Title: Genetic Algorithm for Progenitor Cells

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Background/Introduction:

In this lab we explore how cancer cells' abilities to survive and reproduce are impacted by changes to their genetic information. We start by modifying Lab 5's *Life, Death, and Tumors* simulation. In our new version, the simulation starts with 10 stem cells, whose nuclei are represented by a different color to help us distinguish them. Cells reproduce by dividing themselves. When they divide, the daughter cell inherits its parent's genetic information, which contains its nuclei color, its division rate, its lifespan length, its mutation rate and its telomere length. During reproduction, a cell's genetic information has a 0.1% (one in a thousand) chance of mutating. When a mutation occurs, a cell's division rate, lifespan length, mutation rate or telomere length is set to a random number.

The first simulation will start with 10 stem cells, whose lifespan will range incrementally from 100 to 350. Their mutation will set the lifespan to a random amount between 100 and 350. Our prediction is that the closer the cell type's lifespan is to 350, the higher its chance of survival, and the more of them there will be at the end of the simulation.

The second simulation will also start with 10 stem cells, whose reproduction rate will range incrementally from 0.001 to 0.003, giving the cell a 0.1% to a 0.3% chance of reproducing in each iteration. Their mutation will set the reproduction rate to a random amount between 0.001 to 0.003. Our prediction is that the closer the cell type's reproduction rate is to 0.003, the higher its chance of survival, and the more of these types there will be at the end of the simulation.

Both simulations will end after 10,000 iterations, at which point we may examine which cell types survived, as well as their prevalence.

Methods:

- We inherit code from Lab 5's Life, Death, and Tumors program
- We set stemCells to 10, so that the program starts with 10 stem cells, who all have a differently colored nucleus. Each color represents a different cell type
- For simulation 1 we set each of these stem cell's lifespan to somewhere between 100 and 350, with increments of 25 between cell types
- For simulation 2 we set each of these stem cell's reproduction rate to somewhere between 0.001 and 0.003, with increments of 0.0002 between cell types
- We create the colorSpecturm function which takes an integer as input and returns a color. The color is picked by mapping the integer to a rainbow-like color spectrum, where 0 is the far left side, and 255 is the far right side of the spectrum. This is used to select the nuclei color of the cells

- The prolif attribute, which was used to adjust the proliferation rate of cells, has been renamed to divisionRate, and has been moved out of the tumor class to the CellWalker class, so that various cell types within a tumor can have different proliferation rates
- CellWalker's display method was changed to use an imputed color as the nucleus color
- CellWalker's reproduce method was changed to return a cell, whose nucleus color, division rate, lifespan, mutation rate and telomere length are the same as the current cell
- The mutate method was added to CellWalker, which when called has chance, which is determined by the nutationRate attribute, of mutation. A mutation changes the division rate, lifespan, mutation rate, or telomere length (depending on which one we select) to a random amount.
- Setters setDivisionRate, setLifespan, setMutationRate, and setTelomeres were added to CellWalker
- StemCell's reproduce method was changed to function like CellWalker's reproduce method, but like in Lab 5's Life, Death, and Tumors program, it returns either a CellWalker or a StemCell object. The probability of each is determined by StemCell's symprob attribute

Results:

We modified the code from Lab 5's Life, Death, and Tumors program, to more accurately simulate the impact that genetics have on cell behavior. Our new program allowed us to set a cell's nucleus to a specific color, which its daughter cells would inherit. The cell object's attributes that decide its division rate, lifespan length, mutation rate and telomere length were also treated like genes which could be passed on to the next generation. In our simulations, these genes had a 0.1% chance of mutating. When a gene mutated, the respective attribute was set to a new random value. When a mutated cell reproduced, it's daughter cell inherited the mutation.

