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Sodium Flux in Hemodialysis

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Outline

- History of dialysate sodium
- Methods of sodium measurement
- Effective sodium gradient during hemodialysis
- Ultrafiltration effect



Case presentation

- 52 year old patient with ESRD, presenting for resection of an ear mass
- Pre-op labs show sodium 116 – operation proceeds
- Patient asymptomatic apart from ear pain
- Admitted to ICU post-op for Na monitoring, cautious HD
- Turns out – Na of 116 on outpatient HD labs 5 days earlier

Case - continued

- Dialyzed – 2 hr, Qb 150, Qd 200, Dialysate sodium 130, 2L UF. Measured sodium pre, 1 hr in, and post
- Pre: 116
- 1 hr: 120
- 2 hr: 120

- Why does sodium act unpredictably with hemodialysis?

History of dialysate sodium

- 50's/60's:
 - Filters couldn't tolerate negative pressure
 - Sodium clearance was diffusive, standard Na bath ~126
 - High glucose dialysate (1800 mg/dL) to take fluid off
 - Long dialysis treatments needed (8-24 hr) to manage volume

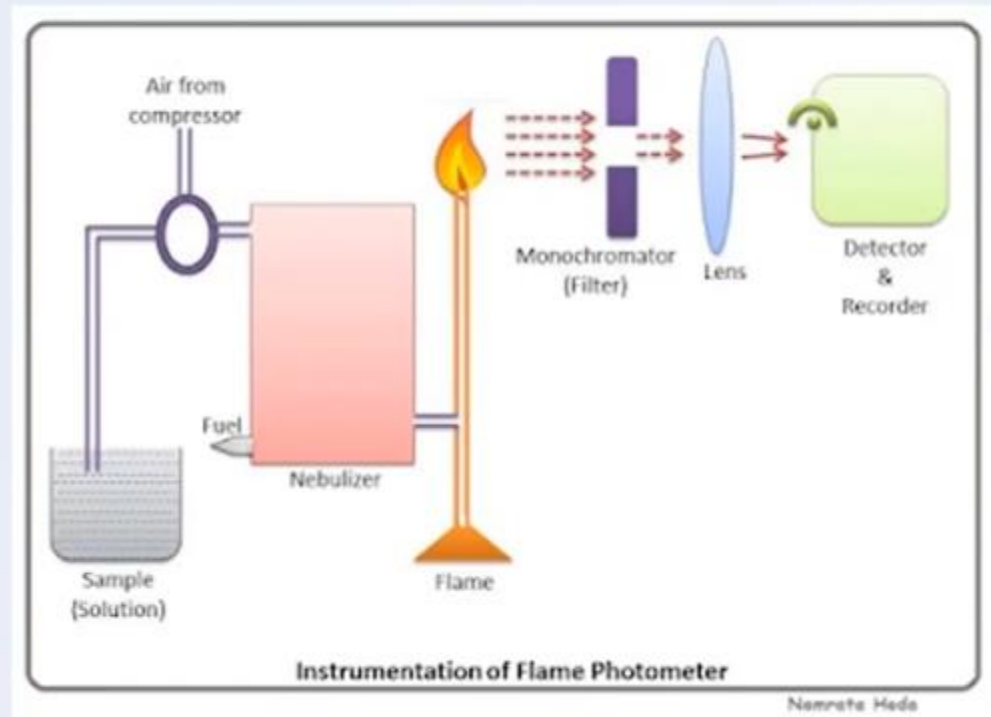


History of dialysate sodium

- 70's:
 - Dialysis filters improve, allowing UF and shortened treatment time. No longer need dialysate Na to be so low
 - Shorter times: more dialysis disequilibrium
- 80's:
 - Average dialysate sodium increases to 130-135
 - Ongoing dialysis discomfort (n/v, cramping)
- 90's:
 - Widespread adoption of "high" Na dialysate, 140 mEq/L

