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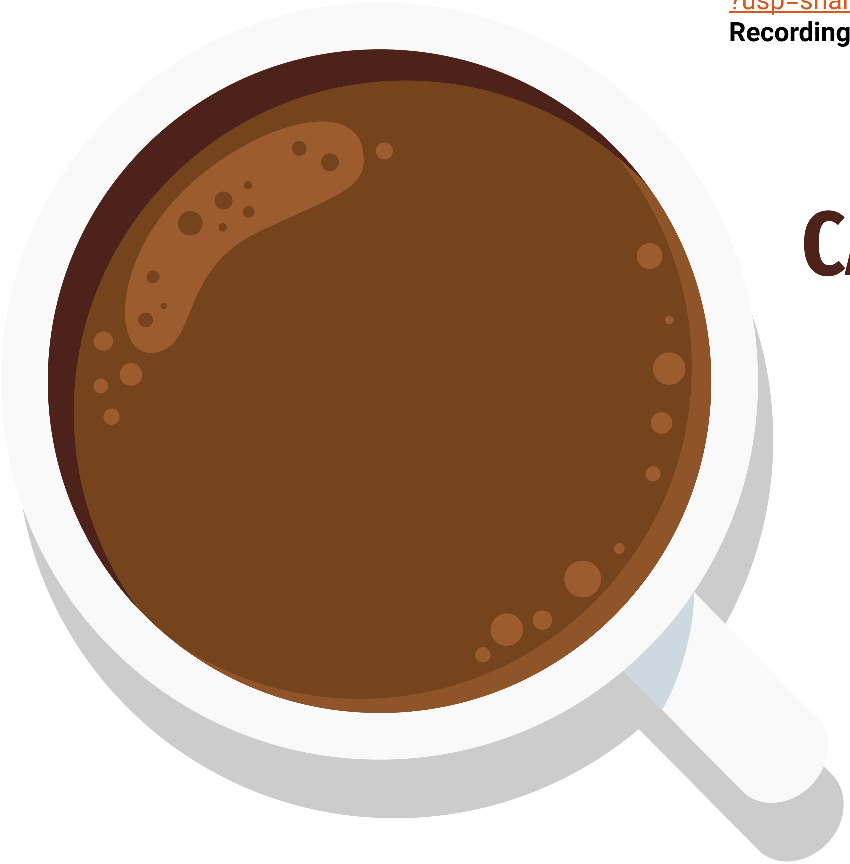
Recording can be found here