Our first experiment started with 10 stem cells, which differed from each other in the color of their nucleus and in the length of their lifespan. The stem cell with the shortest lifespan had a lifespan of 100 and had a red nucleus. The stem cell with the longest lifespan had a lifespan of 350 and had a violet nucleus. The stem cell's lifespan lengths differed by incrementally of 25. The color of the nucleus changed in sync with the difference in lifespan, where the longer a cell's lifespan, the larger the number of its associated nucleus color from figure 3. The simulation ran for 10000 iterations. The screenshots in figure 1 depict the end state of 3 of these simulations. All the cells in this state had purple and blue nuclei, which means that only stem cells that started with a lifespan length of 250 or greater survived. Among the surviving cell types, the most prevalent ones are those with a lifespan length of 300 or more. Mutation didn't appear to play a significant role in the outcomes. Overall our predictions proved to be correct.

Our second experiment started with 10 stem cells, which differed from each other in the color of their nucleus and in their division rate. The stem cell with the lowest reproduction rate had a 0.1% chance of reproducing in each iteration and had a purple nucleus. The stem cell

with the highest reproduction rate had a 0.3% chance of reproducing in each iteration and had a red nucleus. The reproduction rate incrementally increased by 0.02%. The color of the nucleus changed in sync with the difference in reproduction rate, where the lower a cell's reproduction rate, the larger the number of its associated nucleus color in figure 3. The simulation ran for 10000 iterations. The screenshots in figure 2 depict the end state of 3 of these simulations. Most of the cells in this state had red, brown or green nuclei, which means that the higher the reproduction rate, the higher the chance a cell would survive. The simulation's end states also included cells with blue and purple nuclei, meaning that a 0.1% mutation rate can be sufficient to survive. This unexpected outcome may in part be attributed to cell mutation. Our prediction that cells with a higher reproduction rate will generally be more successful proved to be correct. The irregularity of these results was unexpected though. We thought that cells whose odds or reproducing were threefold would be significantly more successful. Discovering why this was not the case is worthy of further inquiry.

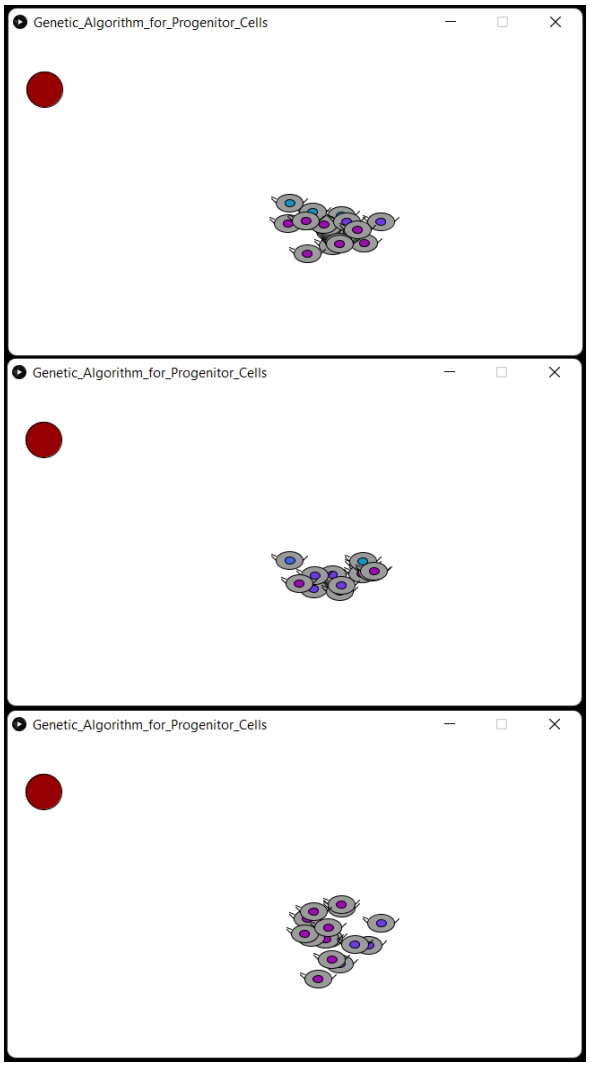

Figure 1: Three outcomes of the first simulation after 10000 iterations. The cells in this figure are characterised by longer lifespans.

