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COGS-Q320

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Infectious Diseases and the Control of Contagion

For this project, I set out to create a world where a pandemic is simulated to understand in greater depth what actually affects contagion, as well as potential ways to halt or slow the spread. I found this idea intriguing due to the current events caused by COVID-19. For this, I largely built and based my algorithm around "Programming Project #1 - Schelling's Segregation Model". In order to reduce the amount of verbal clutter, the initial parameters for the class are as follows:

```
4
5   class City():
6
7       def __init__(self, size, infectionChance, movementProb, deathProb, recoveryRate):
8           self.size = size                    # Size of the neighborhood measured along one dimension
9           self.pop = np.zeros((size,size))    # Houses in a neighborhood
10          self.emptyProb = 0.05               # Probability that a house will be empty
11          self.intitialInfectionProb = 0.01   # Probability that a household will be infected
12          self.infectionChance = infectionChance      # probability of infection when selected (based around infected neighbors)
13          self.movementProb = movementProb            # probability that you'll move when selected
14          self.deathProb = deathProb                  # probability that death will occur if infected
15          self.recoveryRate = recoveryRate            # probability that recovery will occur if infected
16          self.initzeros = 0                          # keep track of the number of vacancies
17          self.infect_cntr = 0                        # keep track of the number of infections
18
```

I'd like to add that the probabilities inputed aren't exactly the numbers being used (as I will describe more in depth when I discuss the relevant methods).

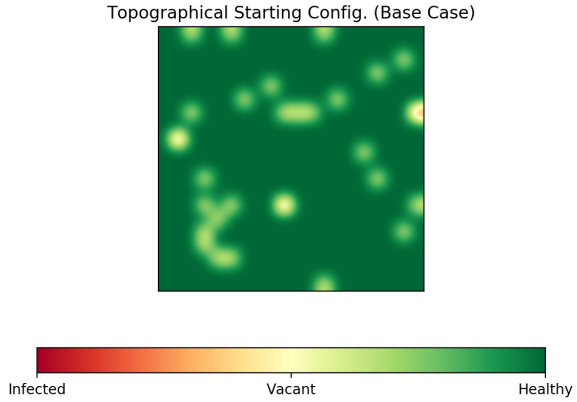
The methods are as follows: Populate, Graphing (4), Step, Random House / Vacant, Infected Neighbors, Move, and Statistics. I'm going to briefly describe the methods as reading about code is quite boring. Populate creates the grid (size by size), the four graphing methods create the PreGraphs (initial set-up) and the PostGraphs (after the simulation has been run). Step

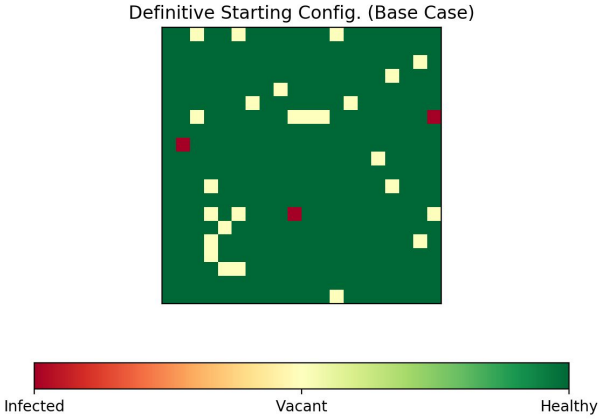
selects an occupied position and evaluates how many neighbors around the individual are infected (using the infected neighbor method), and multiplies the infection chance depending on how many surrounding neighbors are infected; thus, the initial parameter isn't an accurate depiction of the infection chance for the whole population. If the person selected is already infected, then there is a probability that they will either recover or die. The movement method then causes the individual to move positions (once again with altered probabilities to more accurately represent the real world). Lastly, the statistics method keeps track of the four statistics used for graphing purposes: healthy, infected, deaths, recovered. The comments in my code go into more detail if specifics need to be known.

For the simulation, I wanted to test the effects of four deviations from the base case: a lowered infection chance, a lowered movement chance, a combination of a lowered infection chance and a lowered movement chance, and an increased death probability. For all four separate simulations, the other parameters were left unchanged in order to not have a conflation leading to invalid conclusions. Overall, the simulation set up was somewhat simple with an initialization of the class and then keeping track of the change in data throughout the loop (~20,000 iterations). These iterations were later divided by 24 to obtain the number of "Days" that the infection has been occuring. The first simulation was of the base case:

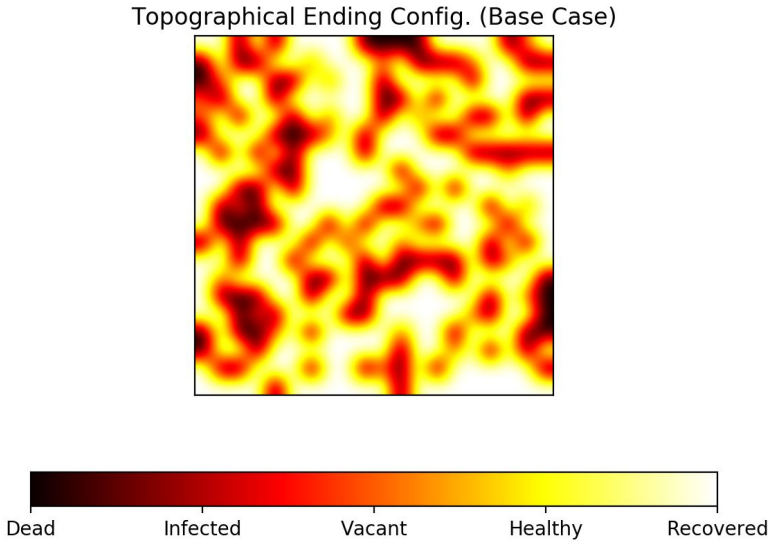
- Size - 20x20
- Infection Chance - 0.2
- Movement Probability - 0.3
- Death Probability - 0.05
- Recovery Probability - 0.1

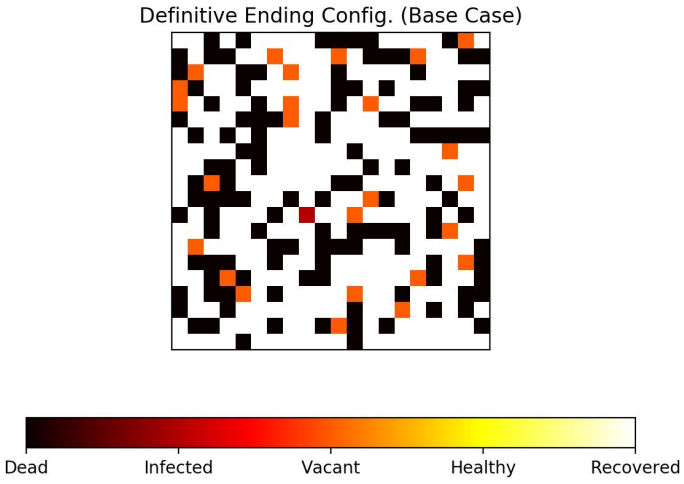
The initial overview of the city is as follows:



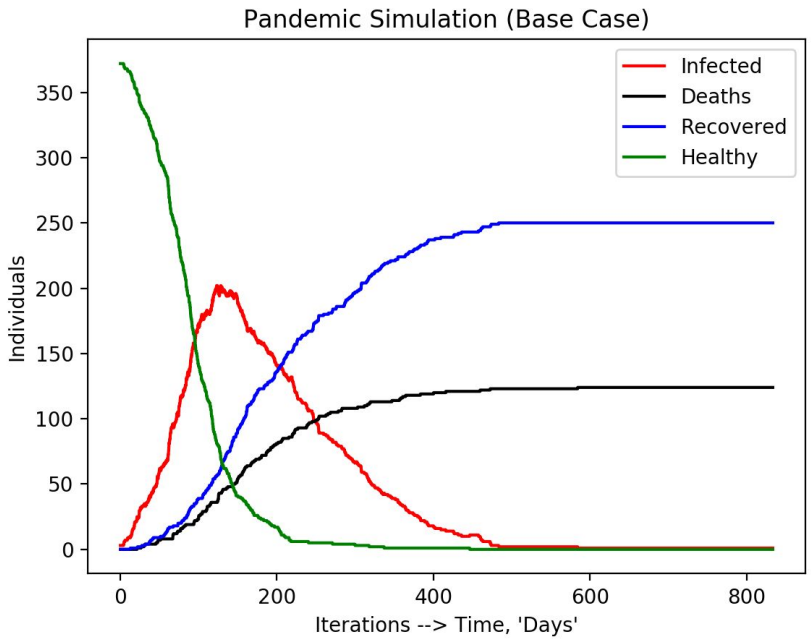


The “Topical” only gives an aesthetically pleasing depiction whereas the “Definitive” gives the actual observable data. After the simulation, the city looks as follows:





As you can tell, almost all of the city has been infected by the virus. The following graph shows the statistical data from the run:

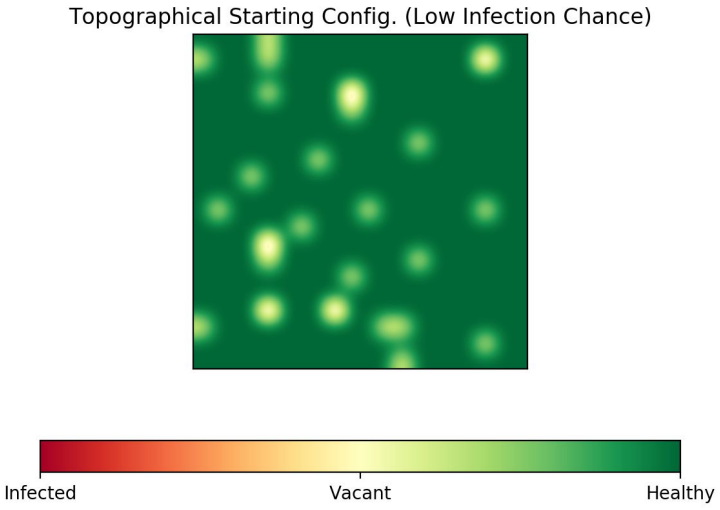


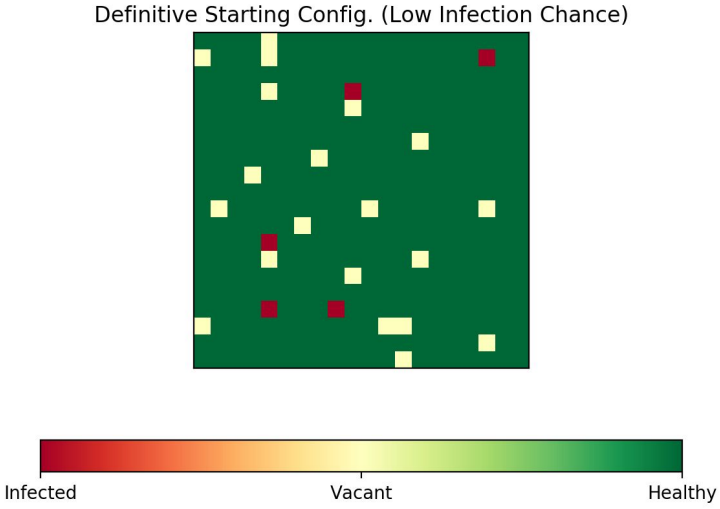
I also added in a series of print statements which give a numerical representation of the data:

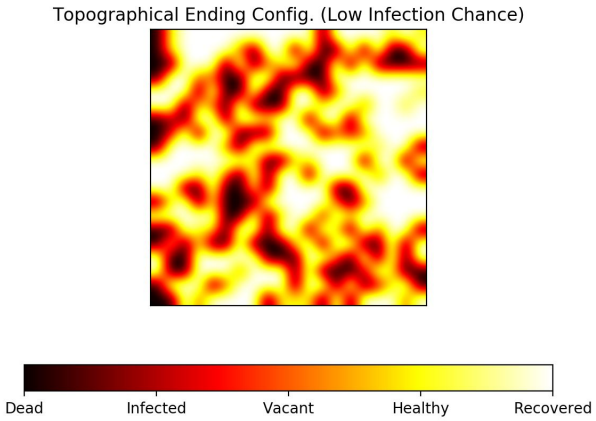
```
Statistical Summary (Base Case)
-------------------------------

Initial Statistics (Base Case)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Area of Space: 400
Population of Size: 375
Total Number of Randomized Empty Spaces to Move (Vacancies): 25
Number of Initial Healthy Individuals: 372.0
Number of Initial Infected Individuals: 3.0

Concluding Statistics (Base Case)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Total Number of Infections: 375
Total Number of Recovered Individuals: 250.0
Total Number of Deaths: 124.0
Total Number of Remaining Infections: 1.0
Total Number of Remaining Healthy Individuals: 0.0
Maximum Number of Infected Individuals at a Given Time: 202.0
'Day' The Max Occurs: 122
Mortality Rate: 33.06666666666666%
Recovery Rate: 66.66666666666666%
```

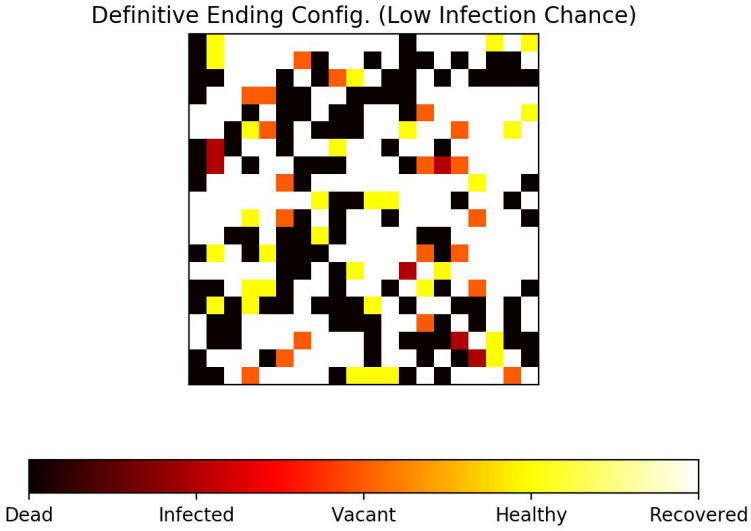
I'd like to point out that the "'Day' The Max Occurs" shows the day where the graph peaks. The goal to preserve the amount of healthy people in the population is to "lower the curve", I'll expound on this later on. Now for the "Lowered Infection Chance" data set:

- Size - 20x20
- Infection Chance - 0.085
- Movement Probability - 0.3
- Death Probability - 0.05
- Recovery Probability - 0.1