CAFFEINE CONTROL ON BRAIN STIMULATION

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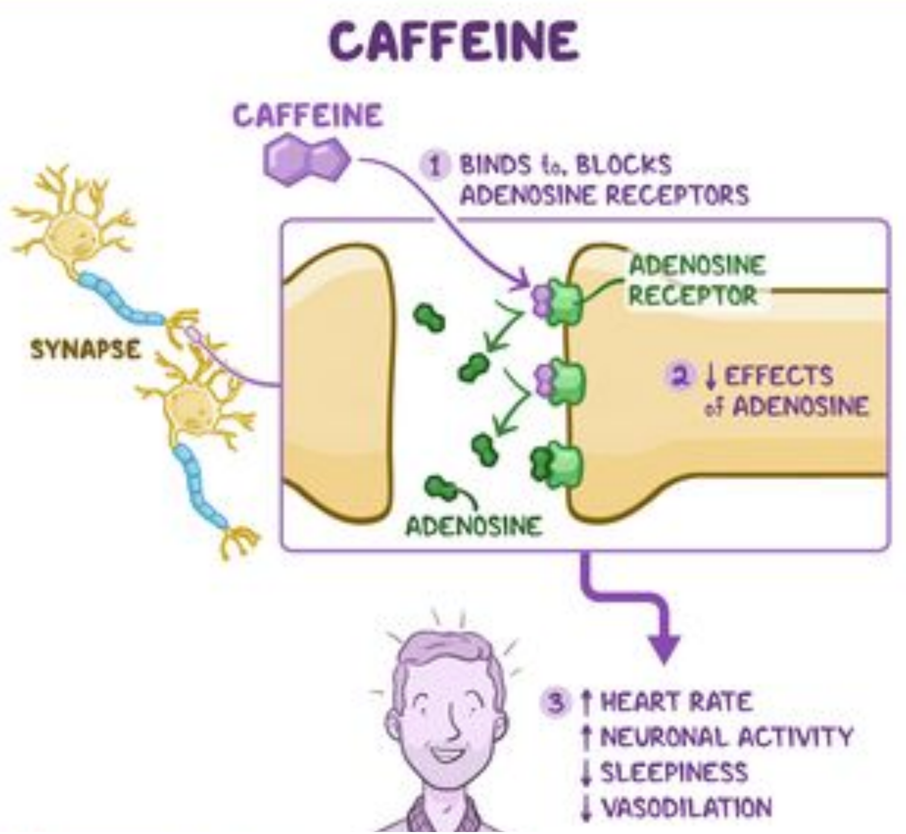
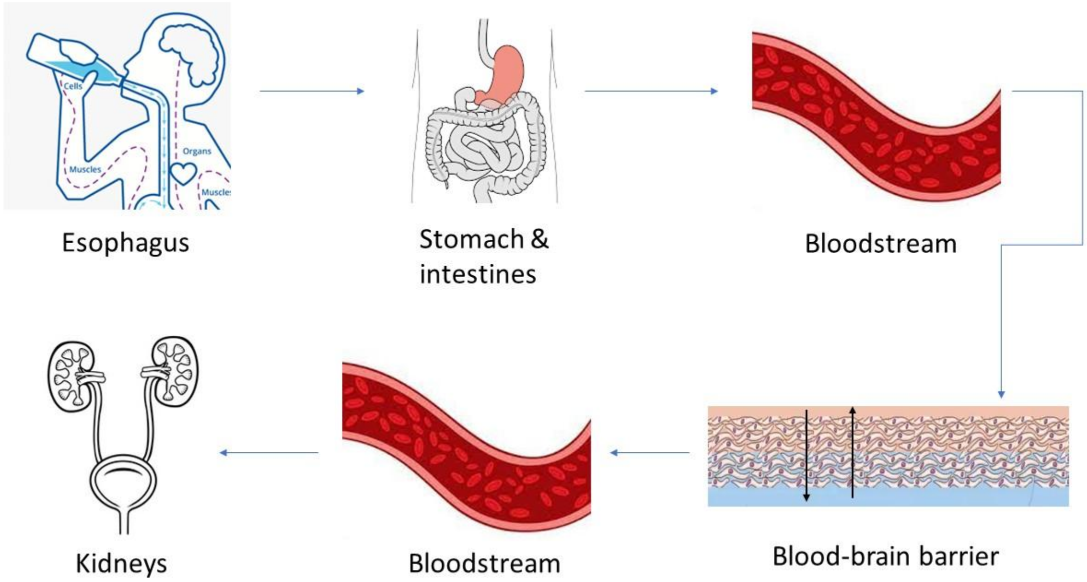
Background


CAFFEINE
CAFFEINE
1 BINDS to, BLOCKS ADENOSINE RECEPTORS
ADENOSINE RECEPTOR
SYNAPSE
2 ↓ EFFECTS of ADENOSINE
ADENOSINE
3 ↑ HEART RATE
↑ NEURONAL ACTIVITY
↓ SLEEPINESS
↓ VASODILATION

Goal

Quantitatively model the effect of caffeine over time as it passes through the stomach, into the bloodstream, to the brain, and is eventually excreted via the kidneys



Assumptions

- Majority of caffeine is filtered out via the kidneys/intestines and excreted - not metabolized
- Don’t take into account the increase in blood flow due to caffeine’s effect on the cardiac function
- Model caffeine absorption from stomach/intestines to bloodstream assuming constant flow instead of an irregular flow pattern