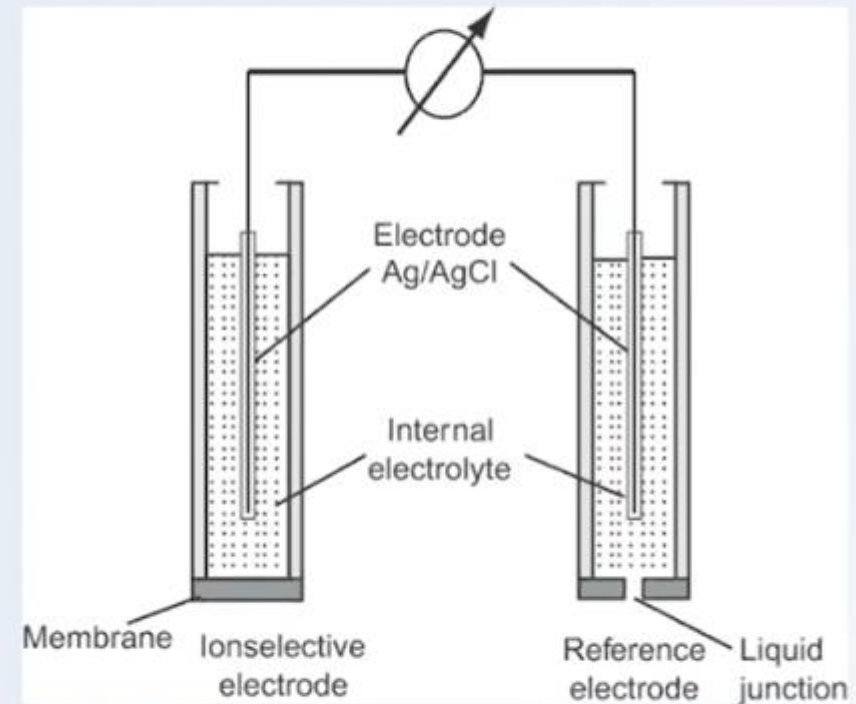
Sodium measurement

- Older method
- Patient's plasma is vaporized
- Target light wavelength is filtered
- Intensity proportional to concentration



Sodium measurement

- Ion selective electrode (UW lab)
- Measures ion activity vs reference solution
- Direct: measurement from plasma
- Indirect: plasma diluted 1:20
- Indirect gives a “cleaner” result, as ions interact less at low concentrations.
- Direct measure is physiologic, as ionic interactions are happening in vivo