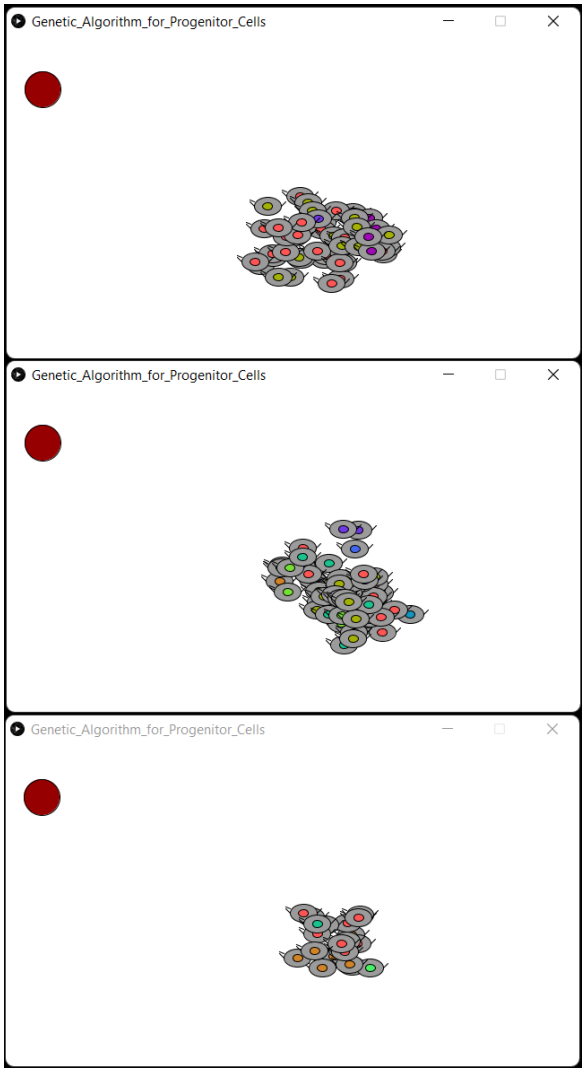

Figure 2: Three outcomes of the second simulation after 10000 iterations. The lower the number associated with the cell's nucleus color from figure 3, the higher the cell's reproduction rate.

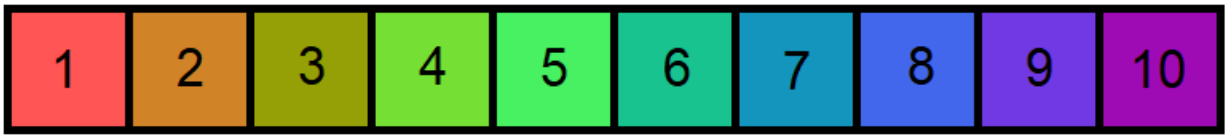

Figure 3: A list of colors that are used as nucleus colors in the simulations. They were obtained using the colorSpectrum function.

Conclusion: We have created a simulation which builds on our *Life, Death, and Tumors* simulation, adding nucleus coloring and genome influence on cell reproduction and behavior. We were able to prove our assumption that cells with longer lifespans and higher reproduction rates are more likely to survive. With the parameters we used, we also found that lifespan length

is significantly more influential in a cell's survival than its reproduction rate. We found no significant effects of the cells' ability to mutate in the first simulation. We found irregularities in the second simulation, which may have been caused by cell mutations.

Credit/Acknowledgements: We used our Life_Death_and_Turmors homework code as a template.

Citations:

Life_Death_and_Tumors, Brightspace - Lab Report 5, Josef Lazar. https://bardcollege.brightspace.com/d2l/le/dropbox/8339/6757/DownloadSubmissionFile?fid=416002&sid=49726