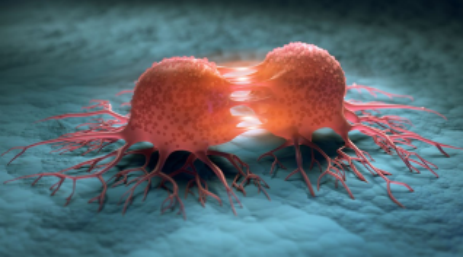
The Importance of Early Detection of Cancer

By Jose Araujo Amaya, Rohan Chadha, Joakim Egeland, Alfonso Pineda-Garza and Kin Xia



Motivation

What is cancer?

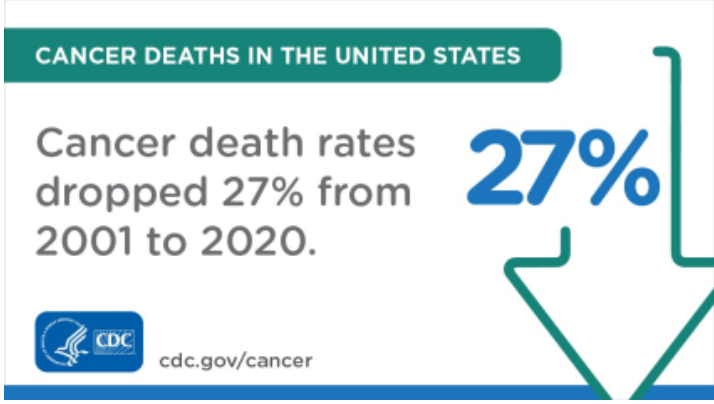
Cancer occurs when a cell in the body undergoes a series of mutations that alter processes such as the cell cycle.

The development of abnormal cells that divide uncontrollably leading to tumors, organ failure, and eventually death.

There are 4 stages:

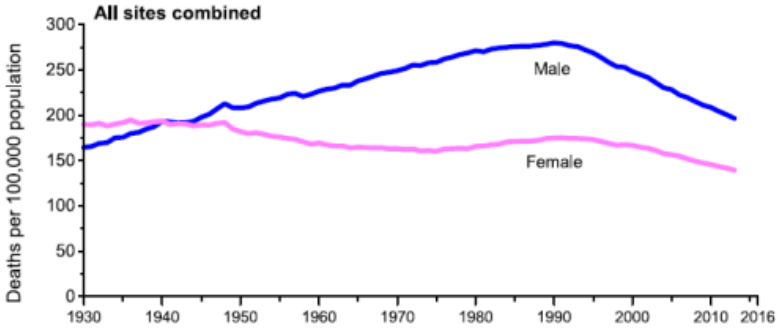
- **stage 1** – the cancer is small and hasn't spread anywhere else
- **stage 2** – the cancer has grown, but hasn't spread
- **stage 3** – the cancer is larger and may have spread to the surrounding tissues and/or the lymph nodes (or "glands", part of the immune system)
- **stage 4** – the cancer has spread from where it started to at least 1 other body organ, also known as "secondary" or "metastatic" cancer

Motivation



- 39.5% of people will be diagnosed with cancer at some point during their lifetimes and the US accounts for 1,806,590 new cases of cancer
- There are 16.9 million cancer survivors in the United States. This is expected to increase to 22.2 million by 2030.
- 606,520 deaths in 2020

$150.8 billion were put into cancer care/research efforts in 2018 in the United States



Motivation

- To bring awareness that one of the best ways to prevent and mitigate cancer is early detection
- Treatments of cancer include surgery, chemotherapy, radiation therapy, bone marrow transplant, immunotherapy, hormone therapy, targeted drug therapy, cryoablation.
- These treatments do not guarantee the total eradication of cancer especially at later stages. It is better to report any unusual changes to the body to your doctor.

Motivation

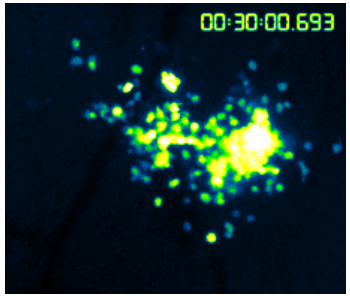
Simulation will show how cancer treatment is impacted by the stage of cancer when treatment begins.

