Potassium

Amandeep Khurana
Transplant Nephrologist
Southwest Kidney Institute

HOW MUCH POTASSIUM IS IN YOU?

What is normal serum K?

a. 2 meq/L
b. 4 meq/L
c. 6 meq/L
d. 8 meq/L

normal serum K = 4 meq/L
normal ECF = 14L

normal extracellular K = 56 meq

What is normal intracellular K?

a. 2 meq/L
b. 4 meq/L
c. 6 meq/L
d. >8 meq/L

normal intracellular K = 140 meq/L
normal ICF = 28L

normal intracellular K = 3920 meq

HOW MUCH POTASSIUM IS IN YOU?

intracellular potassium: 3,920 mmol
extracellular potassium: 56 mmol

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total body potassium: 3,976 mmol

HOW MUCH POTASSIUM IS IN YOU?

intracellular potassium: 3,920 mmol
extracellular potassium: 56 mmol

---

total body potassium: 3,976 mmol

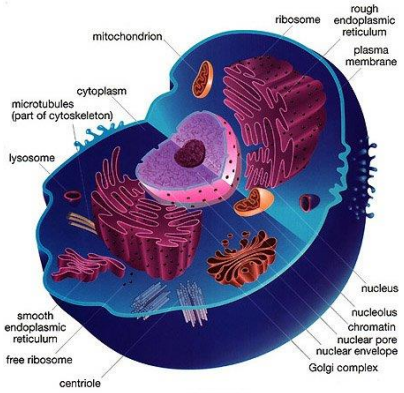
1.4%

ALL your plasma has 12 meq of potassium. What's the IOM recommended daily K intake?

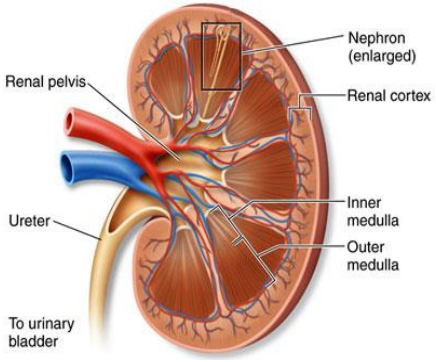
a. 10 meq
b. 60 meq
c. 100 meq
d. 120 meq

POTASSIUM IS REGULATED BY THREE STEPS

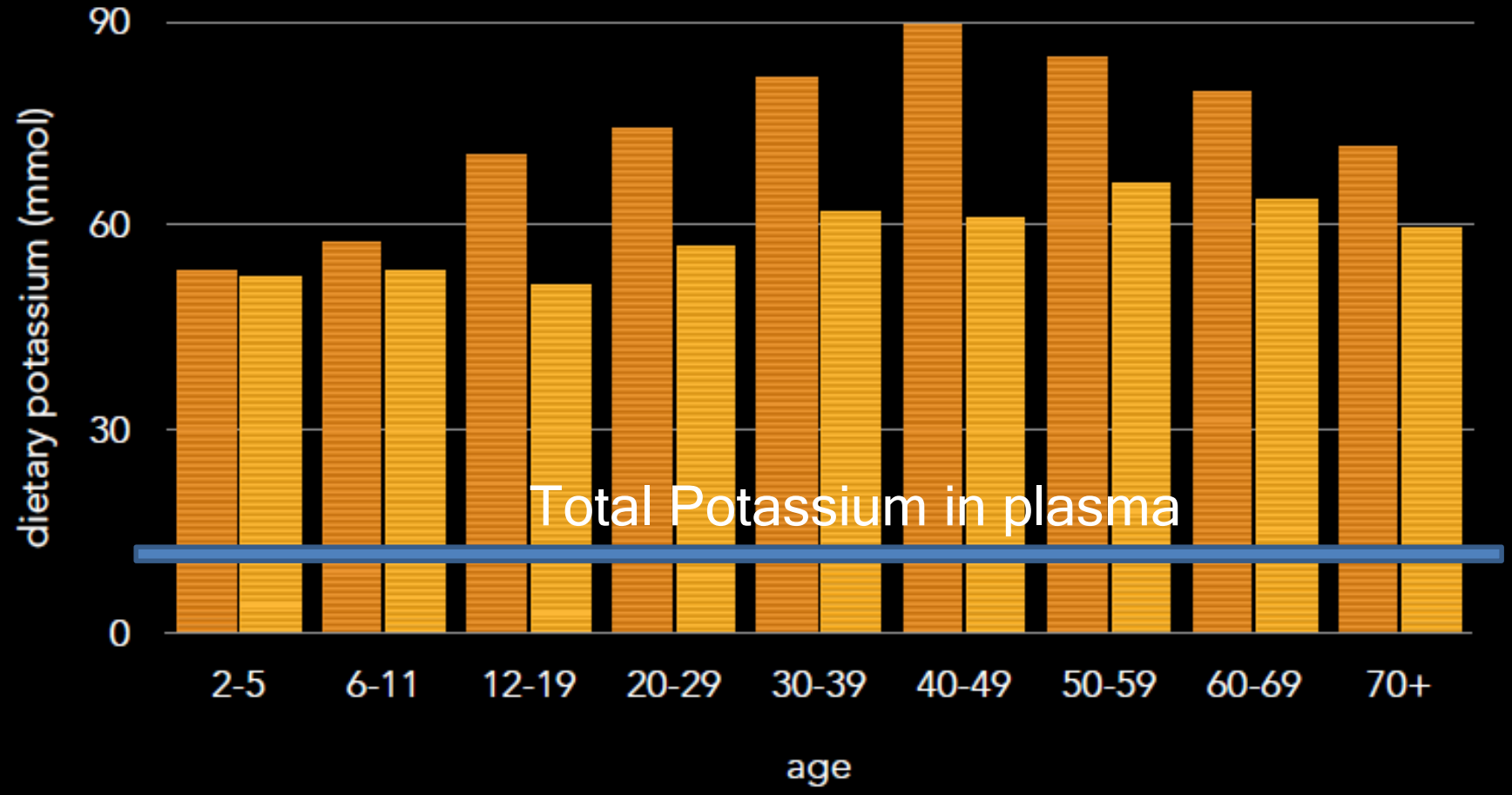
Intake



Cellular Distribution

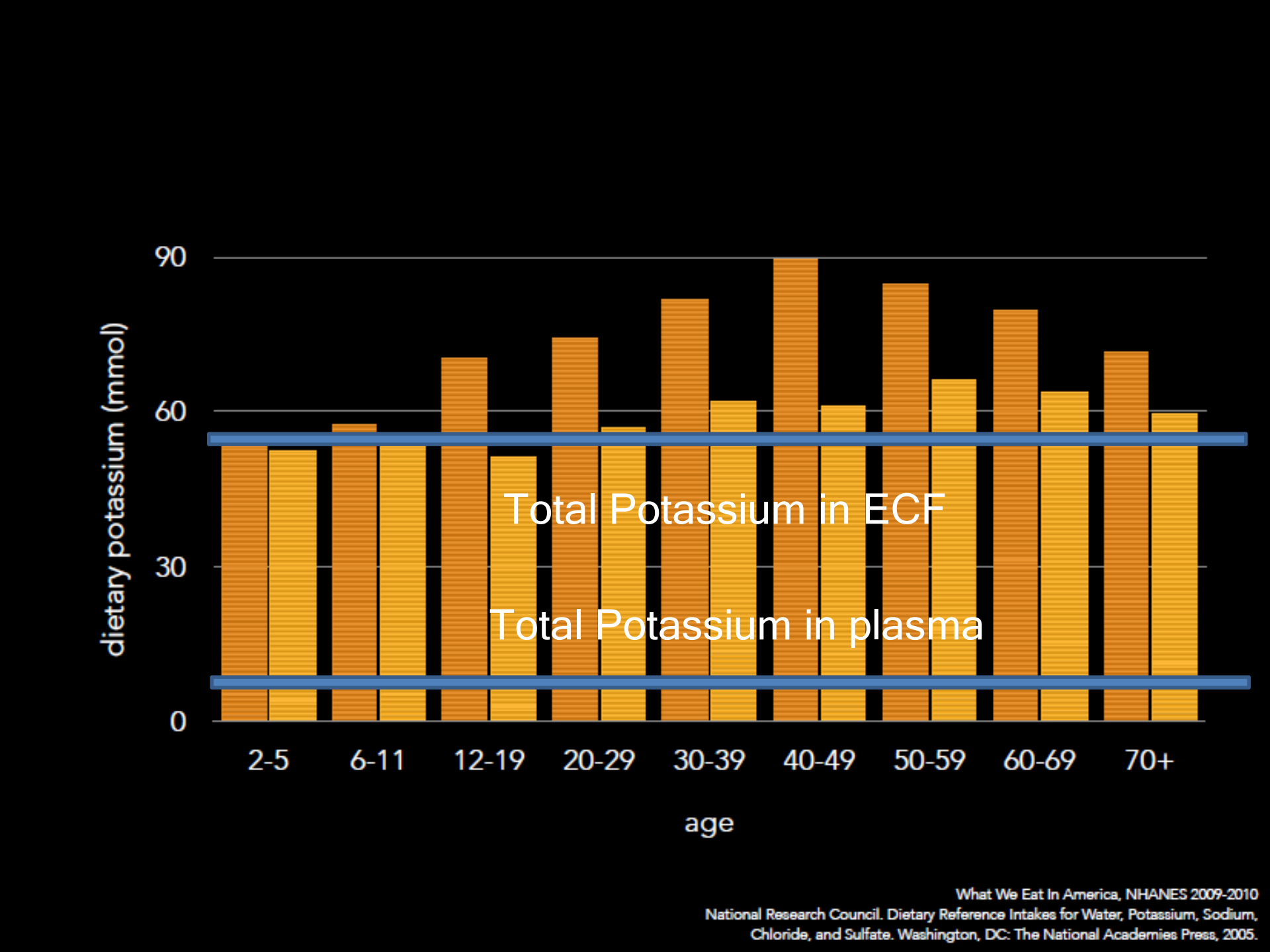


Renal Excretion



What We Eat In America, NHANES 2009-2010

National Research Council. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. Washington, DC: The National Academies Press, 2005.



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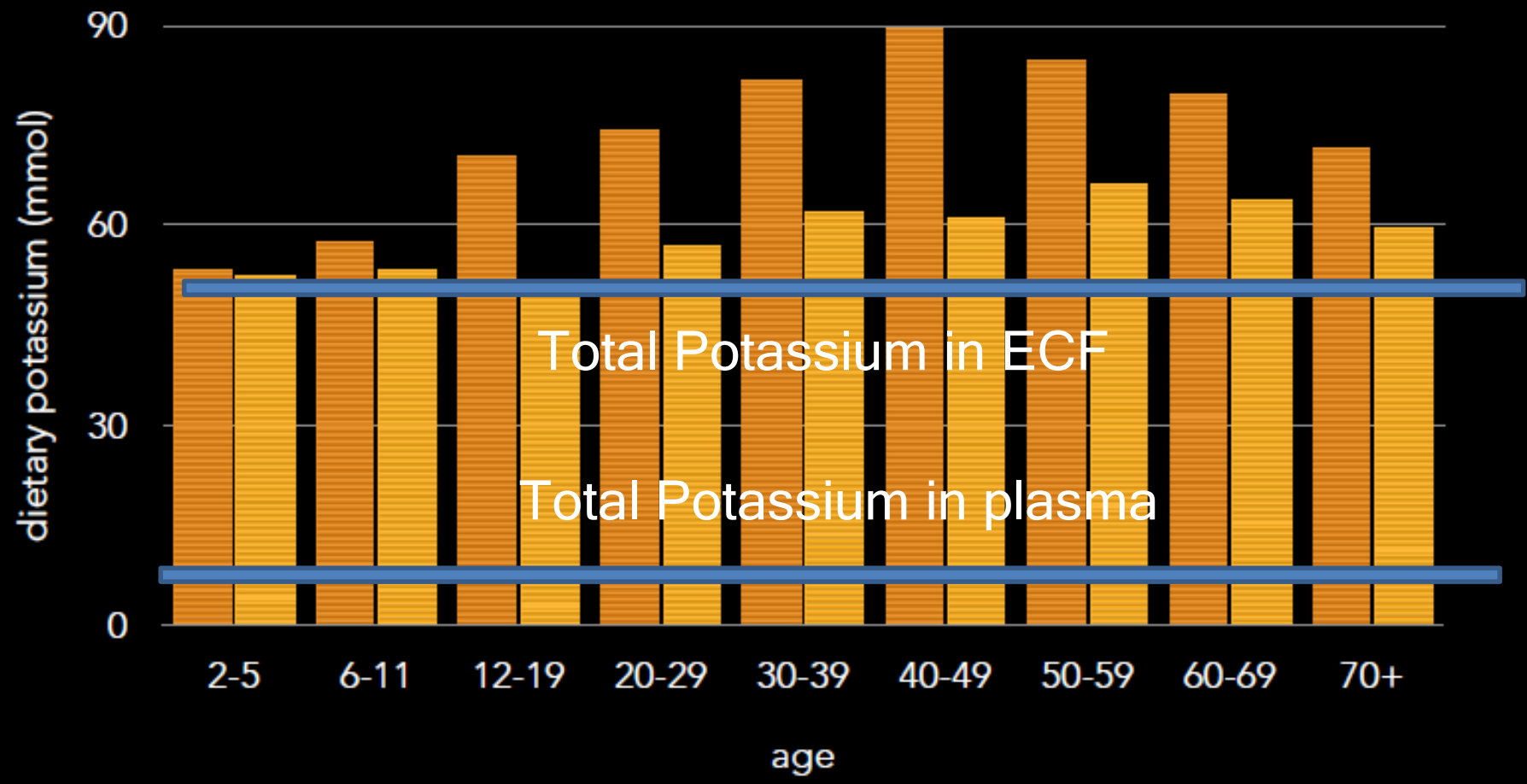
IOM recommended potassium intake = 120 meq/day