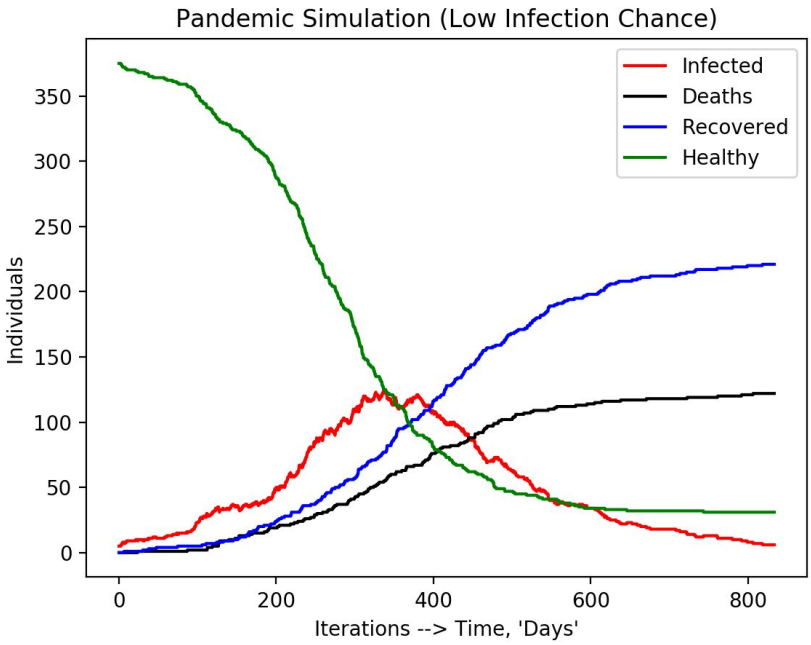








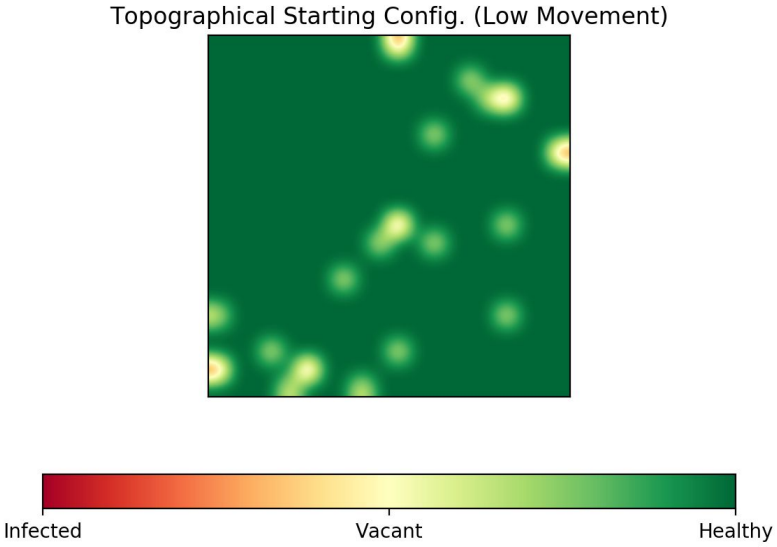
This might appear somewhat worse due to the number of infections, but it's not! This is exactly what we want!



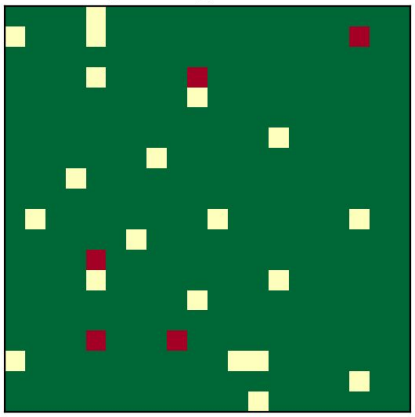

```
Statistical Summary (Lowered Infection Chance)  (Deviation From Base Case)
--------------------------------------------------  -------------------------

Initial Statistics
~~~~~~~~~~~~~~~~~~
Area of Space: 400
Population of Size: 380  (5)
Total Number of Randomized Empty Spaces to Move (Vacancies): 20  (-5)
Number of Initial Healthy Individuals: 375.0  (3.0)
Number of Initial Infected Individuals: 5.0  (2.0)

Concluding Statistics
~~~~~~~~~~~~~~~~~~~~
Total Number of Infections: 349  (-26)
Total Number of Recovered Individuals: 221.0  (-29.0)
Total Number of Deaths: 122.0  (-2.0)
Total Number of Remaining Infections: 6.0  (5.0)
Total Number of Remaining Healthy Individuals: 31.0  (31.0)
Maximum Number of Infected Individuals at a Given Time: 124.0  (-78.0)
'Day' The Max Occurs: 336  (214)
Mortality Rate: 34.95702005730659%  (1.8903533906399304%)
Recovery Rate: 63.323782234957015%  (1.8903533906399304%)
```