People in earlier stages have significantly increased chance of survival after cancer treatment

Cancer tends to grow at an exponential rate

We will focus on nanotechnology in the form of fighter cells targeting cancer directly.

We will simulate stage 1, stage 2, stage 3, and stage 4 cancer



Legend

0 - Healthy

1 - Cancer

2 - Fighter

Algorithm

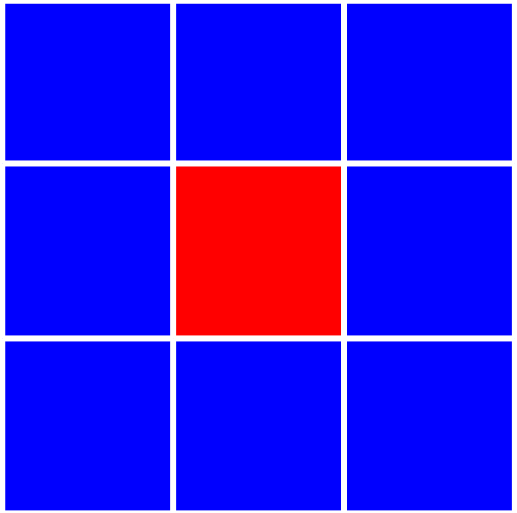
```
def main():
    random.seed(time.time())  # Seed
    sizeX, sizeY = 30, 30  # Size of plot
    domain = np.array([0 for x in range(sizeX*sizeY)]).reshape(sizeY, sizeX)  # 2D numpy array
    cancer = input("Enter the initial number of cancer cells: ")
    while np.count_nonzero(domain == 1) < int(cancer):  # For the number of inputted cancer cells
        randNum1 = int(random.random() * 30)  # Random x position
        randNum2 = int(random.random() * 30)  # Random y position
        domain[randNum1][randNum2] = 1  # Set as cancer cell
    simTime, healthy, cancer = [], [], []  # Blank arrays
    currTime = 0  # Time variable
    plotSpatial(domain, currTime)  # Plot spacial plot
    simTime.append(currTime)  # Log time
    healthy.append(np.count_nonzero(domain == 0)+np.count_nonzero(domain == 2))  # Log number of healthy cells
    cancer.append(np.count_nonzero(domain == 1))  # Log number of cancer cells
    count = 0  # Number of fighter cells
    for currTime in range(1, 101):  # 101 iterations
        domain = update(domain, count)  # Update
        count = count + 1  # Add one fighter cell
        if np.count_nonzero(domain == 1) > 700:  # If there are more than 700 cancer cells
            count = count - 1  # Subtract one fighter cell
        plotSpatial(domain, currTime)  # Plot Spacial
        simTime.append(currTime)  # Log time
        healthy.append(np.count_nonzero(domain == 0)+np.count_nonzero(domain == 2))  # Log number of healthy cells
        cancer.append(np.count_nonzero(domain == 1))  # Log number of cancer cells
    temporal_dynamics = [simTime, healthy, cancer]  # Combine 3 arrays
    plotDynamics(temporal_dynamics)  # Line graph
```

Update

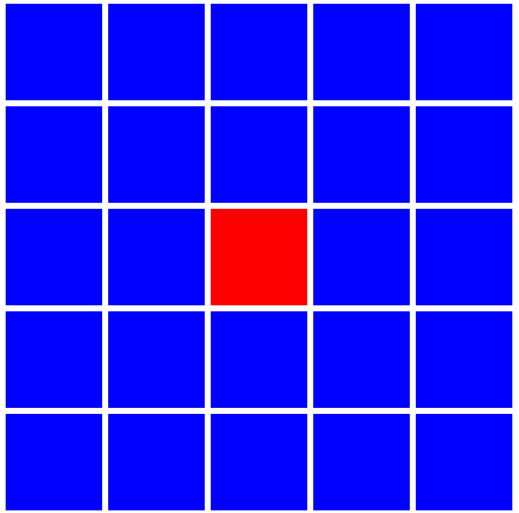
```
def update(array1, fighters):  # Update function creates new spacial plot
    array2 = [[0]*30]*30  # Creates a 30 by 30 array of 0
    array2 = np.array(array2)  # Converts the array to a numpy array
    fighterX = []  # Array to store the x values of the fighter cells
    fighterY = []  # Array to store the y values of the fighter cells
    for i in range(30):  # For loop for each row
        for j in range(30):  # For loop for each column
```

Moore Neighborhood

Radius 1



Radius 2



Rules

- Initial 2.5% chance for multiplication.
- +5% for every cancer cell within a radius of 1
- Fighter cell within a radius of 2 will neutralize the cancer cell.

