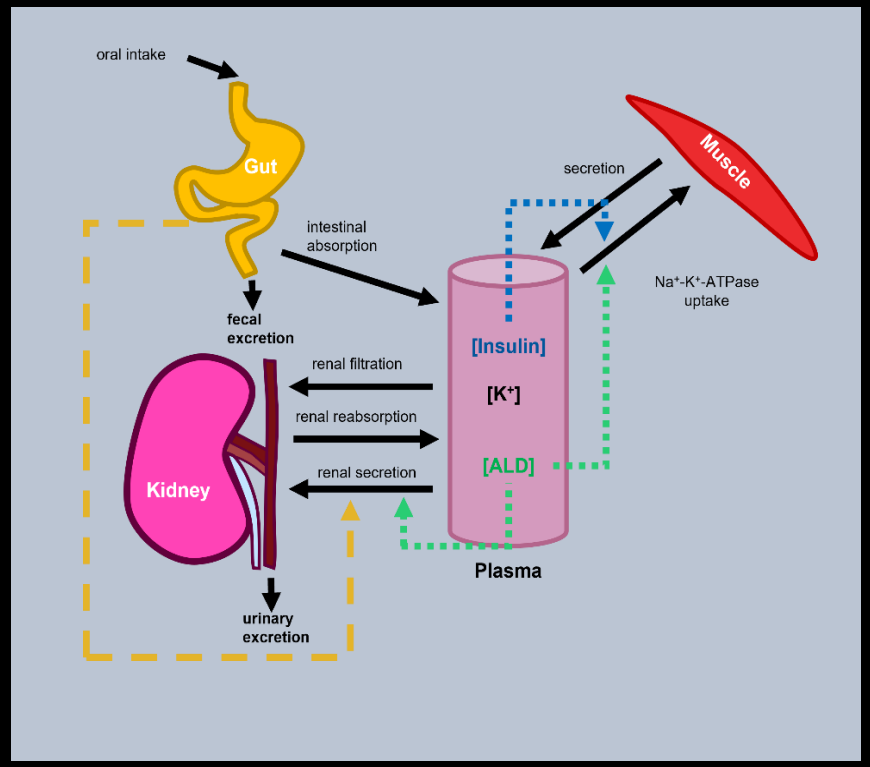
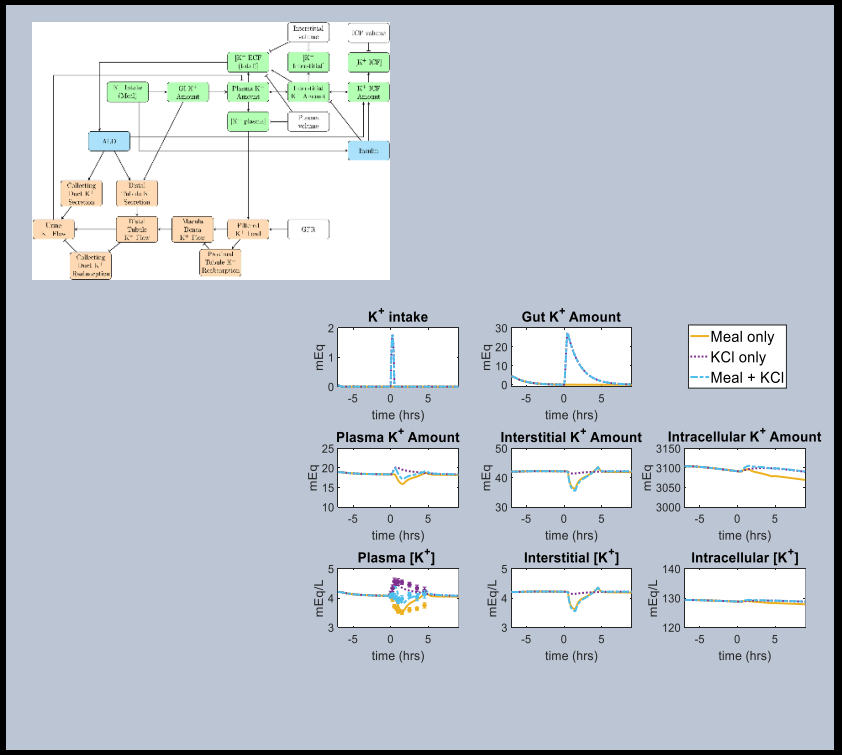
# Mathematical Modelling of $K^+$ Regulation