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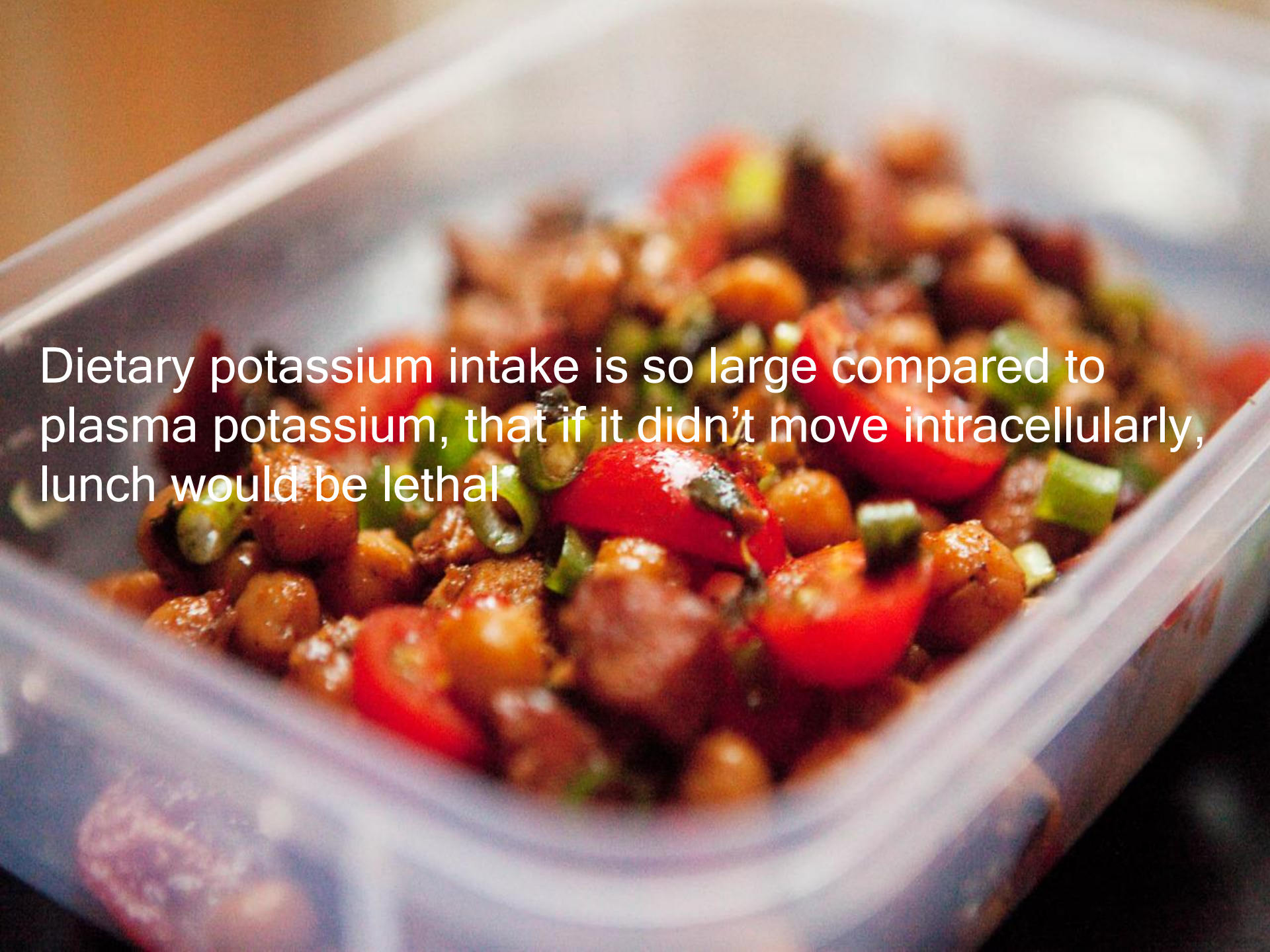
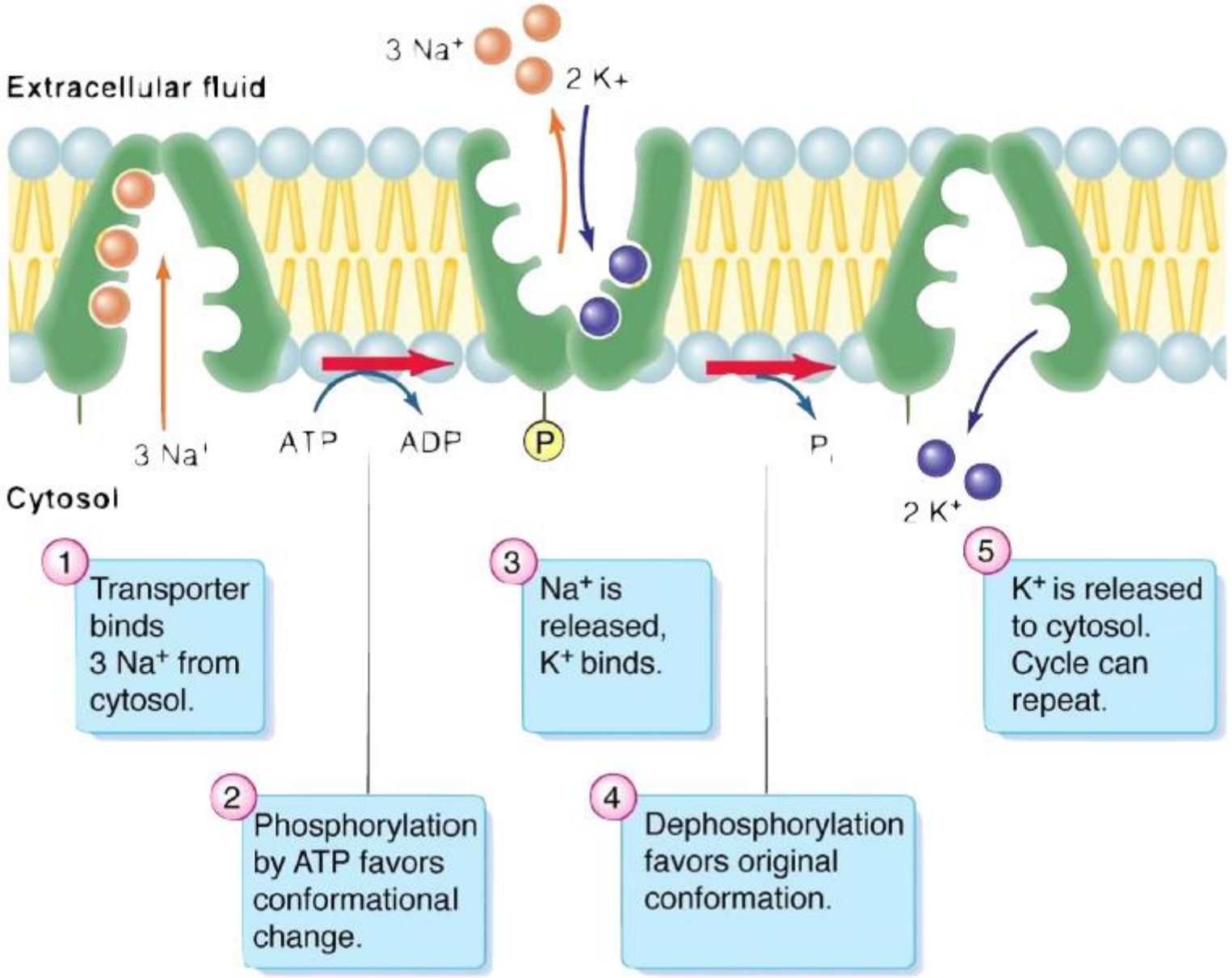
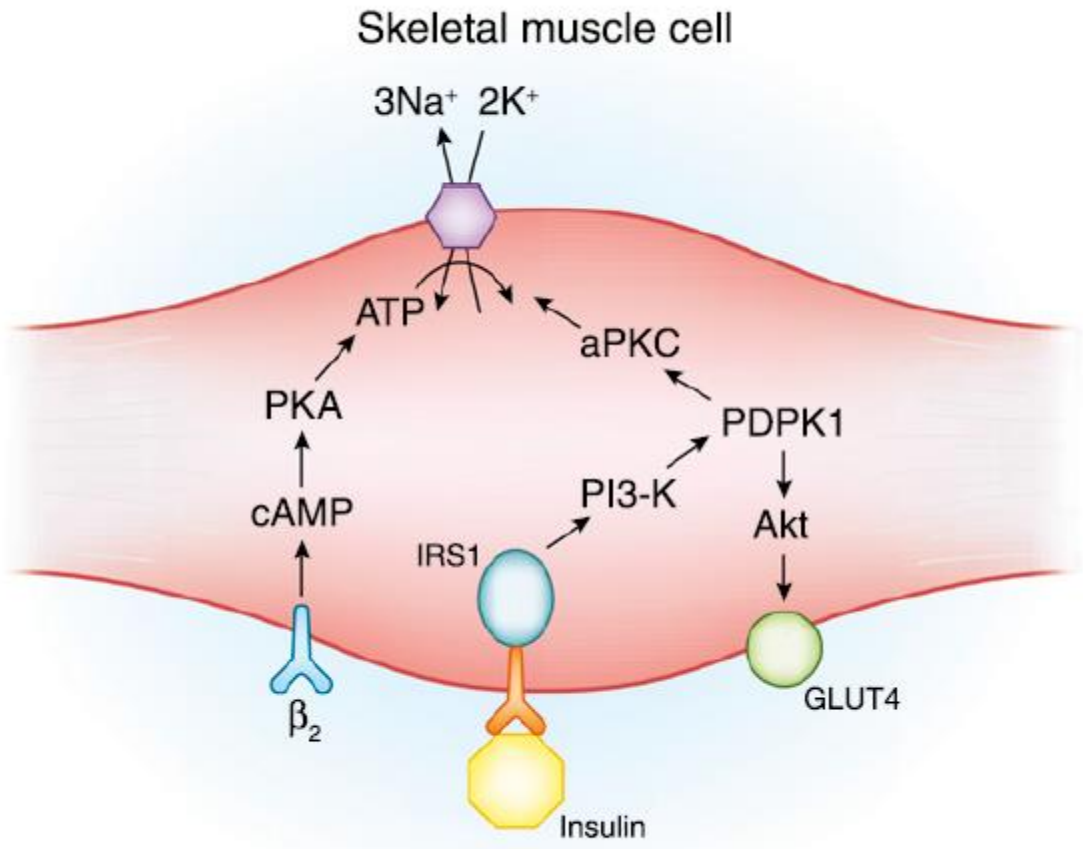
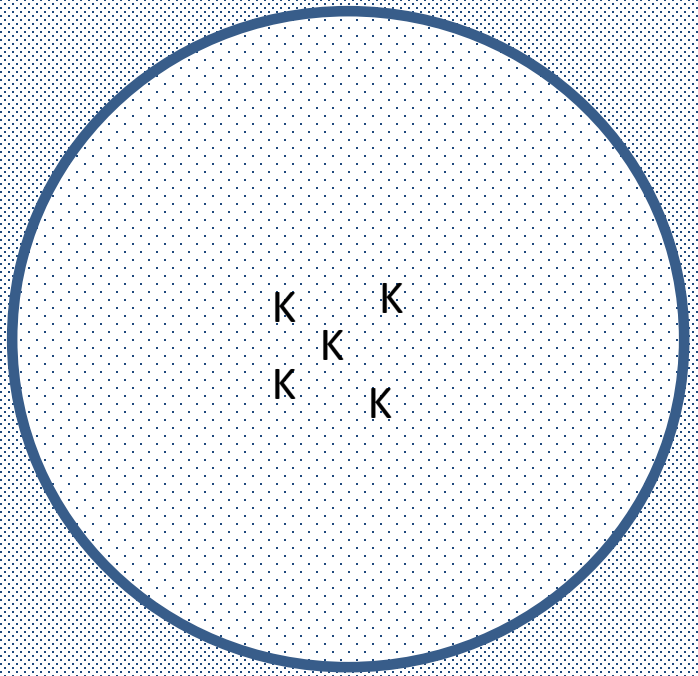

Dietary potassium intake is so large compared to plasma potassium, that if it didn’t move intracellularly, lunch would be lethal


3 Na+
2 K+
Extracellular fluid
3 Na+
ATP
ADP
P
Pi
2 K+
Cytosol
1 Transporter binds 3 Na+ from cytosol.
2 Phosphorylation by ATP favors conformational change.
3 Na+ is released, K+ binds.
4 Dephosphorylation favors original conformation.
5 K+ is released to cytosol. Cycle can repeat.


Skeletal muscle cell
3Na+ 2K+
ATP
aPKC
PKA
PDPK1
cAMP
PI3-K
Akt
IRS1
β2
GLUT4
Insulin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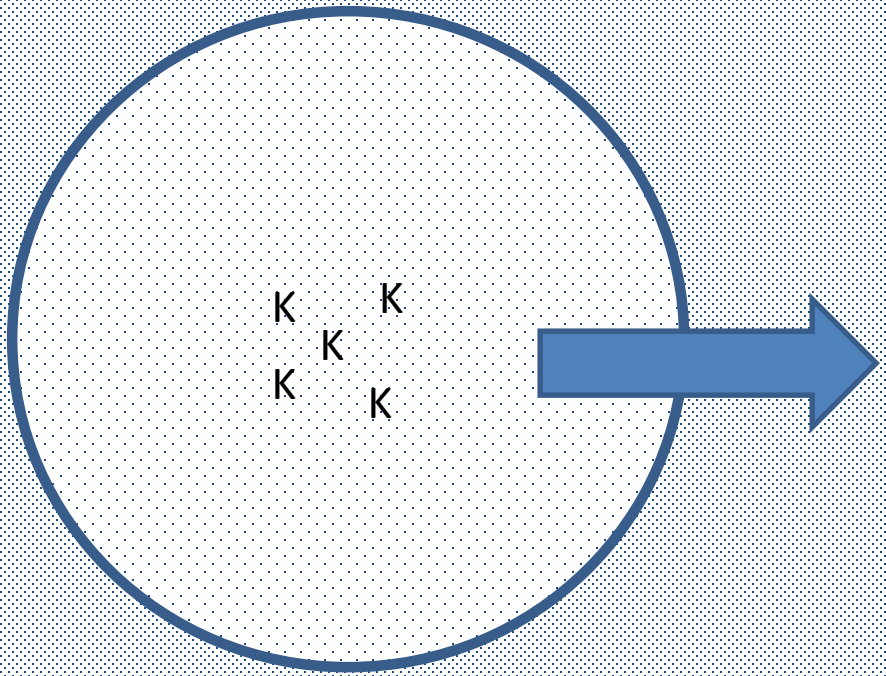
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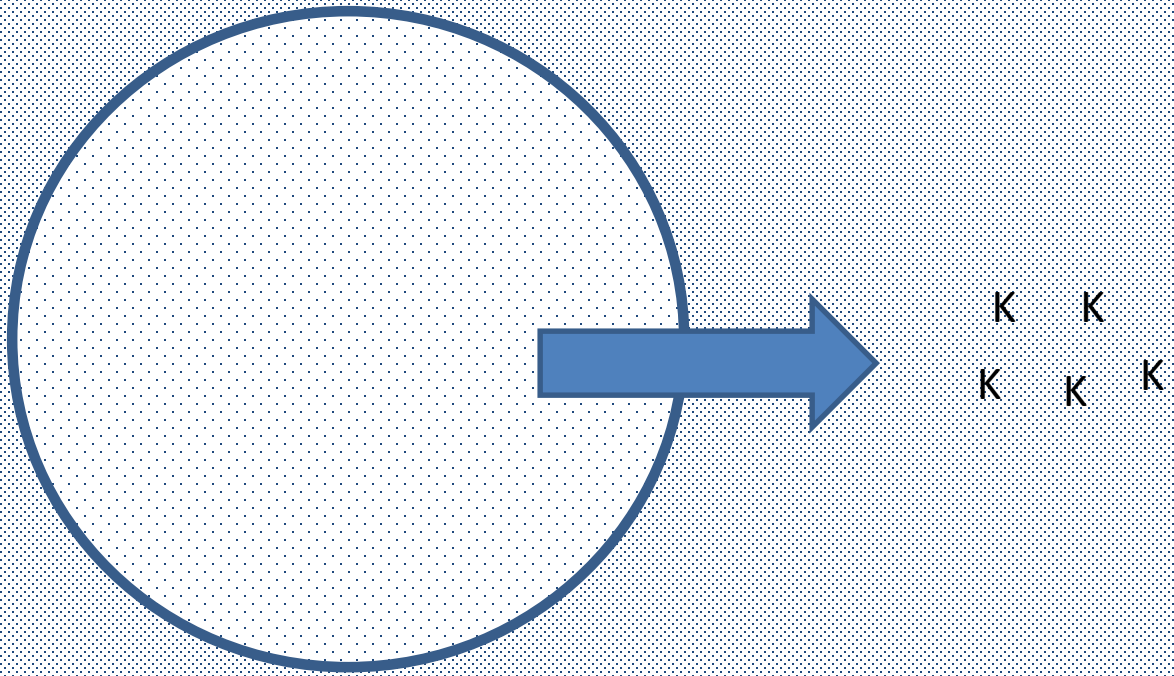
K K
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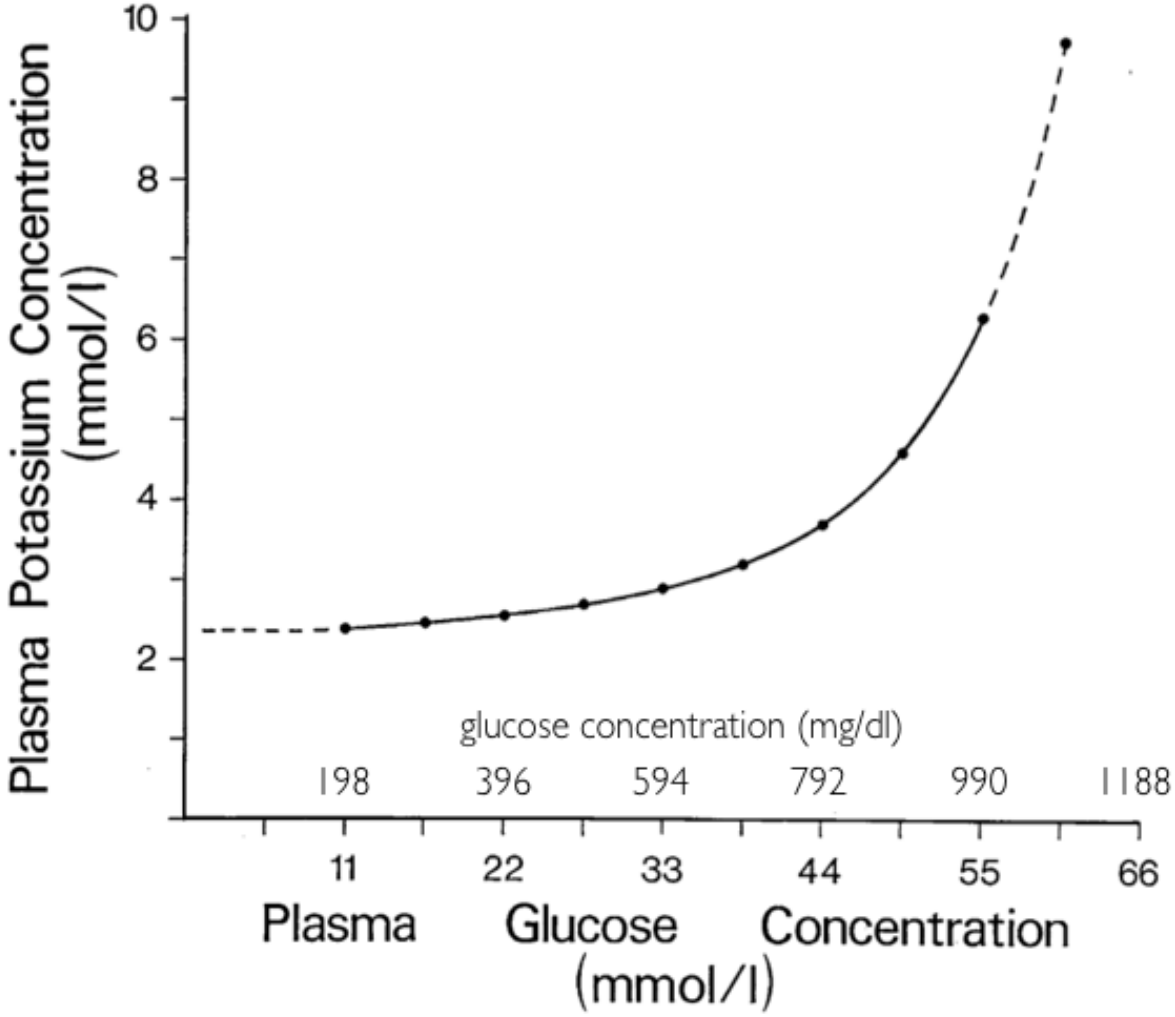


Tzamaloukas AH, Ing TS, Elisaf MS, et al. Abnormalities of serum potassium concentration in dialysis-associated hyperglycemia and their correction with insulin: review of published reports. Int Urol Nephrol. 2011;43(2):451-9.