Cancer Cell Rules

```
if array1[i][j] == 1:  # If the position is a cancer cell
    prob1 = 0.025  # Set probability of multiplication to 2.5%
    # For Moore neighborhood with radius 2
    for k in range(5):
        for l in range(5):
            if i - 2 + k < 30 and j - 2 + l < 30 and i - 2 + k >= 0 and j - 2 + k >= 0:  # Checks for bounds
                if (array1[i - 2 + k][j - 2 + l]) == 2:  # If the neighbor is a fighter cell
                    prob1 = -10  # Set probability of multiplication to -10000%
    # For Moore neighborhood with radius 1
    for x in range(3):
        for z in range(3):
            if i - 1 + x < 30 and j - 1 + z < 30 and i - 1 + x >= 0 and j - 1 + z >= 0:  # Checks for bounds
                if (array1[i - 1 + x][j - 1 + z]) == 1:  # If the neighbor is a cancer cell
                    prob1 = prob1 + 0.05  # Add 5 to probability of multiplication
    # For Moore neighborhood with radius 1
    for a in range(3):
        for b in range(3):
            if i - 1 + a < 30 and j - 1 + b < 30 and i - 1 + a >= 0 and j - 1 + b >= 0:  # Checks for bounds
                randNum = random.random()  # Generate random number between 0 and 1
                if (array1[i - 1 + a][j - 1 + b]) == 1:  # If the neighbor is a cancer cell
                    array2[i - 1 + a][j - 1 + b] = 1  # Keep cancer cell as cancer cell
                if (array1[i - 1 + a][j - 1 + b]) == 0:  # If the neighbor is a healthy cell
                    if prob1 > randNum:  # If probability of multiplication is greater than random number
                        array2[i - 1 + a][j - 1 + b] = 1  # Change healthy cell to cancer cell
                    else:
                        array2[i - 1 + a][j - 1 + b] = 0  # Keep healthy cell as healthy cell
```

Rules

```
for z in range(len(fighterX)):  # For each fighter cell
    randNum1 = random.random()  # Generate random number between 0 and 1
    # For Moore neighborhood with radius 1
    for k in range(3):
        for l in range(3):
            if fighterX[z] - 1 + k < 30 and fighterY[z] - 1 + l < 30 and fighterX[z] - 1 + k >= 0 and fighterY[z] - 1 + k >= 0:  # Checks for bounds
                if randNum1 < 0.65:  # Probability of 65%
                    array2[fighterX[z] - 1 + k][fighterY[z] - 1 + l] = 0  # Change neighbor to healthy cell
```

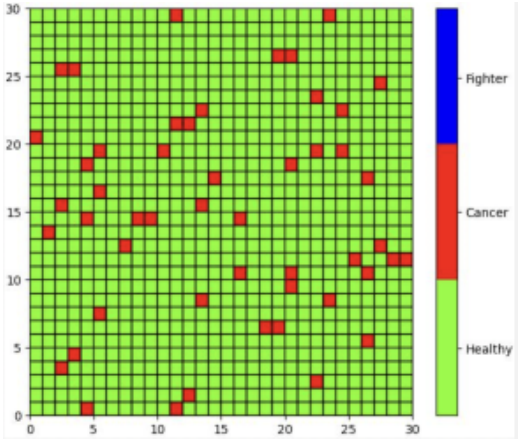
- 65% chance to make neighbors within a 1 radius healthy

