MIT 6.0002 Problem Set 4 Write Up Problem 2: Running and Analyzing a Simple Simulation (No Antibiotic Treatment)

Part 1: Implementing a Simple Simulation (No Antibiotic Treatment)

In this part, I completed the SimpleBacteria and Patient base classes.

SimpleBacteria Class Methods Implemented

- __init__(): class constructor. Type and range check parameters. Set internal class attributes
- Is_killed(): Generates random event and compares event probability with bacteria death prob to determine if bacteria should be killed. Does not mark bacteria as being killed
- killBacteria(): Kills bacteria by setting bacteria object "killed" attribute to True
- reproduce(): Stochastically determines if bacteria cell reproduces at a time step.

Part 2: Running and Analyzing a Simple Simulation (No Antibiotic Treatment)

In this part, I completed calc_pop_avg() and simulation_without_antibiotics() functions.

Functions Implemented

- calc_pop_avg(): Calculates a time step average across all trials for a given time step
- simulation_without_antibiotics(): Executes simulation and calls make_one_curve_plot() of simulation output data, plot listed below (figure 1)

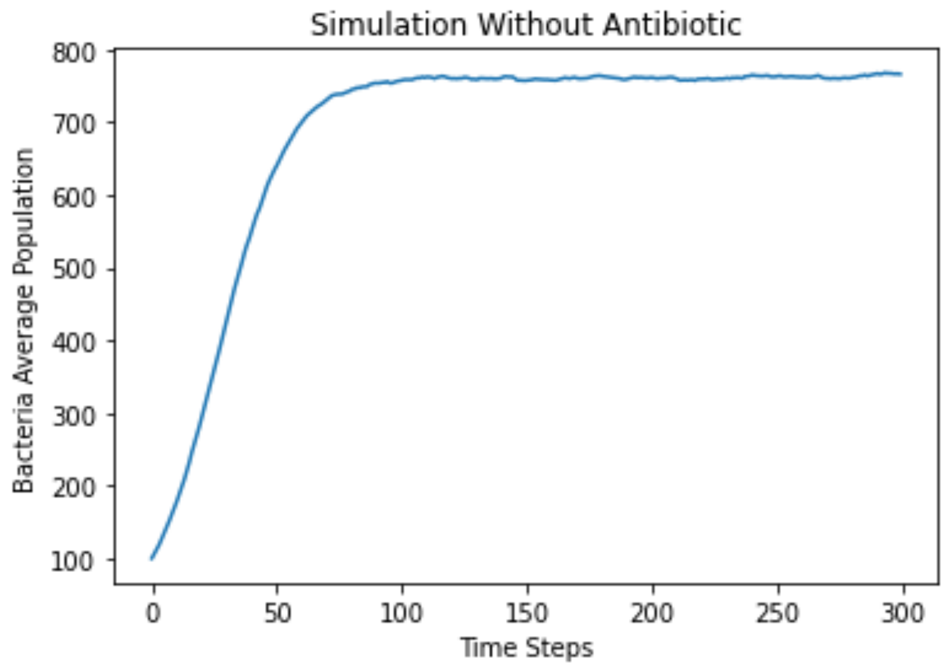

Figure 1: Simulation without Antibiotics

Part 3: Calculating a Confidence Interval

For the simulation without antibiotics, the following statistics were calculated by calc_pop_std() and calc_95_ci() functions that I implemented. Note that the standard deviation calculation function does not utilize any built-in math functions provided by Python libraries.

Statistics calculated on the bacteria total populations used the following formulas:

standard deviation	$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$
standard error of the mean	$SEM = \frac{\sigma}{\sqrt{n}}$
95% confidence interval	$\bar{x} \pm 1.96(SEM)$

- Standard Deviation of Time Step 299: 12.95569
- 95% Confidence Interval of Time Step 299: {760.10886, 767.29114}
- Simulations with Patient with antibiotics and resistant bacteria

Part 4: Implementing a Simulation with an Antibiotic

Simulation A (Birth Rate > Death Rate Probabilities) Trends Questions

Figure 2 shows the plot of output for the simulation where the birth rate probability (0.3) was greater than the death rate probability (0.2) for the bacteria. These rates were used to determine if the bacteria would reproduce and perish based upon a random event sampling.