Variables

C_{brain}	Concentration of caffeine in the brain
C_{blood}	Concentration of caffeine in the blood
$C_{stomach}$	Concentration of caffeine in the stomach
V_{brain}	Volume of blood in the brain
$V_{stomach}$	Volume of the stomach
V_{blood}	Blood volume in circulatory system
D_{brain}	Concentration of dopamine in the brain
R_b	Resistivity of the blood brain barrier
R_s	Resistivity of the stomach lining
k_f	“Reaction rate” of caffeine → dopamine
τ_D	Time constant of dopamine
Q_s	Flow in stomach
Q_b	Flow of blood

ODEs

$$\frac{dD_{brain}}{dt} = k_f C_{brain} - \frac{1}{\tau_D} D_{brain}$$

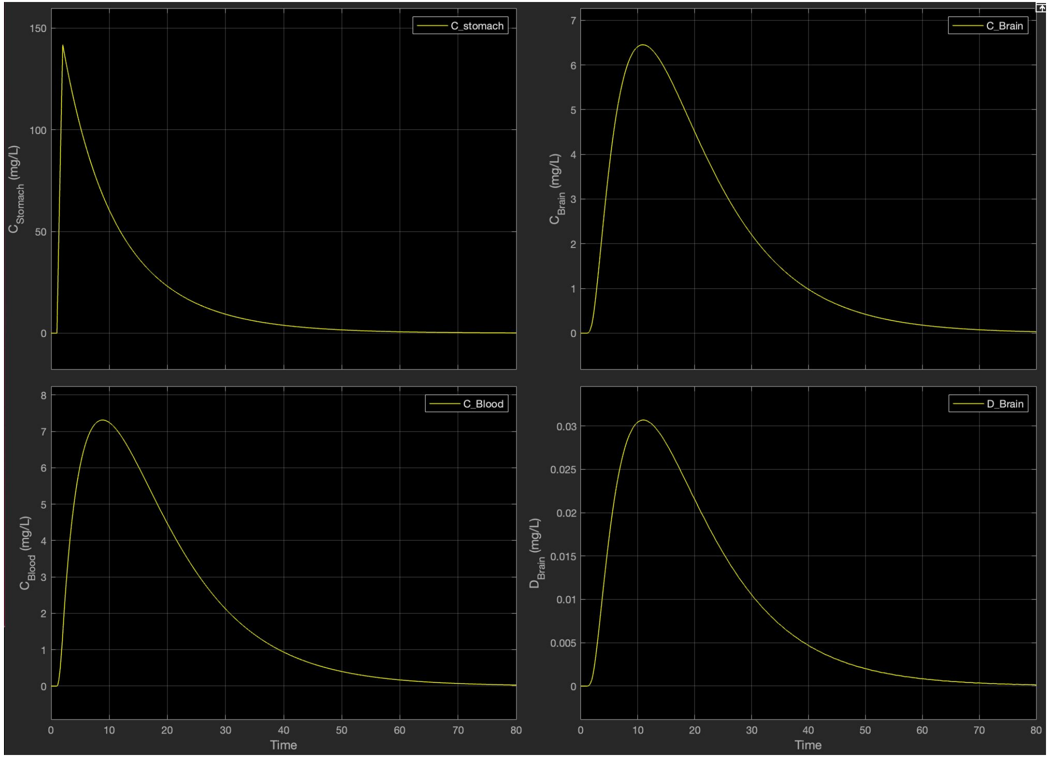
$$\frac{dC_{brain}}{dt} = \frac{1}{R_b V_{brain}} (C_{blood} - C_{brain}) - k_f C_{brain}$$

