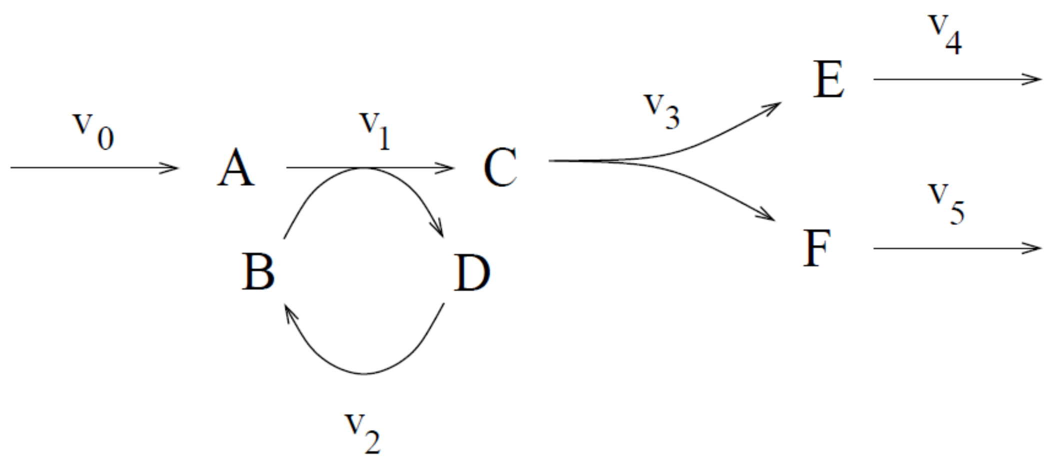
EE3009 Introduction to Biomedical Engineering
Fall 2024

Homework 1

Due 10/2/2024 Midnight

Q1. Consider the following biochemical reaction network:



where v_i is reaction rates, k_i is rate constants, and

$v_0 = k_0$, $v_1 = k_1[A][B]$, $v_2 = k_2[D]$, $v_3 = k_3[C]$, $v_4 = k_4[E]$, and $v_5 = k_5[F]$

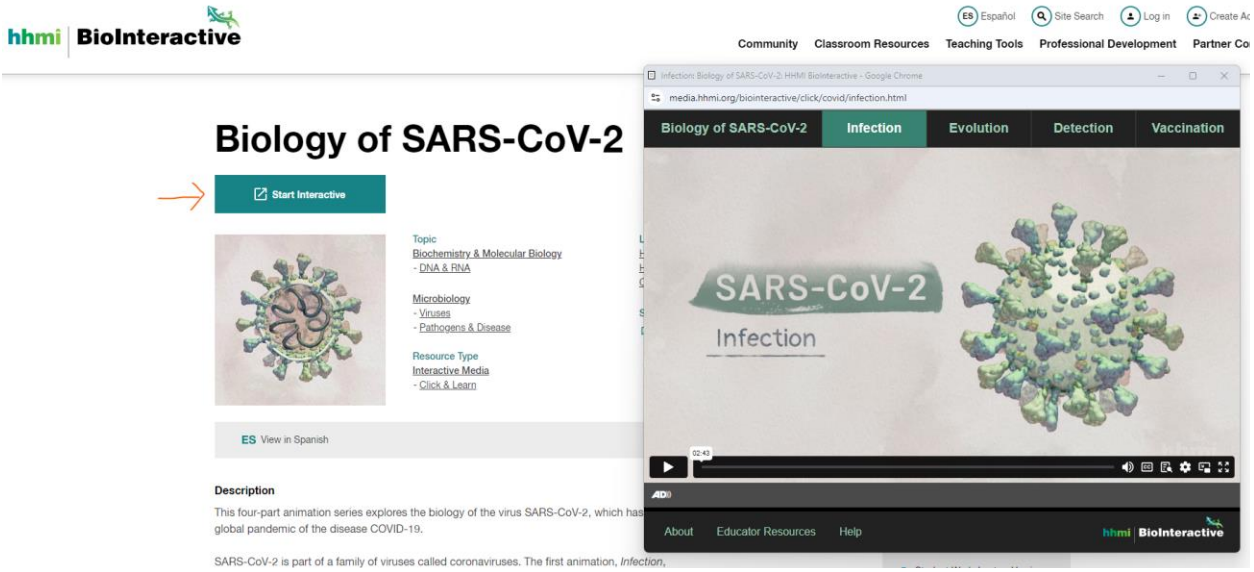
(1) Please construct a differential equation model for the reaction network.

(2) Please define which ones are the state variables and which ones are the parameters in your model.

Q2. SARS-CoV-2

Watch the animation video in HHMI Biointeractive and answer the following questions.

Link: https://www.biointeractive.org/classroom-resources/biology-sars-cov-2



1. List the three types of molecules detected by the tests in the animation.
2. The animation describes the following types of SARS-CoV-2 vaccines. Briefly summarize how each type of vaccine triggers an immune response. (Hint: Remember that the immune system responds specifically to antigens.) a. Inactive whole virus b. Antigen proteins c. mRNA (genetic instructions) d. DNA (genetic instructions)

Q3. SIR model extension

We introduce the SIR model in the class to simulate COVID-19 infection. To simulate the vaccination effect on S, I, R population, we need to modify the SIR model to include a vaccination term. Assume a fraction of the susceptible population is vaccinated per day, reducing the number of susceptible individuals. The modified equations are:

$$\frac{dS}{dt} = -\beta S * I/N - \nu S$$

$$\frac{dI}{dt} = \beta S * I/N - \gamma I$$

$$\frac{dR}{dt} = \gamma I + \nu S$$

where ν is the vaccination rate.

1. Implement this modified model in a computer programming code (Python, or your choice of program…) and solve the differential equations using initial conditions and parameters:

$S(0)$=990, $I(0)$=10, and $R(0)$=0
β=0.3 (per day per individual) and γ=0.1 (per day)
ν=0.05 (per day)

2. Plot the number of susceptible, infected, and recovered individuals over time for different vaccination rates. Discuss the impact of vaccination on the epidemic.

Here are some examples of python codes for SIR model:

1. https://python.quantecon.org/sir_model.html
2. https://scientific-python.readthedocs.io/en/latest/notebooks_rst/3_Ordinary_Differential_Equations/02_Examples/Epidemic_model_SIR.html
3. https://scipython.com/book/chapter-8-scipy/additional-examples/the-sir-epidemic-model/