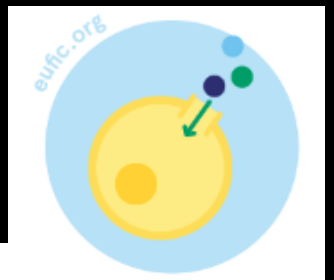
Betty Zhang and Lily Zhou

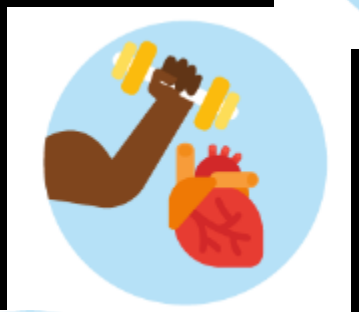


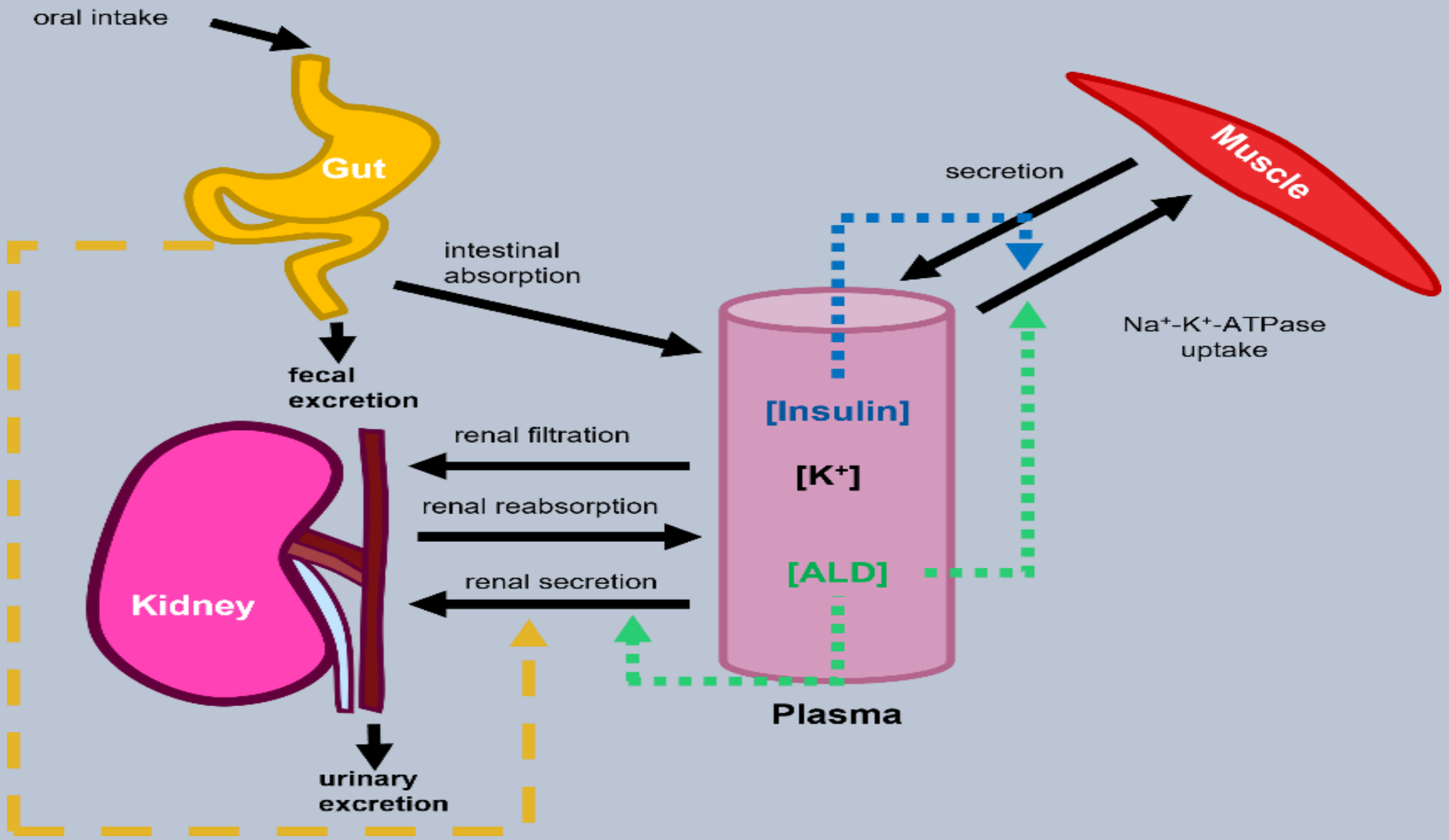
# Importance of Potassium Homeostasis

- Nerve impulse transmission
- Muscle contraction
- Fluid balance
- Blood pressure regulation

