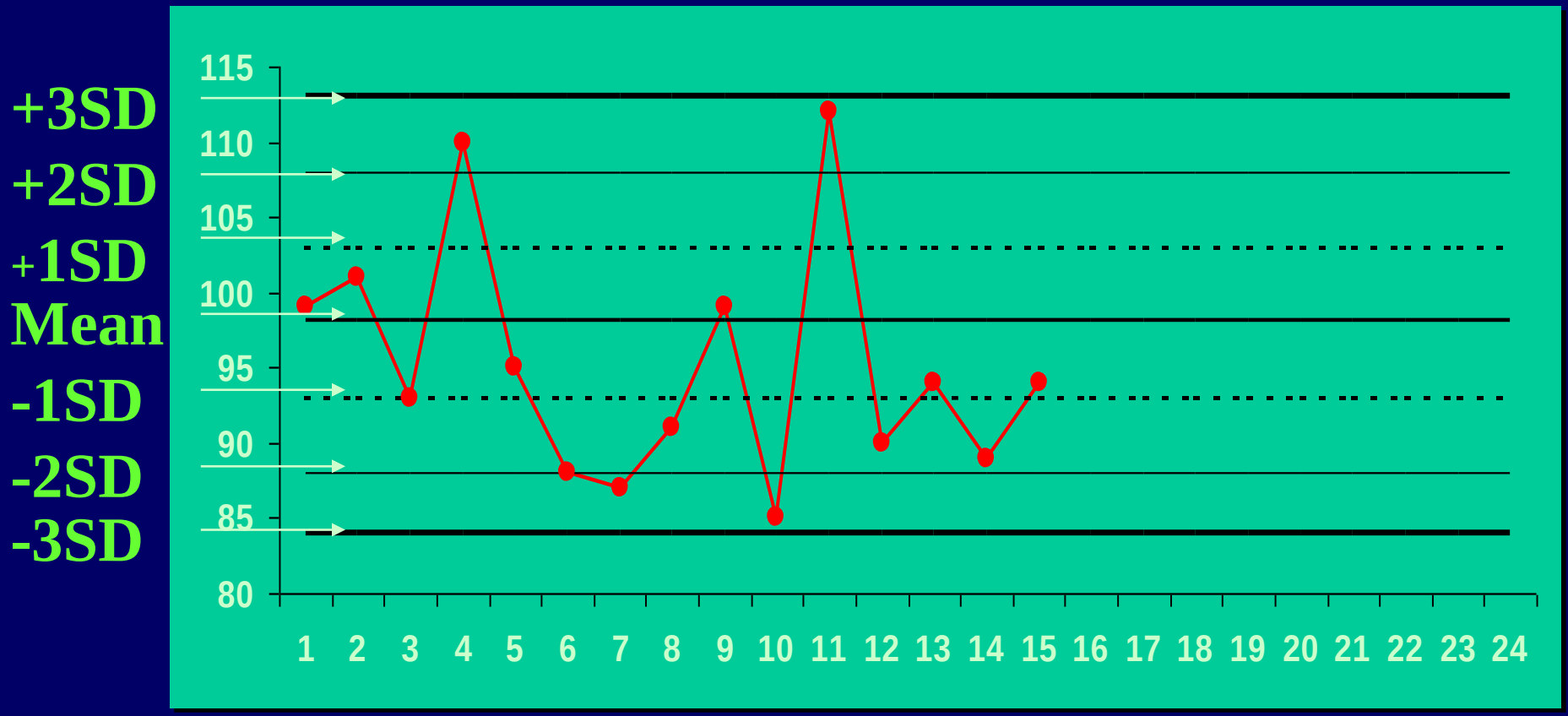
Levey-Jennings chart

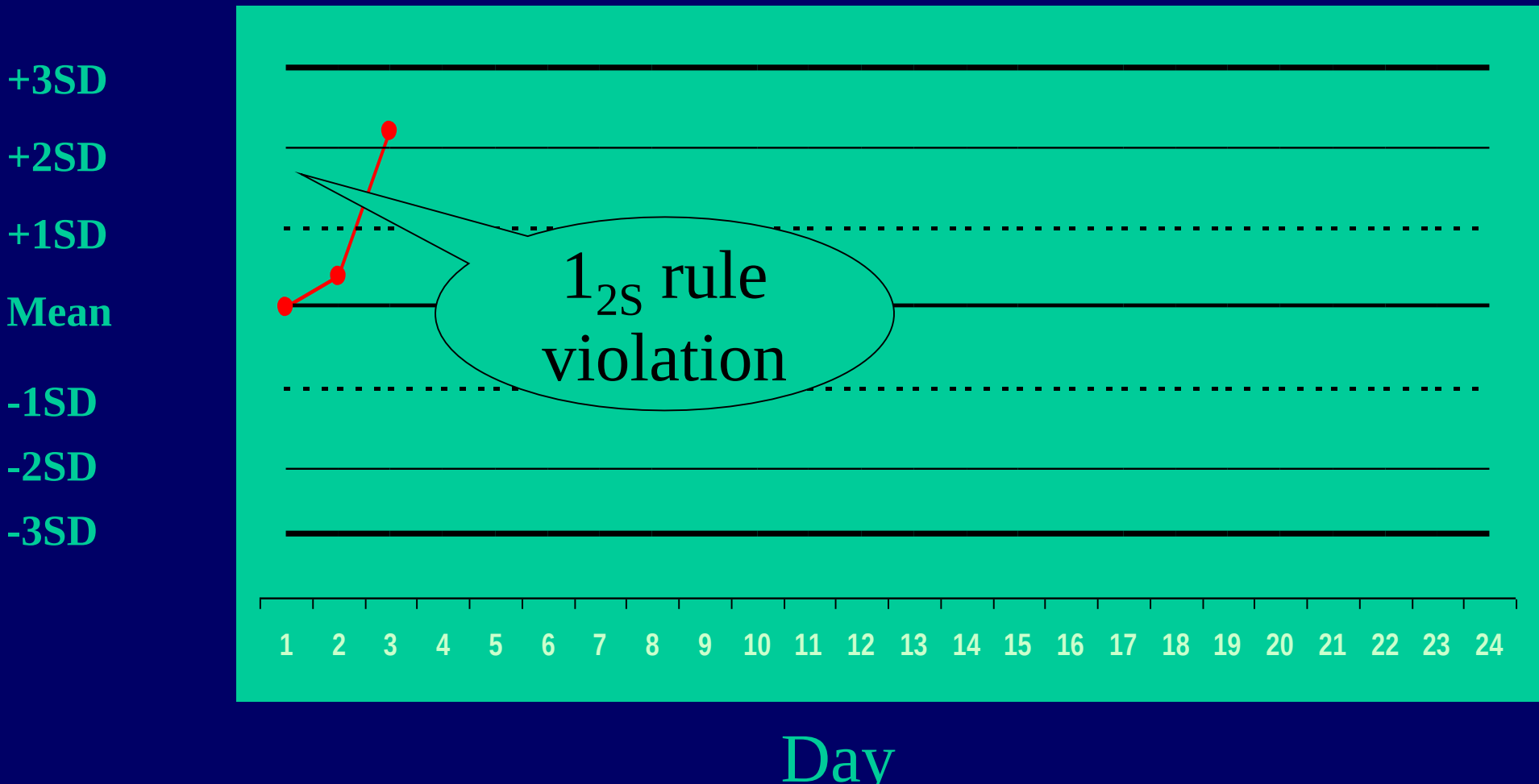