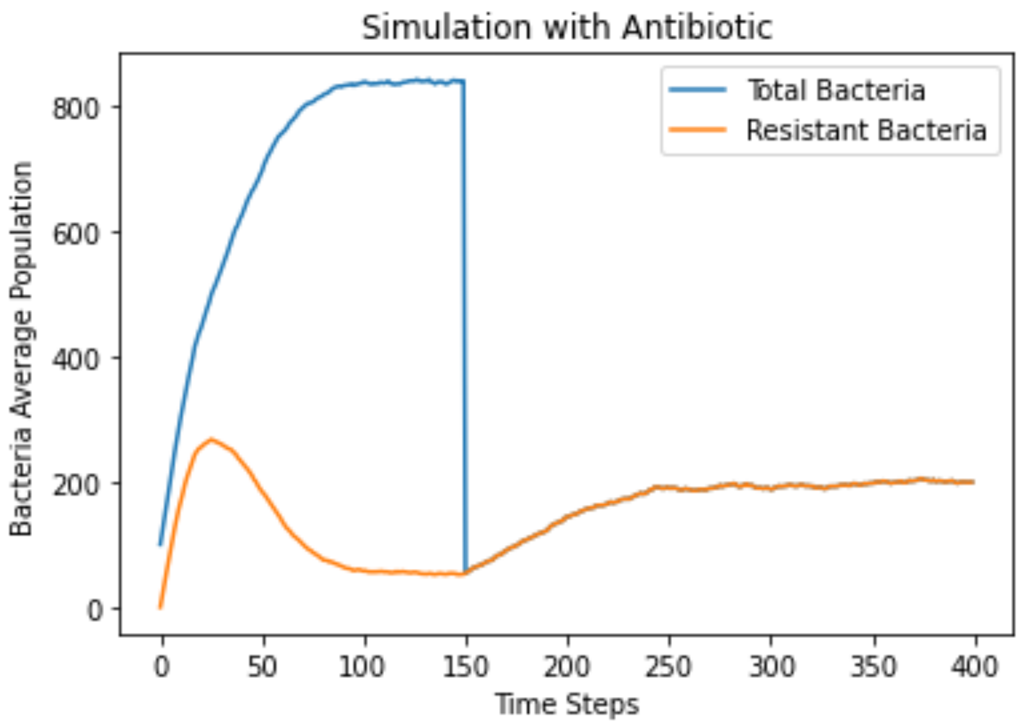

Figure 2: Simulation A with Bacteria Birth Probability > Death Probability

- *What happens to the total population before introducing the antibiotic?*
    - Before the vaccine was administered to the patient, the overall bacteria growth steadily increased to about time step 75, after which the growth slowed to a plateau. This is consistent with the results from the simulation which was run before where the patient did not have any antibiotics for the entire simulation.
- *What happens to the resistant bacteria population before introducing the antibiotic?*
    - Initially the resistant bacteria growth increases to its maximum population size, around time step 40. After that, the resistant bacteria population decreases to a steady-state population of 100. This will change after the patient the vaccine at time step 150.
- *What happens to the total population after introducing the antibiotic?*
    - The total population immediately decreases around the time step of 150, when the antibiotic is given to the patient, reaching population of 150. At that point, all of the bacteria are now antibiotic resistant, with no non-resistant bacteria present. From time steps 150 to 250, the resistant bacteria population grows from 100 to 200 population. After time step 250, the grow rate of the bacteria is negligible. The total population total seems to be steady (not declining or increasing) until the remainder of the simulation.
- *What happens to the resistant bacteria population after introducing the antibiotic?*
    - The resistant bacteria population is the only surviving bacteria, non-resistant bacteria is no longer present after the antibiotic at time step 150. Also, the non-

resistant bacteria are never completely removed from the patient, but rather increases a bit until a new steady-state population plateau is prevalent.