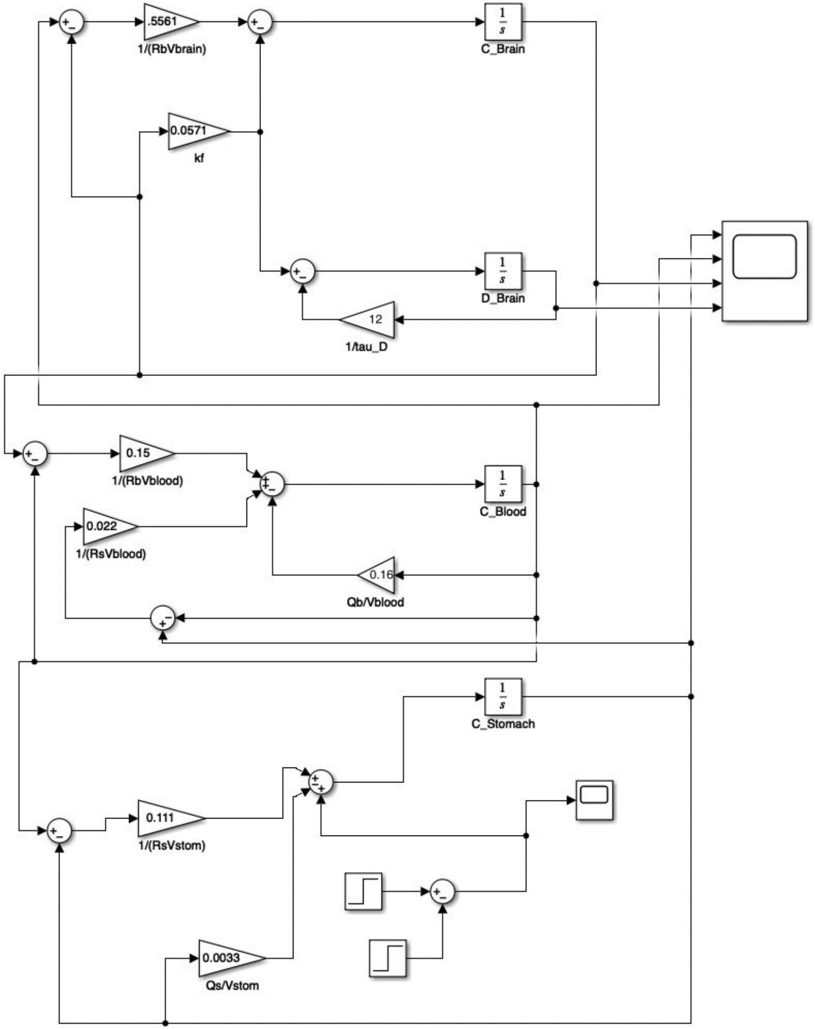
$$\frac{dC_{blood}}{dt} = \frac{1}{R_s V_{blood}} (C_{stomach} - C_{blood}) + \frac{1}{R_b V_{blood}} (C_{brain} - C_{blood}) - \frac{Q_b}{V_{blood}} C_{blood}$$

$$\frac{dC_{stomach}}{dt} = \frac{I(t)}{V_{stomach}} + \frac{1}{R_s V_{stomach}} (C_{blood} - C_{stomach}) - \frac{Q_s}{V_{stomach}} C_{stomach}$$

