Urine Osmolality and Electrolytes

Why do we do it?

What does it mean?

and What can go wrong?

BCSLS Telehealth Presentation
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Outline

- Definitions
- Osmometry
- Applications
  - Polyuria
  - Hyponatraemia
  - Renal Failure

Definition

- Concentration
  - Number of moles per L of solution
- Osmolarity
  number of osmoles per L of solution
- Osmolality
  number of osmoles per kg solvent
- Tonicity
  non-penetrating osmoles
- Plasma osmolarity is 1-2% less than osmolality

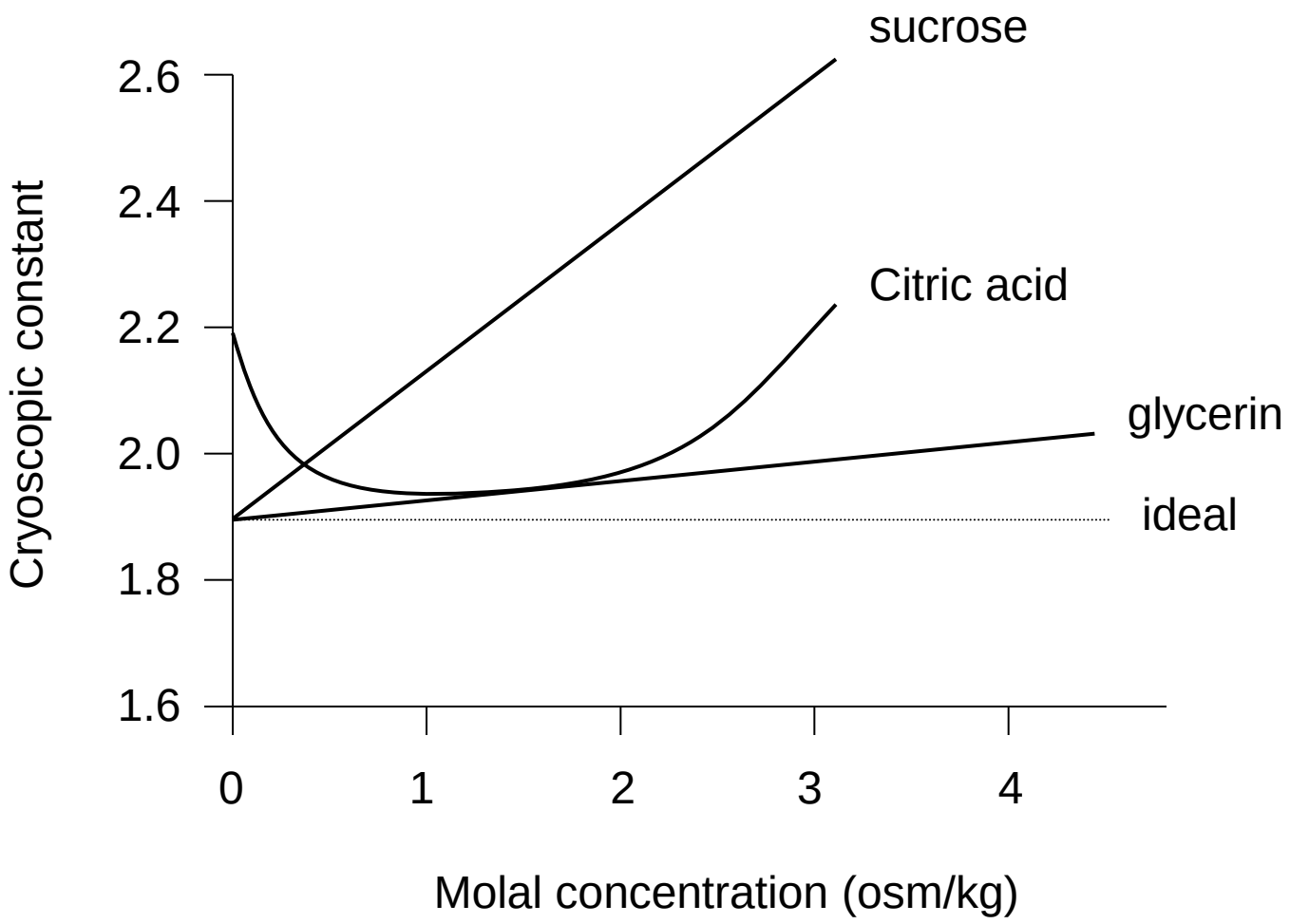
Colligative properties

- Parameters proportional to # osmoles:
  - Depressing freezing point
  - Elevating boiling point
  - Increasing osmotic pressure
  - Lowering vapour pressure

Osmolality Measurement

FP↓	ΔT ≈ -1.86 C°/osm	Simple, common
BP↑	ΔT ≈ +0.52 C°/osm	Organic compounds unstable.
VP↓	ΔP ≈ -0.3 mmHg/osm	Volatile chemicals invalidate
OP↑	ΔΠ ≈ 17000 mmHg/osm	Technically hard

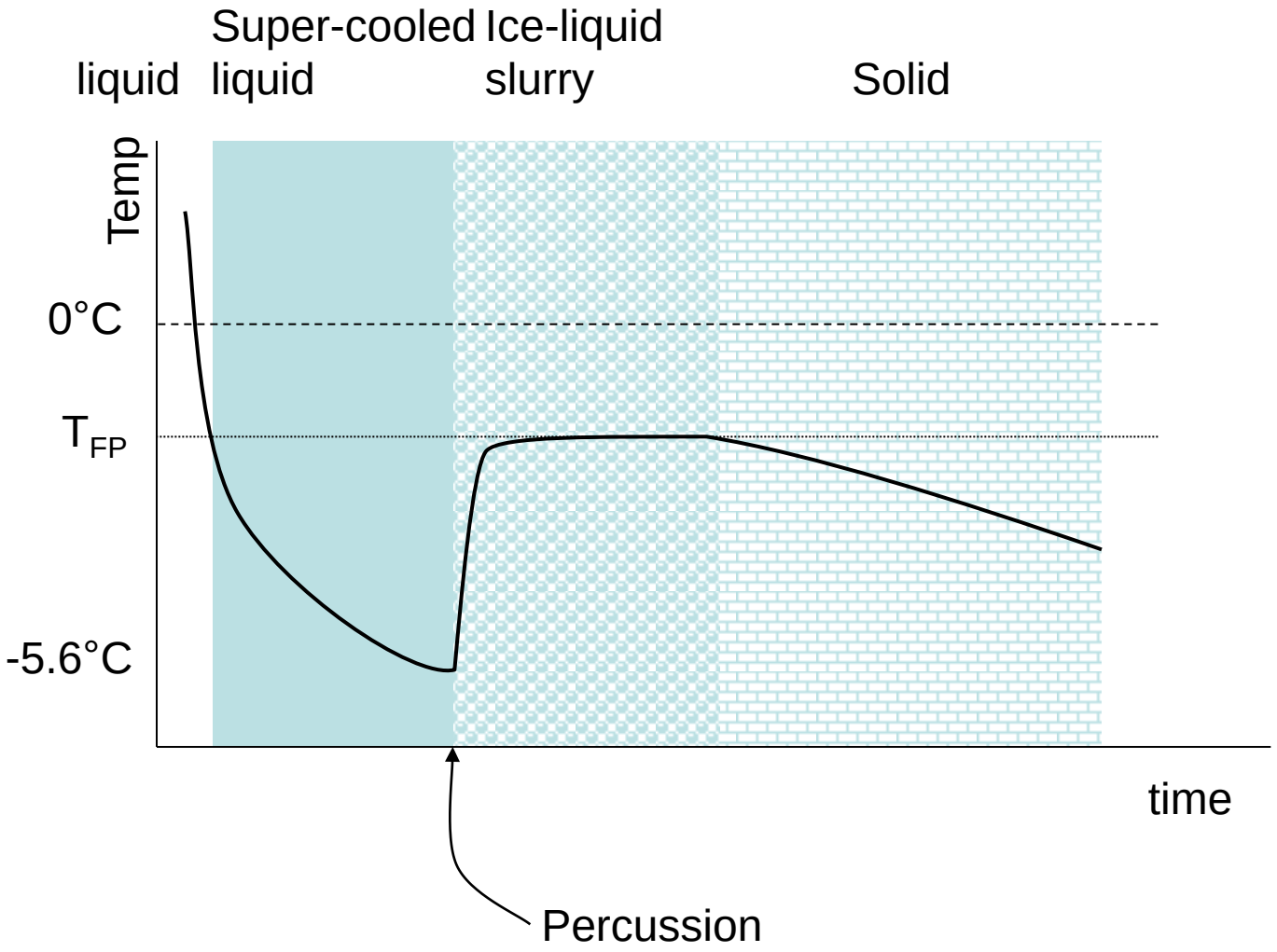
Why “≈” in those equations?