STOOL LOSSES ARE 10 MMOL/DAY

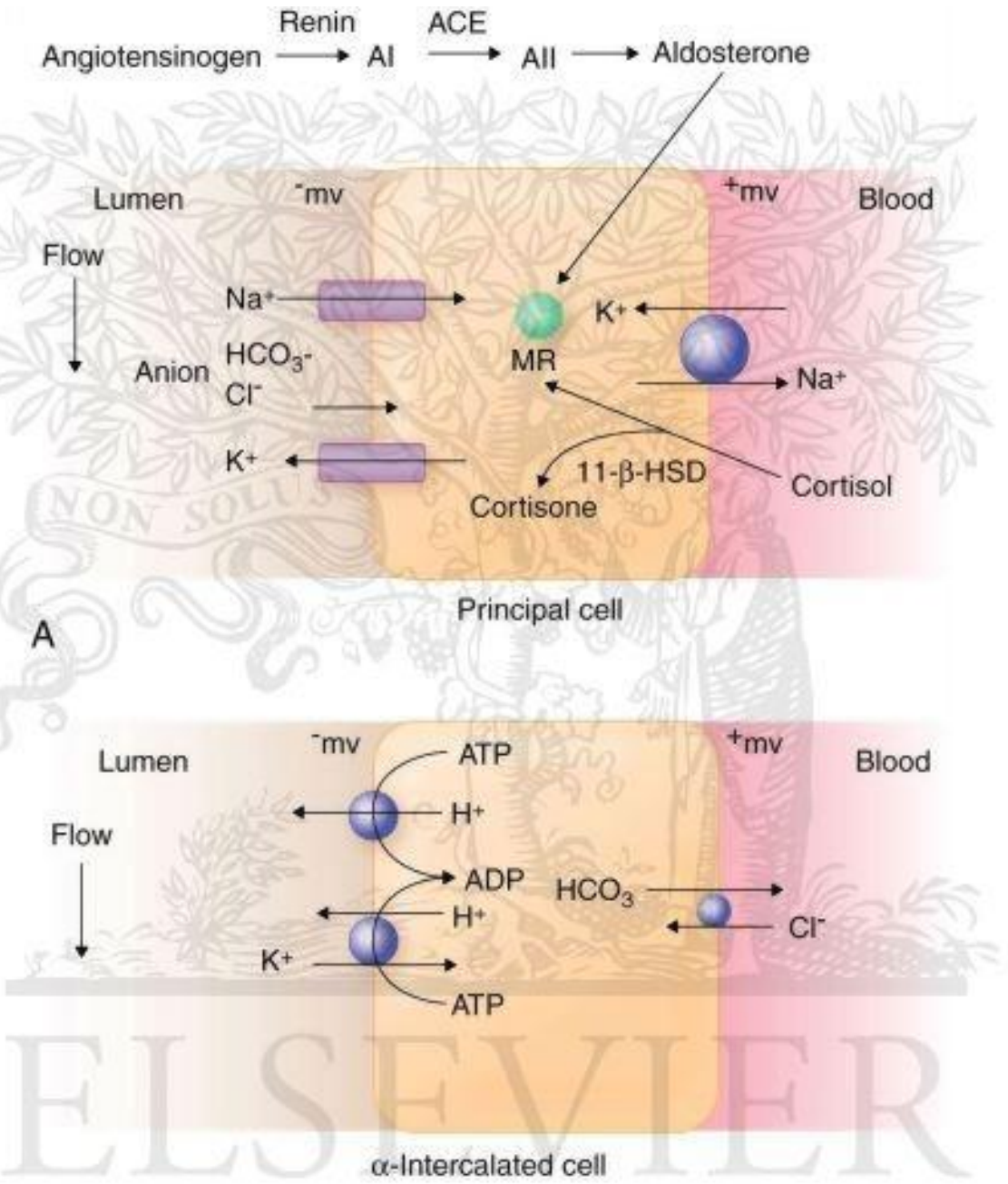
THE REST IS RENAL LOSS

How does the kidney handle Na or glucose?

a. Reabsorb 30-40% in each segment
b. Reabsorb 80% proximally & fine tune distally
c. Reabsorb 100% proximally & secrete distally

How does the kidney handle K?

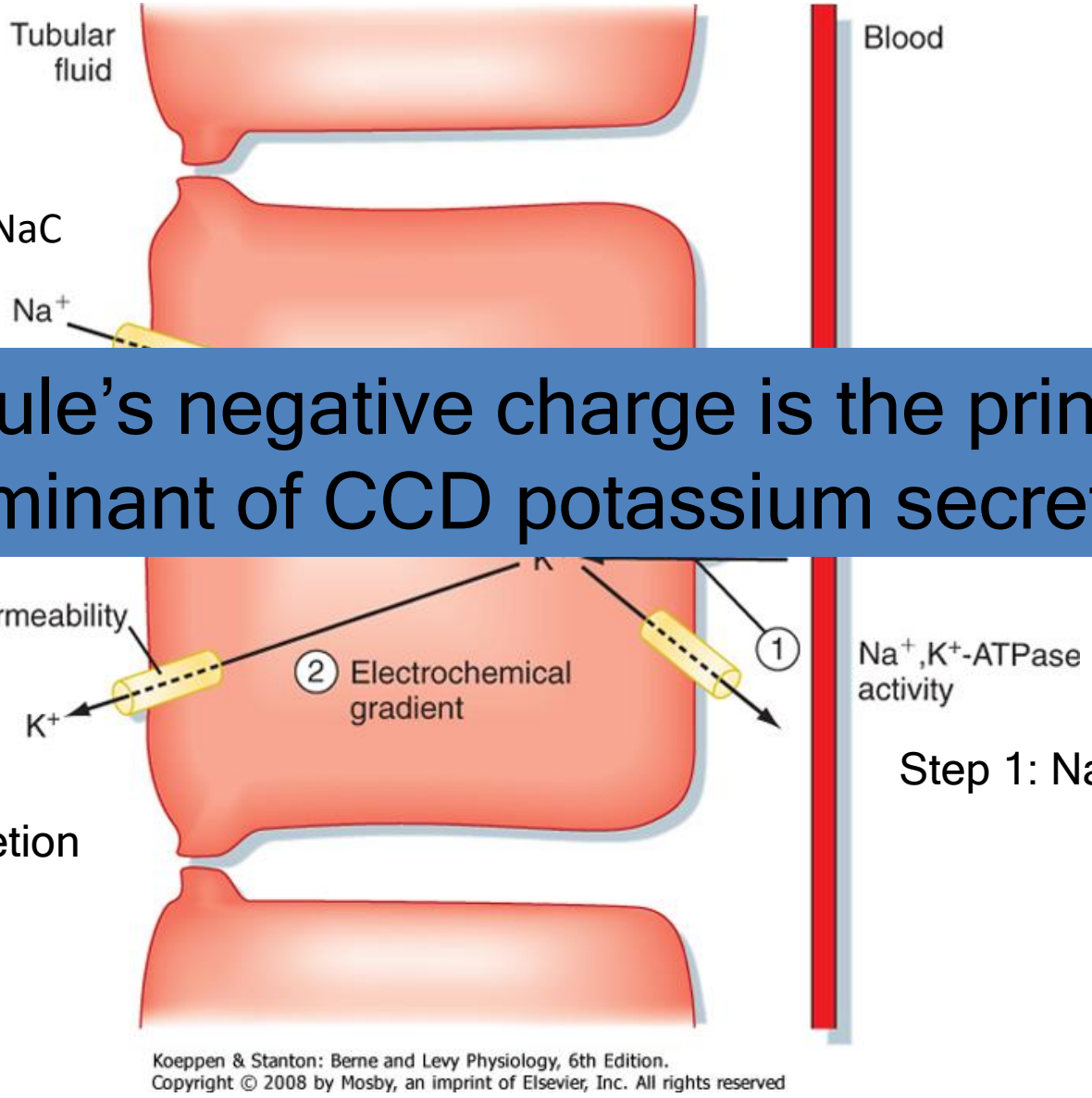
a. Reabsorb 30-40% in each segment
b. Reabsorb 80% proximally & fine tune distally
c. Reabsorb 100% proximally & secrete distally



Principal cells = K

Intercalated cells = H

How to secrete K



K secretion is determined by

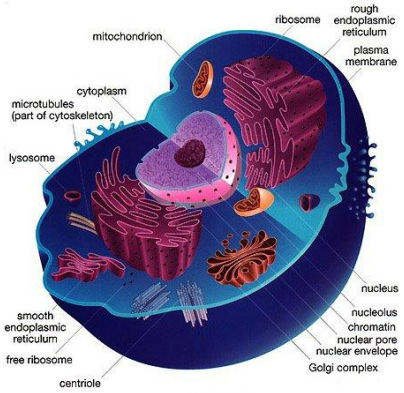
1. Distal Na delivery + flow rate

2. Aldosterone: Increases number and activity of:
   - Na-K ATPase
   - ENaC
   - K channel

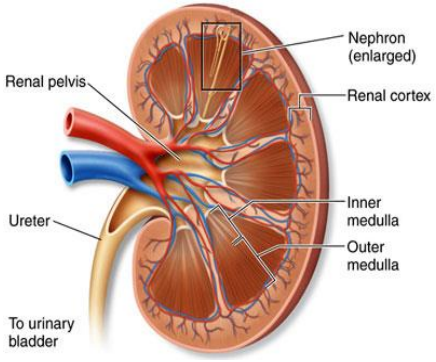
Hyperkalemia

POTASSIUM IS REGULATED BY THREE STEPS

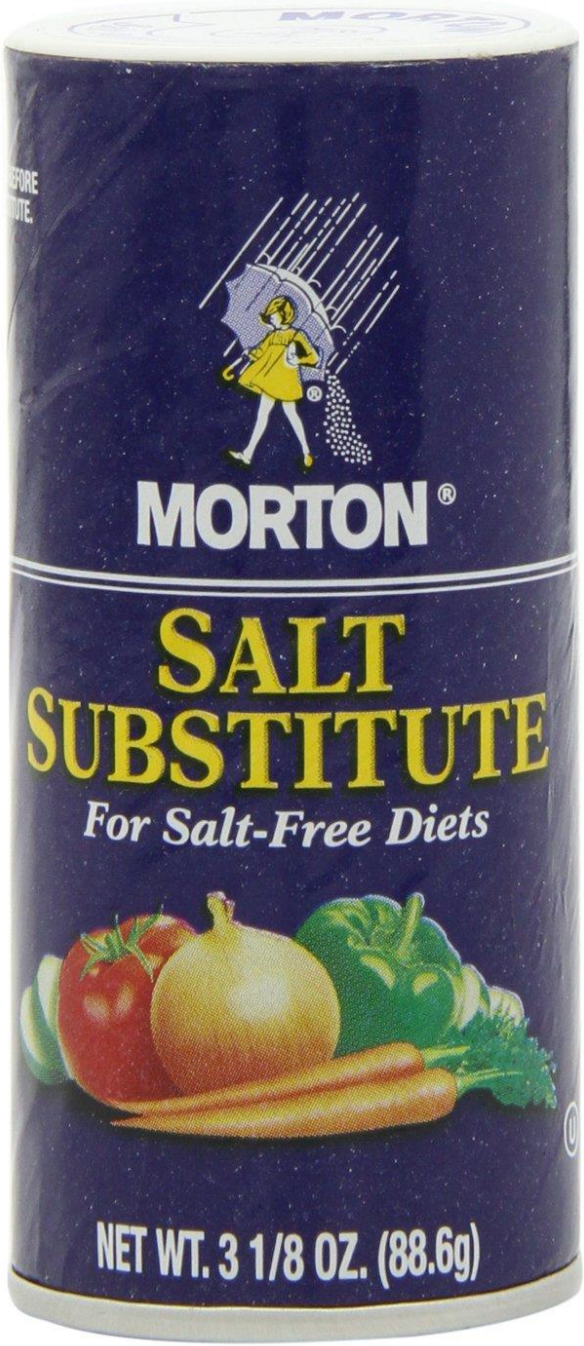
Intake

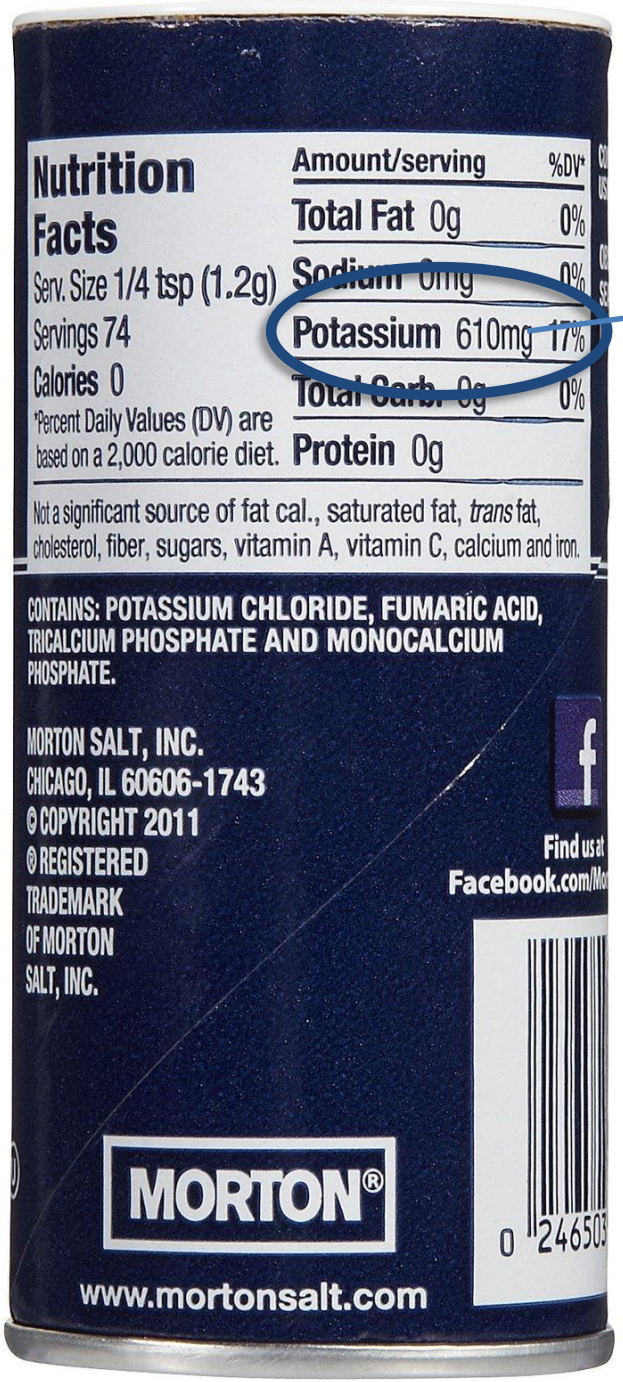


Cellular Distribution



Renal Excretion


MORTON®
SALT
SUBSTITUTE
For Salt-Free Diets
NET WT. 3 1/8 OZ. (88.6g)



15 meq in ¼ teaspoon
60 meq in 1 teaspoon

Who is prescribed sodium restriction?

- CHF
- CKD
- HYPERTENSION

What other medicines are they taking?

- ACEI
- ARB
- ALDOSTERONE ANTAGONISTS
- BETA BLOCKERS

Unusual cause of hyperkalemia without renal failure:

- Salt substitues
- TPN
- Enteral supplements
- Blood transfusions
- High potassium foods
- Penicillin
- Dialysate

Increased Intake

Malone, A. Enteral Formula Selection: A Review of Selected Product Categories. Practical Gastroenterology; June 2005, p44-74.