Simulink Model

Caffeine uptake at rate 150 mg/min for 1 min





Creating the Transfer Function

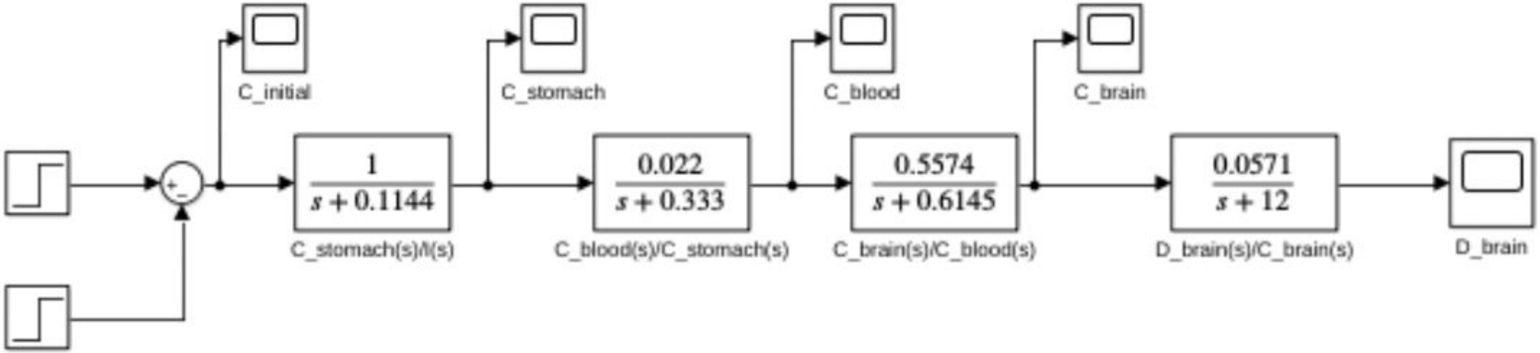
$$\frac{dD_{brain}}{dt} = k_f C_{brain} - \frac{1}{\tau_D} D_{brain}$$

$$\frac{dC_{brain}}{dt} = \frac{1}{R_b V_{brain}} (C_{blood} - C_{brain}) - k_f C_{brain}$$

$$\frac{dC_{blood}}{dt} = \frac{1}{R_s V_{blood}} (C_{stomach} - C_{blood}) + \frac{1}{R_b V_{blood}} (C_{brain} - C_{blood}) - \frac{Q_b}{V_{blood}} C_{blood}$$

$$\frac{dC_{stomach}}{dt} = \frac{I(t)}{V_{stomach}} + \frac{1}{R_s V_{stomach}} (C_{blood} - C_{stomach}) - \frac{Q_s}{V_{stomach}} C_{stomach}$$

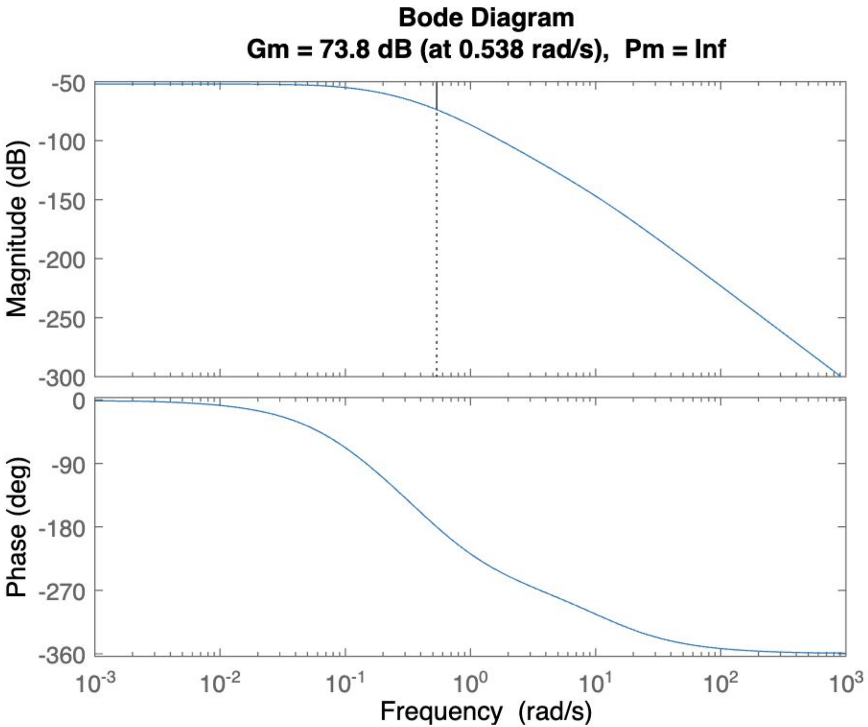
Transfer Function Simulink



$$H(s) = \frac{D_{brain}(s)}{I(s)} \frac{0.0007}{(s+0.1144)(s+0.333)(s+0.6145)(s+12)}$$

$$H(s) = \frac{D_{brain}(s)}{I(s)} = \frac{0.0007}{s^4 + 13.06s^3 + 13.06s^2 + 3.777s + 0.2809}$$