Physical Pharmacy 1983 p. 159


Osmometer Ready
11/28/2011 18:10 24
The Advanced™ Micro Osmometer
Model 3300
Chamber Cleaners
Sampler Tips

Freezing point osmometry

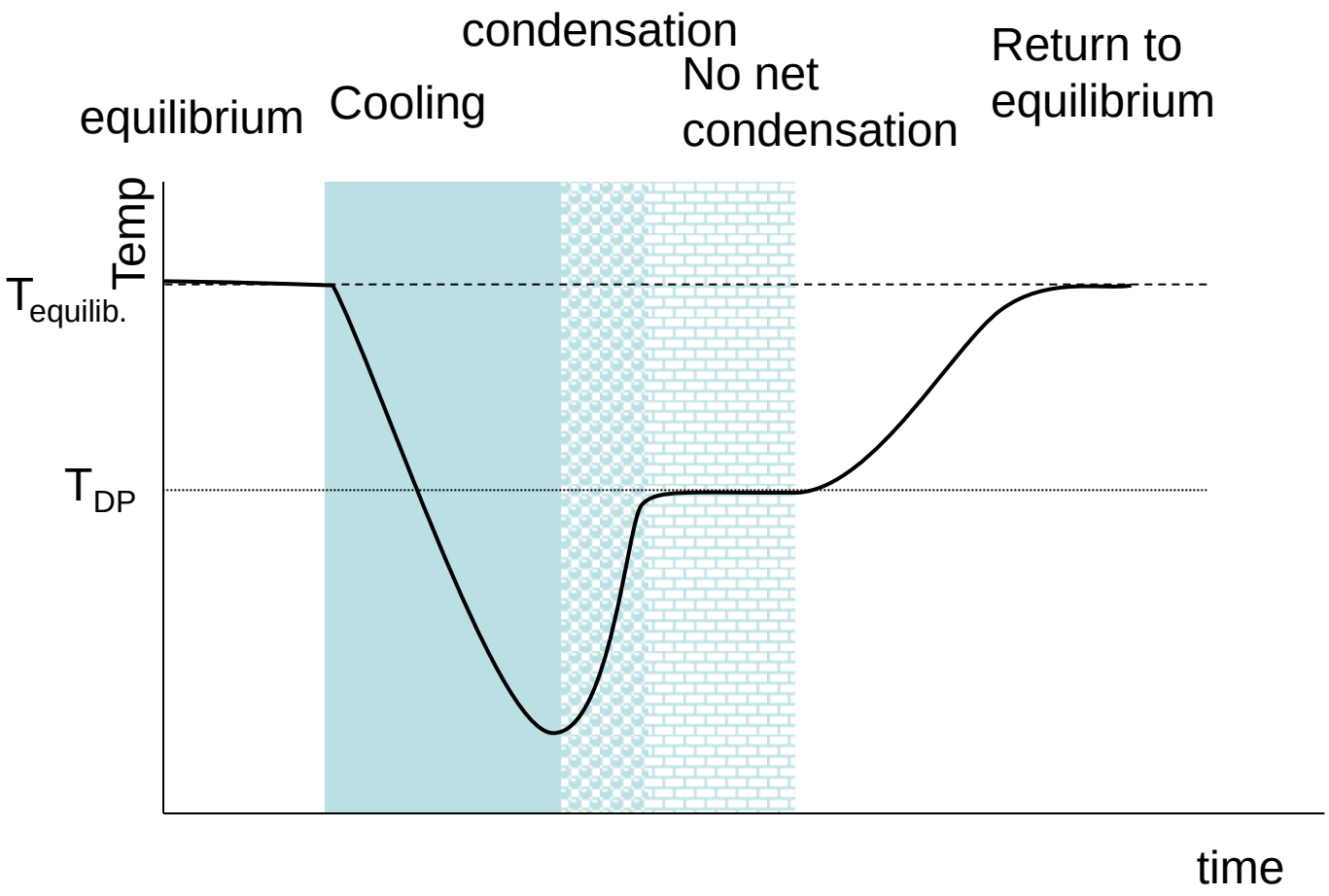


Freezing Point Analytical Interferents

- High viscosity
- Particles

Specimen

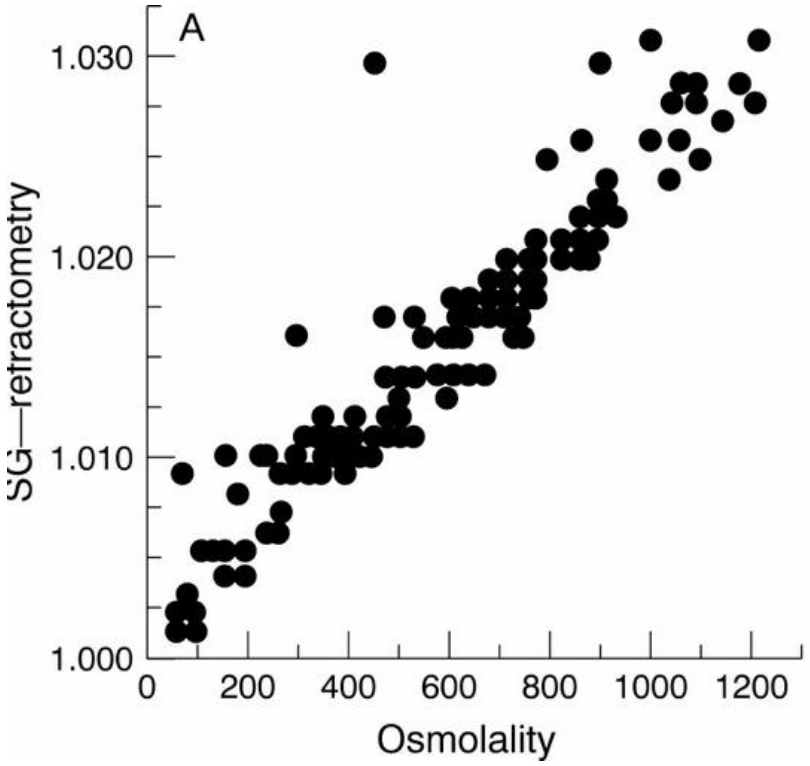
Dew Point

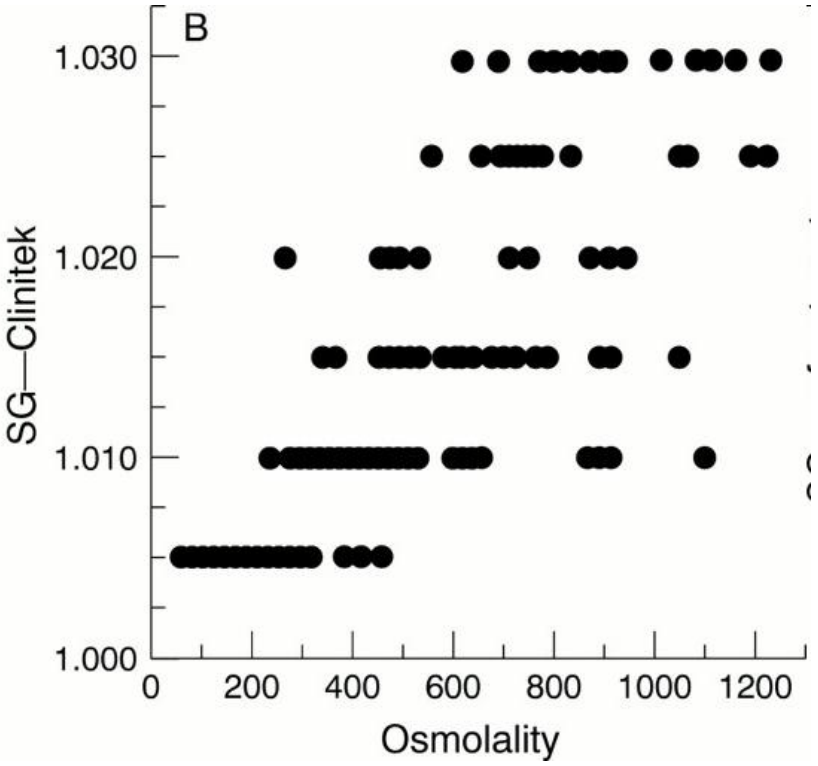

condensation
Return to equilibrium
No net condensation
equilibrium
Cooling
Temp
$T_{equilib.}$
T_{DP}
time

Methods

- Freezing point depression
  - Almost exclusive method now
  - Large coefficient so good CV's
  - Simple, robust instruments
- Dew Point
  - Invalid for volatiles

Alternative Test





→Refractometry correlates with osmolality

→weaker correlation with dipstick SG and osmolality

Limitation: glucose and protein lessen relationship

Arch. Dis. Child **85**: 155

Specimen

- No special preparation
  - Usually need serum/plasma results
- Random urine
  - Acute conditions/decisions
  - Simple to collect
  - Creatinine improves interpretation
- Timed urine
  - More reliable (Na excretion is variable)

Normal values

- No normal values for urine electrolytes & osmolality
- Range of physiologically expected results
  - U.osm 50-1200 mosm/kg
  - Range narrows as one ages
- “Expected” values depend on clinical picture

Urine Osmolaltiy

- Typical values
  - 500-800 mosm/kg (24 hour)
    300-900 mosm/kg (random)
  - After 12 hours fasting >850 mosm/kg
  - A.m. specimen ≈3 times serum osmolality

Urine Osmolality

- Increased
  - Dehydration
  - SIADH
  - Adrenal insufficiency
  - Glycosuria
  - Hypernatraemia
  - High protein diet
- Decreased
  - Diabetes insipidus
  - Excess fluid intake
  - Renal insufficiency
  - glomerulonephritis

Urine Osmolality Cautions

- EtOH
- Extremes of protein in diet
- Diuretics

Other Specimens

- Pleural, ascitic
  - In equilibrium with serum
  - Thus, equal to serum
  - Rarely indicated
  - No special requirements for measurement

