PROBLEM 2: DESIGNING A TREATMENT PLAN WITH TWO DRUGS : 30.0 POINTS

One approach to addressing the problem of acquired drug resistance is to use cocktails – administration of multiple drugs that act independently to attack the virus population.

In this problem, we use two independently-acting drugs to treat the virus. We will use this model to decide the best way of administering the two drugs. Specifically, we examine the effect of a lag time between administering the first and second drugs on patient outcomes.

Use the following parameters to initialize a `TreatedPatient`:

- `viruses`, a list of 100 `ResistantVirus` instances.
- `maxPop`, maximum sustainable virus population = 1000

Each `ResistantVirus` instance in the viruses list should be initialized with the following parameters:

- `maxBirthProb`, maximum reproduction probability for a virus particle = 0.1
- `clearProb`, maximum clearance probability for a virus particle = 0.05
- `resistances`, the virus's genetic resistance to drugs in the experiment: {'guttagonol': False, 'grimpex': False}
- `mutProb`, probability of a mutation in a virus particle's offspring = 0.005

Run the simulation for 150 time steps before administering guttagonol to the patient. Then run the simulation for 300, 150, 75, and 0 time steps before administering a second drug, grimpex, to the patient. Finally, run the simulation for an additional 150 time steps.

For each of these 4 conditions, repeat the experiment for enough trials to get a reasonable condition, while recording the final virus populations. Use pylab's `hist()` function to plot a histogram of the final total virus populations under each condition.

> **HINT**: As with Problem 1, the simulation will take a few minutes to run. Use print statements to monitor the simulation's progress.

Fill in the function `simulationTwoDrugsDelayedTreatment(numTrials)` to perform this simulation. Feel free to break down the problem into smaller subparts and define helper functions for each.

Create 4 histograms (for 300, 150, 75, and 0 time steps) and then answer the following set of questions.

1. If you consider final virus particle counts of 0-50 to be cured (or in remission), approximately what percentage of patients were cured (or in remission) at the end of the simulation?
    1. delay of 2nd drug = 300

- 0 - 15%
- 16 - 30%
- 31 - 60%
- 61 - 85%
- 86 - 100%

2. delay of 2nd drug = 150

- 0 - 30%
- 31 - 60%
- 61 - 85%
- 86 - 100%

3. delay of 2nd drug = 75

- 0 - 30%
- 31 - 65%
- 66 - 100%

4. delay of 2nd drug = 0

- 0 - 30%
- 31 - 65%
- 66 - 100%

2. What is the relationship between when drugs are applied and patients being cured?

- Applying the 2nd drug earlier means the patient is more likely to be cured.
- Applying the 2nd drug later means the patient is more likely to be cured.
- Applying the 2nd drug too late means the patient will never be cured.
- None of the above.

3. Increasing mutProb will increase the number of cured patients.

- True
- False

4. The relationship between number of cured patients and when the delay occurs linear.

- True
- False

5. Of the four delay values tested, which has the lowest variance?

- delay of 2nd drug = 300
- delay of 2nd drug = 150
- delay of 2nd drug = 75
- delay of 2nd drug = 0

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