Update

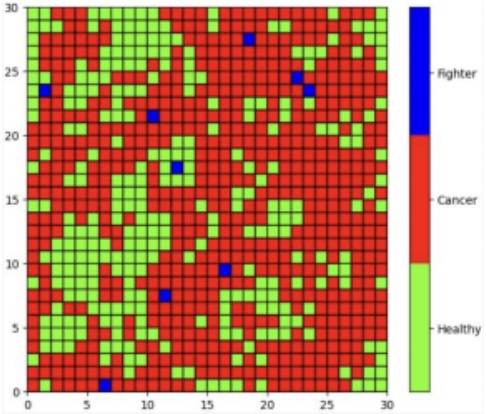
```
while np.count_nonzero(array2 == 2) < fighters:  # For the number of fighters
    randNum1 = int(random.random()*30)  # Generate random x position
    randNum2 = int(random.random()*30)  # Generate random y position
    array2[randNum1][randNum2] = 2  # Place fighter cell
return array2  # Return new plot
```

Simulations

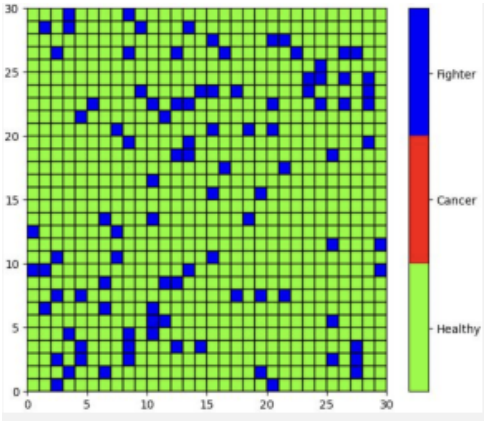
Stage 1



Week 1



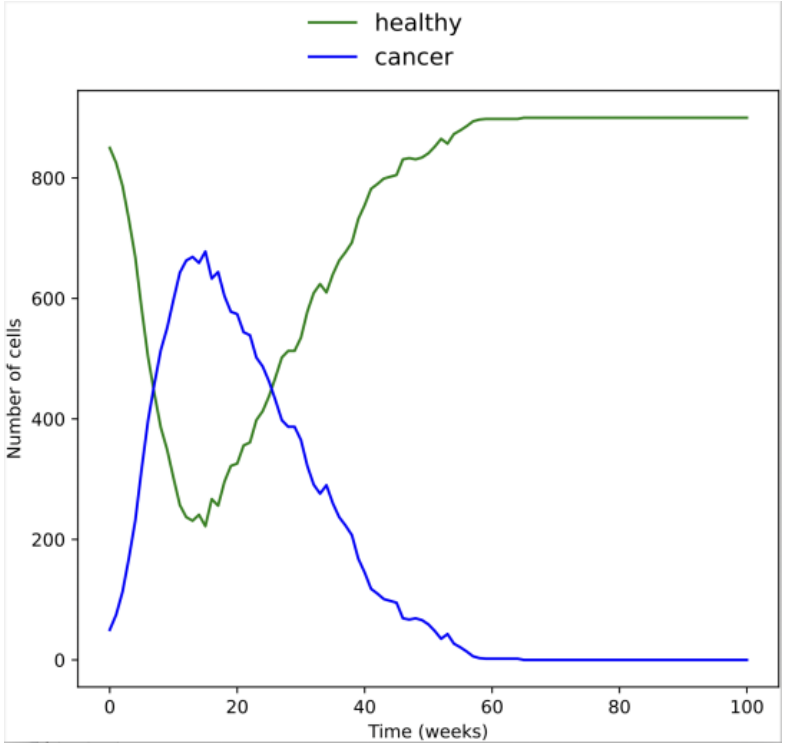
Week 10



Week 100

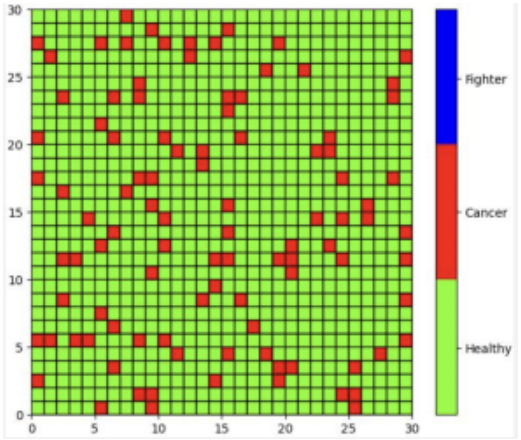