Faecal specimens

- Rare test for cause of diarrhoea
- F.osm - 2(F.Na + F.K)
  - <50: non-osmotic
  - >150: osmotic diarrhoea
    - Laxatives
    - Malabsorption (including lactose intolerance)
    - Sorbitol, mannitol, lactulose
- Limitation:
  - bacterial activity ↑'s gap
  - Only very watery specimens

Clinical Indications

- Polyuria
- Hyponatraemia
- Renal failure
- Low anion-gap metabolic acidosis

Polyuria

Case

- 65 year old
- c/o going to the w/c 4 or 5 times/night
- Constantly thirsty
- Drinks 4 or 5 L of ice cold water/day
- Urine output measured at 3.5 L/day

Normal Urine Output

- <50 mL/day anuria
- <500 mL/day oligouria
- >3L /day polyuria

- Depends on individual
  - If hypernatramic or hypovolaemic >800 mL/d is polyuria

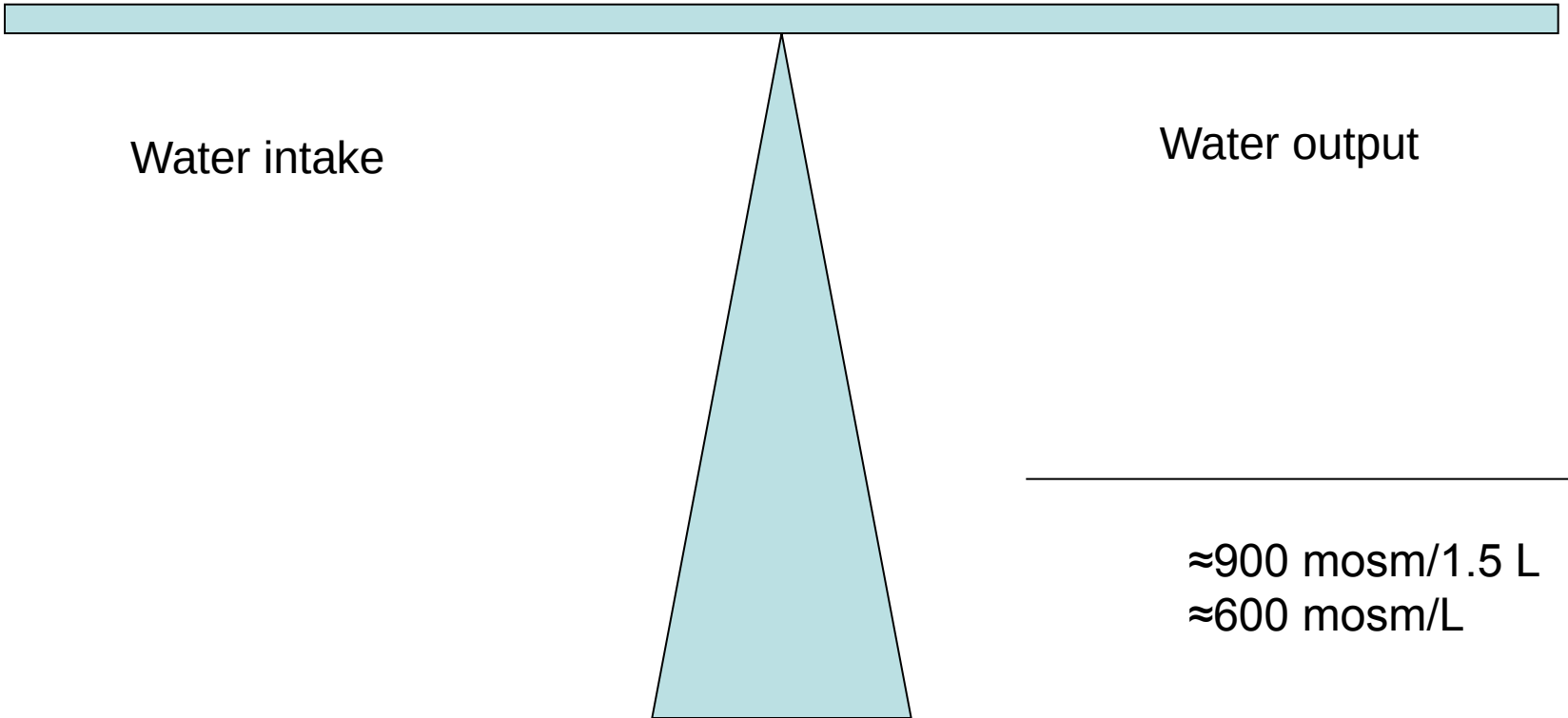
Water & Electrolyte Balance

Na/K/Cl intake

Protein intake

Na/K/Cl output
≈400 mosm/day

Protein (urea) output
≈500 mosm/day



Water intake

Water output

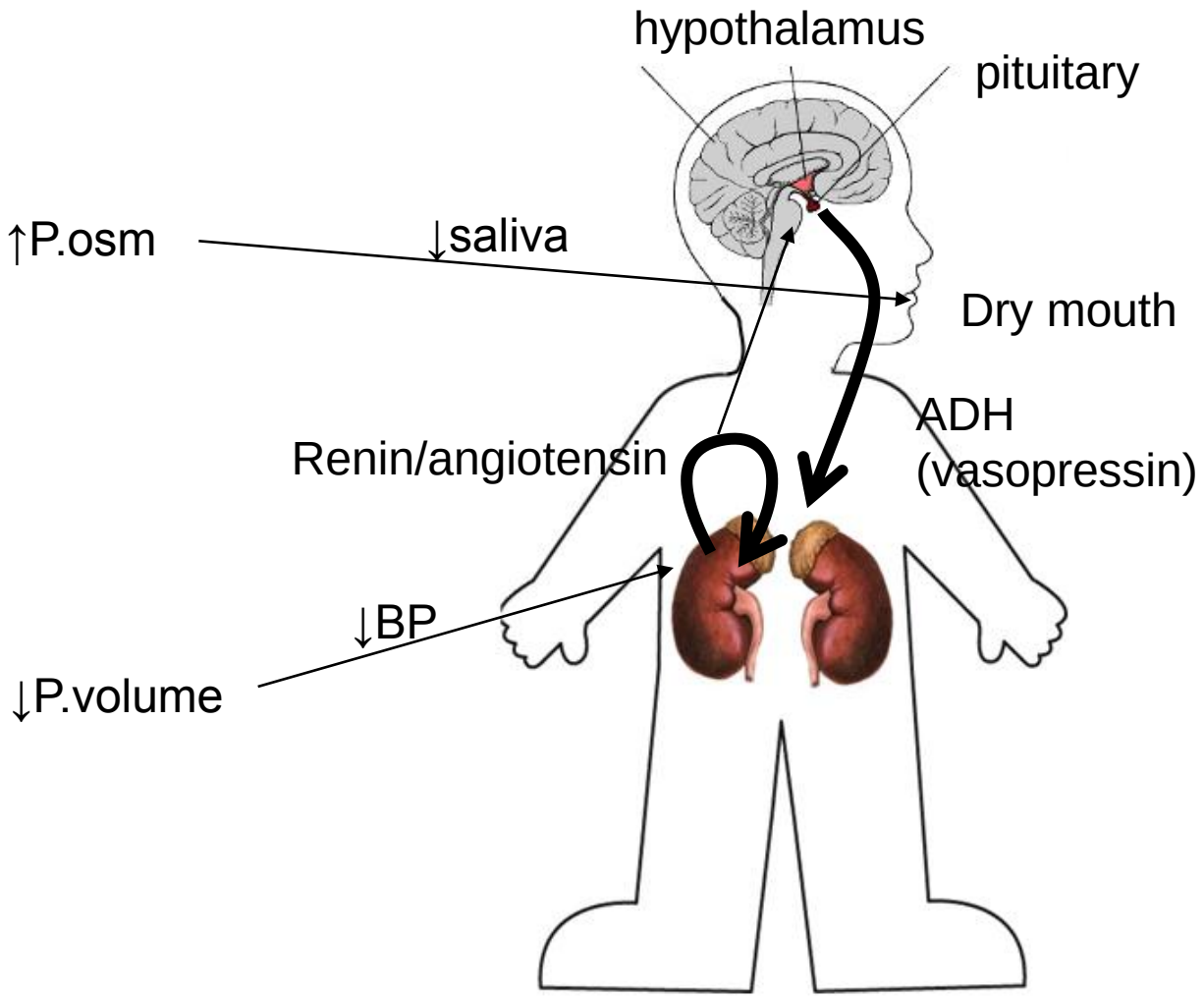
≈900 mosm/1.5 L
≈600 mosm/L

Water Balance

- Metabolism 10% 250mL
- Food 30% 750mL
- Beverages 60% 1500 mL

- Faeces 4% 100 mL
- Sweat 8% 200 mL
- “Insensible” (skin + lungs) 28% 700 mL
- Urine 60% 1500 mL