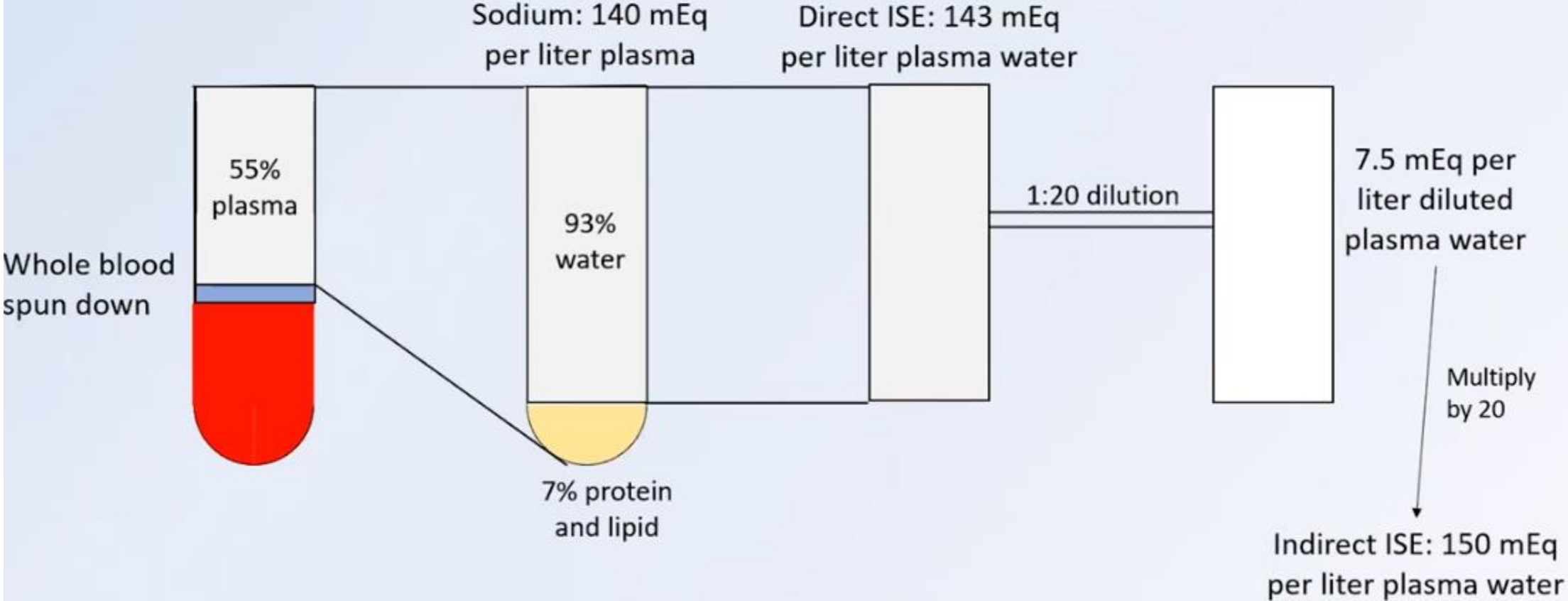
Sodium ion activity

	Flame photometry	Indirect selective electrode	Direct selective electrode
Na plasma	140 mEq/L	150 mEq/L	143 mEq/L
Na dialysate	140 mEq/L	140 mEq/L	135 mEq/L

- Indirect ISE activity > concentration because ions are active only in the water portion of plasma, roughly 93% of plasma ($140 / 0.93 = 150$)
- Ion activity is then adjusted to give a plasma concentration, to keep the “normal” values the same between measurements
- Direct ISE measurement determines gradient for diffusion in dialysis
 - Conceptually similar to total Ca vs ionized Ca