Simulations

Stage 1

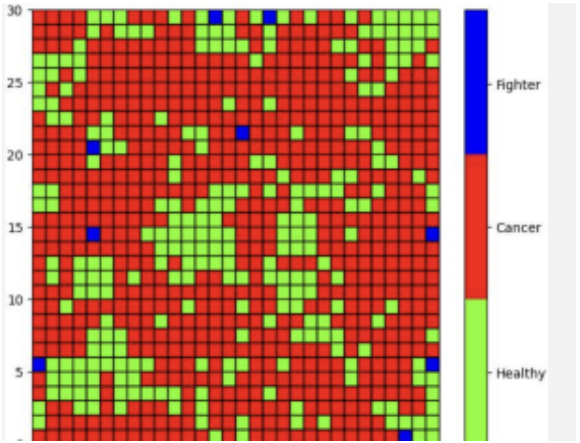


Simulations

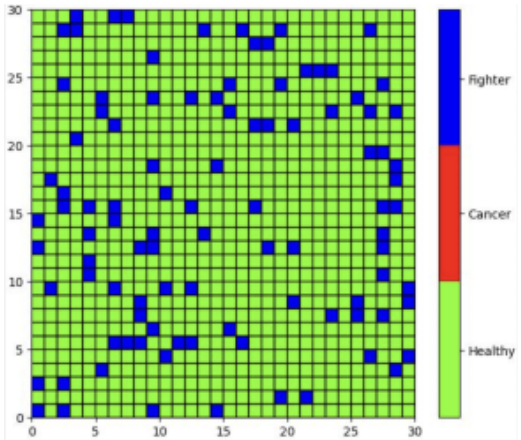
Stage 2



Week 1



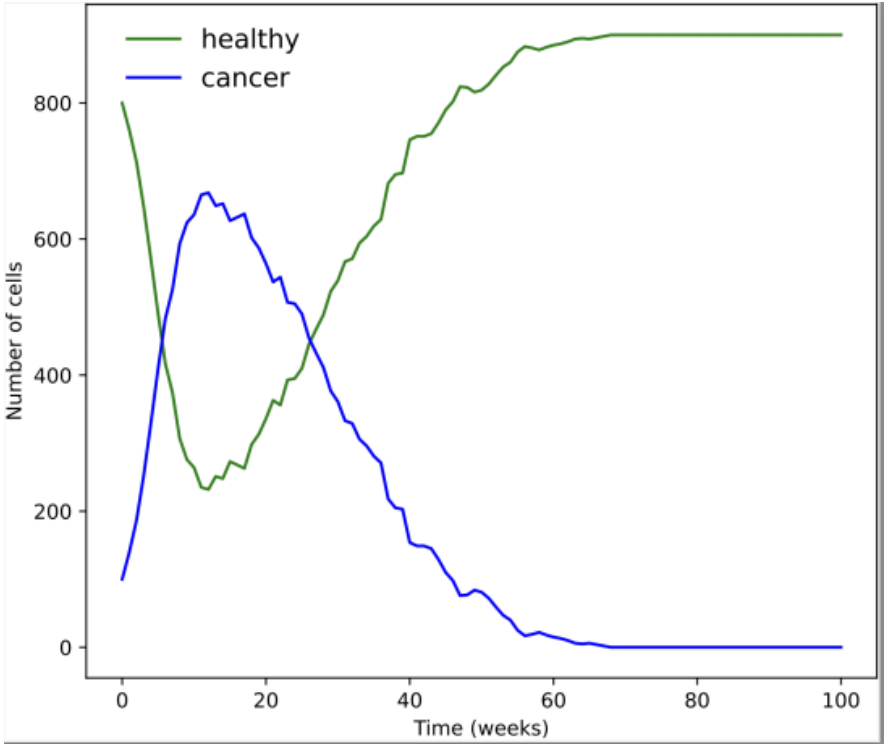
Week 10



Week 100

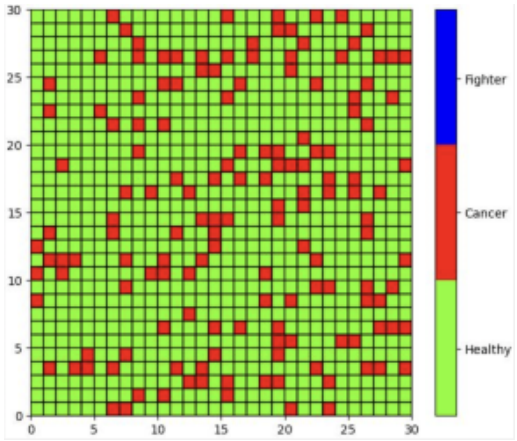
Simulations

Stage 2

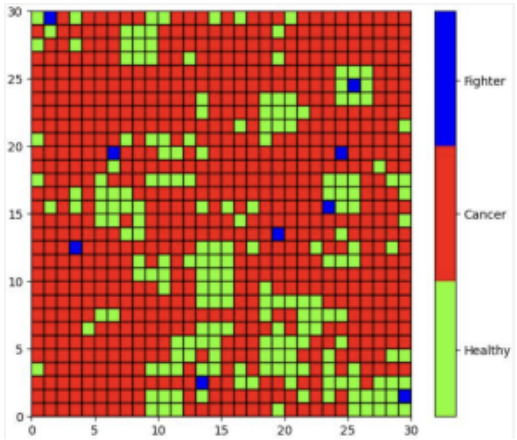


Simulations

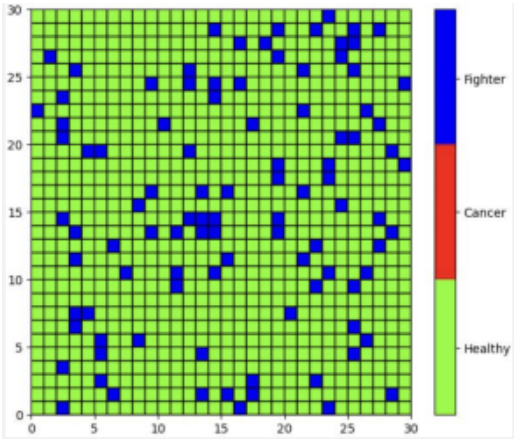
Stage 3



Week 1



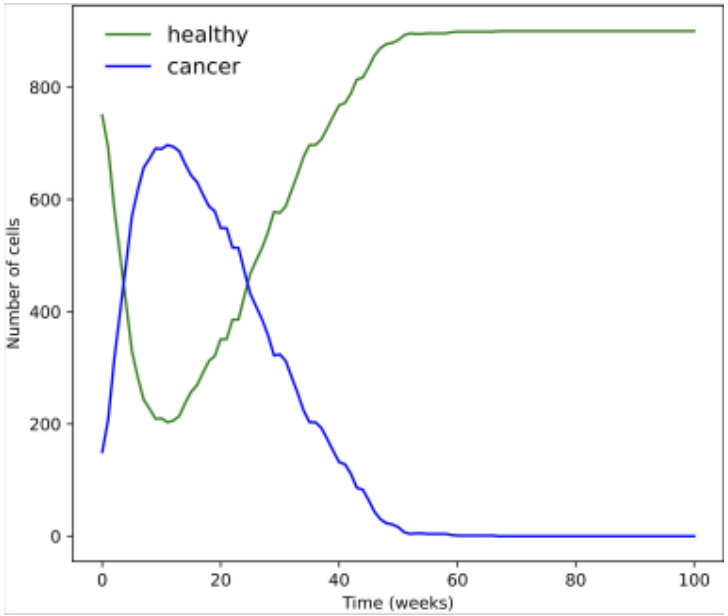
Week 10

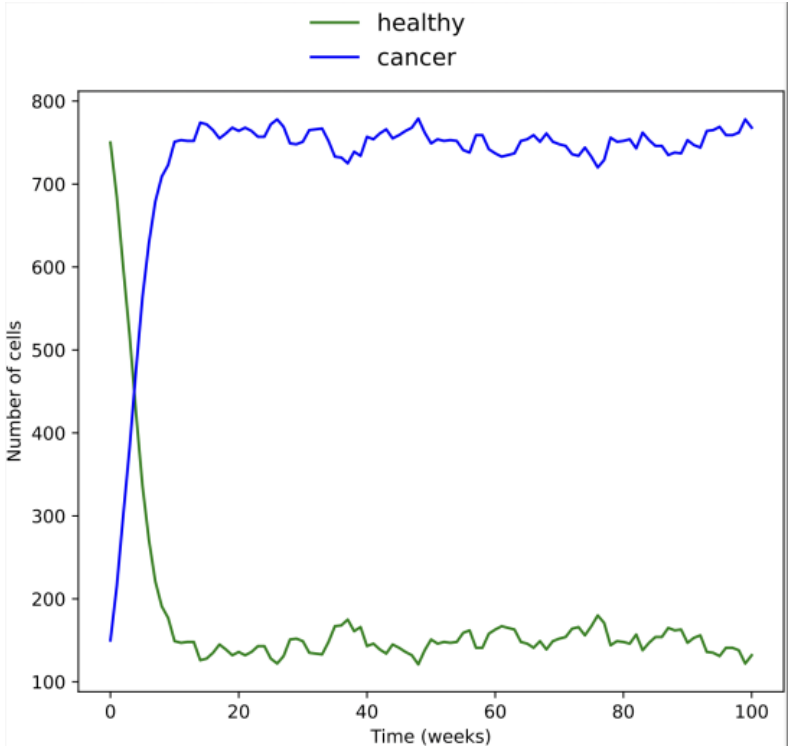


Week 100

Simulations

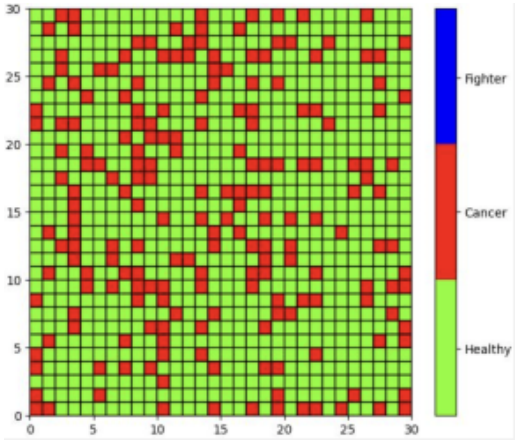