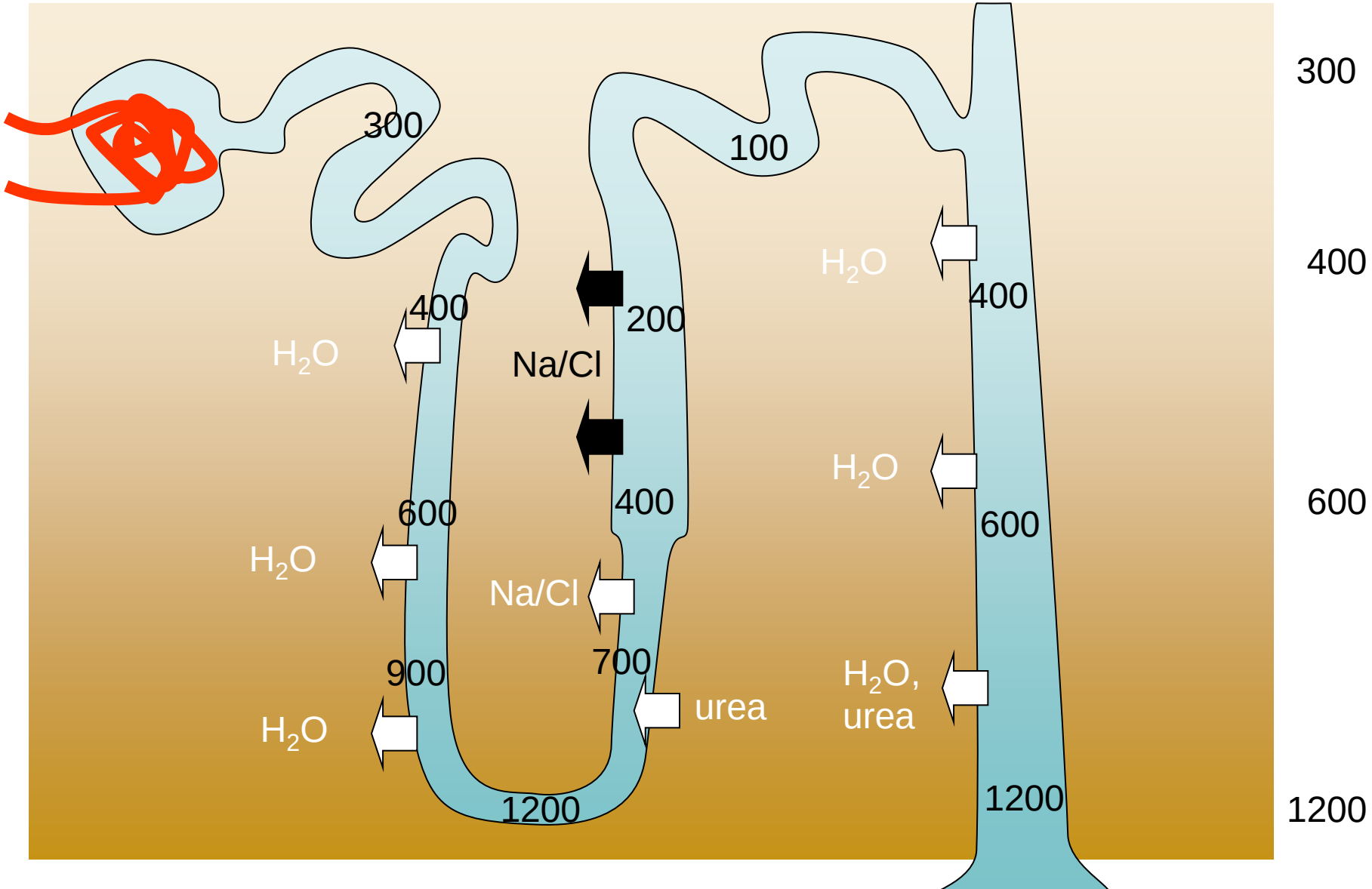
Water Regulation



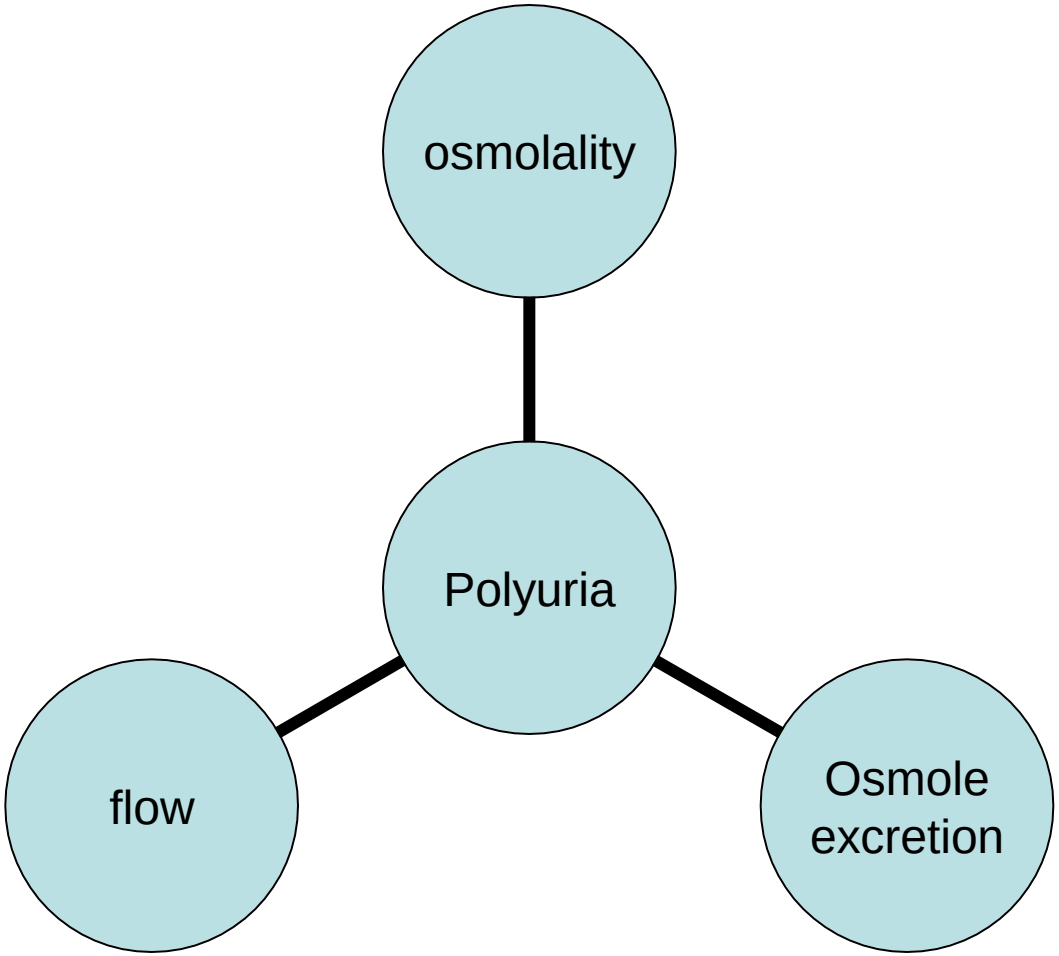
Assessing Intravascular Volume

- Clinical (sensitivity ~50%)
  - Orthostatic hypotension
  - Weak pulse
  - Cool extremeties
  - HR
  - Skin turgor
  - Mucous membranes
  - JVP
- Investigation
  - Urine Volume & Colour
  - Chest X-ray
  - Haemoconcentration
  - Creatinine, urea
  - Radioactive albumin dilution
  - BNP