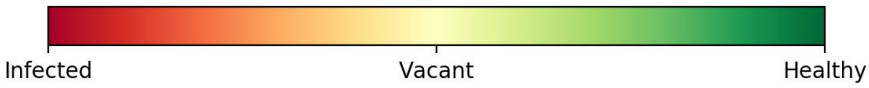
The reason there were a lot of infections in the Ending Configuration is because the infection is moving slower throughout the population which means flattening the curve! Looking at the statistical data, the "'Day' The Max Occurs" takes place 214 days after the Base Case (the parentheses show the difference between the base case and the current model). The peak was down by 78 individuals from the base case. The mortality rate in my simulation wasn't altered significantly, and this is because the mortality rate doesn't take into account the number of infected needing medical care at a single time (which is an interesting idea for a continuation of the project). Now let's look at the data for "Lowered Movement":

- Size - 20x20
- Infection Chance - 0.2
- Movement Probability - 0.08
- Death Probability - 0.05
- Recovery Probability - 0.1

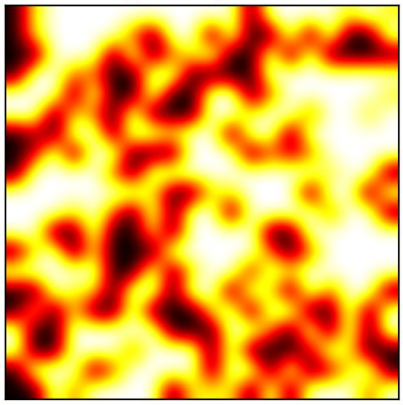


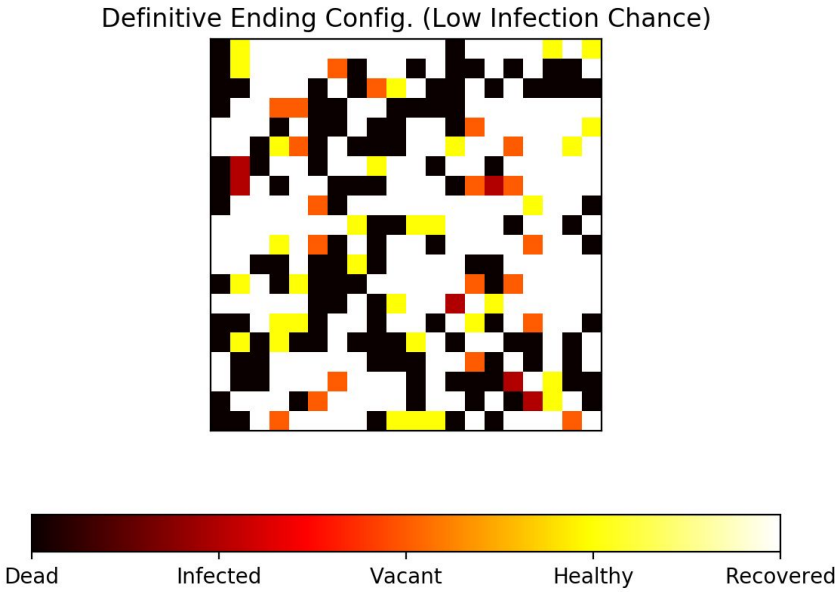
Definitive Starting Config. (Low Infection Chance)

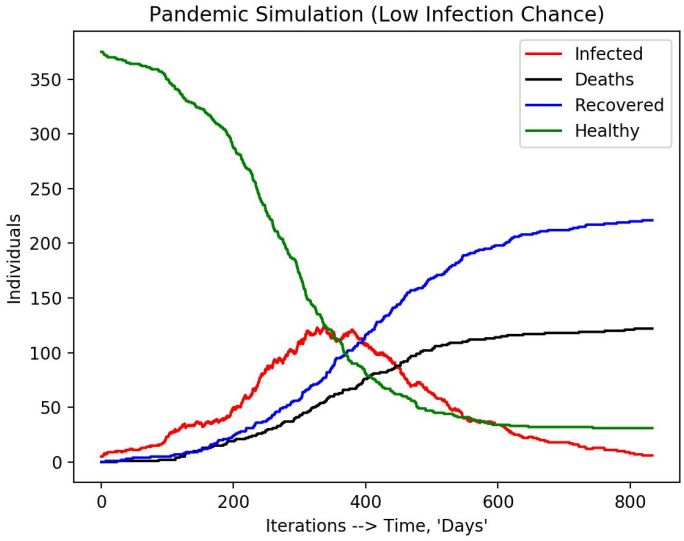




Topographical Ending Config. (Low Infection Chance)




Definitive Ending Config. (Low Infection Chance)
Dead
Infected
Vacant
Healthy
Recovered