Quality control
Westgard criteria

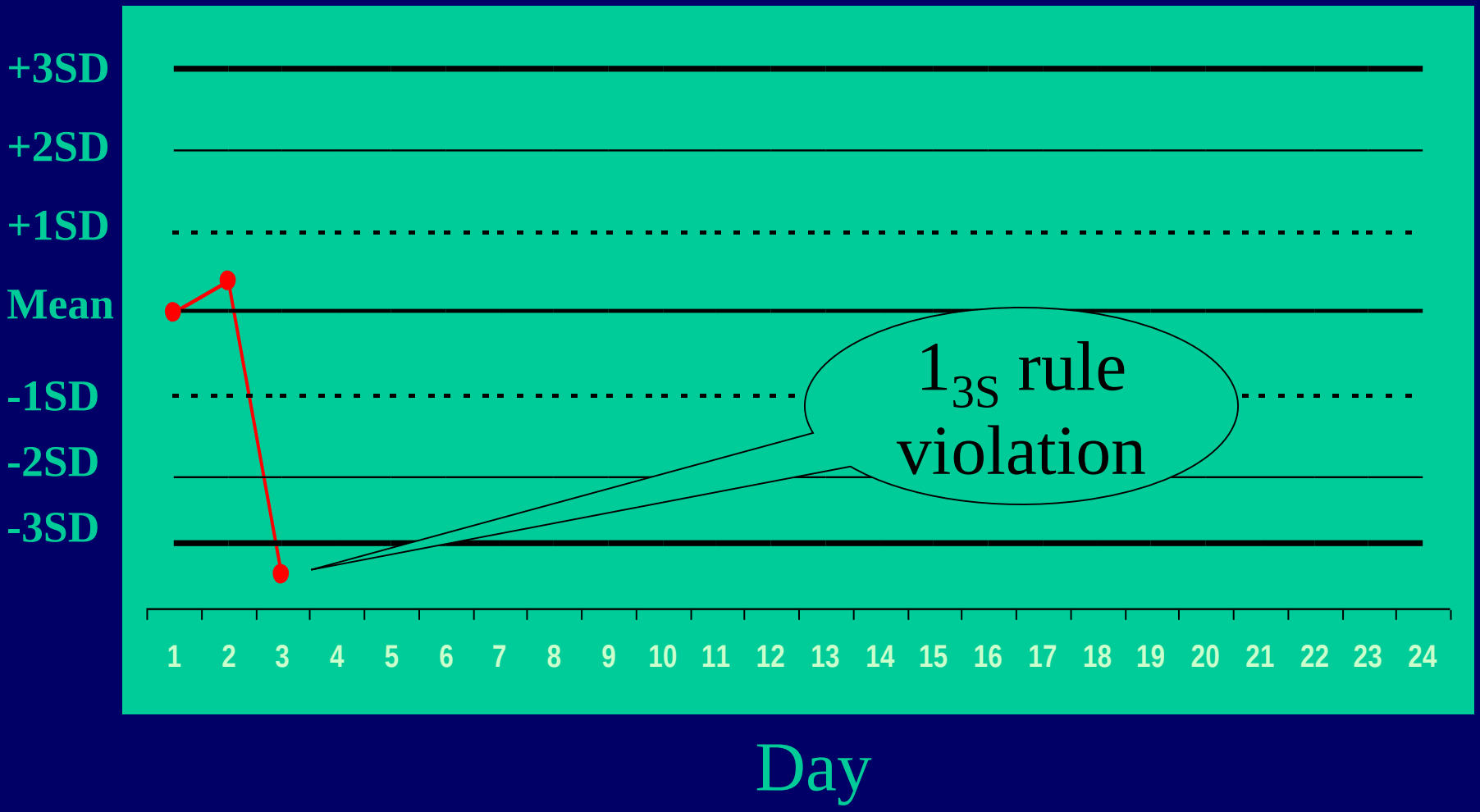
(Generally used where 2 levels of control material are analyzed per run)

- 1_{2S} rule
- 1_{3S} rule
- 2_{2S} rule
- R_{4S} rule
- 4_{1S} rule
- 10_{X} rule