Urine Concentration



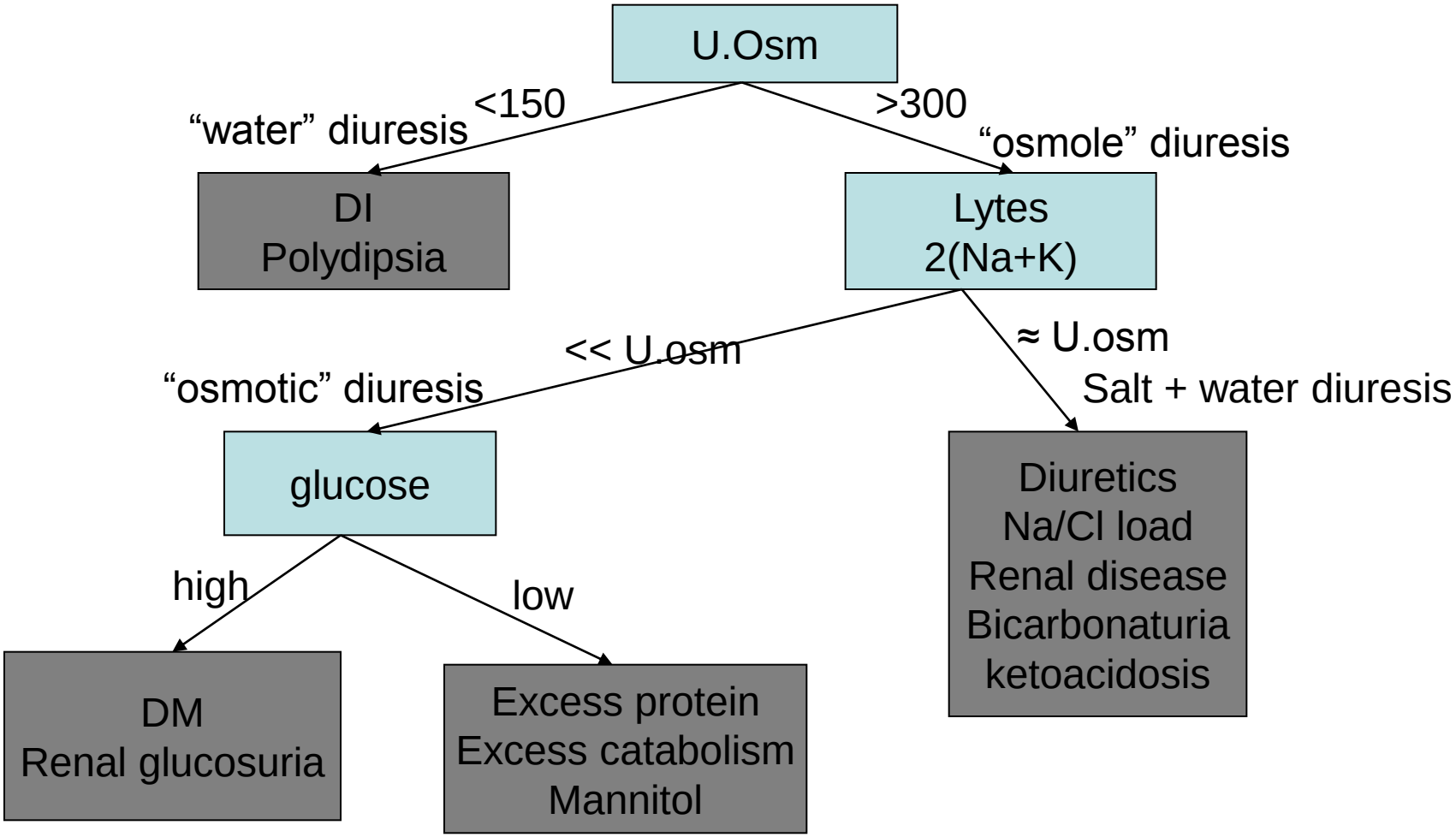
Polyuria Assessment



Polyuria

- <150 mosm/kg
  - Water diuresis
    - Diabetes Insipidus (P.Na high/normal)
    - Polydipsia (P.Na low/normal)
- >300 mosm/kg
  - Solute diuresis

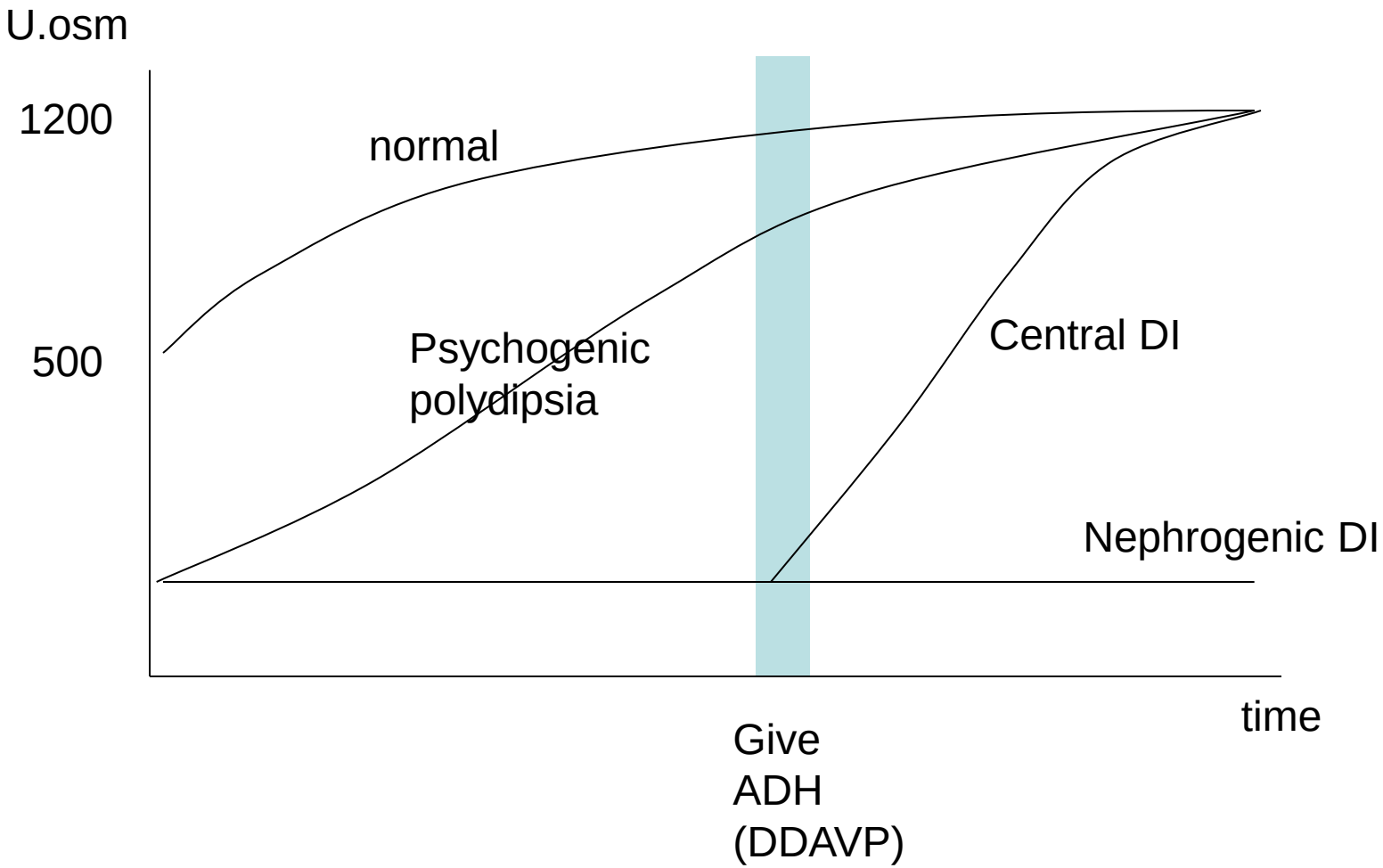
Polyuria


U.Osm
<150
“water” diuresis
>300
“osmole” diuresis
DI
Polydipsia
Lytes
2(Na+K)
<< U.osm
“osmotic” diuresis
≈ U.osm
Salt + water diuresis
glucose
Diuretics
Na/Cl load
Renal disease
Bicarbonaturia
ketoacidosis
high
low
DM
Renal glucosuria
Excess protein
Excess catabolism
Mannitol

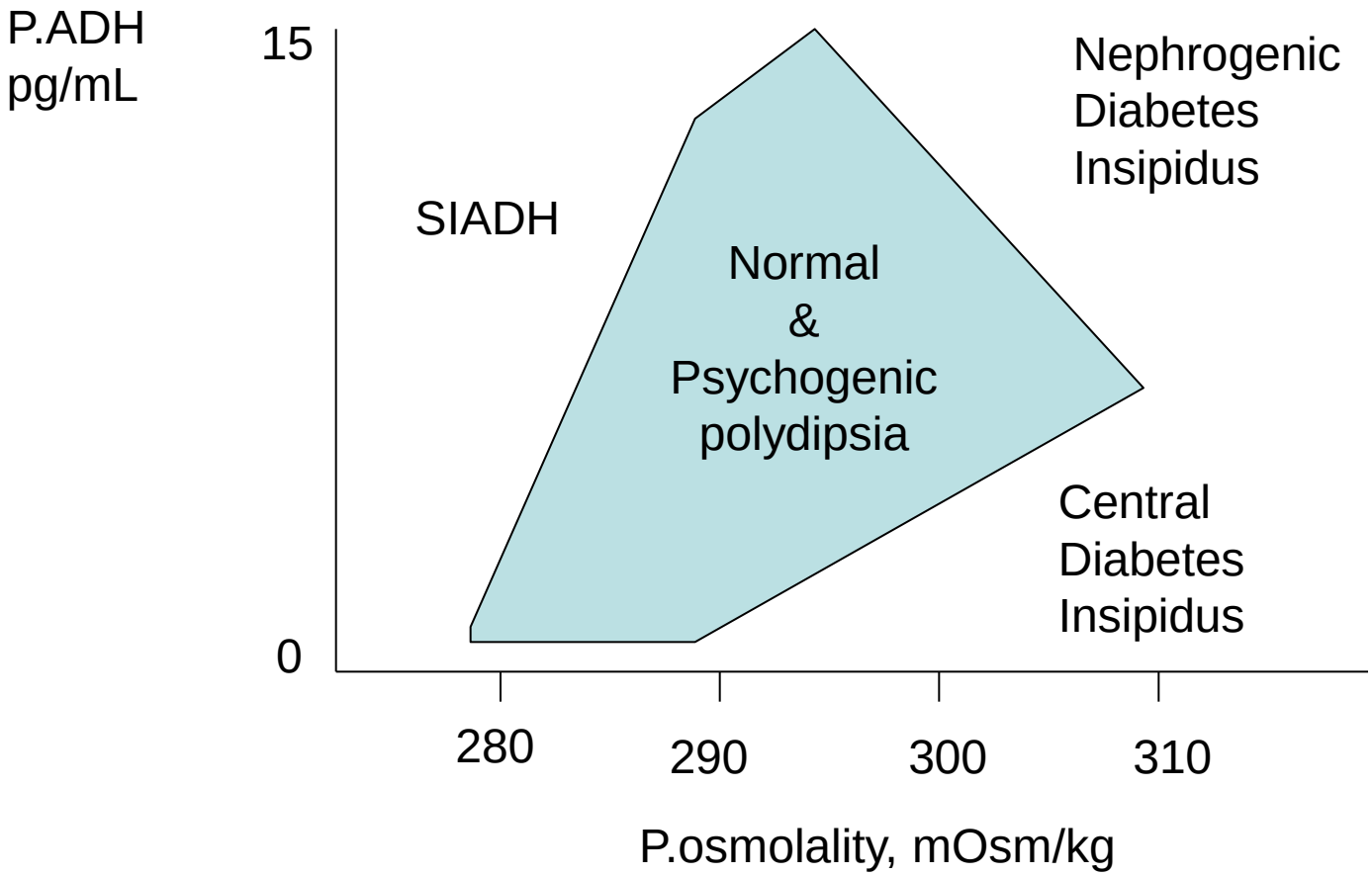
Water Deprivation Test

- Preparation: Patient drinks until 6:00 am morning of test
- Weight, P.osm, P.Na, U.osm, U.Na
- Nothing to eat/drink during test
- Urine hourly
- Stop test if U.osm > 500, P.Na >145, weight loss >10%.
- +/- DDAVP