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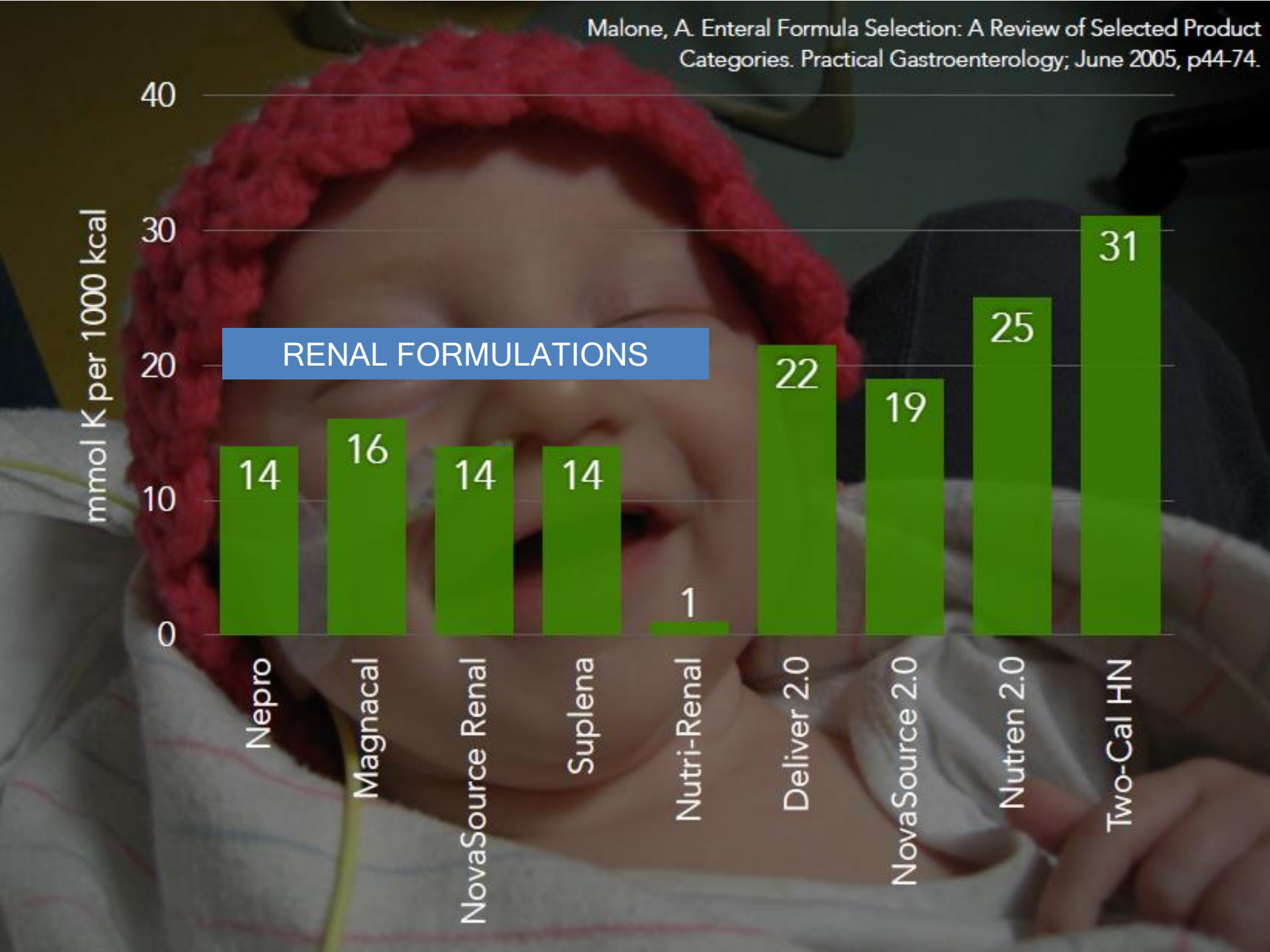


POTASSIUM CONTENT

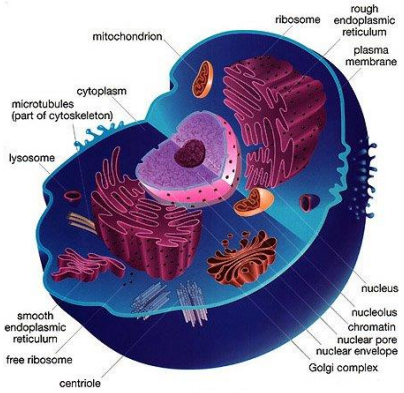
Tomato Juice: 58 mmol/L

Noni Juice: 56 mmol/L

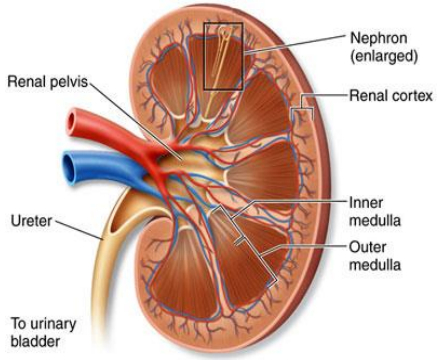
Orange Juice: 51 mmol/L

Pineapple Juice: 34 mmol/L

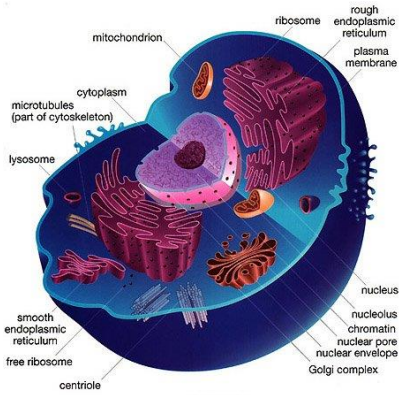
Intake



Cellular Distribution

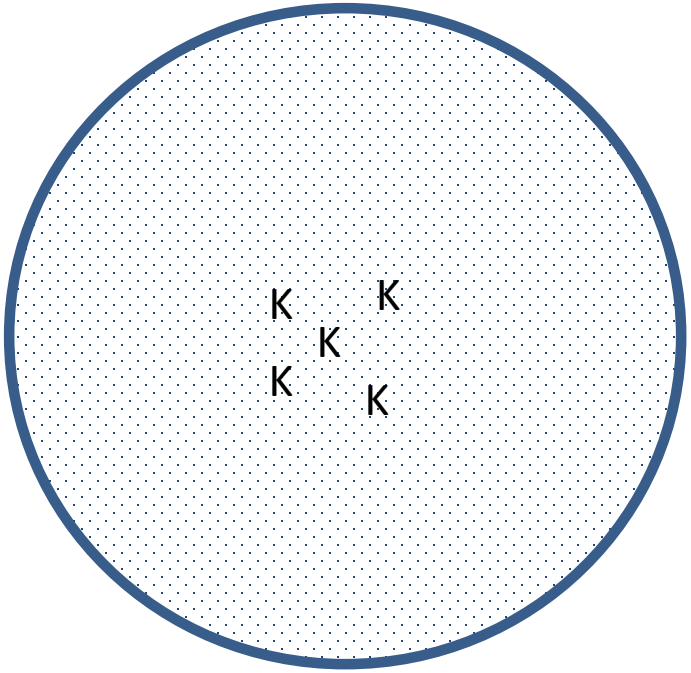


Renal Excretion



Cellular Distribution

- Hyperosmolality
  - DKA and hyperglycemia
- Cell destruction
  - Rhabdomyolysis
  - Tumor lysis syndrome
- Drugs
  - Beta blockers
  - Digoxin
  - Succinylcholine
- Acidemia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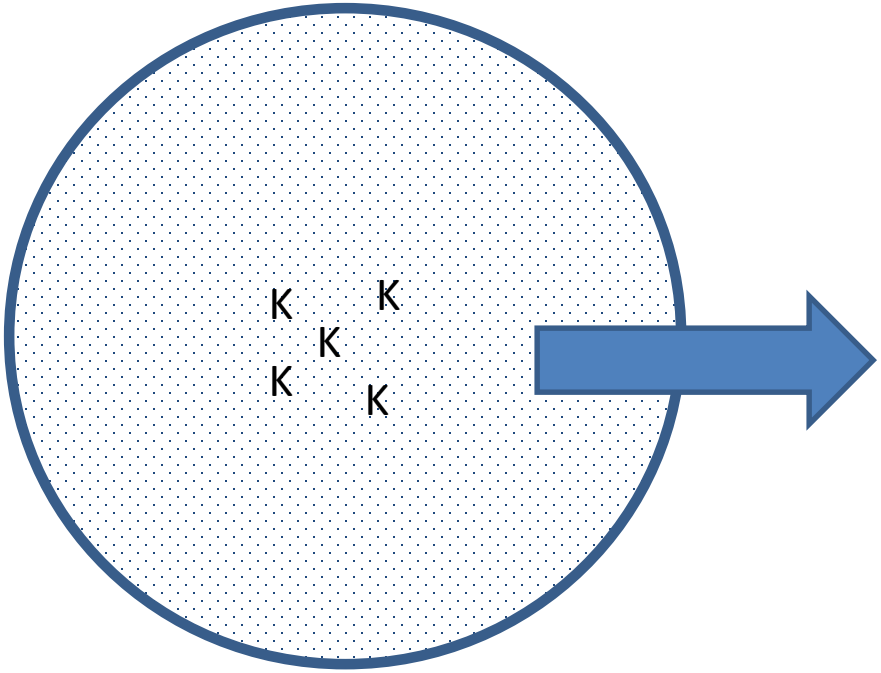
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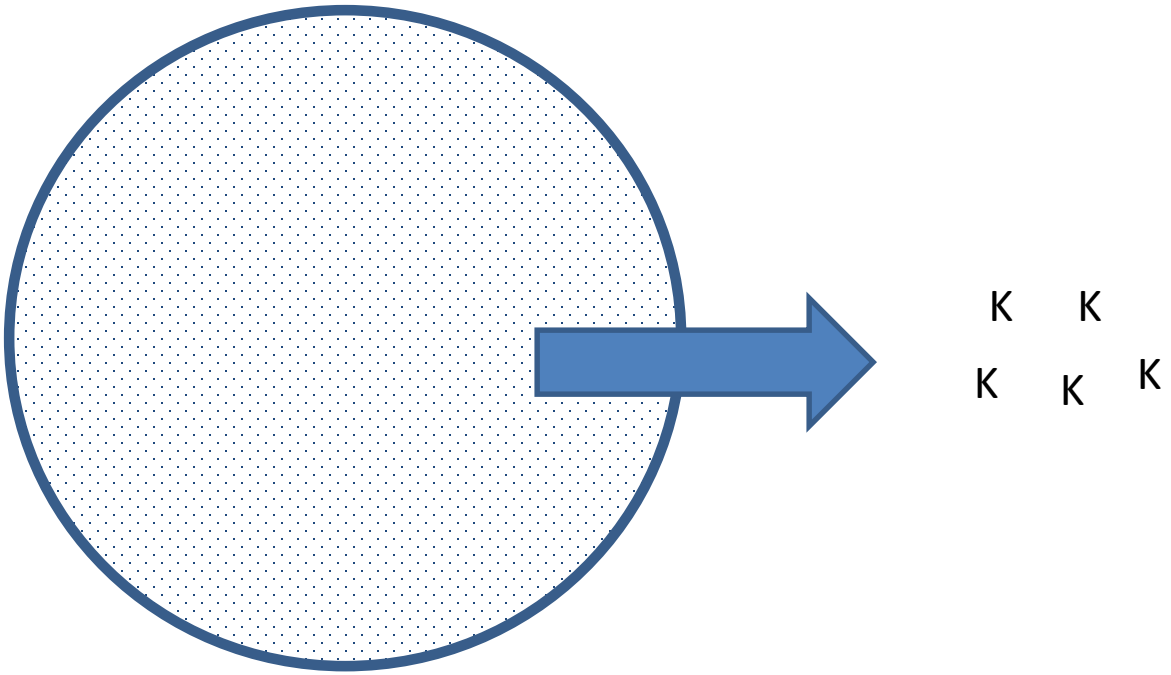
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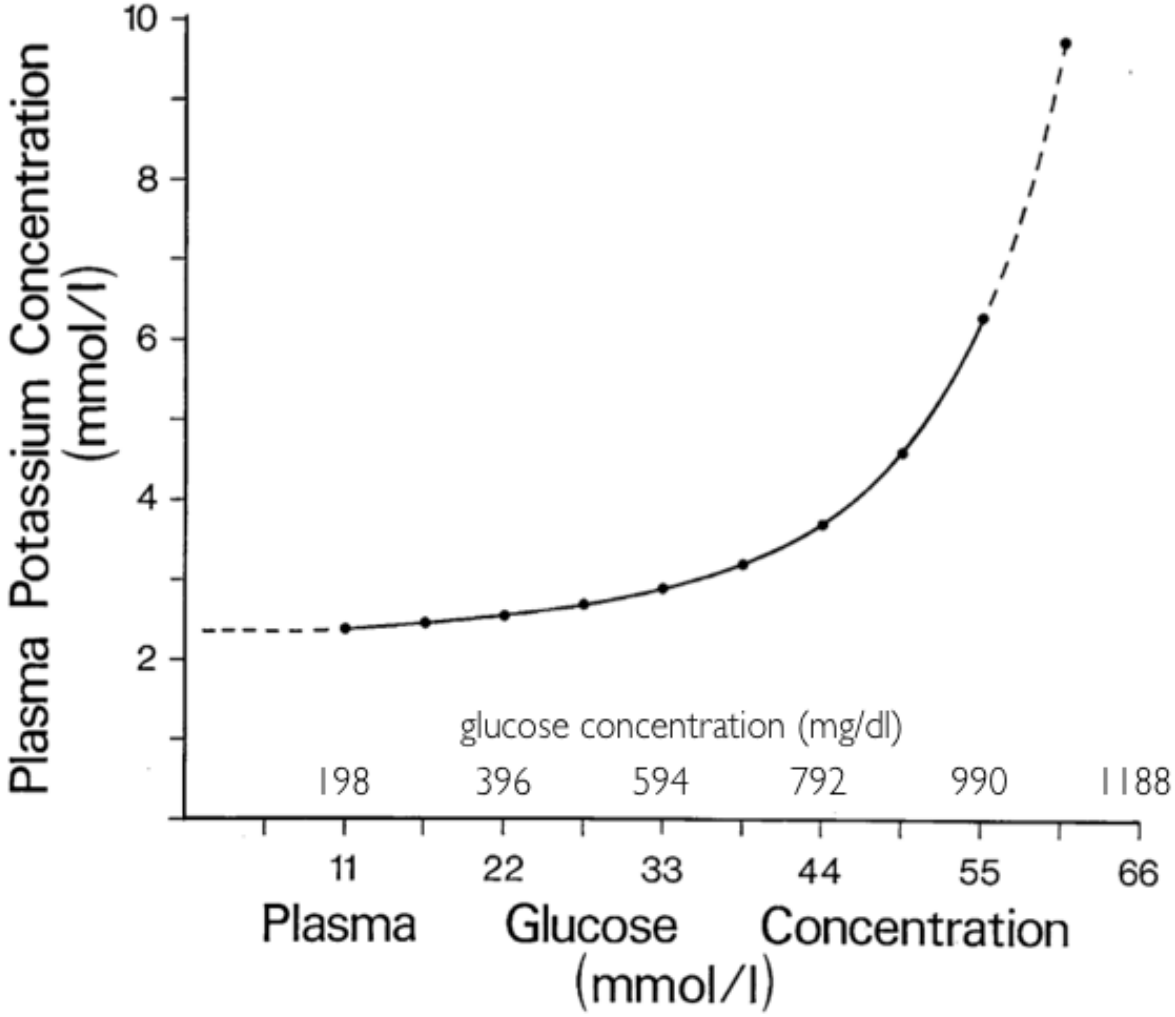
K K K



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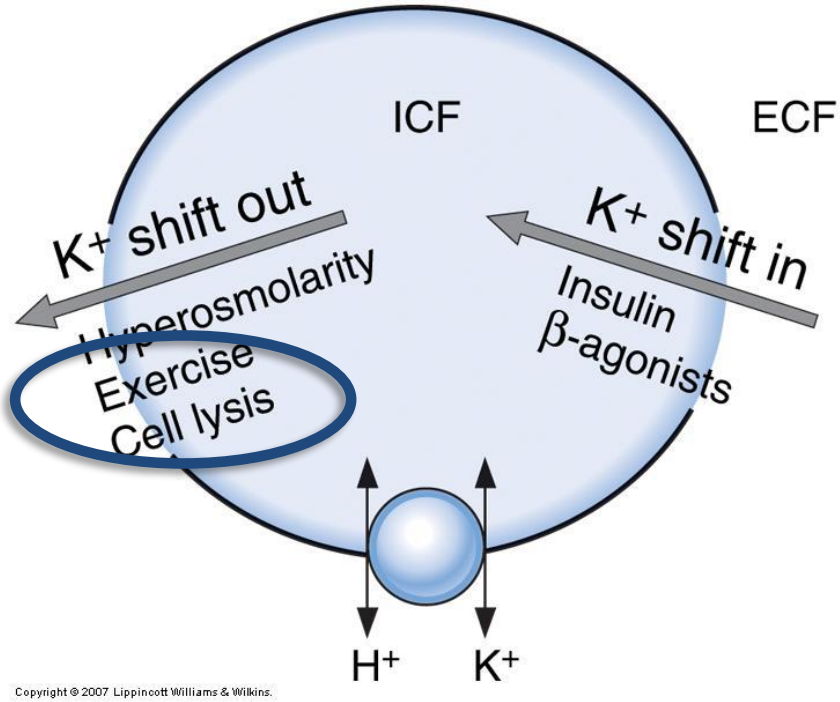
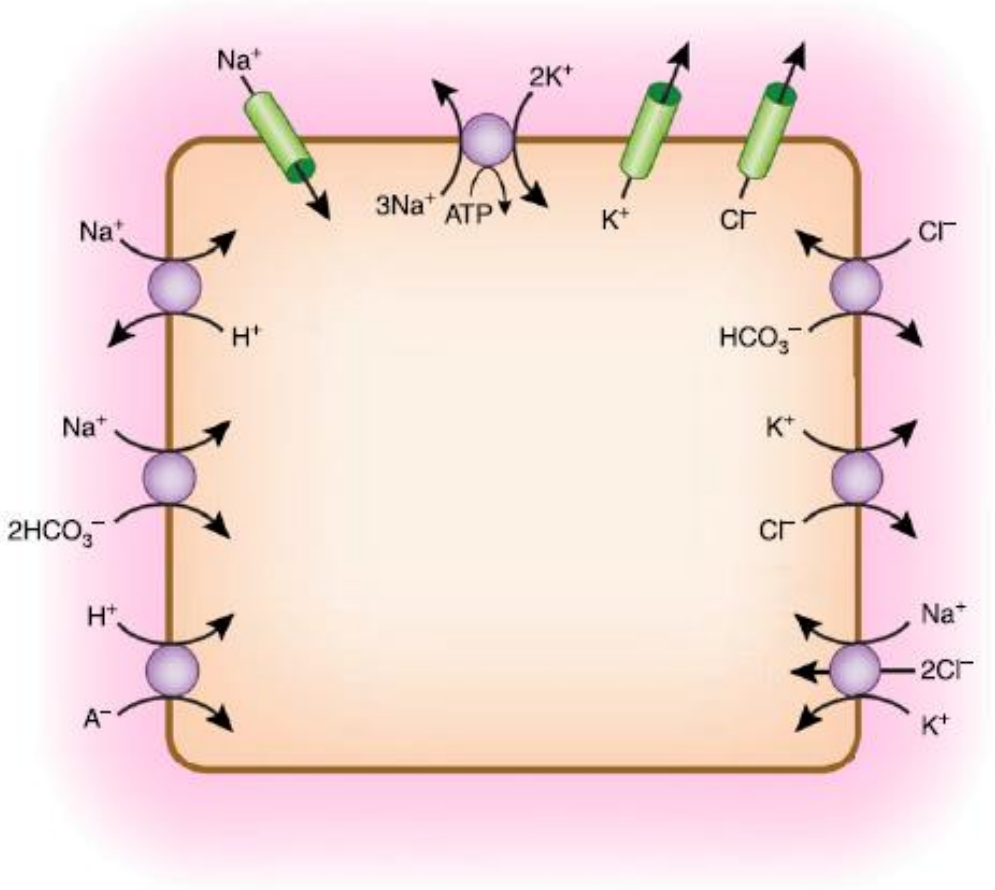
- tissue destruction
  - trauma
  - tumor lysis syndrome
  - hypothermia
  - hemolysis



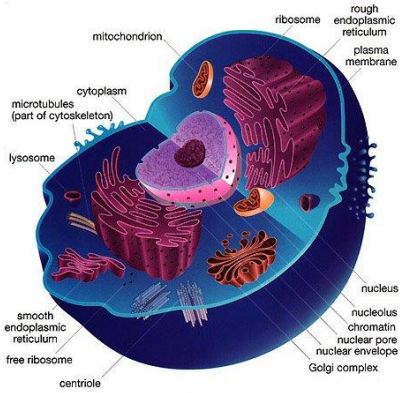
Acidemia and potassium



H-K antiport
Does NOT exist

Figure 28. Multiple ion transport pathways directly or indirectly affect net K^+ flux in skeletal muscle cells. Reprinted with permission from Aronson PS, Giebisch G: Effects of pH on potassium: New explanations for old observations. *J Am Soc Nephrol* 22: 1981–1989, 2011.