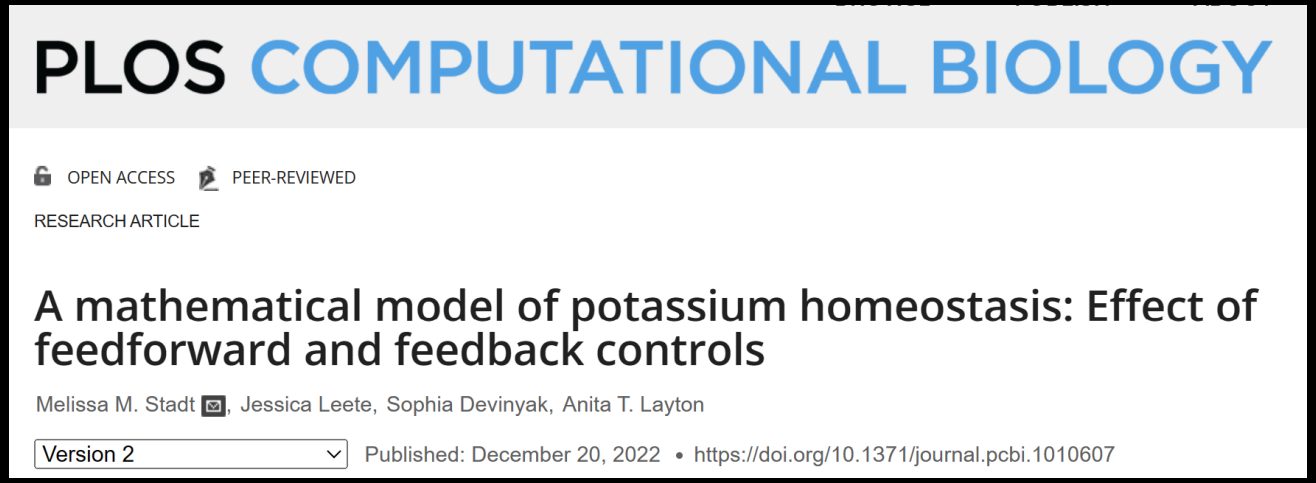


***Potassium homeostasis*** is the maintenance of a **stable plasma concentration**


oral intake
Gut
intestinal absorption
fecal excretion
secretion
Muscle
Na⁺-K⁺-ATPase uptake
[Insulin]
[K⁺]
[ALD]
Plasma
renal filtration
renal reabsorption
renal secretion
Kidney
urinary excretion

# The Original Mathematical Model



PLOS COMPUTATIONAL BIOLOGY

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

A mathematical model of potassium homeostasis: Effect of feedforward and feedback controls

Melissa M. Stadt, Jessica Leete, Sophia Devinyak, Anita T. Layton

Version 2 Published: December 20, 2022 • https://doi.org/10.1371/journal.pcbi.1010607

# Set Up

## Response to a Single Meal

Fast for 6 hours then give meal of one of the following types:

**Meal only**

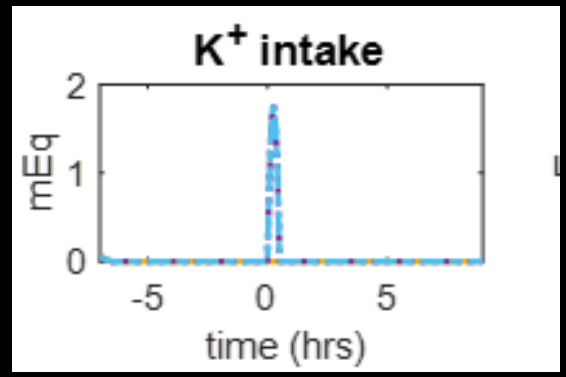
- No $K^+$ input
- Insulin effect

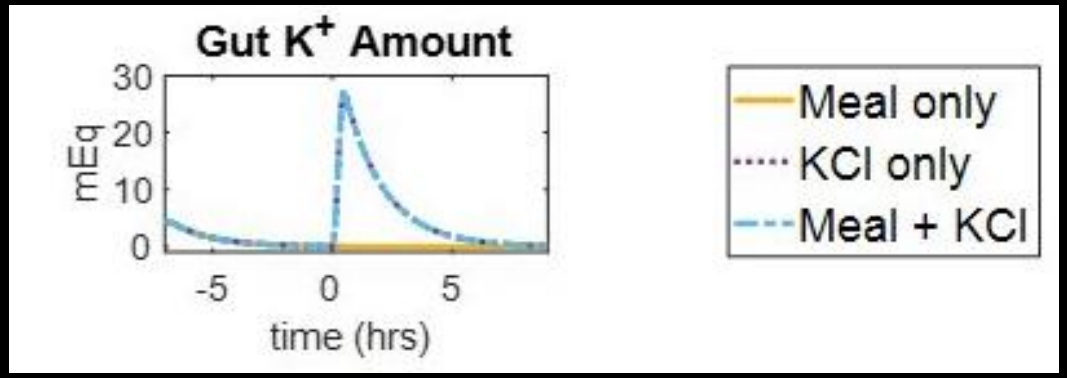
**KCl only**

- Only $K^+$ input
- No insulin effect

**Meal + KCl**

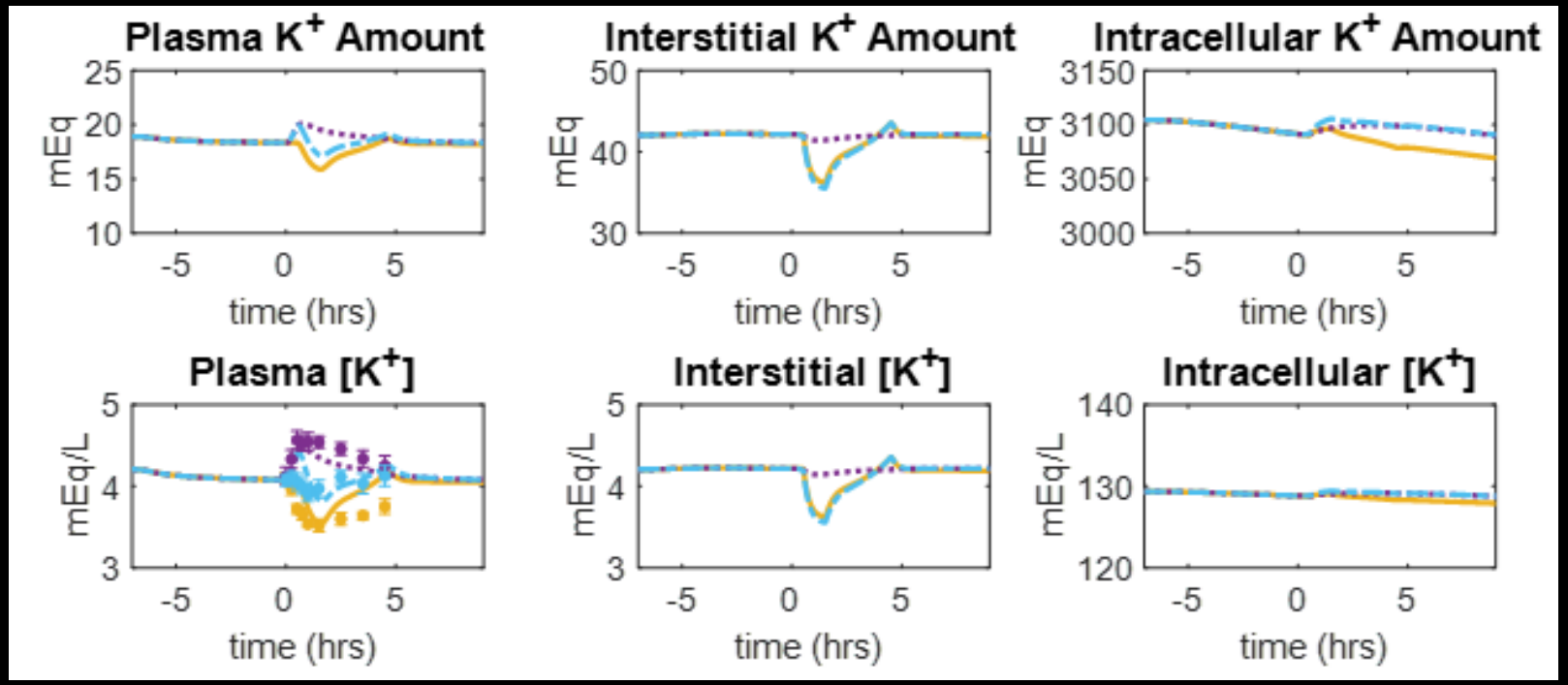
- Typical meal
- Includes both $K^+$ input and insulin effect