Water Deprivation Test



ADH & plasma osmolality

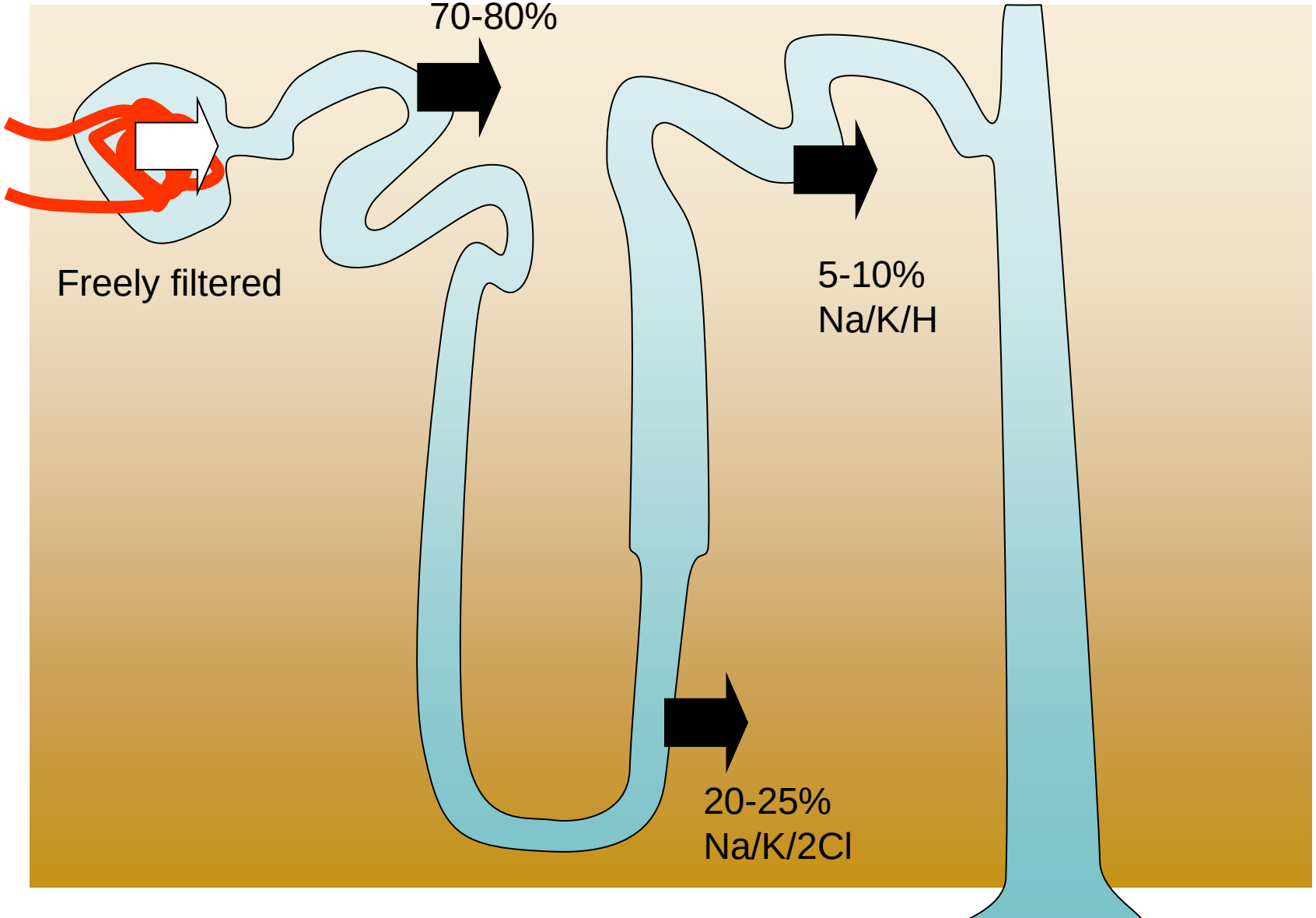


Hyponatraemia

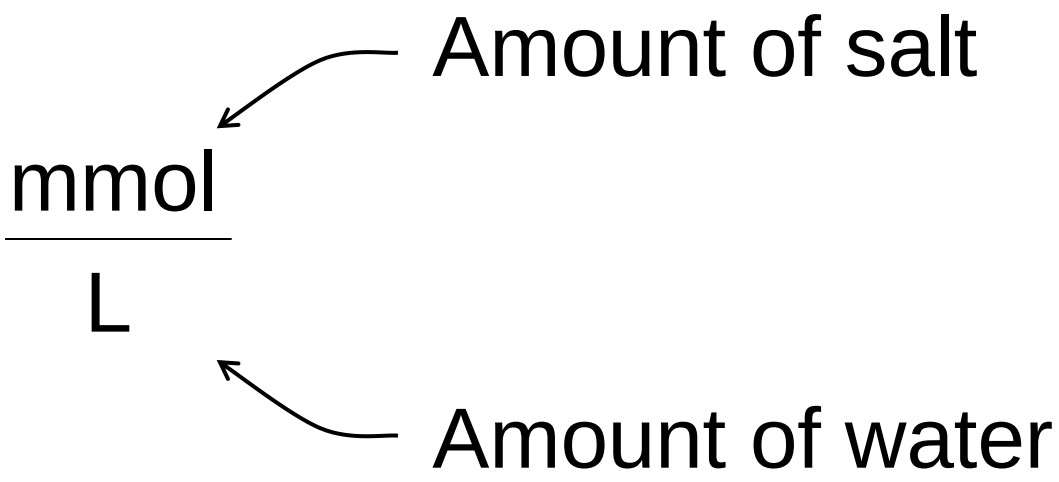
Renal Handling

- Average 70 kg male filters approximately 1.2 kg of salt per day!
- Vast majority must be reabsorbed

Urine Sodium



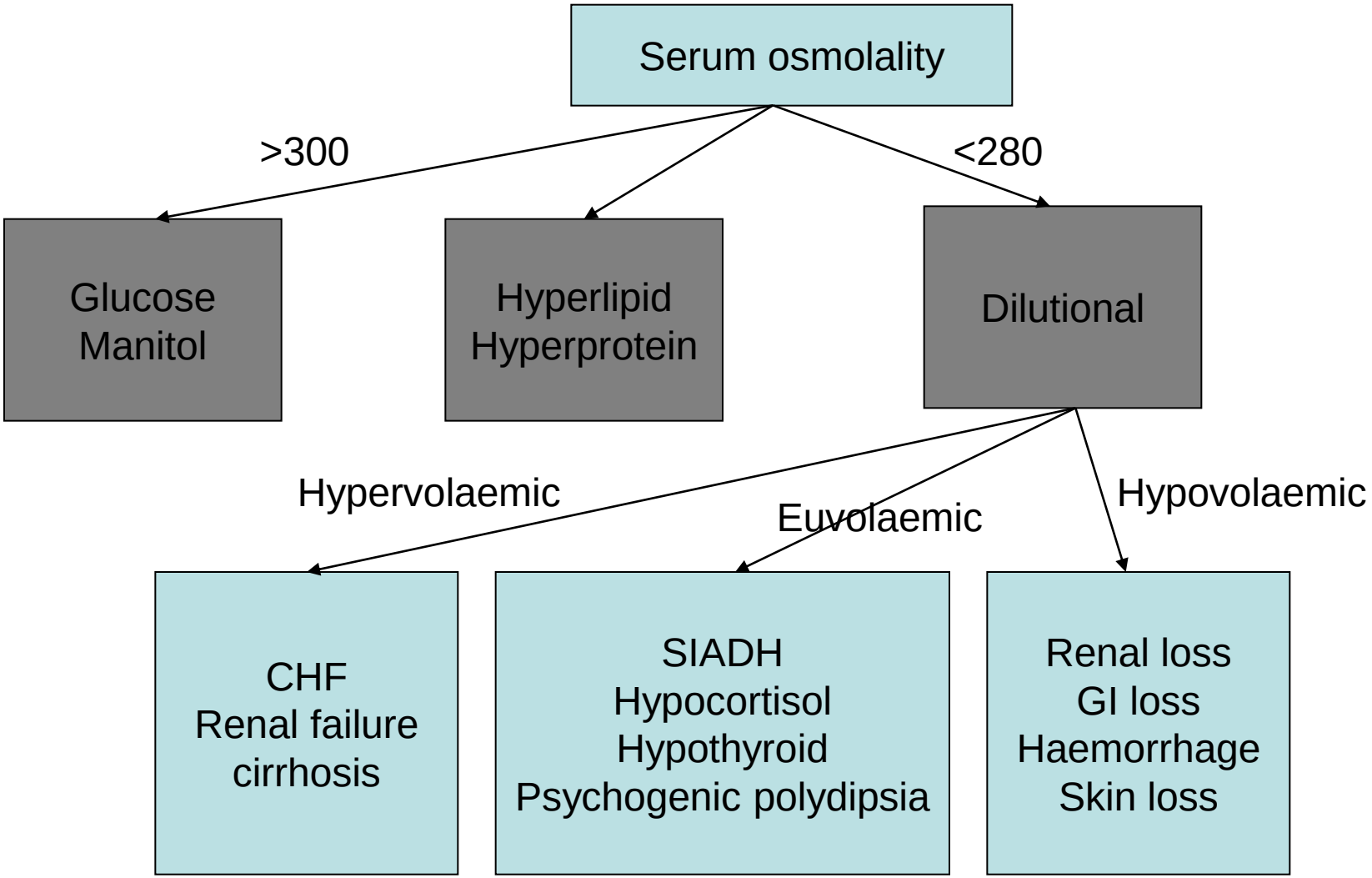
Dysnatraemia



Case

- 6 month old with astrocytoma on vincristine
- P.Na 126 L 135-145 mmol/L
- P.Osm 255 L 280-300 mosm/kg
  U.Na 32
- Cerebral salt wasting vs SIADH