Intake



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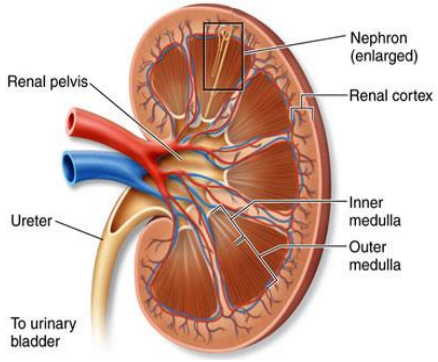
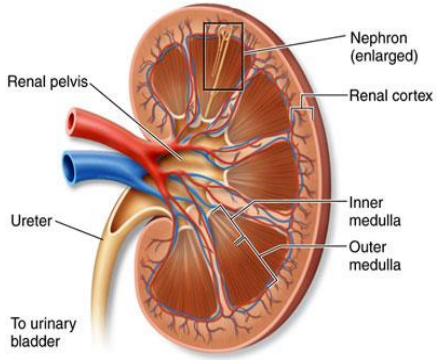


Renal Excretion

Decreased renal potassium excretion

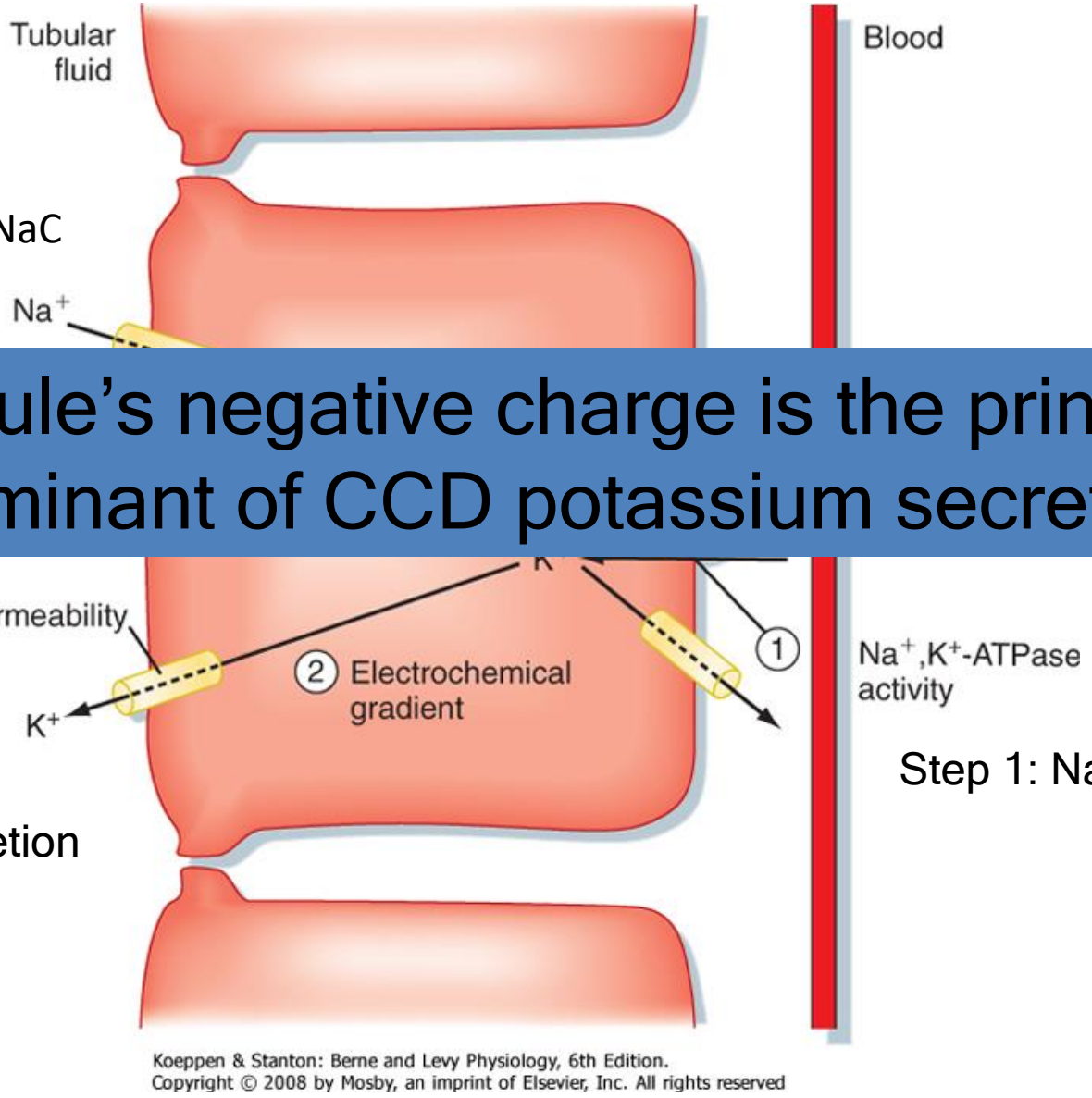
- Renal failure
- Hypoaldosteronism
- Drugs
    - ACEi, ARB
    - NSAIDs
    - spironolactone
    - amiloride, triamterene
    - trimethoprim
- RTA 1 and 4
- Gordon's Syndrome (PHA)



Renal Excretion

As a general rule, persistent hyperkalemia is always due to a failure of renal potassium handling

How to secrete K



K secretion is determined by

1. Distal Na delivery + flow rate

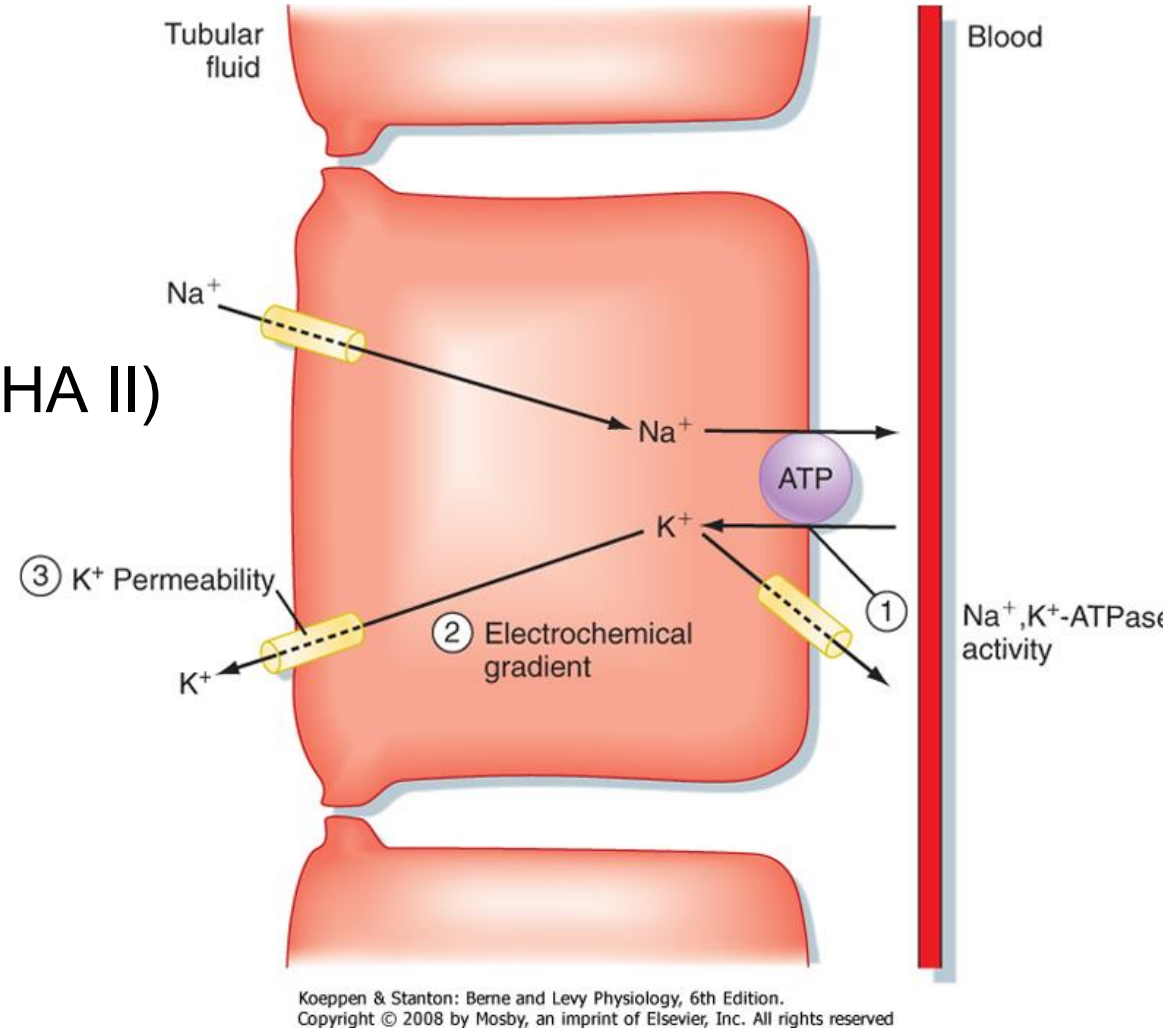
2. Aldosterone: Increases number and activity of:
   - Na-K ATPase
   - ENaC
   - K channels
     - ROMK (Renal outer medullary K channel)
     - Maxi-K/BK (Flow dependent)

Can ibuprofen cause hyperK?

a. No
b. Yes, because it's high in K
c. Yes, because it decreases Na delivery
d. Yes, because it blocks eNAC
e. Yes, because it causes hypoaldosterism

Decreased Na delivery & flow rate

- Kidney failure
- NSAID
- Gordon's Syndrome (PHA II)



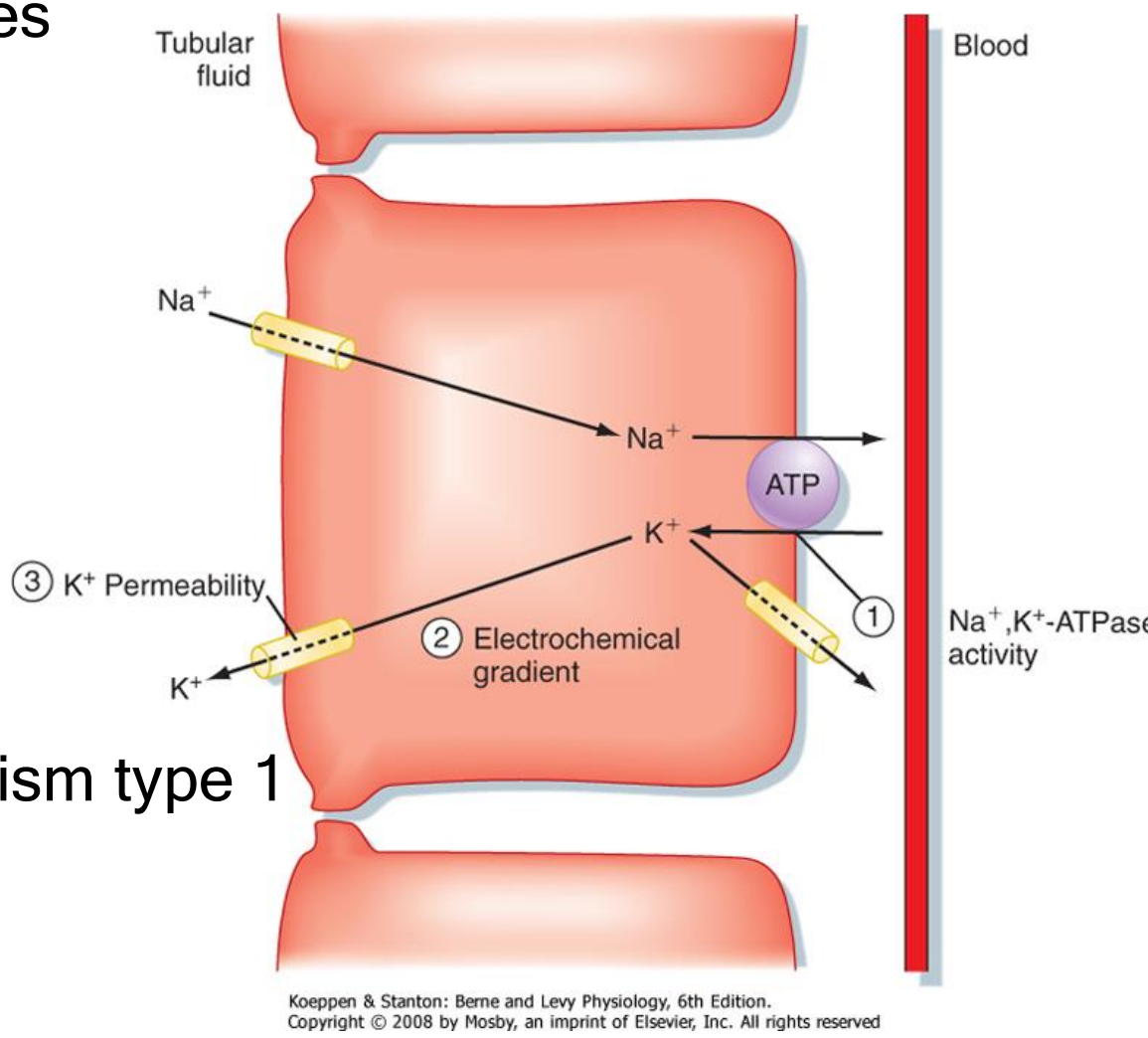
Can bactrim cause hyperK?

a. No
b. Yes, because it's high in K
c. Yes, because it decreases Na delivery
d. Yes, because it blocks eNAC
e. Yes, because it causes hypoaldosterism

Blocking the eNaC causes hyperkalemia

Drugs
- Triamterene
- Amiloride
- Trimethoprim

Diseases
- Type 1 RTA
- Pseudohypoaldosteronism type 1

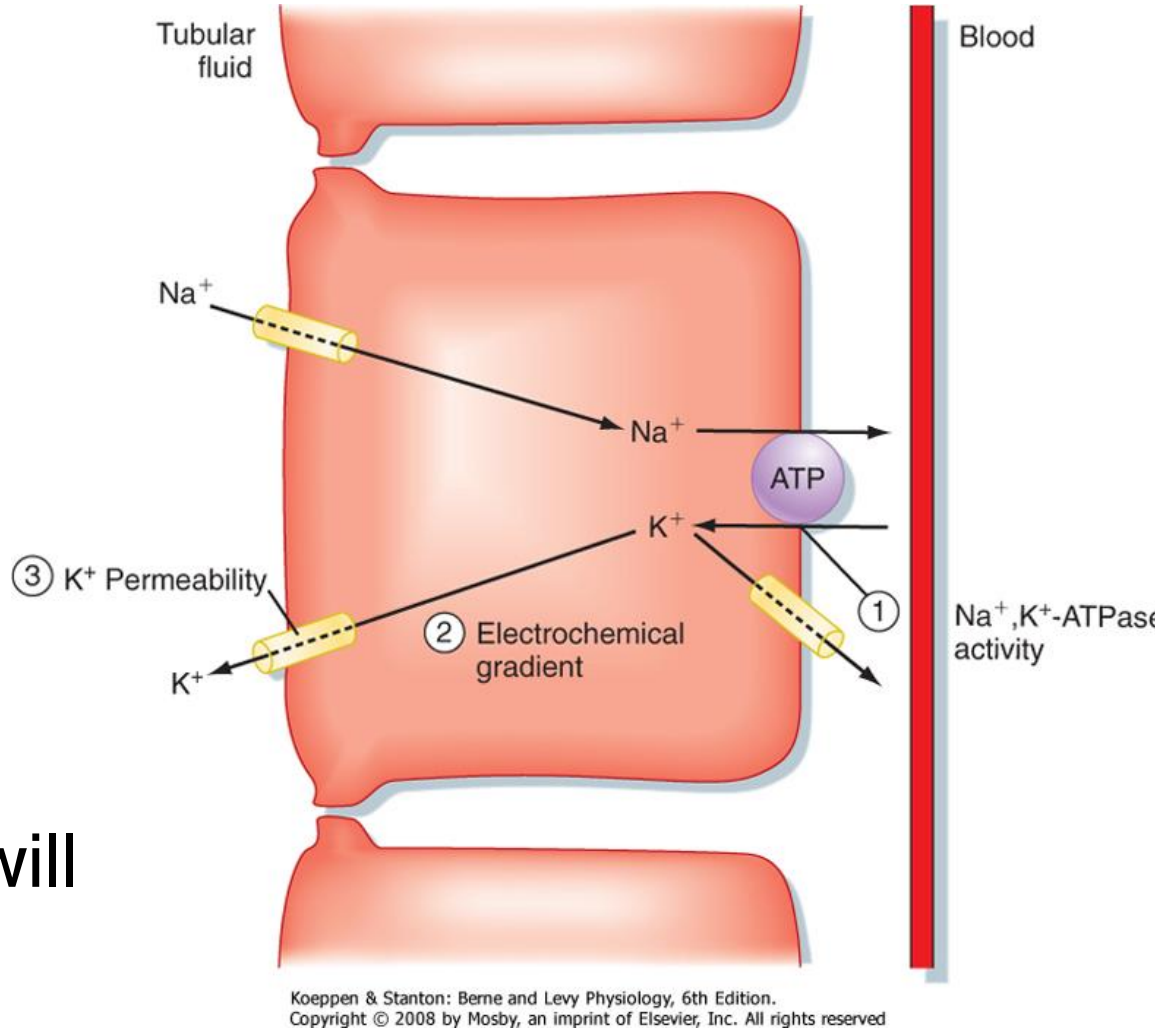


Can heparin cause hyperK?