Bode Plot



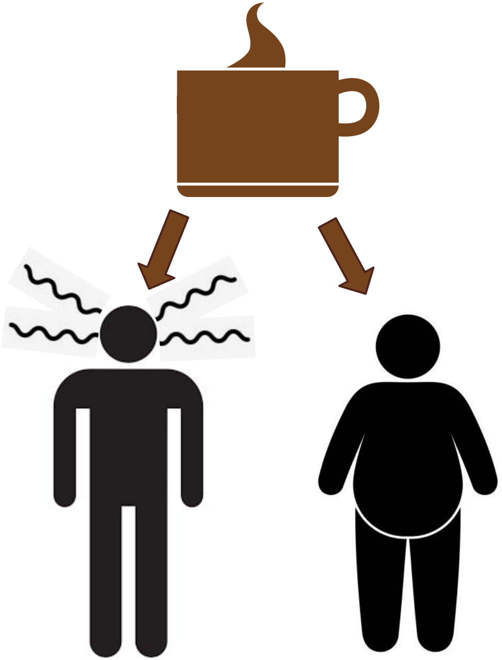

```
z =  no zeros

p = 4x1
   -12.0000
    -0.6156
    -0.3316
    -0.1147

k = 7.0000e-04
```

All poles are negative!

Potential Errors in the Model

- Other organs are also responsible for removal of caffeine from the bloodstream
- Caffeine typically causes an increase in heart rate
- Caffeine is different for everyone
    - Smokers metabolize caffeine twice as fast
    - Genetics can determine # of adenosine receptors
    - Tolerance increase due to consistent intake of caffeine

Heart rate increases with caffeine intake



Caffeine affects people differently

Discussion/Future Directions

- Our model can predict caffeine concentration in different organs
- Future directions:
  - Study effects of caffeine on different bodily processes
  - Revise the model to account for a rise in heart rate
  - Use this model to predict dopamine release in the brain as a result of caffeine intake

References and Acknowledgements

Thank you Professor Cauwenberghs!

- https://pulse.kitware.com/_gastrointestinal_methodology.html#:~:text=A%20static%20absorption%20flow%20rate,chyme%20into%20small%20intestine%20vasculature.
- https://pubmed.ncbi.nlm.nih.gov/30252333/#:~:text=The%20amount%20of%20blood%20circulating,by%20roughly%2050%25%20during%20pregnancy
- https://www.reference.com/science-technology/much-food-can-human-stomach-hold-29b345ff9b3bbf1d]
- https://www.jneurosci.org/content/22/15/6321
- https://www.discovermagazine.com/planet-earth/the-human-brain-has-been-getting-smaller-since-the-stone-age
- https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiOztiu4Nf7AhVqRzABHQFrAvwQFnoECAsQAw&url=https%3A%2F%2Fmyhealth.alberta.ca%2FAlberta%2FPages%2FSubstance-use-caffeine.aspx%23%3A~%3Atext%3DThe%2520effects%2520of%2520caffeine%2520usually%2Cmake%2520you%2520feel%2520less%2520tired.&usg=AOvVaw0gA2MFrCeR2T051R8azXEY
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3381939/#:~:text=Caffeine%20is%20almost%20completely%20metabolized,in%20the%20liver%20%5B6%5D.
- https://med.libretexts.org/Bookshelves/Anatomy_and_Physiology/Book%3A_Anatomy_and_Physiology_(Boundless)/18%3A_Cardiovascular_System%3A_Blood_Vessels/18.7%3A_Blood_Flow_Through_the_Body/18.7D%3A_Blood_Flow_in_the_Brain
- https://www.mdpi.com/1424-8220/8/9/5516