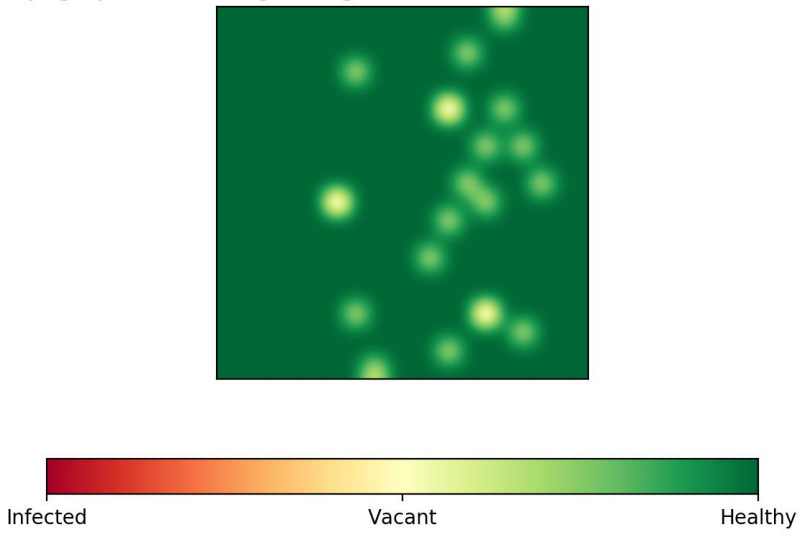

Pandemic Simulation (Low Infection Chance)
Infected
Deaths
Recovered
Healthy
Individuals
0
50
100
150
200
250
300
350
0
200
400
600
800
Iterations --> Time, 'Days'

```
Statistical Summary (Low Movement Probability)
-----------------------------------------------

Initial Statistics
~~~~~~~~~~~~~~~~~~
Area of Space: 400
Population of Size: 387  (12)
Total Number of Randomized Empty Spaces to Move (Vacancies): 13  (-12)
Number of Initial Healthy Individuals: 381.0  (9.0)
Number of Initial Infected Individuals: 6.0  (3.0)

Concluding Statistics
~~~~~~~~~~~~~~~~~~~~~
Total Number of Infections: 386  (11)
Total Number of Recovered Individuals: 245.0  (-5.0)
Total Number of Deaths: 140.0  (16.0)
Total Number of Remaining Infections: 1.0  (0.0)
Total Number of Remaining Healthy Individuals: 1.0  (1.0)
Maximum Number of Infected Individuals at a Given Time: 181.0  (-21.0)
'Day' The Max Occurs: 179  (57)
Mortality Rate: 36.26943005181347%  (3.2027633851468096%)
Recovery Rate: 63.47150259067358%  (3.2027633851468096%)
```

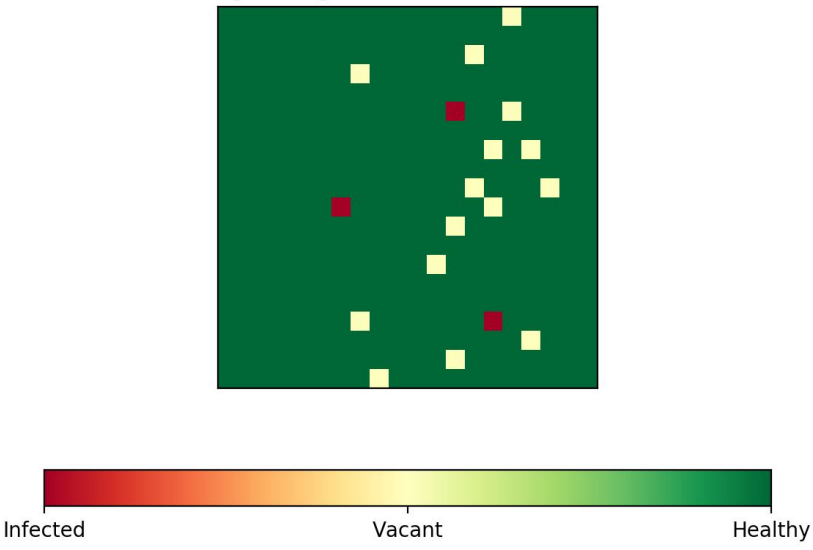
As you can see, the curve wasn't lowered very significantly. What happens is the infection spreads from location of the initial infection; meaning, the infection won't spread around the map as quickly with lowered movement. Now in this simulation, there's no space between each individual, so movement doesn't necessarily play as big of a role as I believe it should in a more realistic scenario. But what happens if we combine a lowered infection chance with lowered movement?

- Size - 20x20
- Infection Chance - 0.085
- Movement Probability - 0.08
- Death Probability - 0.05
- Recovery Probability - 0.1

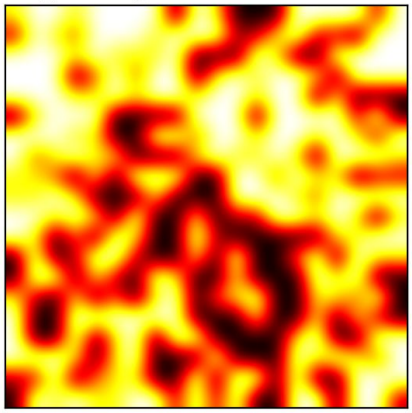
Topographical Starting Config. (Low Infection Chance & Movement)