a. No
b. Yes, because it's high in K
c. Yes, because it decreases Na delivery
d. Yes, because it blocks eNAC
e. Yes, because it causes hypoaldosterism

Aldosterone increases

- eNaC
- Na-K-ATPase
- K channels
  - ROMK
  - Maxi-K/BK



Loss of aldosterone will predictably increase potassium

HYPOALDOSTERONISM

- Congenital
- Adrenal insufficiency

(addison's disease)

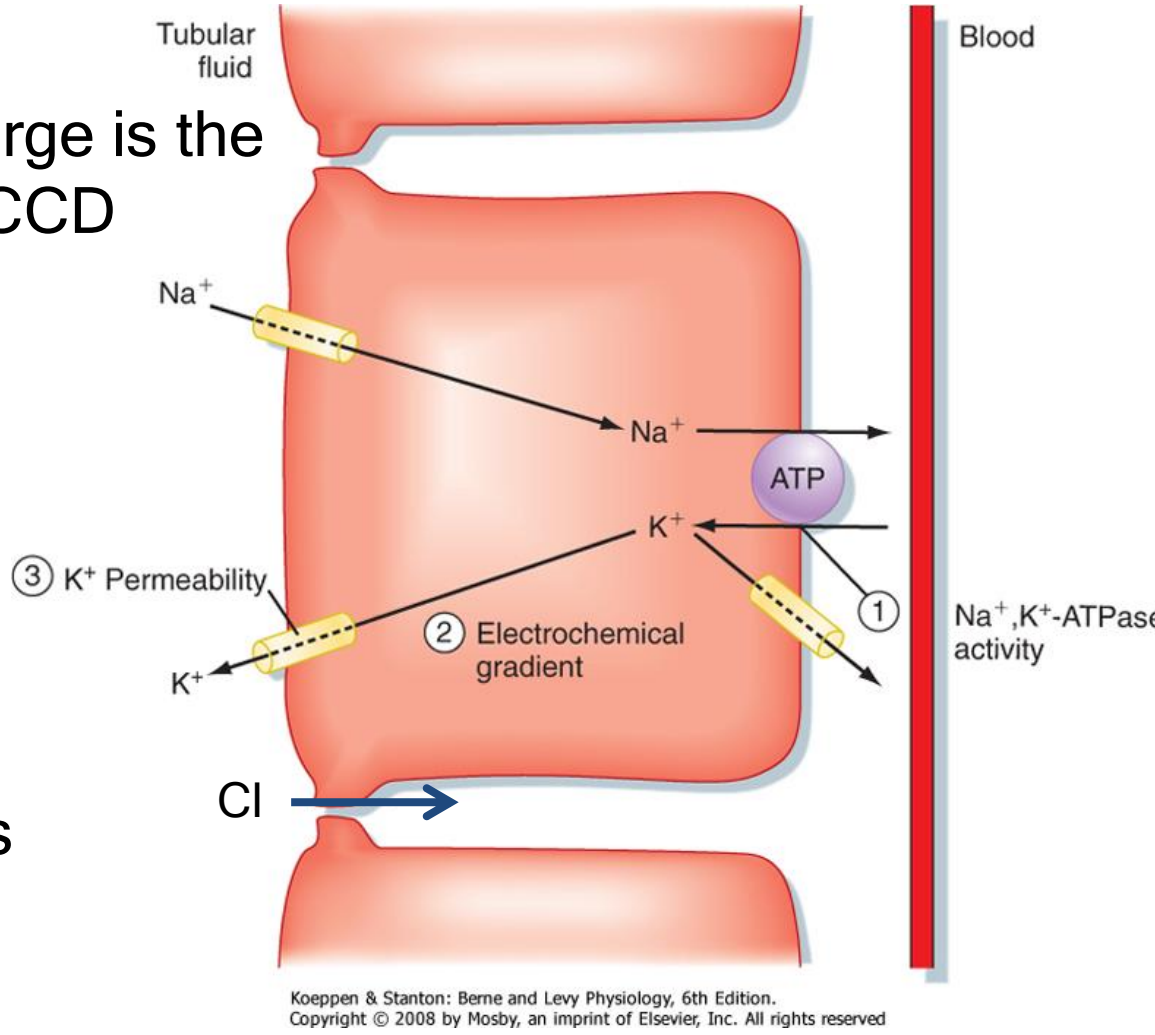
- Diabetes
  - Hyporenin-hypoaldosterone
- Drugs:
  - ACEi/ARB/Renin inhibitors
  - Heparin
  - ketoconazole
- Competitive inhibition
  - spironolactone

the tubule's negative charge is the principle determinant of CCD potassium secretion

disrupted by chloride reabsorption

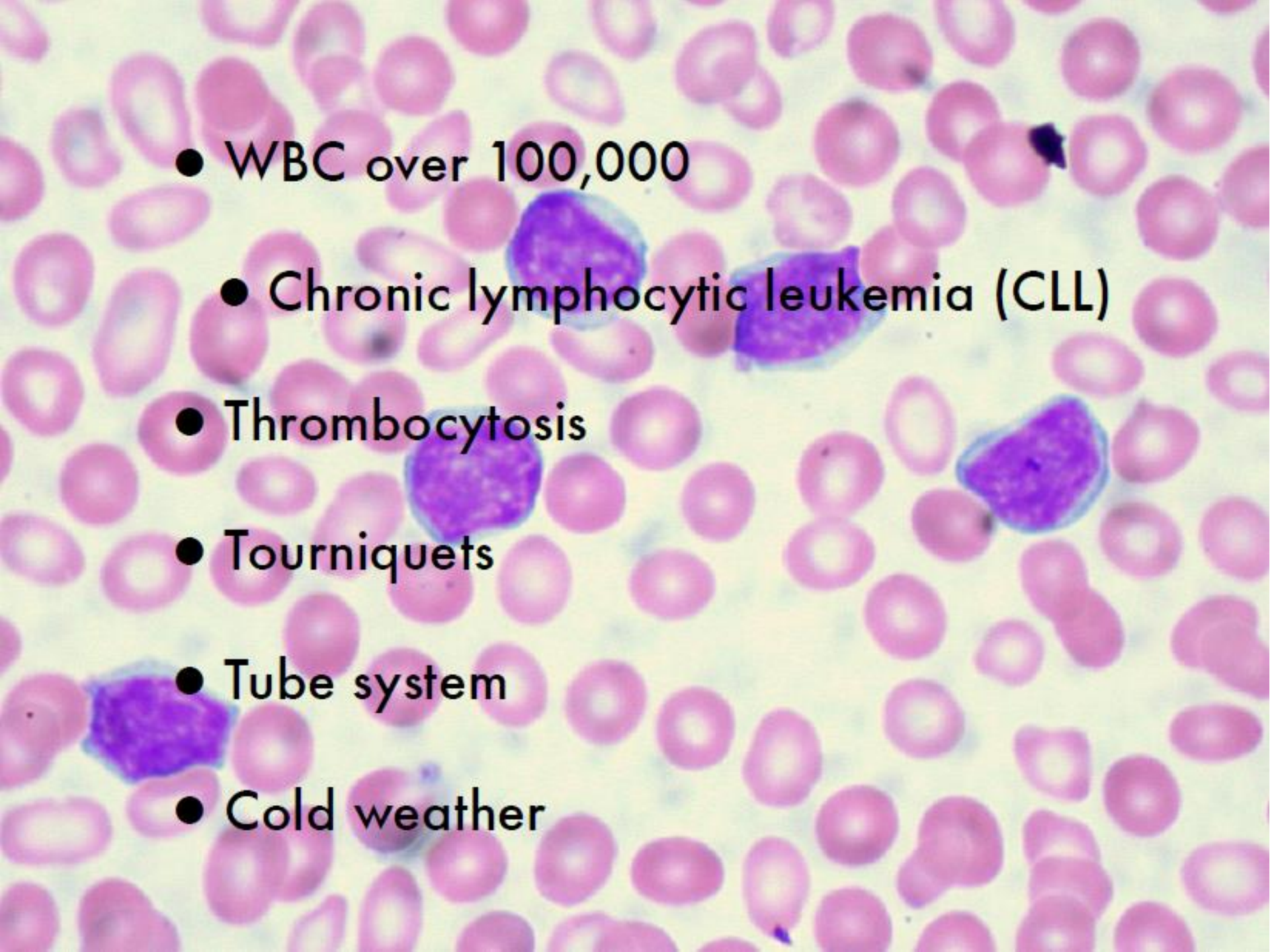
increased chloride reabsorption antagonizes potassium secretion

- Tacrolimus
- Cyclosporine



35 yr w/ CLL (WBC 150K) w/ K = 6.5.

You recheck K = 3.5. What's going on?



- WBC over 100,000
  - Chronic lymphocytic leukemia (CLL)
- Thrombocytosis
- Tourniquets
- Tube system
- Cold weather

What's the main concern w/ hyperK?

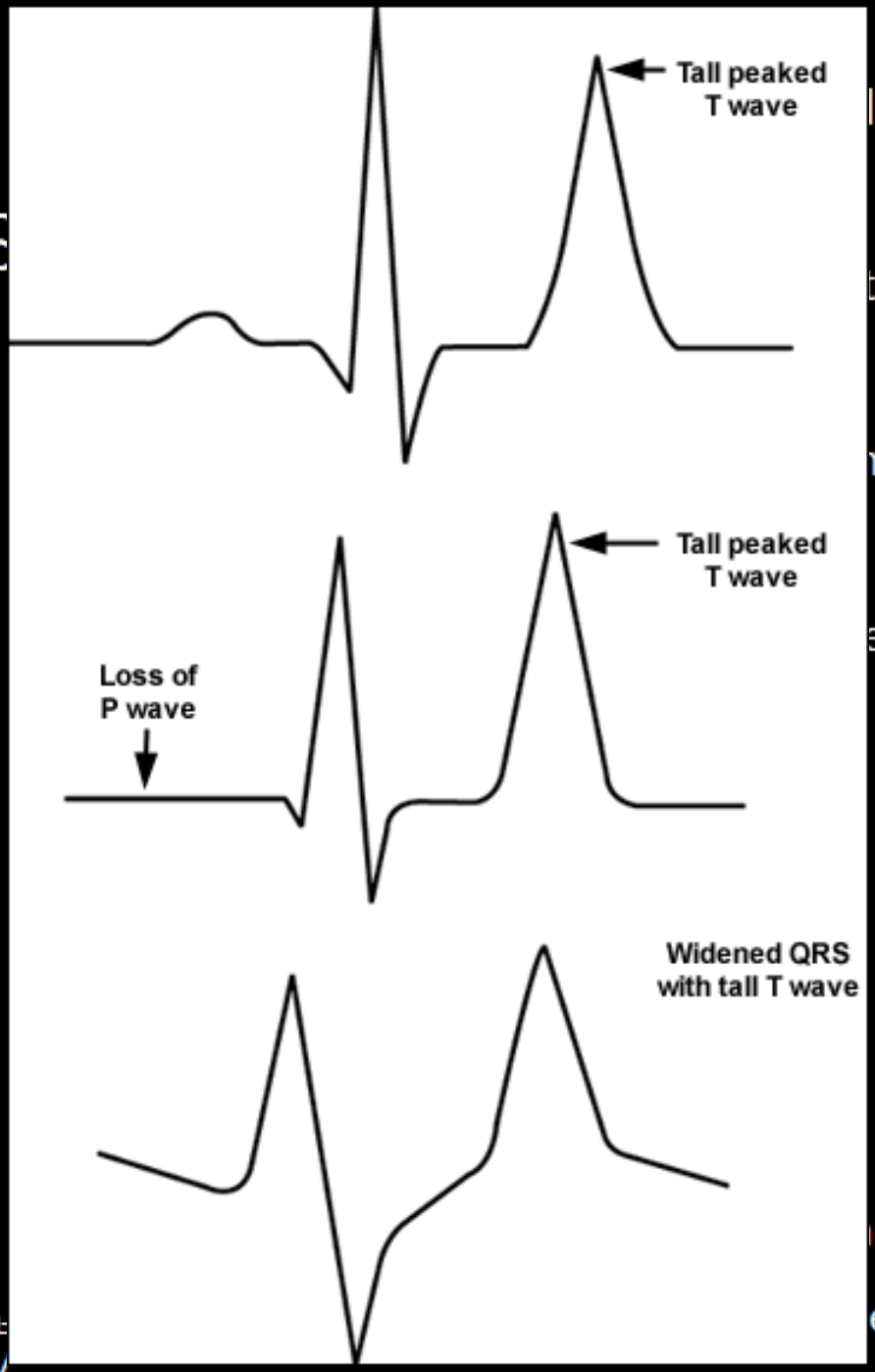
a. Irritability
b. Muscle weakness
c. EKG changes
d. Arrythmia

CONSEQUENCES OF HYPERKALEMIA

- muscle weakness/paralysis
- ECG changes and arrhythmia
  - Increased extracellular potassium reduces myocardial excitability, with depression of both pacemaking and conducting tissues.
  - Increasing potassium leads to suppression of the SA node and conduction by the AV node and His-Purkinje system.

http://lifeinthefastlane.com/ecg-library/basics/hyperkalaemia/

ECG CHANGES



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es and bradycardia

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http://lifeinthefastlane.com/ecg-library/basics/hyperkalaemia/

TREATMENT

- Goal of therapy is to prevent arrhythmia
- Calcium stabilizes cardiac membranes

40 yr w/ HFrEF, normal Cr, no weakness/EKG changes, K 7

Is this an emergency?

a. Yes
b. No

40 yr w/ HFrEF, normal Cr, no weakness/EKG changes, K 7

What's the next step?

a. Repeat K
b. Give Ca
c. Give albuterol/insulin
d. Give Lasix/cation binders

Hyperkalemic emergency

1. Ca gluconate 1g IV X 1
2. Insulin (10 units regular insulin + 50 mL of 50% dextrose) → closely monitor glucose levels Q1hr x 6
3. Albuterol 10-20 mg by nebulization over 10 minutes
4. Remove K (Lasix/binder/dialysis)

40 yr w/ HFrEF, normal Cr, weakness/EKG changes present, K 5

Is this an emergency?

a. Yes
b. No

40 yr w/ HFrEF, AKI, ongoing GI bleed, no weakness/EKG changes present, K 6

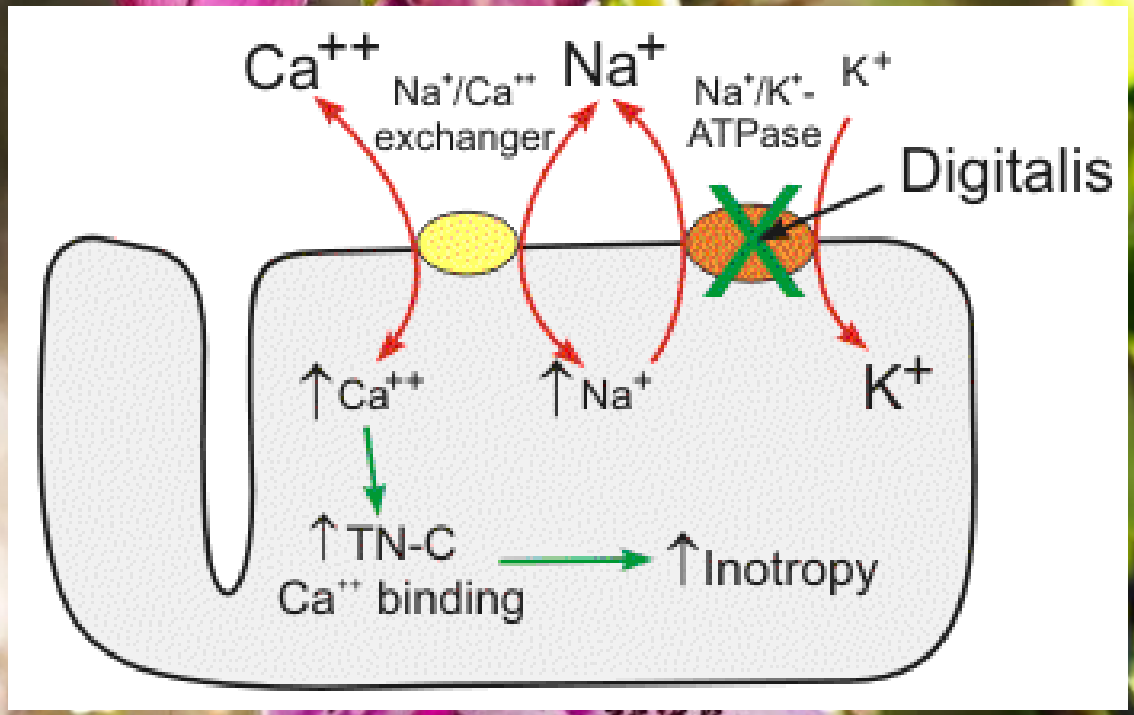
Is this an emergency?