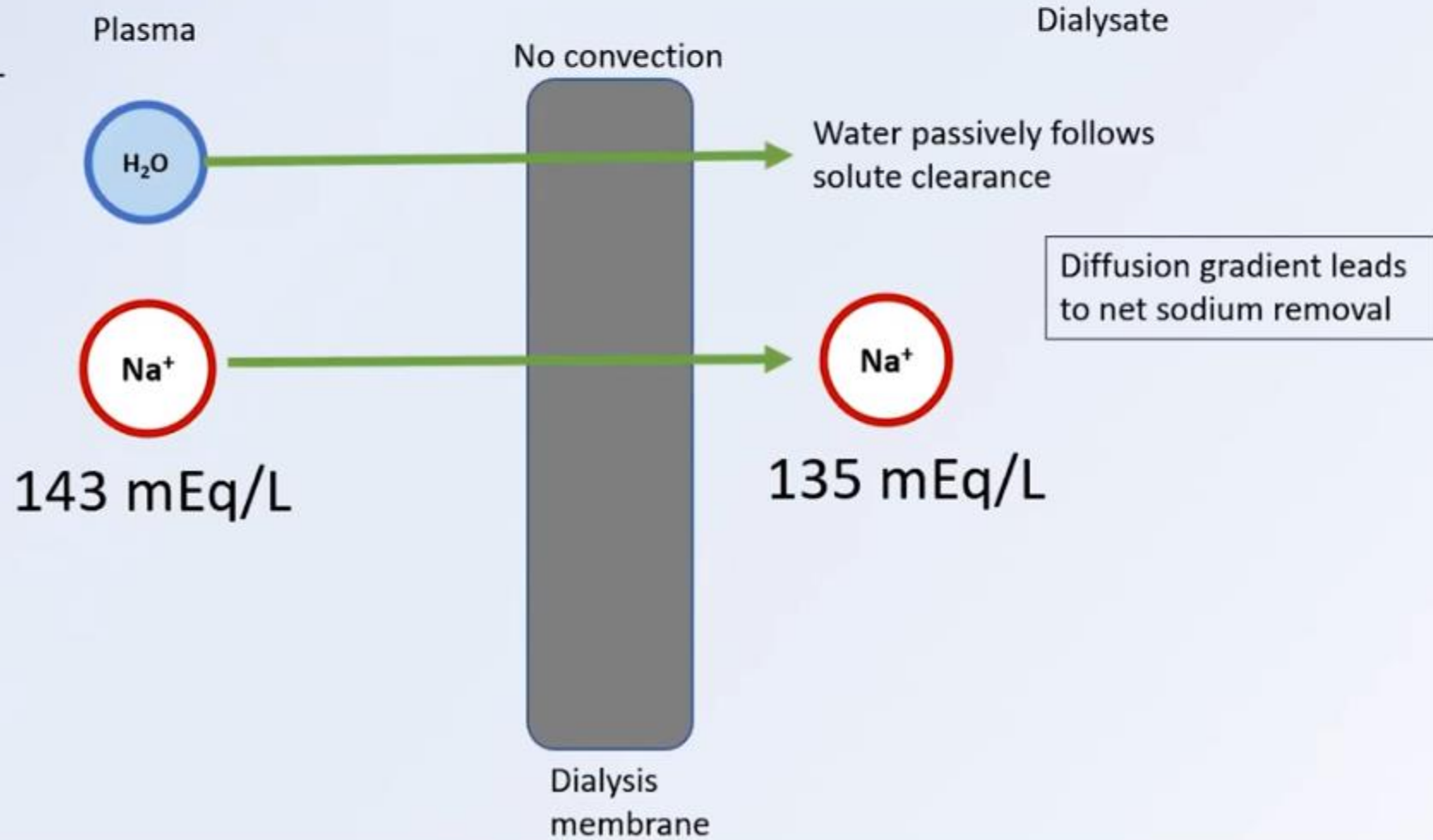
Sodium concentration vs activity



Diffusive sodium clearance

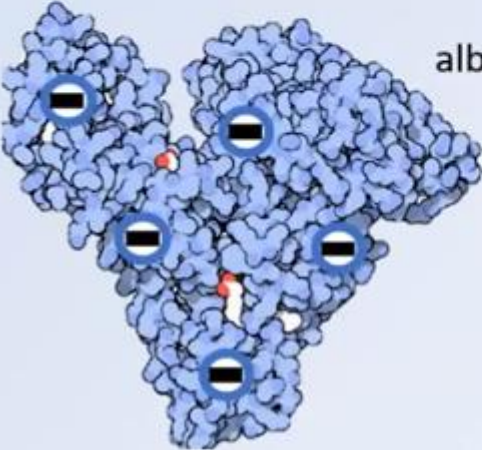


Lab measurement:
Plasma 140 mEq/L
Dialysate 140 mEq/L



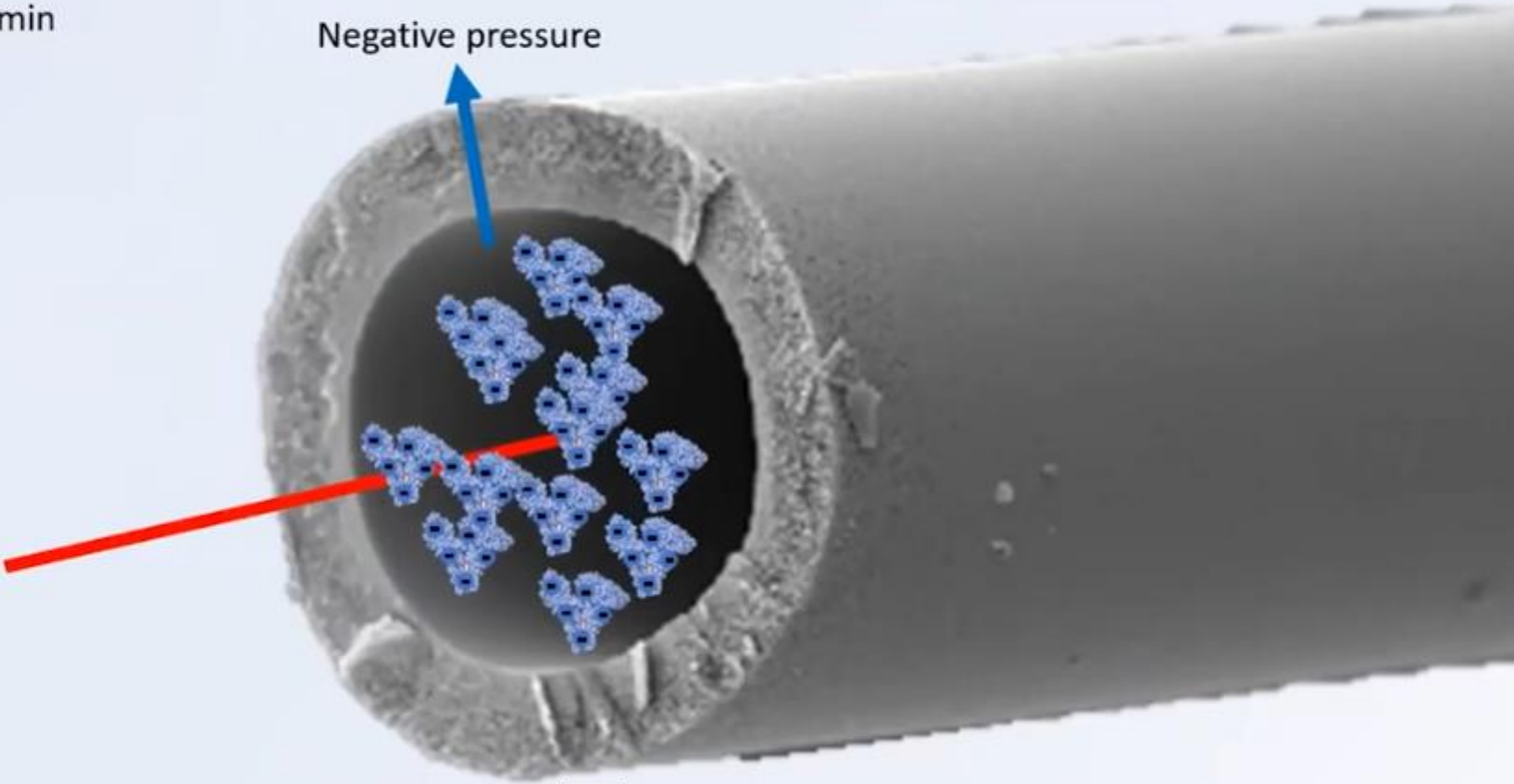


Gibbs-Donnan Effect