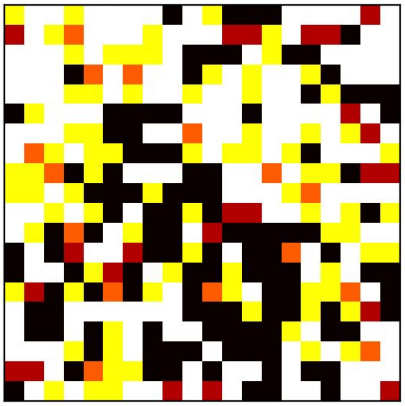
Definitive Starting Config. (Low Infection Chance & Movement)

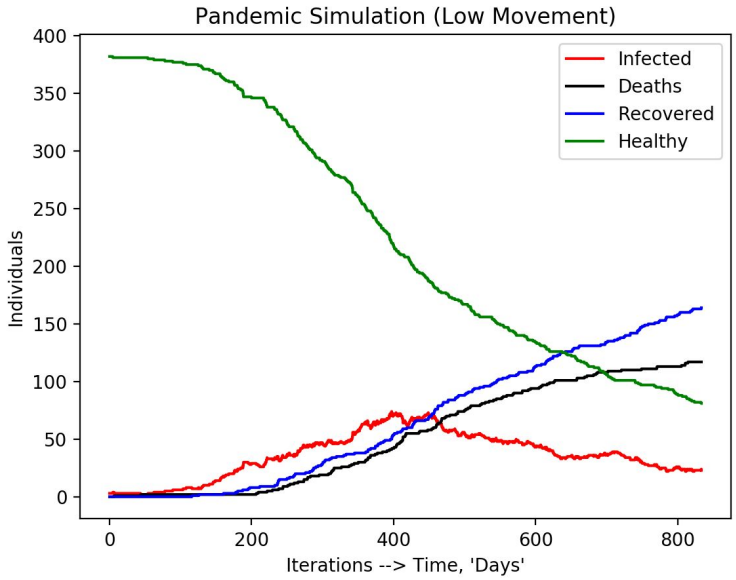


Topographical Ending Config. (Low Infection Chance & Movement)



Definitive Ending Config. (Low Infection Chance & Movement)

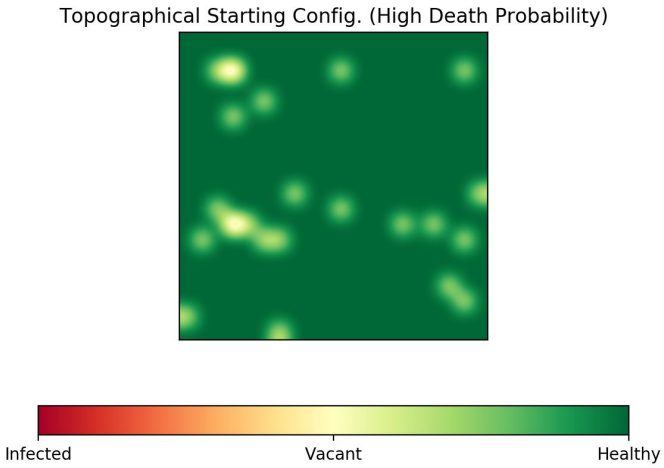


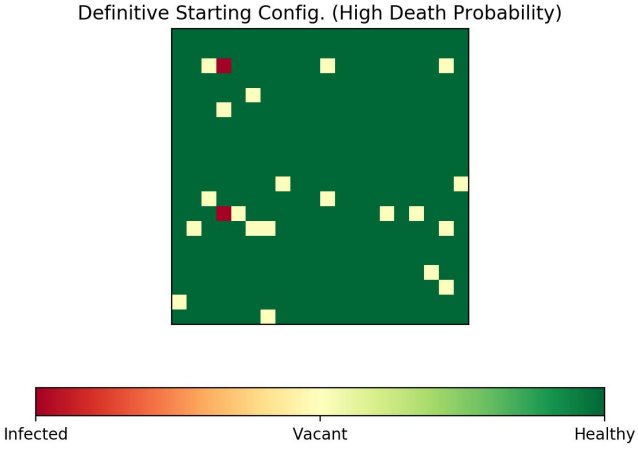



```
Statistical Summary (Low Infection Chance & Movement)
_____________________________________________________

Initial Statistics
~~~~~~~~~~~~~~~~~~
Area of Space: 400
Population of Size: 385  (10)
Total Number of Randomized Empty Spaces to Move (Vacancies): 15  (-10)
Number of Initial Healthy Individuals: 382.0  (10.0)
Number of Initial Infected Individuals: 3.0  (0.0)

Concluding Statistics
~~~~~~~~~~~~~~~~~~~~
Total Number of Infections: 304  (-71)
Total Number of Recovered Individuals: 164.0  (-86.0)
Total Number of Deaths: 117.0  (-7.0)
Total Number of Remaining Infections: 23.0  (22.0)
Total Number of Remaining Healthy Individuals: 81.0  (81.0)
Maximum Number of Infected Individuals at a Given Time: 74.0  (-128.0)
'Day' The Max Occurs: 397  (275)
Mortality Rate: 38.48684210526316%  (5.420175438596495%)
Recovery Rate: 53.94736842105263%  (5.420175438596495%)
```