Model input for single meal

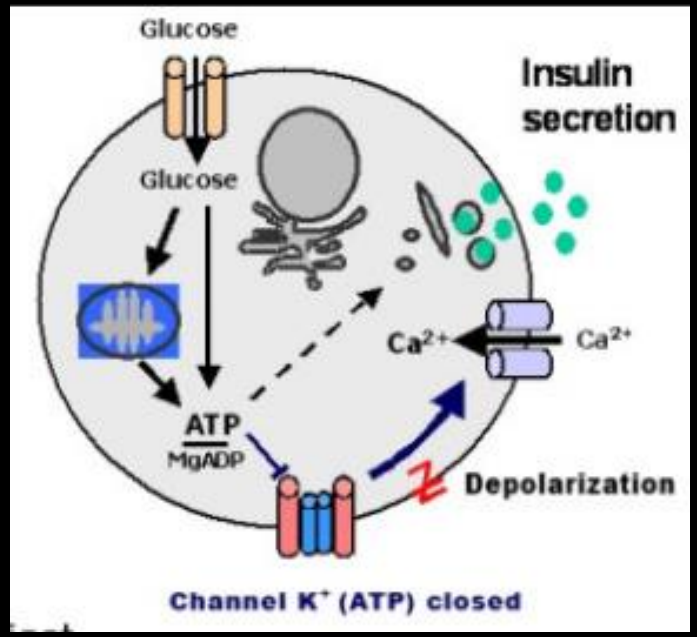
# Results


Meal only
KCl only
Meal + KCl
Plasma K+ Amount
Interstitial K+ Amount
Intracellular K+ Amount
Plasma [K+]
Interstitial [K+]
Intracellular [K+]
mEq
mEq/L
time (hrs)
25
20
15
10
50
40
30
3150
3100
3050
3000
5
4
3
140
130
120
-5
0
5

# Modification + Further Investigation: Effect of Insulin on Potassium Homeostasis

# Insulin, Diabetes and Potassium Homeostasis

- Facilitates uptake of potassium
- Regulation of potassium secretion
- Impact on electrolyte balance
- Hyperkalemia in diabetes patients
- Use ODE to explore clinical applications