a. Yes
b. No

Hyperkalemic emergency

a. Muscle weakness/EKG changes
b. K > 6.5
c. K > 5.5 + AKI/CKD4/ESRD + K intake

- Digoxin antidote for dig toxicity (DigFAB)
- Albuterol
- Insulin



Foxglove

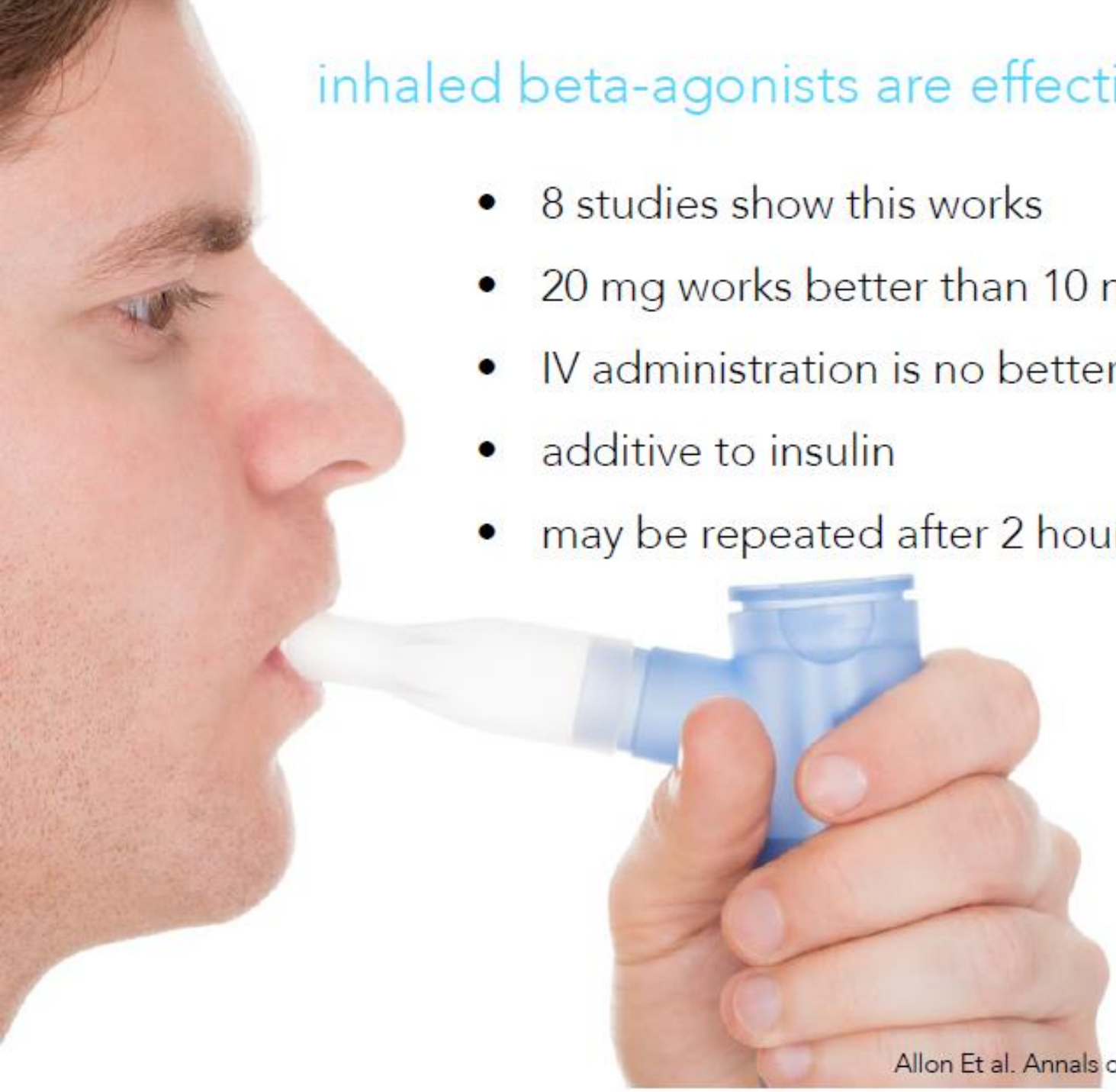
Digitalis

inhaled beta-agonists are effective

Allon Et al. Annals of Int Med; 1989: 110, 426-429

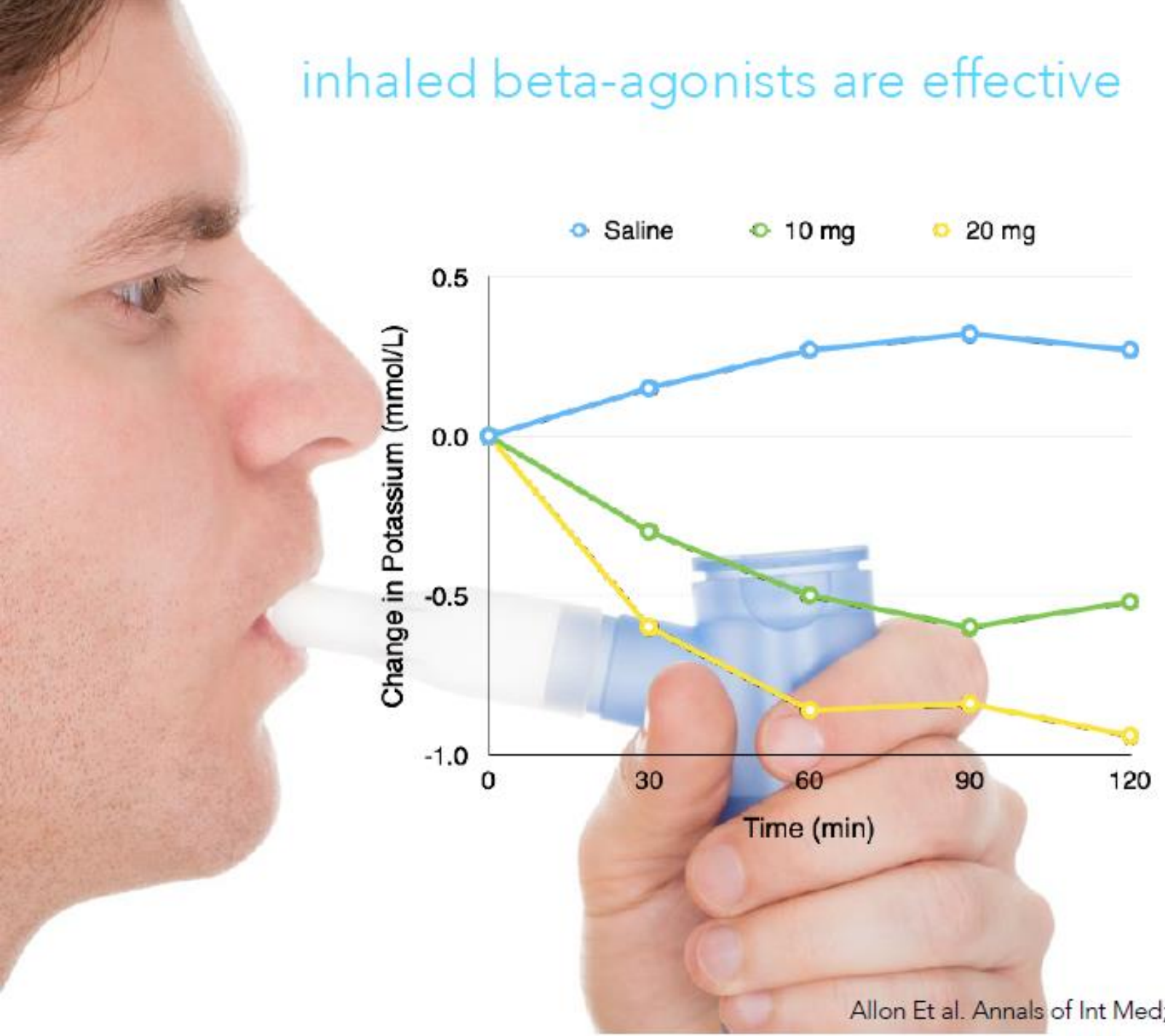
inhaled beta-agonists are effective

- 8 studies show this works
- 20 mg works better than 10 mg
- IV administration is no better than nebulized
- additive to insulin
- may be repeated after 2 hours



Allon Et al. Annals of Int Med; 1989: 110, 426-429

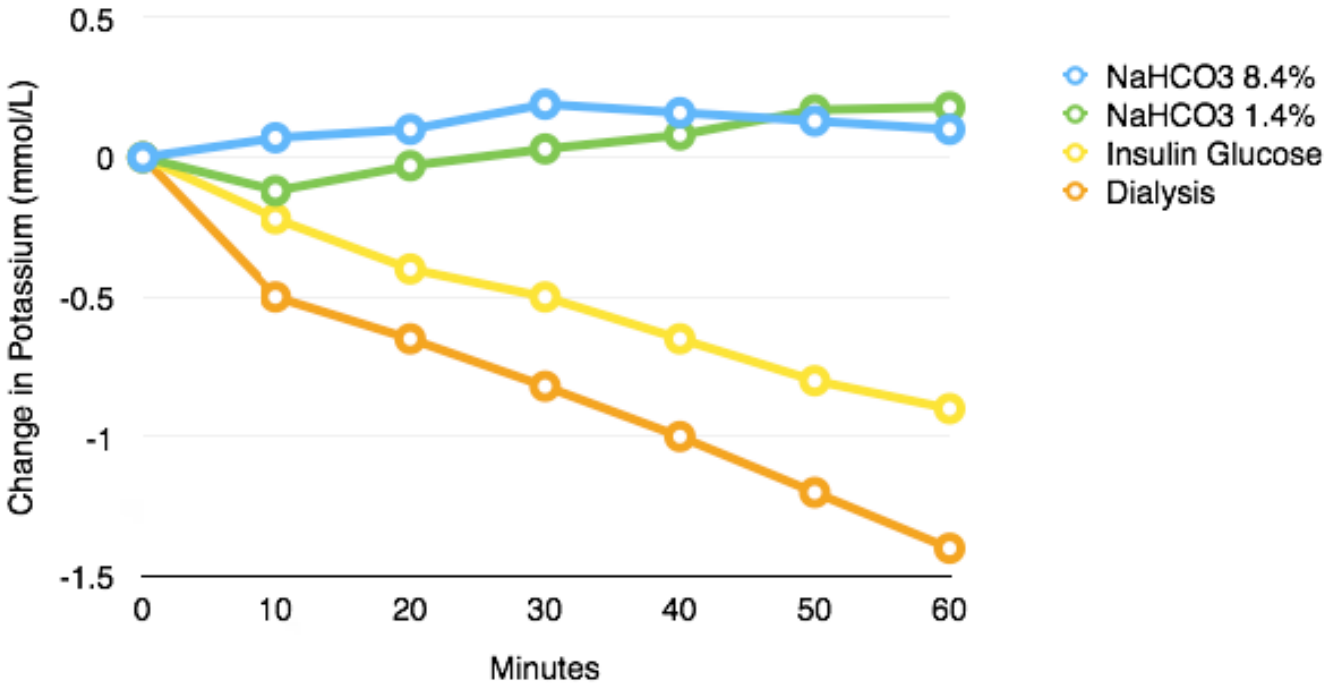
inhaled beta-agonists are effective

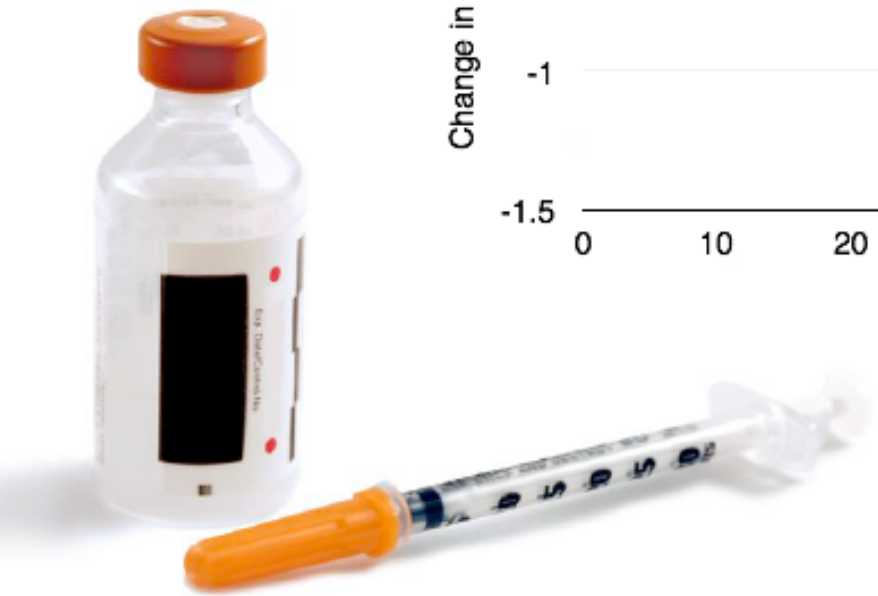


Allon Et al. Annals of Int Med; 1989: 110, 426-429

as is intravenous insulin

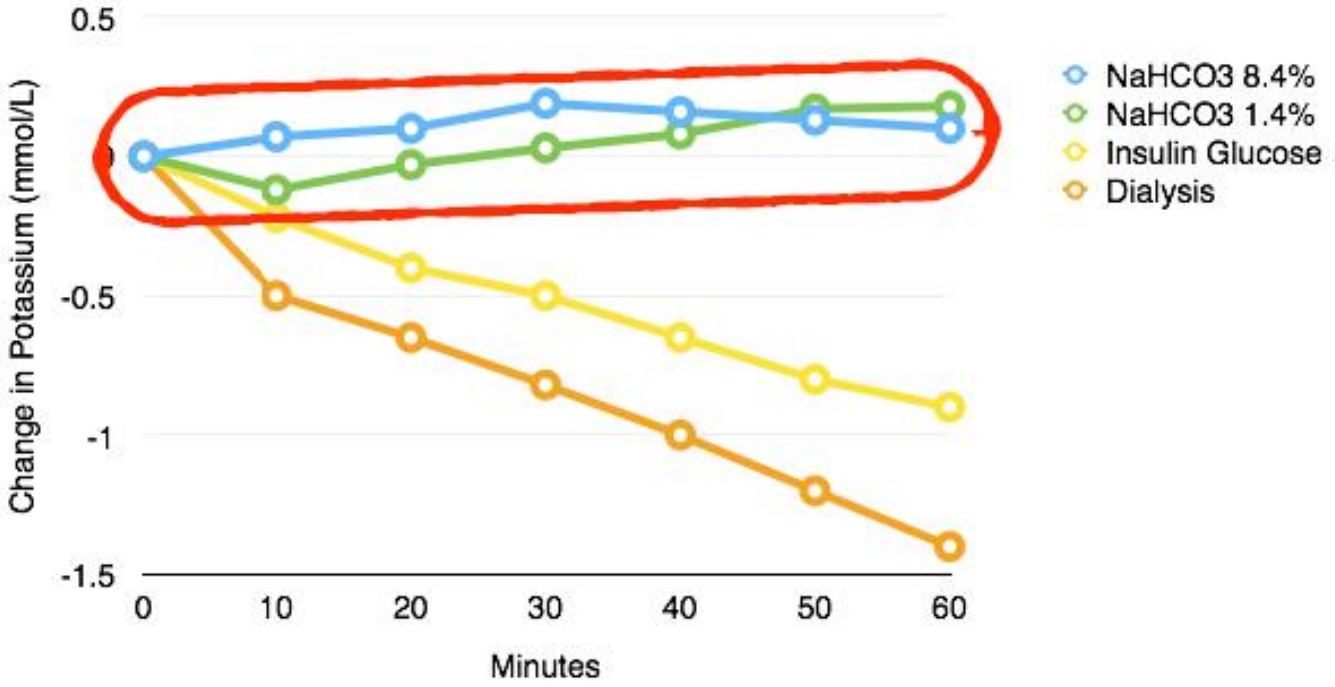
- give regular insulin intravenously rather than subcutaneously





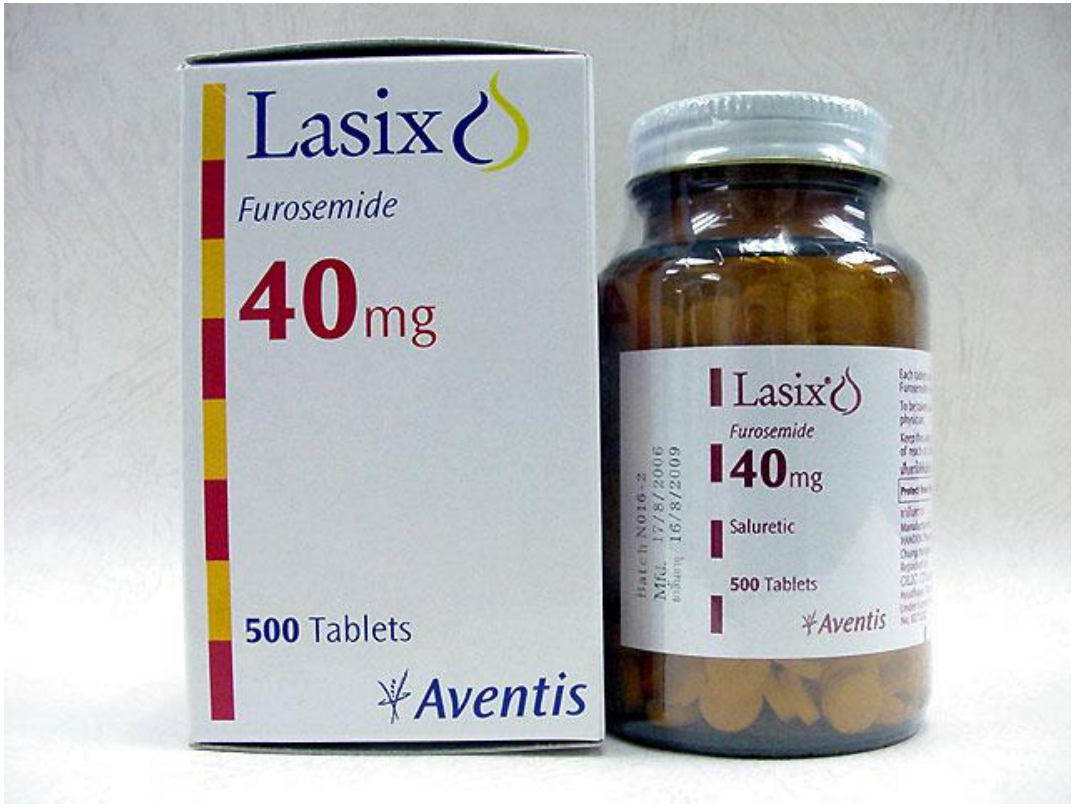
Blumberg Et al. Amer J Med; 1988: 85, 507-512.

but sodium bicarbonate is not



Blumberg Et al. Amer J Med; 1988: 85, 507-512.