Hyponatraemia



Case…

- SIADH:
  - Kidneys act to preserve perfusion
  - SIADH = excess of water, hence intravascular volume, in face of low Na.
  - Kidney response is to lose Na
- Cerebral Salt Wasting
  - Inappropriate Na excretion →
    ↑urine volume →
    ↓intravascular volume

SIADH

- Laboratory Features
  - ↓S.Na
  - ↓P.osm
  - ↑U.osm (typ. >50 mosm/L)
  - U.Na >20 mmol/L
  - Normal renal, thyroid & adrenals
  - Euvolaemic

SIADH Causes

- Tumour
  - Small cell, bronchogenic CA, pancreatic, Hodgkin's
- Pulmonary
  - Pneumonia, lung abscess, TB
- Medications
  - NSAID, barbiturates, carbamazepine, TCA, oxytocin
- CNS
  - Brain tumour, encephalitis, SAH, AIP, trauma
- AIDS
- Ventilation
- Post-operative

SIADH Treatment

- Water restriction (~1 L/day)
- Salt
- Weigh daily
- Loop diuretic
- Urea (rarely used)

Cautions

- No renal or adrenal problems
- No bicarbonaturia
  - Obligate excretion of Na
  - E.g. recent vomiting
- No carbonic anhydrase inhibitors
- No acid/base disturbance
- No diuretics

Hyponatraemia

- Reset osmostat
  - Test: water load to further drop S.Na
  - Rarely performed test
  - Only done in patients with mild hyponatraemia
  - SIADH → urine remains concentrated
  - Reset osmostat → urine becomes dilute
- Importance: treatment different

Treatment cautions

- Dangerous to correct too correctly
- Central pontine myelinolysis
- ↑Na by 1-2 mmol/L/h,
  maximum of 8 mmol/L/day

Hypernatraemia

- Very rarely *need* urine studies
  - Can be used as an adjunct study

Urine Potassium

- Less predictable due to many influences
  - Potassium intake variable
  - Na effects via aldosterone
  - Hydration
- Range 10-400 mmol/d
- Transtubular potassium gradient
  - Can be calculated
  - Clinically doesn’t add much information
  - Rarely used now

Renal Failure

Renal Failure Classifications

- Duration
  - Acute renal failure
  - Chronic renal failure
- Location
  - Pre-renal
  - Renal
  - Post-renal

Renal Failure

- Pre-renal
  - Dehydration
  - CHF
  - Arterial supply
- Renal
  - Glomeruli
  - Renal tubules
  - Interstitium
- Post-renal
  - Stone
  - Tumour
  - Prostate

Fractional Excretion

- Corrects for urine concentration
- FENa = [U.Na * P.Cr]/[U.Cr * P.Na]
- N.B. match units
  - Plasma creatinine in µmol/L
  - Urine creatinine in mmol/L
- FeNa <1% pre-renal
- FeNa >1% renal

Case #1

- 50 y.o. goes to the ER with history of vomiting and diarrhoea. Looks dehydrated

Plasma.Na	140		135-145 mmol/L
Plasma.Cre	150	HΔ	umol/L
U.Na	25		mmol/L
U.Cre	1		mmol/L
FENa	2.7%		
U.osm	320		mosm/kg

Case #2

- 50 y.o. goes to the ER with history of vomiting and diarrhoea. Looks dehydrated

Plasma.Na	140		135-145 mmol/L
Plasma.Cre	150	HΔ	umol/L
U.Na	25		mmol/L
U.Cre	10		mmol/L
FENa	0.27%		
U.osm	600		mosm/kg

Interpretation

- FENa <1% -- pre-renal
- FENa >3% -- acute kidney injury
- U.Osm >500 – pre-renal
- U.Osm <350 – acute kidney injury

- No gold-standard test
- Acute kidney injury can develop from pre-renal failure

Caution

- Loop diuretics increase FENa
  - Cannot interpret while on diuretics
- Severe protein malnutrition/starvation or wash-out of kidney

RTA

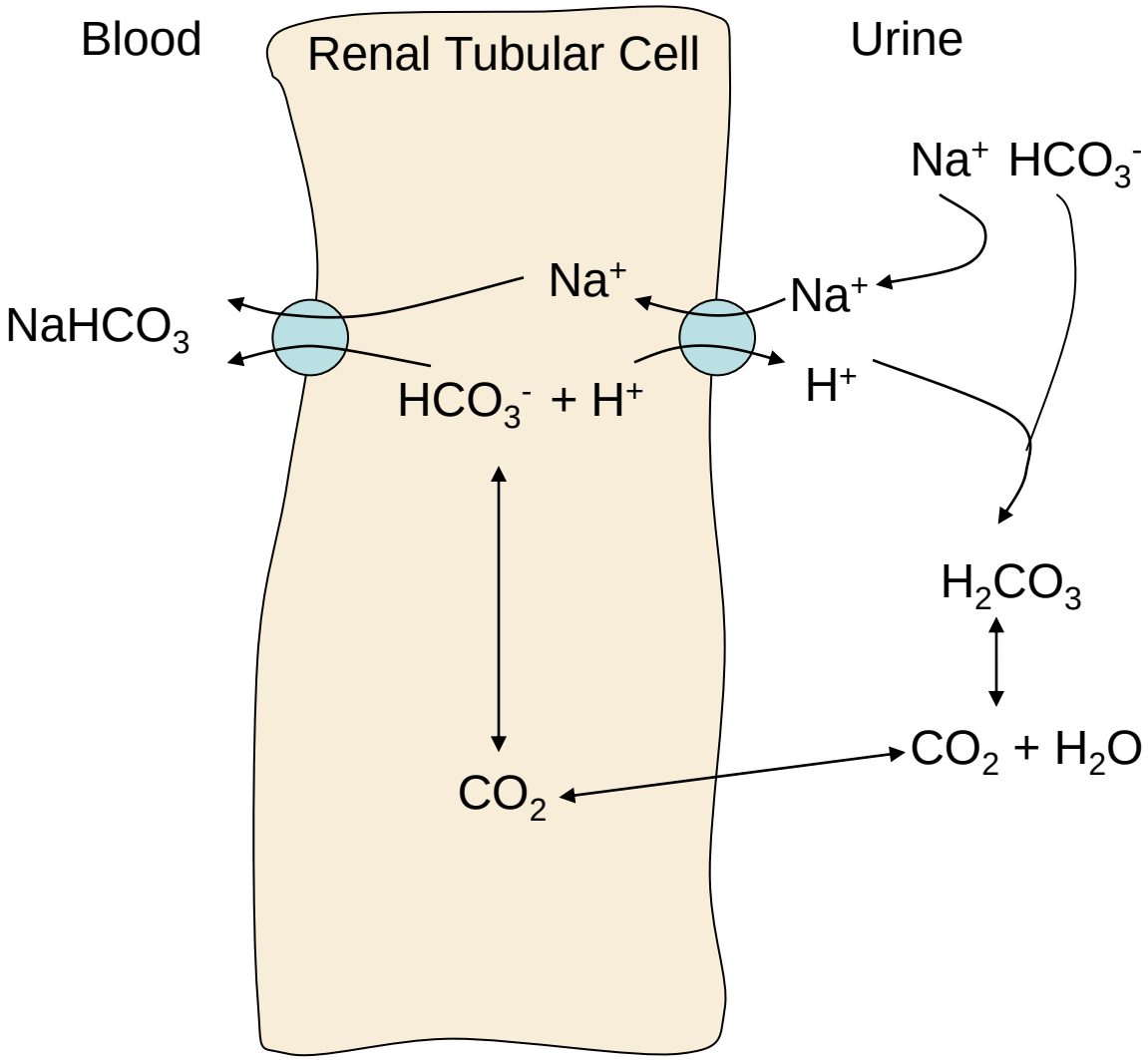
Metabolic Acidosis

- Increased anion gap
  - Relatively straight-forward
  - “MUDPILES”
- Normal anion gap
  - Factitious
    - Hypoalbuminaemia
    - Unusual cations (e.g. monoclonal band)
  - HCl or NH_4Cl loading
  - HCO_3 loss
    - GI (diarrhoea, illeus)
    - Renal (proximal RTA, carbonic anhydrase inhibitor)
  - Failure to generate “new” bicarbonate (distal RTA)
  - Gain of an acid with excretion of conjugate base