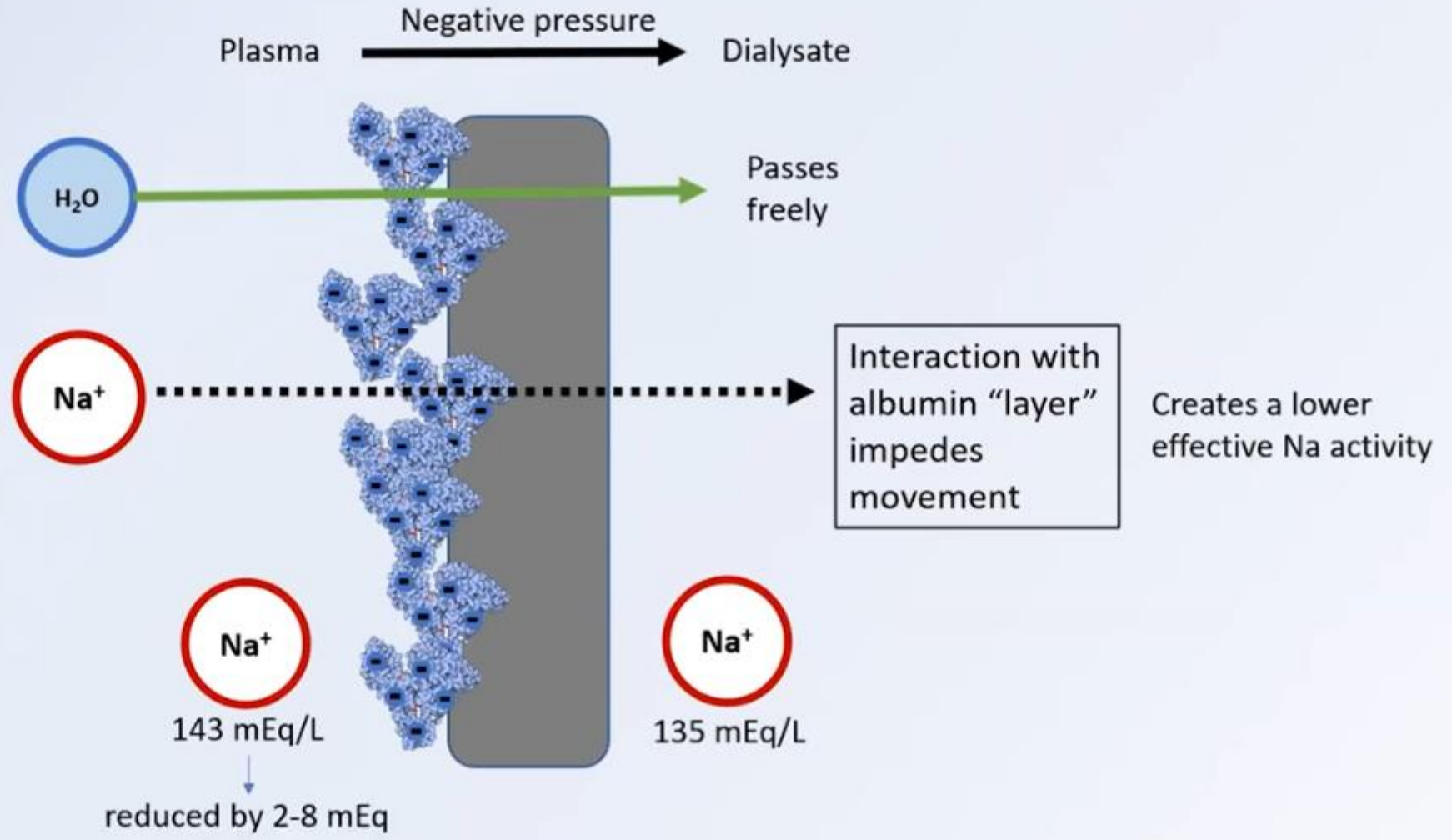


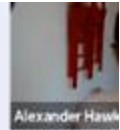
albumin

Negative pressure



Gibbs-Donnan Effect



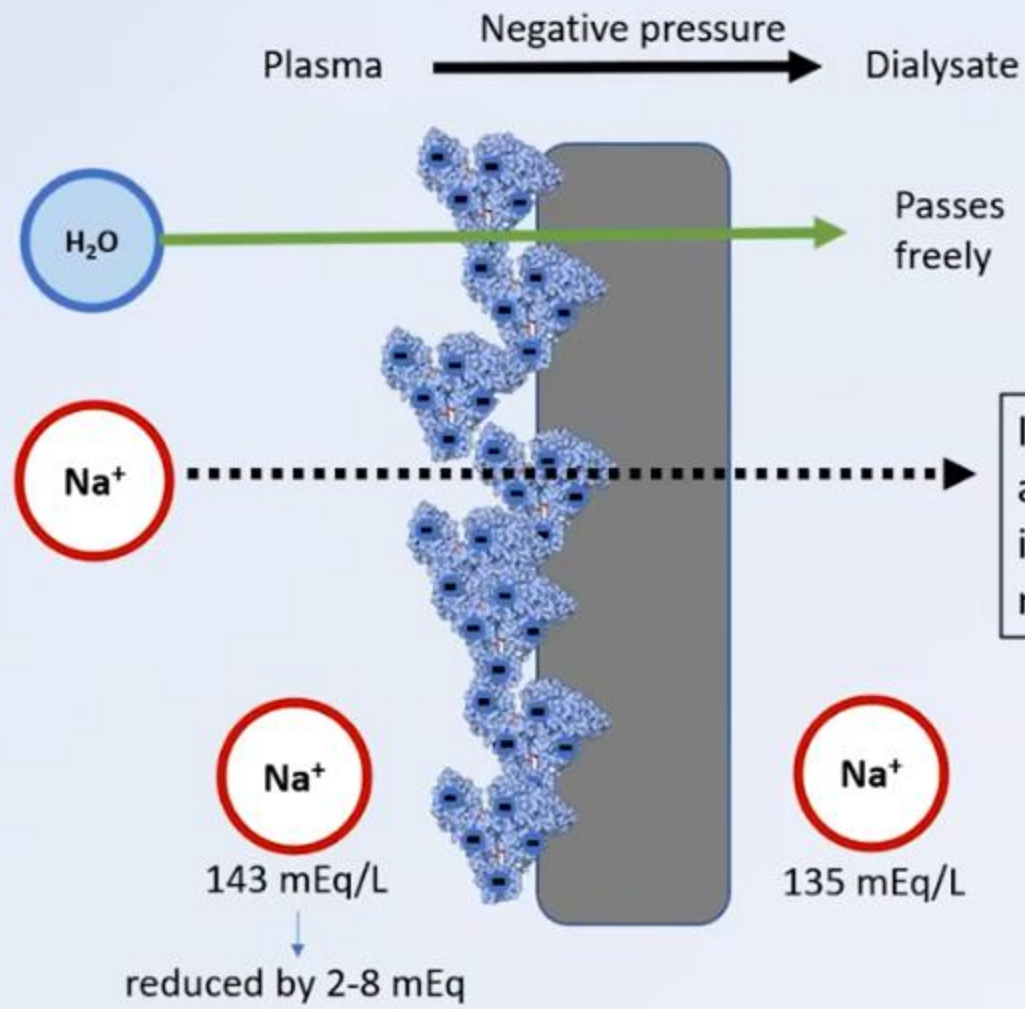


Putting it together

- Sodium ion activity in plasma is higher than measured concentration
- Direct ISE measurement is the best approximation of “in vivo” ion activity, but labs don’t report this
- Gibbs-Donnan effectively lowers the plasma sodium activity relative to dialysate sodium during hemodialysis
 - Magnitude of effect is difficult to quantify
- Do these effects “cancel out”, making the lab reported concentration difference close enough to the true diffusion gradient?
 - Probably

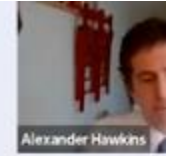
- How does ultrafiltration fit into this?

Gibbs-Donnan Effect



Is loss of free water contributing to change in plasma sodium level?