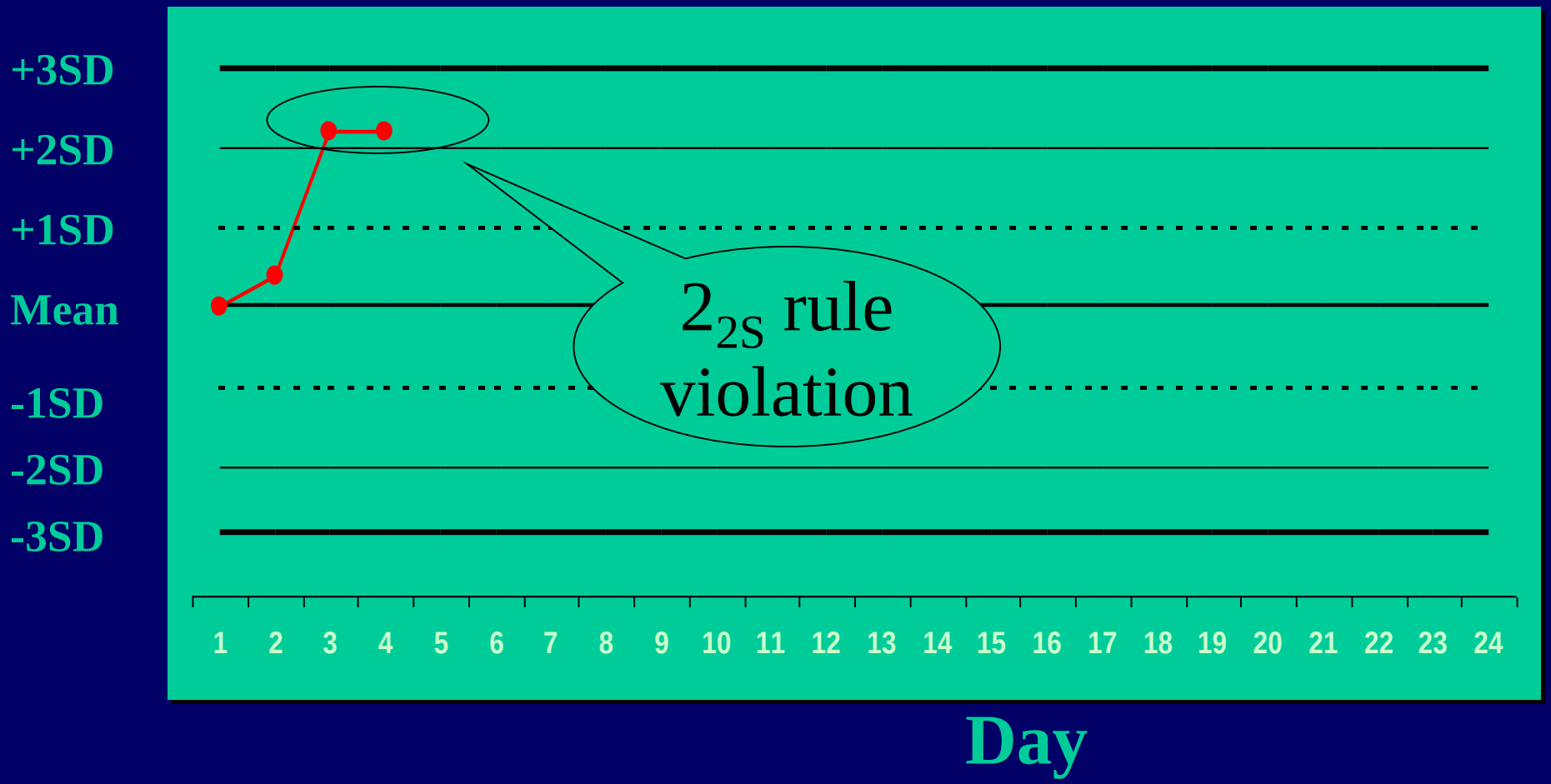
Quality control
Westgard criteria 1



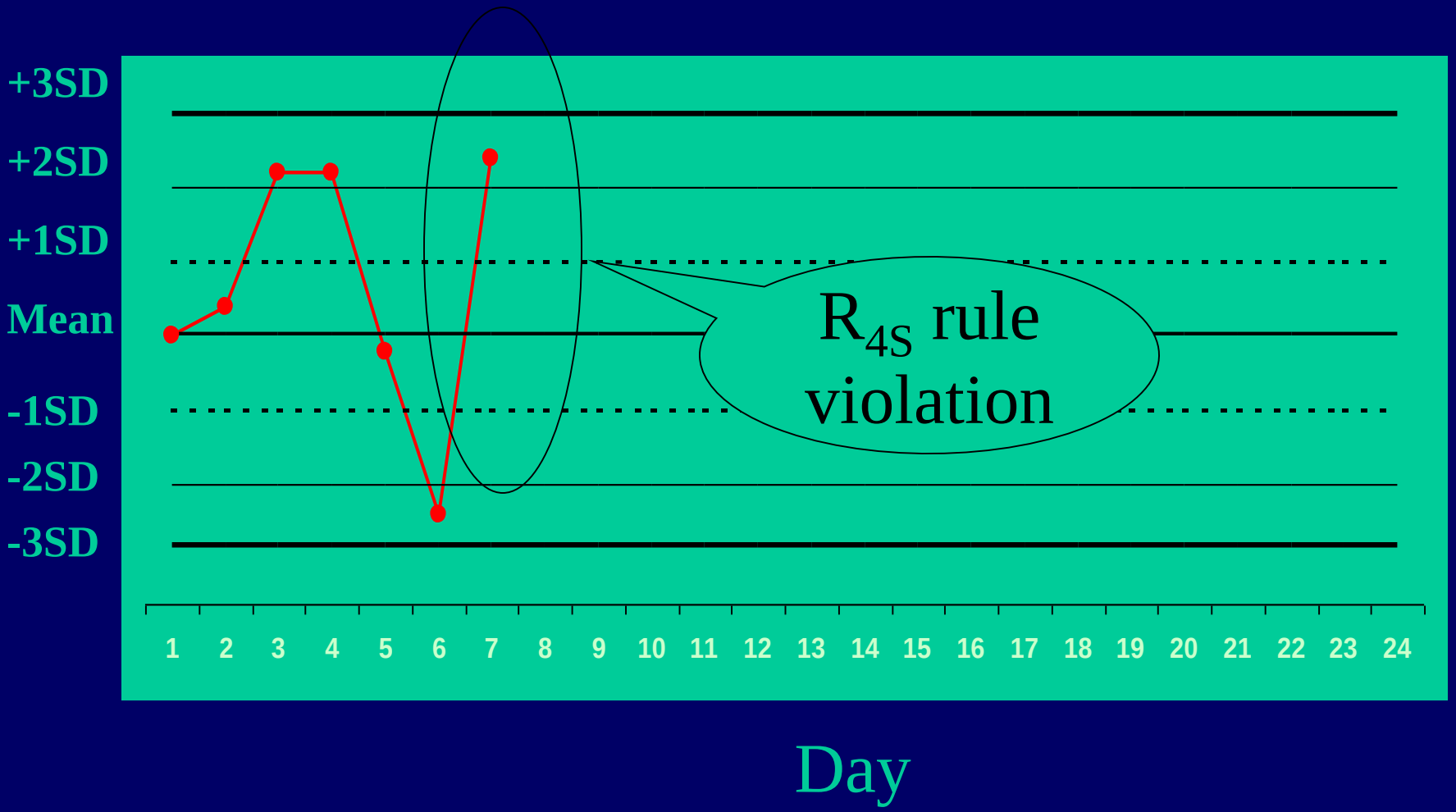
Quality control
Westgard criteria 2



Quality control
Westgard criteria 3



Quality control
Westgard criteria 4



Quality control
Westgard criteria 5