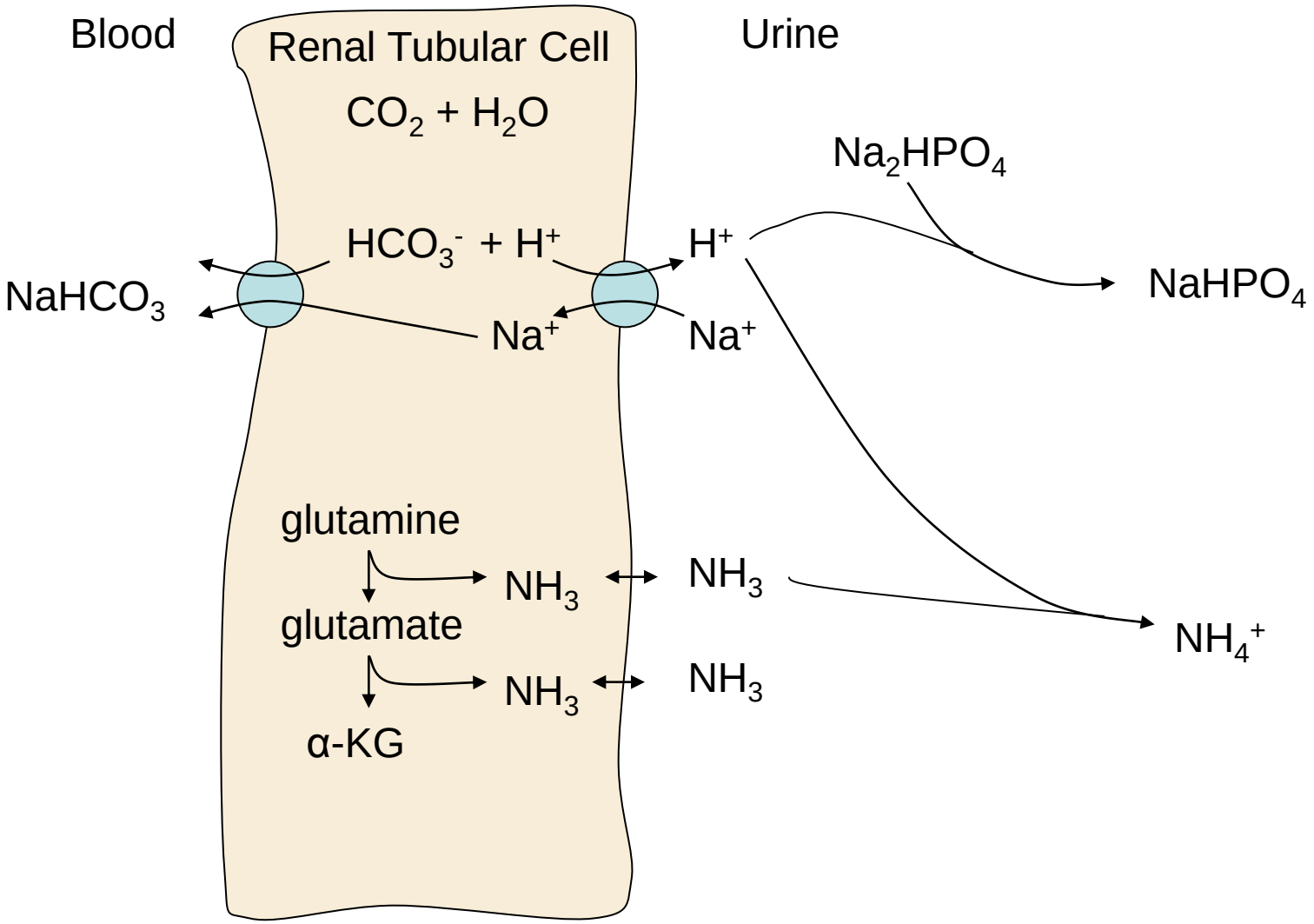
Acid production

- Typical North American diet produces 1 mmol H^+/kg body weight/day
- Mainly from protein oxidation
- Buffering acid load consumes equivalent amount of bicarbonate.
- S.pH ~7.4, U.pH ~6.0

Renal Acid-Base: Recovery



Renal Acid-Base: Loss of H^+



Ammonia

- Theoretically can be measured; however, technically very difficult in urine
- Essentially research-only method
- Calculating

Electroneutrality

+ Na^{+}
+ K^{+}
+ $2Ca^{++}$
+ $2Mg^{++}$
+ $NH4^{+}$

+ Cl^{-}
+ HCO_3^{-}
+ $H_2PO_4^{-}$
+ $2HPO_4^{=}$
+ $2SO_4^{=}$
+ organic anions

Electroneutrality

+ Na^+
+ K^+
+ ~~$2Ca^{++}$~~
+ ~~$2Mg^{++}$~~
+ $NH4^+$

≈80 mEq/day

+ Cl^-
+ HCO_3^-
+ $H_2PO_4^-$
+ $2HPO_4^=$
+ $2SO_4^=$
+ organic anions

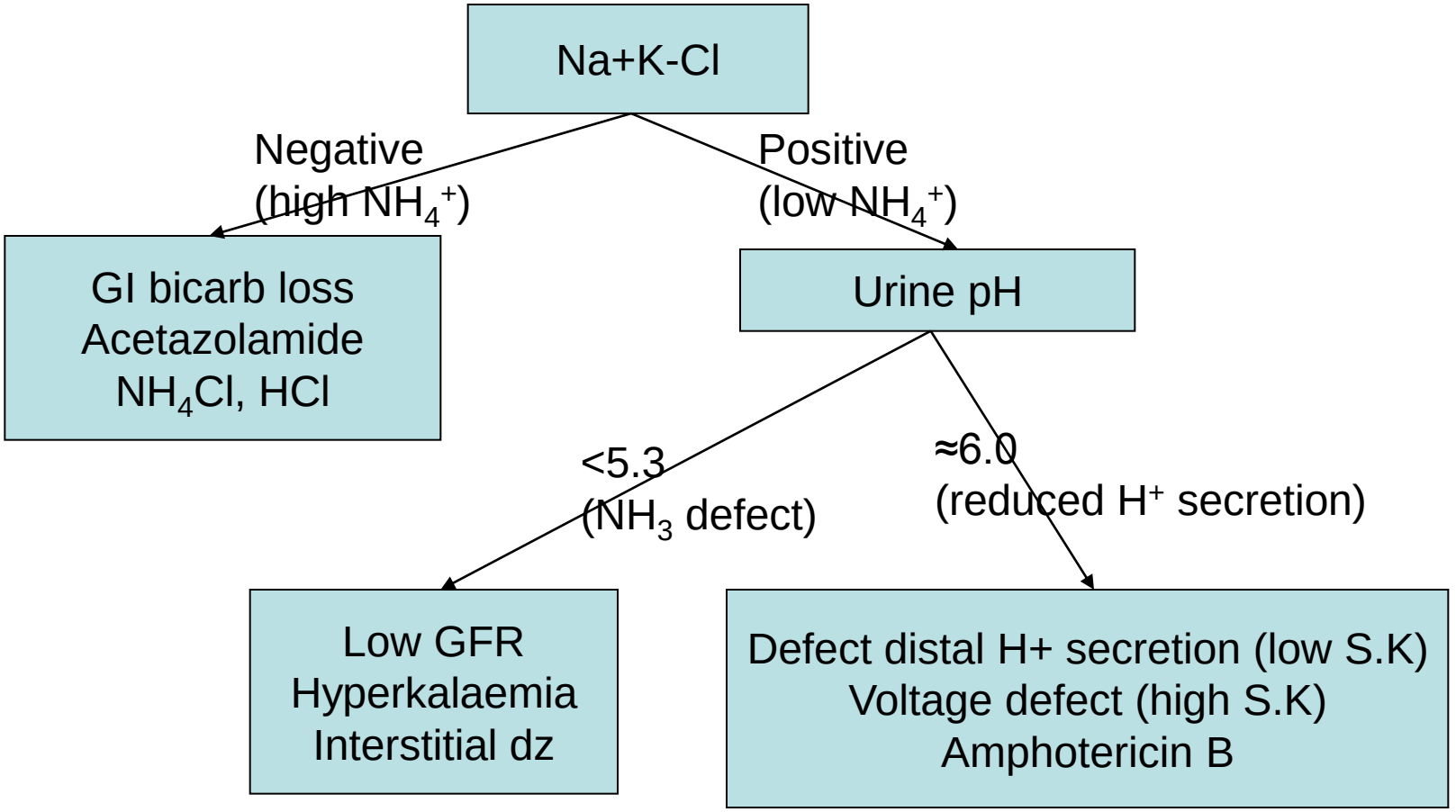
$Na^+ + K^+ + NH4^+ = Cl^- + 80$

$NH4^+ \alpha\ Na^+ + K^+ - Cl^-$

Cautions of net charge

- Unmeasured anions → underestimate NH4
  - Ketonuria
  - DKA
  - Drugs (penicillin, salicylates)

Non-Anion gap Metabolic Acidosis



Conclusions

Urine Osmolality & Lytes Utility

- Rarely needed, but critical test
  - Polyuria
  - Hypernatramia
  - Supportive role
    - Pre-renal vs renal oliguria
    - Integrity of the medullary interstitium

Summary

- No “normal” ranges – interpret in clinical context
- Cautions:
  - No diuretics
  - No adrenal or thyroid disease
  - Relatively normal diet