Interaction with albumin "layer" impedes movement



Ultrafiltration effect

- 1984 study, looking at 30 UF only treatments
- Compared regular UF to an “in vitro” study
 - Details for in vitro not clear, but blood had saline and other things added

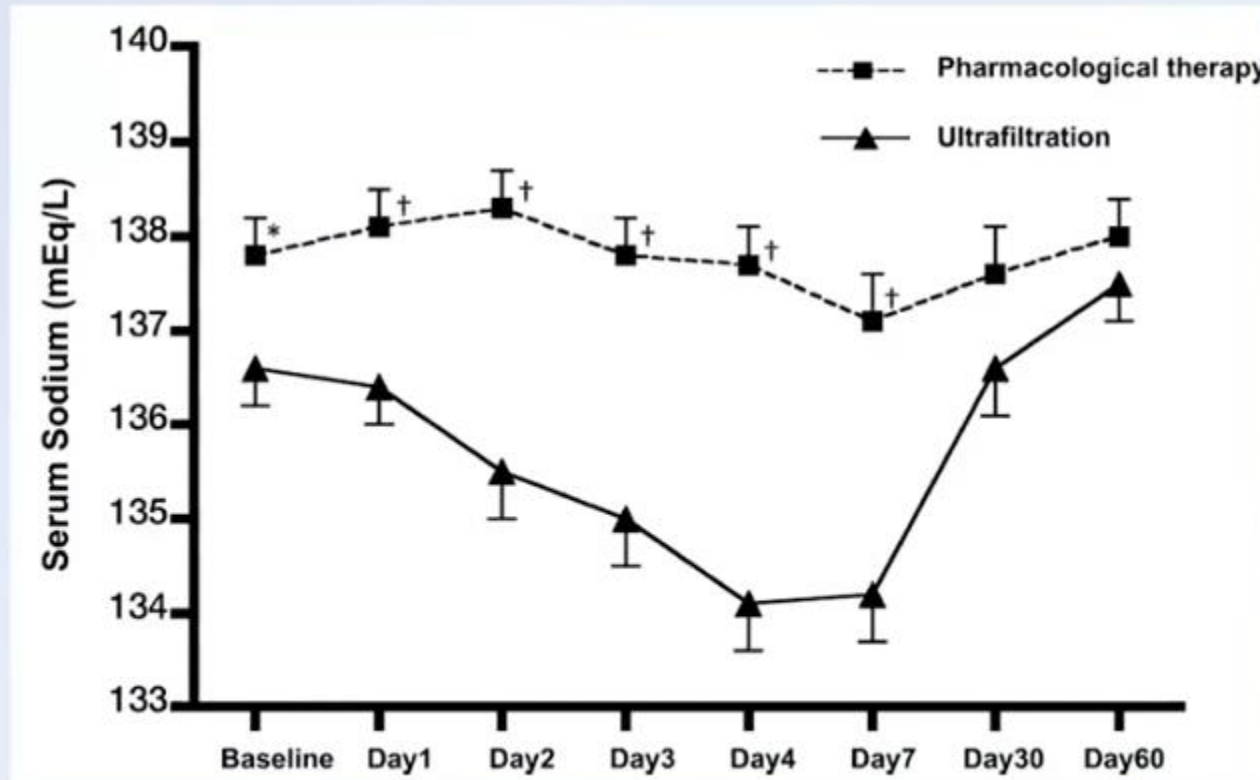
	Sodium at inlet	Sodium at outlet	Sodium in ultrafiltrate
In vivo UF	150.2	151.0	142.0
In vitro UF	161.5	162.5	159.0

- Plasma sodium level increases slightly from inlet to outlet
- Effluent is slightly hypotonic, moreso for in vivo treatment



Ultrafiltration effect

- For heart disease, 2017 study showed worsened hyponatremia with UF



With working kidneys, suspect that UF is activating RAAS and ADH, leading to free water retention



Conclusions

- Dialysis is complicated
- Current dialysate sodium practices evolved out of necessity, alleviating the symptoms of dialysis in shorter treatment times
- Many factors of relatively small magnitude contribute, in terms of diffusion gradient and effluent composition
- In practice, nothing that will significantly affect dialysate sodium prescribing
- Might explain some of the variability in response to a prescribed sodium gradient