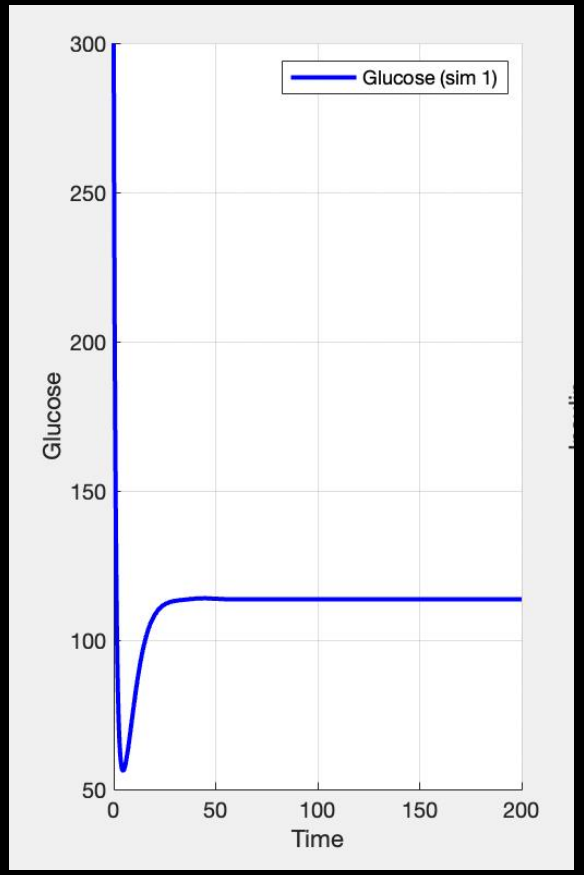


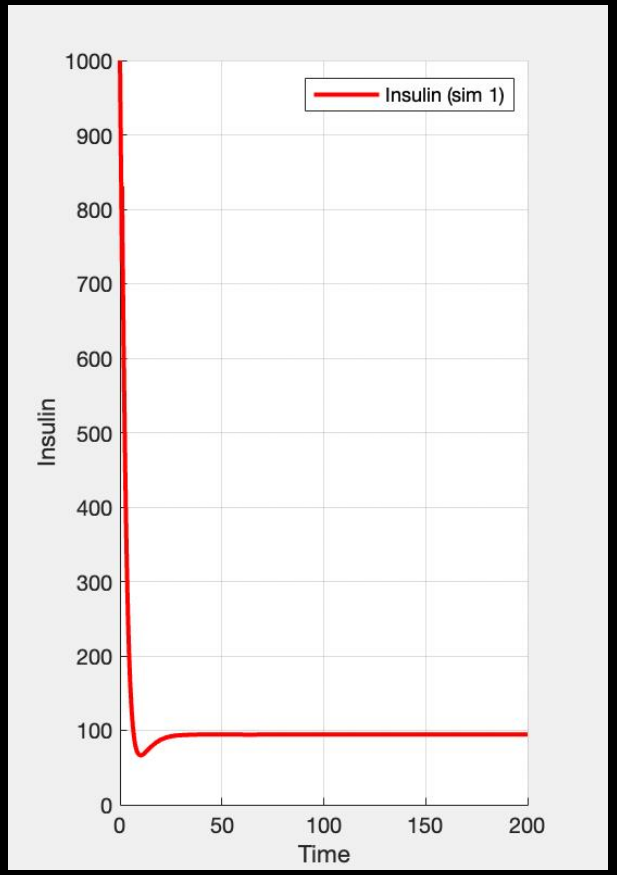
# Modification and Results

- The Equations we use:

  dG/dt=Gin_ss-aG-bGI

  dI/dt=Iin_ss+cG-dI/(e+I)