Stage 3



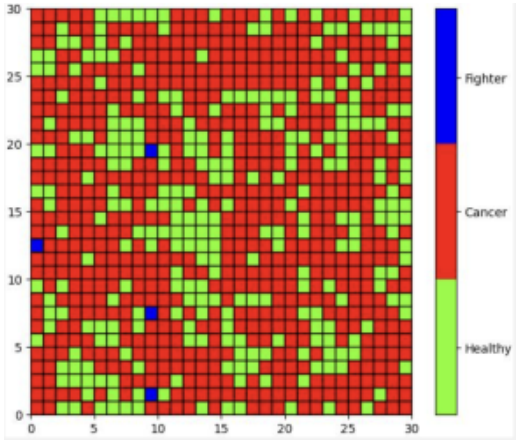


Simulations

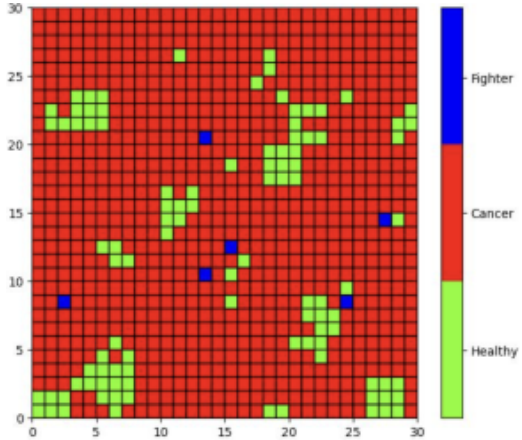
Stage 4



Week 1



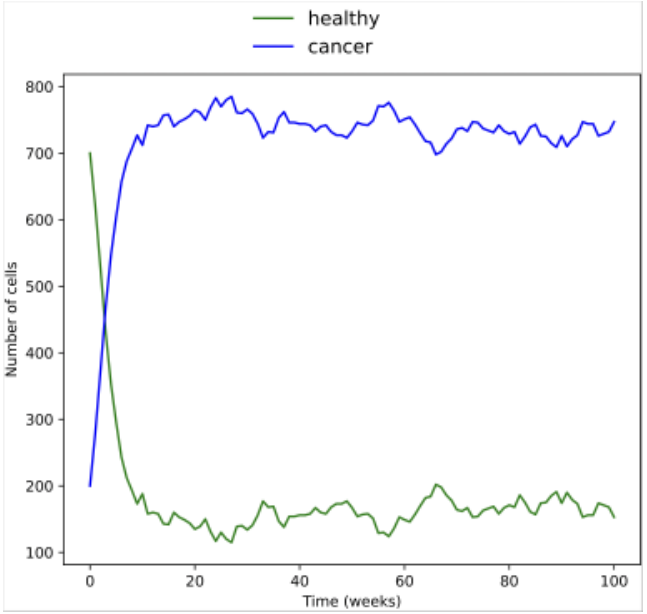
Week 5

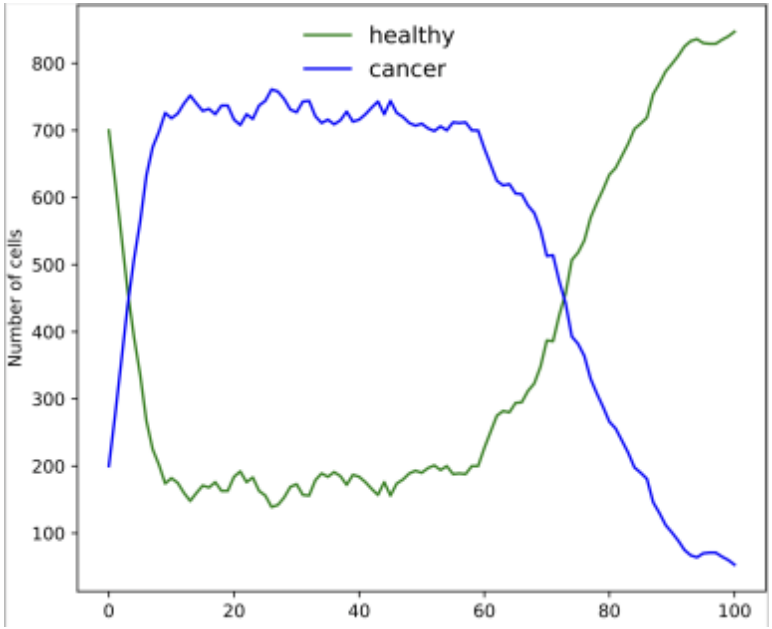


Week 50

Simulations

Stage 4





Challenges

Language: Python
No Classes Used

Borders

```
if i - 1 + x < 30 and j - 1 + z < 30 and i - 1 + x >= 0 and j - 1 + z >= 0:  # Checks for bounds
```

```
if i - 2 + k < 30 and j - 2 + l < 30 and i - 2 + k >= 0 and j - 2 + k >= 0:  # Checks for bounds
```

Limitations

- The update function simulates the action of the cells in top row and first column first
- There are other cells in the human body such as white blood cells that interact with cancer and foreign substances.
- Cancer mutates, rendering certain treatments useless

Conclusion

- Early detection is crucial for survival of the patient.
- Diagnosing cancer before it has the chance to spread too far means that treatment is more likely to be successful
- When cancer care is delayed or inaccessible there is a lower chance of survival, greater problems associated with treatment and higher costs of care.

References

https://www.cancer.gov/about-cancer/understanding/statistics

https://www.who.int/activities/promoting-cancer-early-diagnosis#:~:text=Early%20diagnosis%20of%20cancer%20focuses,and%20higher%20costs%20of%20care.

https://www.mayoclinic.org/tests-procedures/cancer-treatment/about/pac-20393344

https://www.worldcancerday.org/what-cancer

https://www.who.int/activities/promoting-cancer-early-diagnosis#:~:text=Early%20diagnosis%20of%20cancer%20focuses,and%20higher%20costs%20of%20care.