- diuretics
- fludrocortisone
- polystyrene resins
- dialysis



Diuretics

Increased sodium delivery to the CCD

Increased sodium reabsorption through the eNaC

Enhanced negative charge in the tubule

KAYEXALATE

Studies published were done in a world without dialysis. Patients were maintained for days with repetitive dosing. Not representative of single dose use we see now.

WARNINGS

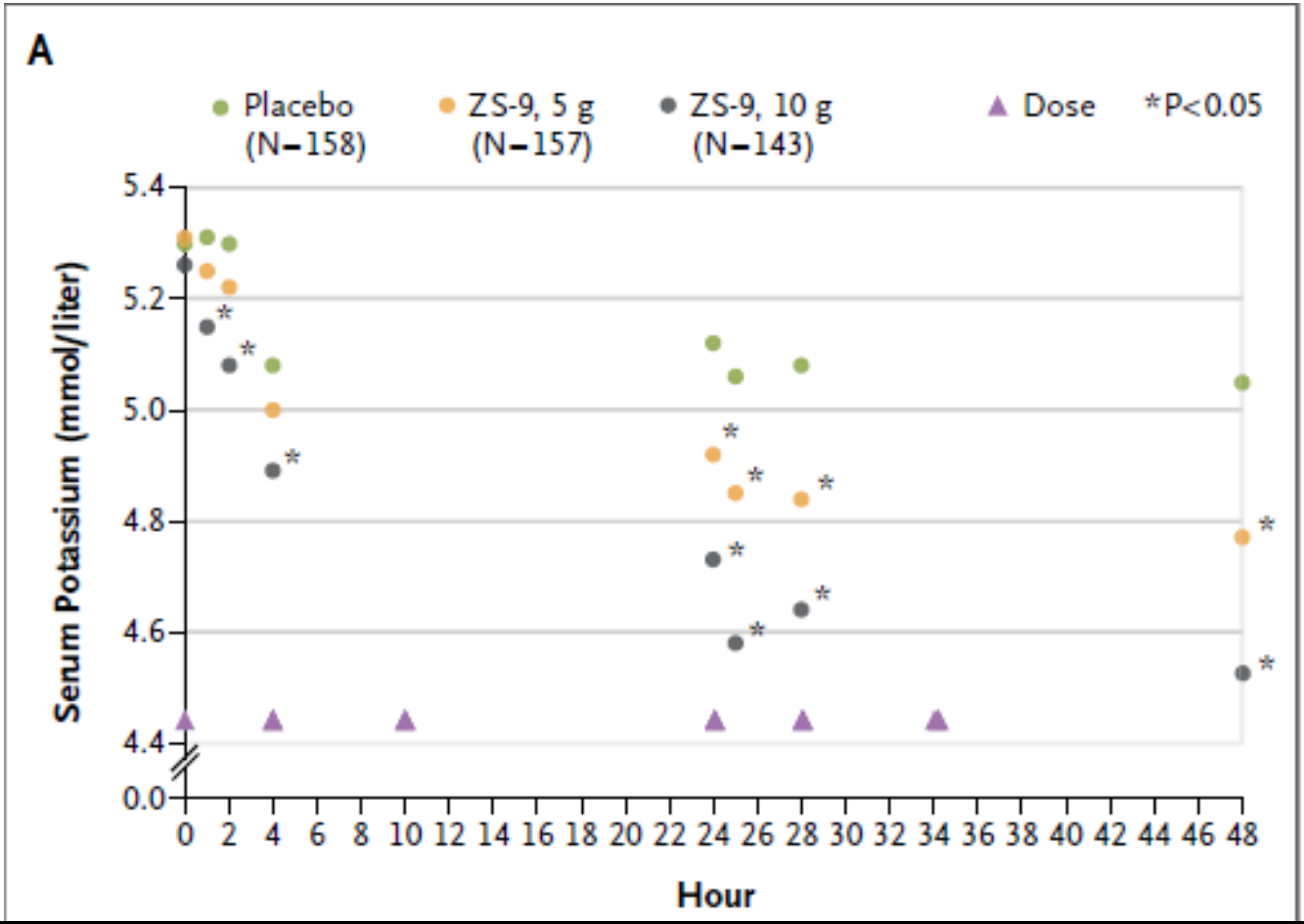
Colonic Necrosis

- Cases of intestinal necrosis, which may be fatal, and other serious gastrointestinal adverse events (bleeding, ischemic colitis, perforation) have been reported in association with Kayexalate use.
- Do not use in patients who do not have normal bowel function. This includes postoperative patients who have not had a bowel movement post surgery.
- Do not use in patients who are at risk for developing constipation or impaction (including those with history of impaction, chronic constipation, inflammatory bowel disease, ischemic colitis, vascular intestinal atherosclerosis, previous bowel resection, or bowel obstruction)
- Discontinue use in patients who develop constipation. Do not administer repeated doses in patients who have not passed a bowel movement.

SPS should **not** be given to the following patients because they may be at high risk for intestinal necrosis

- Postoperative patients
- Ileus or who are receiving opiates
- Large or small bowel obstruction
- Underlying bowel disease, eg, ulcerative colitis or Clostridium difficile colitis

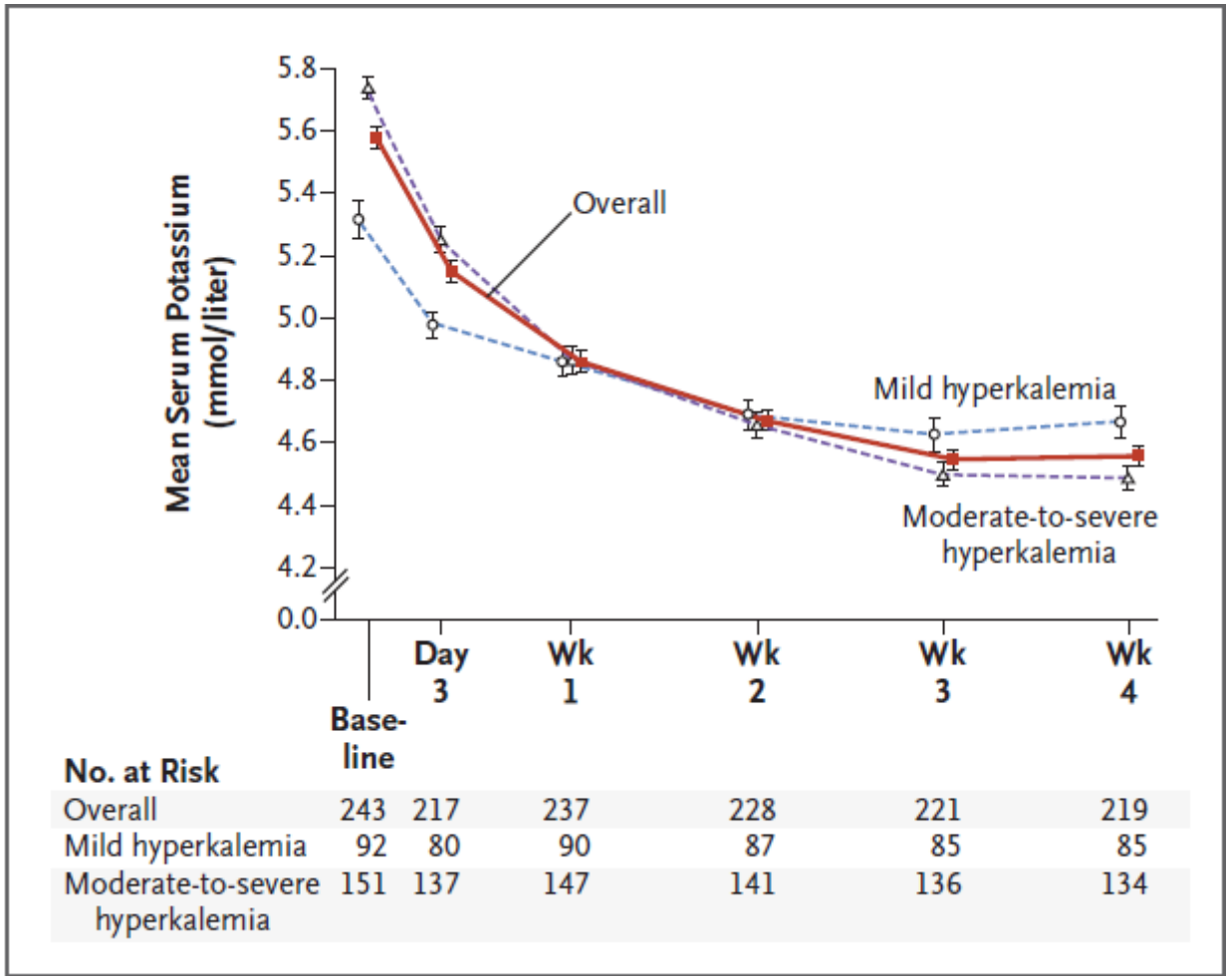
zirconium silicate crystal



- steepest decline in serum potassium with ZS-9 occurred during the first four hours of therapy.

Packham DK et al. Sodium zirconium cyclosilicate in hyperkalemia. N Engl J Med. DOI: 10.1056

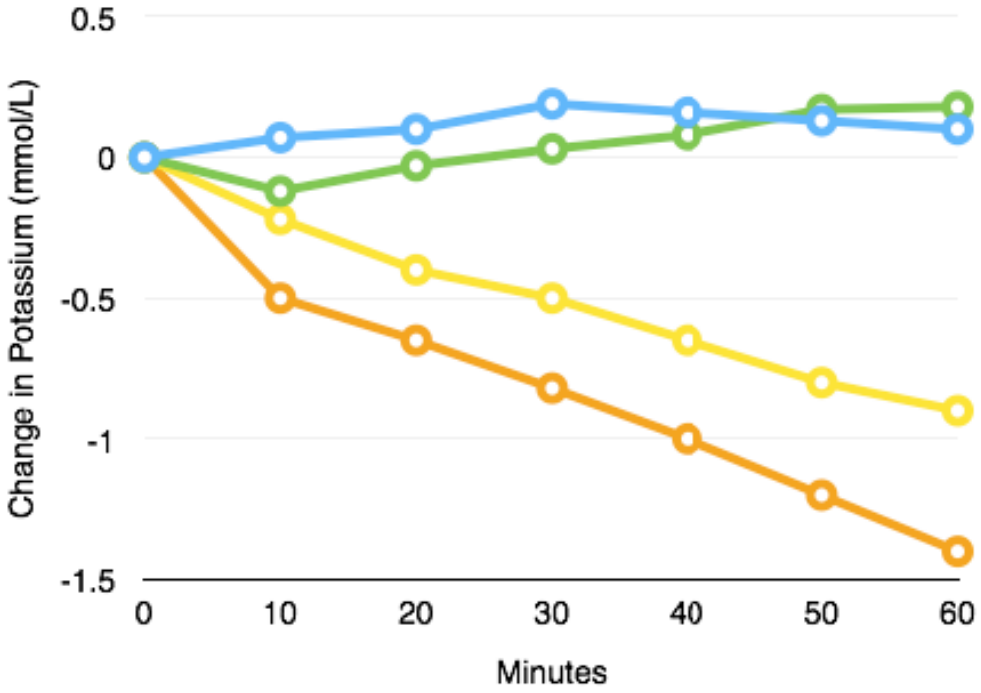
patiromer

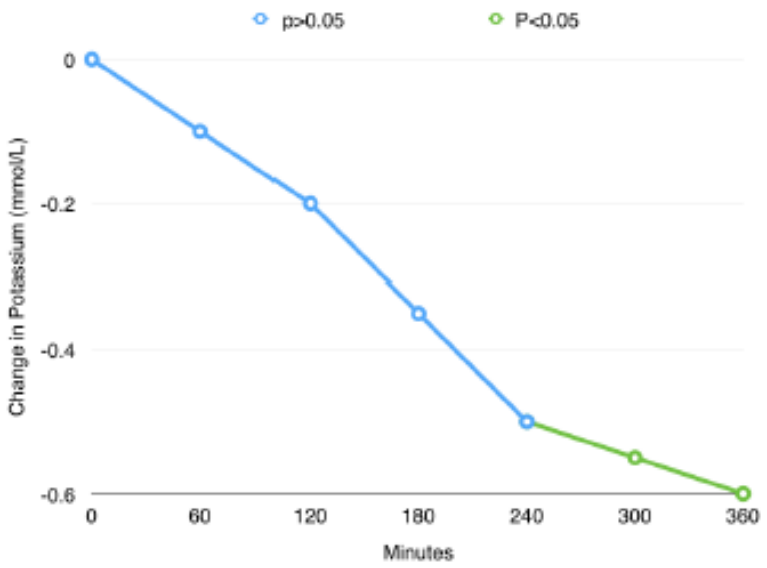


No. at Risk	Base-line	Day 3	Wk 1	Wk 2	Wk 3	Wk 4
Overall	243	217	237	228	221	219
Mild hyperkalemia	92	80	90	87	85	85
Moderate-to-severe hyperkalemia	151	137	147	141	136	134

Weir MR et al. Patiromer in patients with kidney disease and hyperkalemia receiving RAAS inhibitors. N Engl J Med. DOI: 10.1056/NEJMoa1410853

Of course, dialysis always works!





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40 yr w/ HFrEF, normal Cr, no weakness/EKG changes, K 5.7

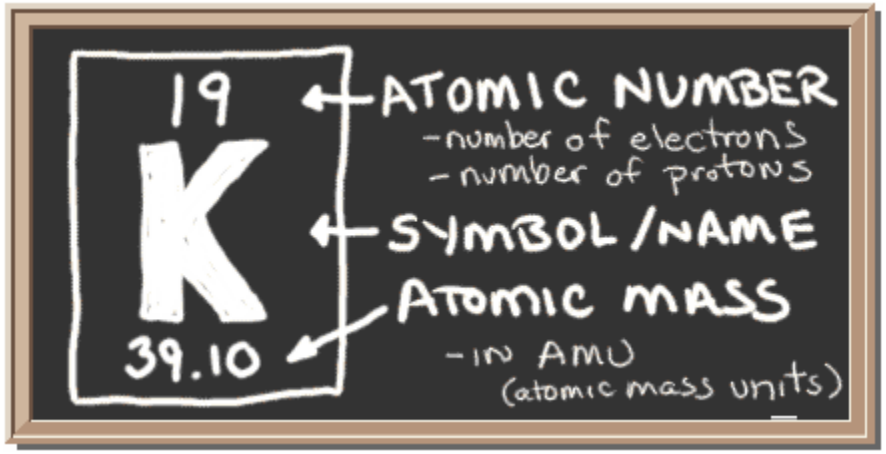
Is this an emergency?

a. Yes
b. No

40 yr w/ HFrEF, normal Cr, no weakness/EKG changes, K 5.7

What's the next step?

a. Give Ca
b. Give albuterol/insulin
c. Give cation binders
d. low-potassium diet, loop or thiazide diuretics, or a reduction or cessation of ACEI/aldactone


19
K
39.10
ATOMIC NUMBER
-number of electrons
-number of protons
SYMBOL/NAME
ATOMIC MASS
-IN AMU
(atomic mass units)

Questions?