Simulation B (Birth Rate < Death Rate Probabilities) Trends Questions

Figure 3 shows the plot of output for the simulation where the birth rate probability (0.17) was less than the death rate probability (0.2) for the bacteria. These rates were used to determine if the bacteria would reproduce and perish based upon a random event sampling.

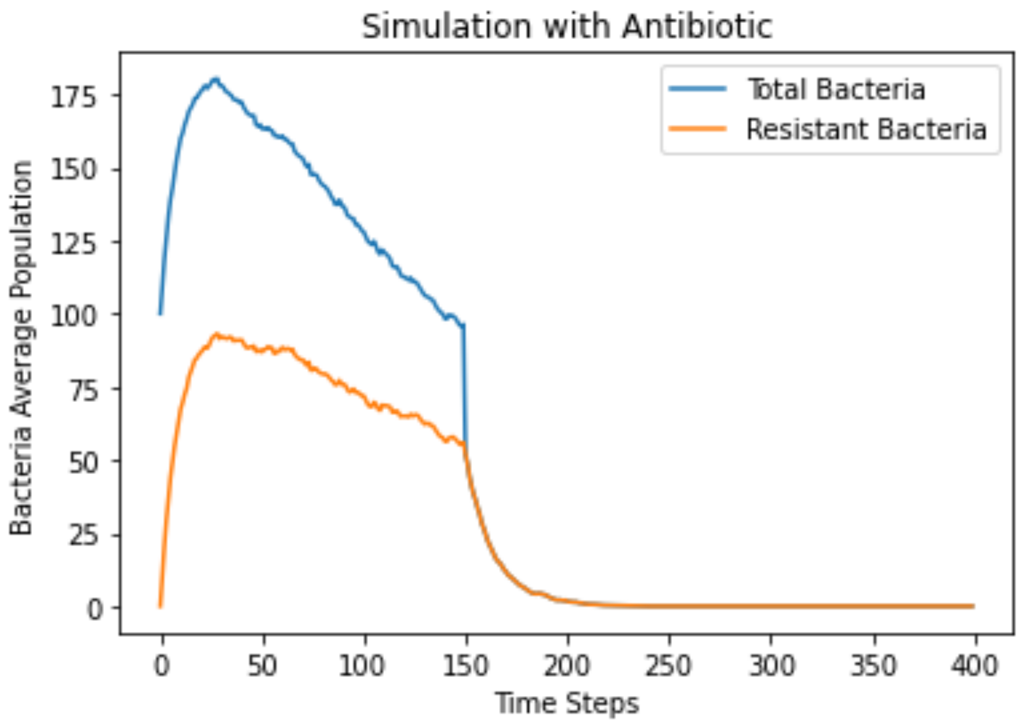

Figure 3: Simulation B with Bacteria Birth Probability < Death Probability

- *What happens to the total population before introducing the antibiotic?*
  - Before the vaccine was administered to the patient, the overall bacteria growth steadily increased to about time step 45, after which the population decreased to the initial population size of about 100. This is consistent with the fact that the overall death rate probability was greater than the birth rate probability. Given no introduction of antibiotics, eyeballing the trajectory of the population decline, the patient possibly would have a near zero bacteria count around time step 350.
- *What happens to the resistant bacteria population before introducing the antibiotic?*
  - The resistant bacteria population follows a similar growth path, roughly 100 counts below the overall total bacteria population.
- *What happens to the total population after introducing the antibiotic?*
  - Like Simulation A, the total population of the bacteria quickly decreased to being only resistant bacteria. The non-resistant bacteria disappeared.
- *What happens to the resistant bacteria population after introducing the antibiotic?*

- Like Simulation A, the resistant bacteria were the only bacteria to survive the introduction of the antibiotic. But unlike Simulation A, the resistant bacteria quickly decreased to near zero.