# Conclusion:

Further exploration

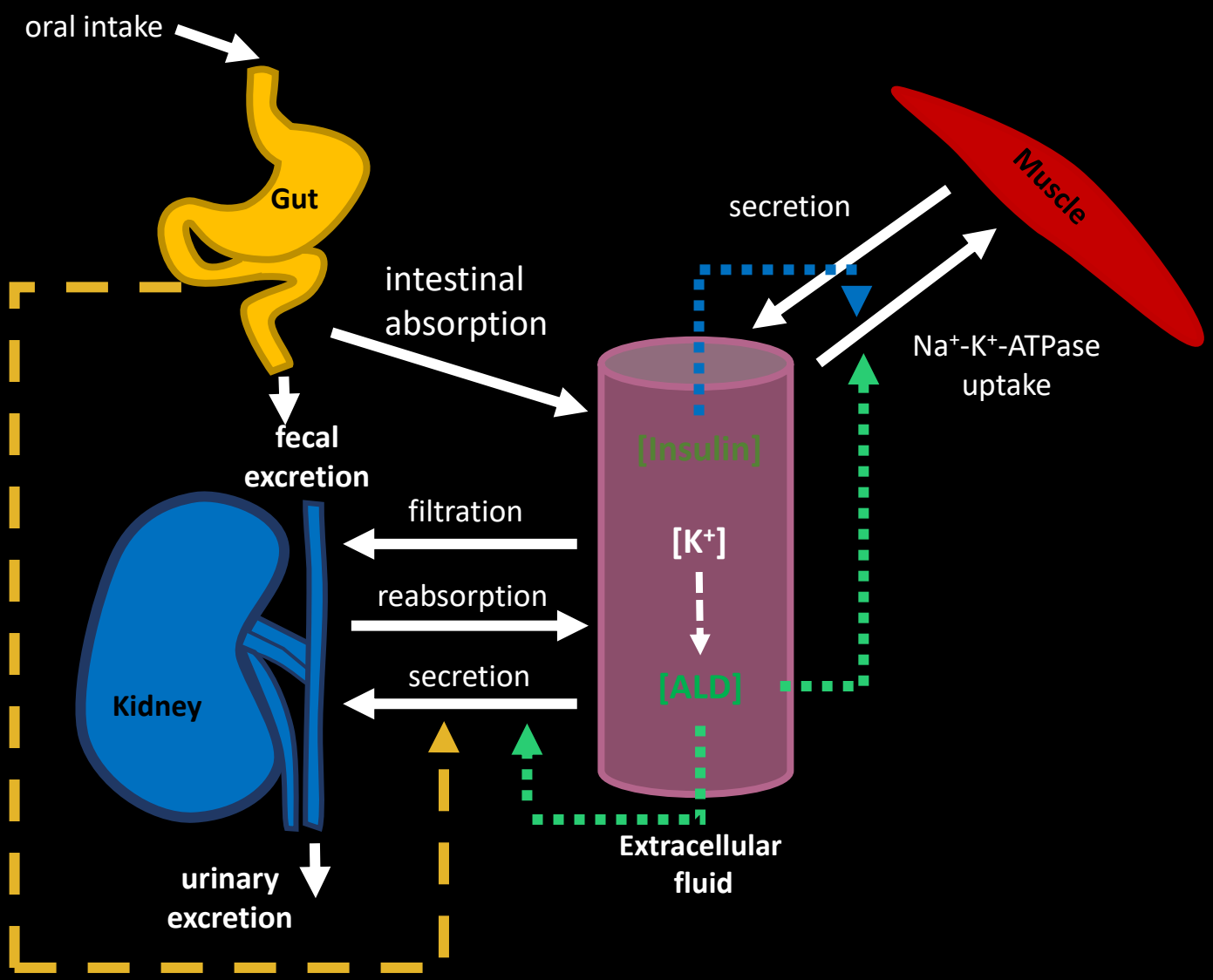
What we learned

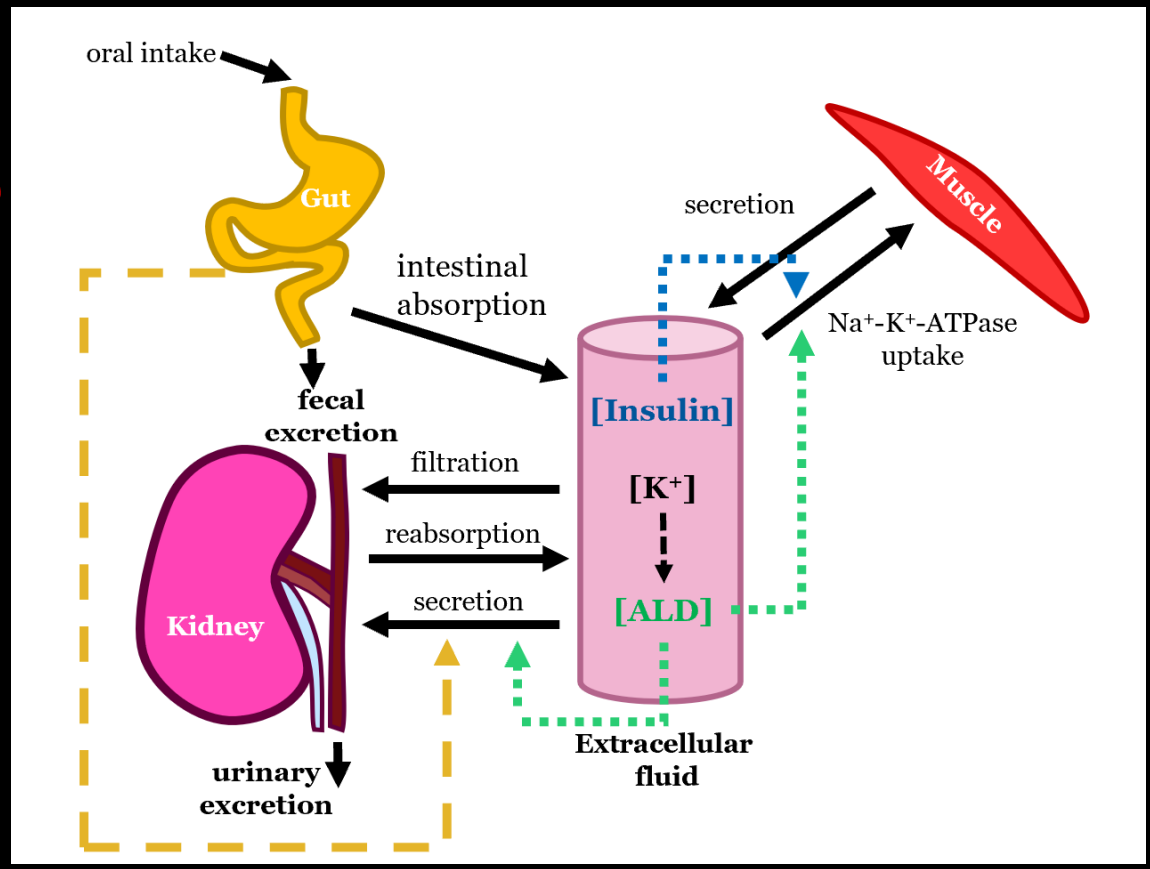
# References

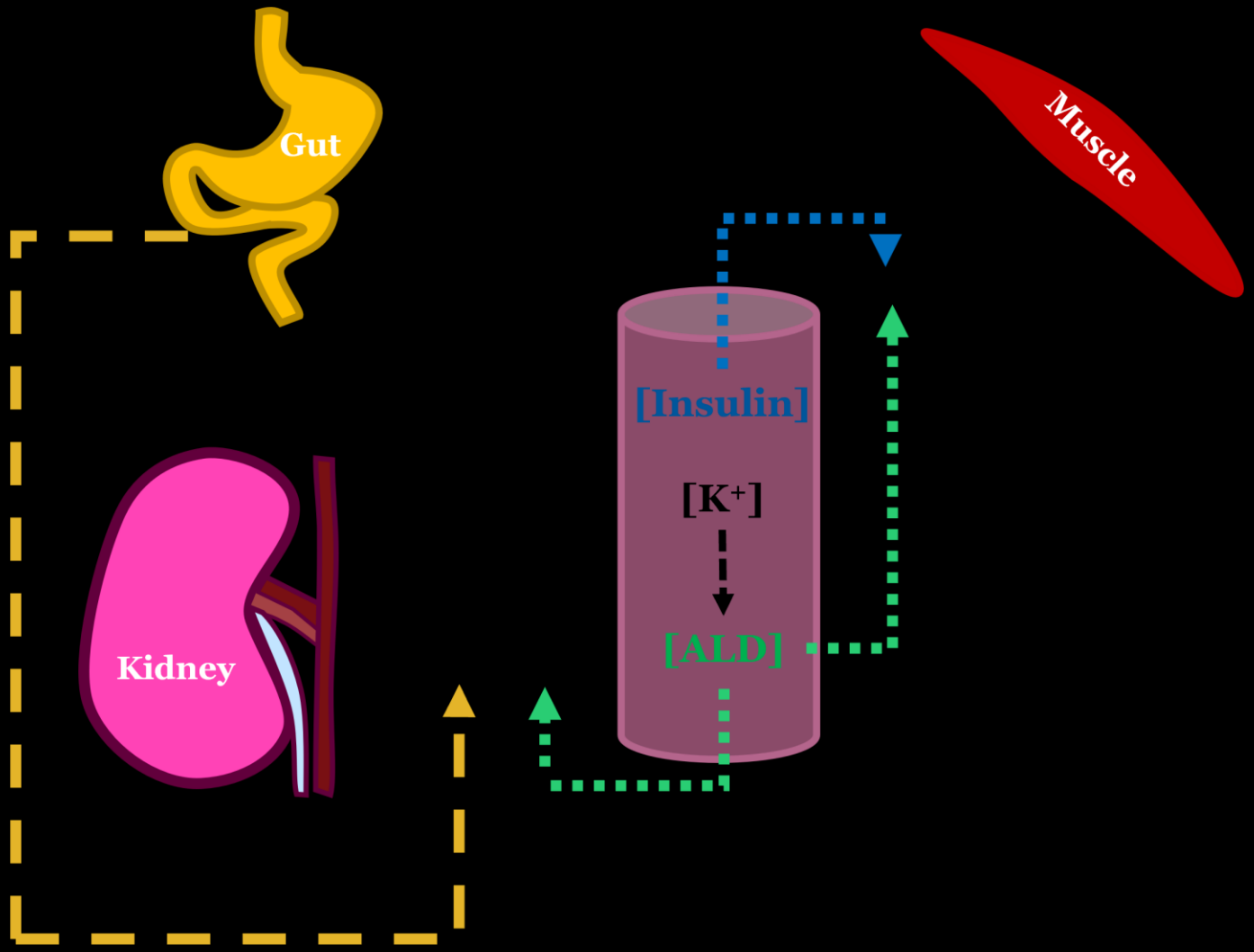

- Ma, Mingju, and Jun Li. 2022. “Dynamics of a Glucose–Insulin Model.” *Journal of Biological Dynamics* 16 (1): 733–45. https://doi.org/10.1080/17513758.2022.2146769.

- Preston, Richard A., David Afshartous, Rolando Rodco, Alberto B. Alonso, and Dyal Garg. 2015. “Evidence for a Gastrointestinal–Renal Kaliuretic Signaling Axis in Humans.” *Kidney International* 88 (6): 1383–91. https://doi.org/10.1038/ki.2015.243.

- Stadt, Melissa M., Jessica Leete, Sophia Devinyak, and Anita T. Layton. 2022. “A Mathematical Model of Potassium Homeostasis: Effect of Feedforward and Feedback Controls.” *PLOS Computational Biology* 18 (12): e1010607. https://doi.org/10.1371/journal.pcbi.1010607.


oral intake
Gut
intestinal absorption
fecal excretion
Muscle
secretion
Na⁺-K⁺-ATPase uptake
[Insulin]
[K⁺]
[ALD]
filtration
reabsorption
secretion
Kidney
urinary excretion
Extracellular fluid


oral intake
Gut
intestinal absorption
fecal excretion
Muscle
secretion
Na⁺-K⁺-ATPase uptake
[Insulin]
[K⁺]
[ALD]
filtration
reabsorption
secretion
Kidney
urinary excretion
Extracellular fluid


Gut
Muscle
[Insulin]
[K+]
[ALD]
Kidney