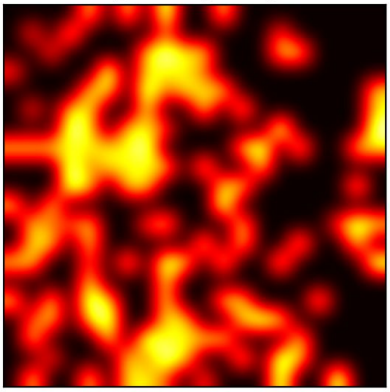
The curve is super flat! The “‘Day The Max Occurs” is 275 days further than the Base Case. Together the lowered infection chance, decreasing the rate of infection, as well as the lowered movement, decreasing the vast spread, show how much these factors play off of each other to affect the overall spread. Now to look at one of the most interesting alterations, increased mortality rate:

- Size - 20x20
- Infection Chance - 0.2
- Movement Probability - 0.3
- Death Probability - 0.55
- Recovery Probability - 0.1

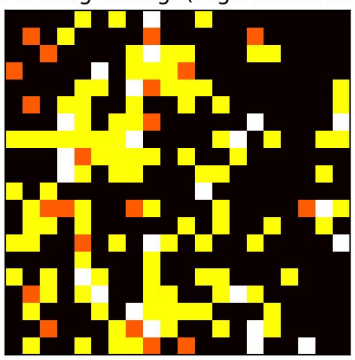


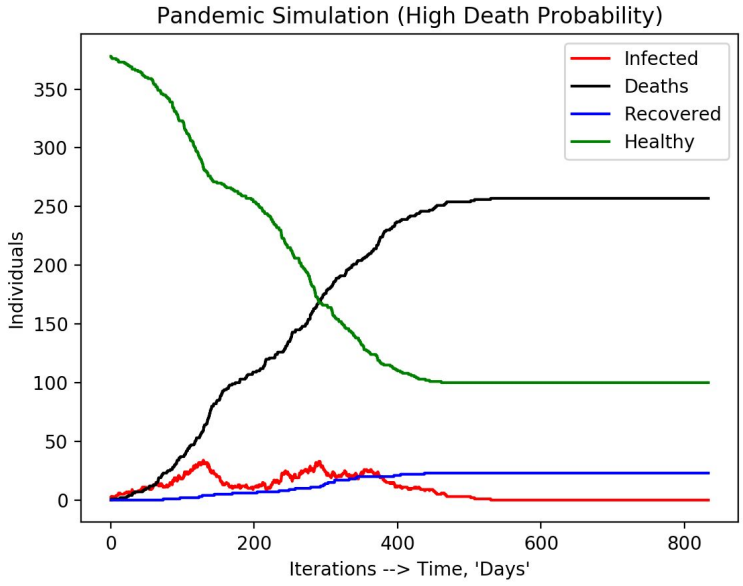


Topographical Ending Config. (High Death Probability)



Definitive Ending Config. (High Death Probability)






```
Statistical Summary (High Death Probability)
--------------------------------------------

Initial Statistics
~~~~~~~~~~~~~~~~~~
Area of Space: 400
Population of Size: 380  (5)
Total Number of Randomized Empty Spaces to Move (Vacancies): 20  (-5)
Number of Initial Healthy Individuals: 378.0  (6.0)
Number of Initial Infected Individuals: 2.0  (-1.0)

Concluding Statistics
~~~~~~~~~~~~~~~~~~~~~
Total Number of Infections: 280  (-95)
Total Number of Recovered Individuals: 23.0  (-227.0)
Total Number of Deaths: 257.0  (133.0)
Total Number of Remaining Infections: 0.0  (-1.0)
Total Number of Remaining Healthy Individuals: 100.0  (100.0)
Maximum Number of Infected Individuals at a Given Time: 34.0  (-168.0)
'Day' The Max Occurs: 128  (6)
Mortality Rate: 91.78571428571428%  (58.719047619047615%)
Recovery Rate: 8.214285714285714%  (58.719047619047615%)
```

I find this really intriguing, the infection practically eradicates itself due to killing the host before it can spread to other people. Now the same would also be true if the recovery rate was increased as the disease would be eradicated from people recovering from it before it can spread (the former not being an optimal future for obvious reasons).

Overall I'm really happy with how the project turned out. I feel like I learned a decent bit about the nature of a pandemic, but more importantly I sharpened some of my coding skills. I ran into some trouble when generating the printed statistics (and I'm still not sure what exactly was wrong). But the bug disappeared after I deleted the section and typed it back out. Also, the code probably could have been condensed, but I was worried about organizing it after it began to work properly.

In conclusion, although these figures by no means represent COVID-19 projections, I believe they show the importance of flattening the curve through lowering the infection chance (taking proper precautions: washing hands, not touching one's face, social distancing, etc.) as well as lowering the movement probability (not spreading the disease to an unaffected part of the community). Hopefully we can debug the world one thoughtful line of code at a time.