Simulating the Immune System

Aditya Suresh

Oakridge Elementary

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Question

We all get sick. What defends us from invading pathogens like bacteria and viruses? **Our immune system.** Our immune system has many kinds of white blood cells. These cells each have an important role in killing pathogens.

I wondered how the immune system works. What do the different cell types do and how do they interact together to kill pathogens?

To answer this question I used Processing, a programming language, to simulate the immune system and to model how different pathogenic infections so we can better understand how our immune system works.

Hypothesis

A realistic immune system simulator can be built using Processing (a Java-based visualization language).

Research

- I have learned many things about the immune system, including what cells are in it. Here is some information about the cells I have simulated:
- **Dendritic cells** eat a pathogen and deliver digested parts of it to a helper-T cell. They do this so that the immune system can tell what to attack.
- **Helper-T cells** deliver the parts to a b-cell, so the b-cell can target the invading pathogens.
- **B-cells** use the parts to create proteins called antibodies which stick to the specific type of pathogen.
- **Macrophages** migrate to the pathogens with antibodies and swallow them, killing them instantly. They can only kill viruses flagged with antibodies, but they can kill bacteria without needing an antibody.
- Finally, **killer-T cells** kill infected cells. Since viruses reproduce inside cells, they can also be killed inside them.

Procedure

- First, I researched about immune cells and pathogens to create an accurate simulation.
- Next, I programmed the simulation using Processing.
- Then, I ran several experiments with the code simulating various immune system encounters.
- Last, I recorded the data with Microsoft Excel and made my poster with PowerPoint.

Data/Observations

For my project, I have ran my simulation several times to produce many experiments including the following:

- A virus infection
- A protected virus infection(with only Killer-T cells)
- A virus infection with the entire immune system

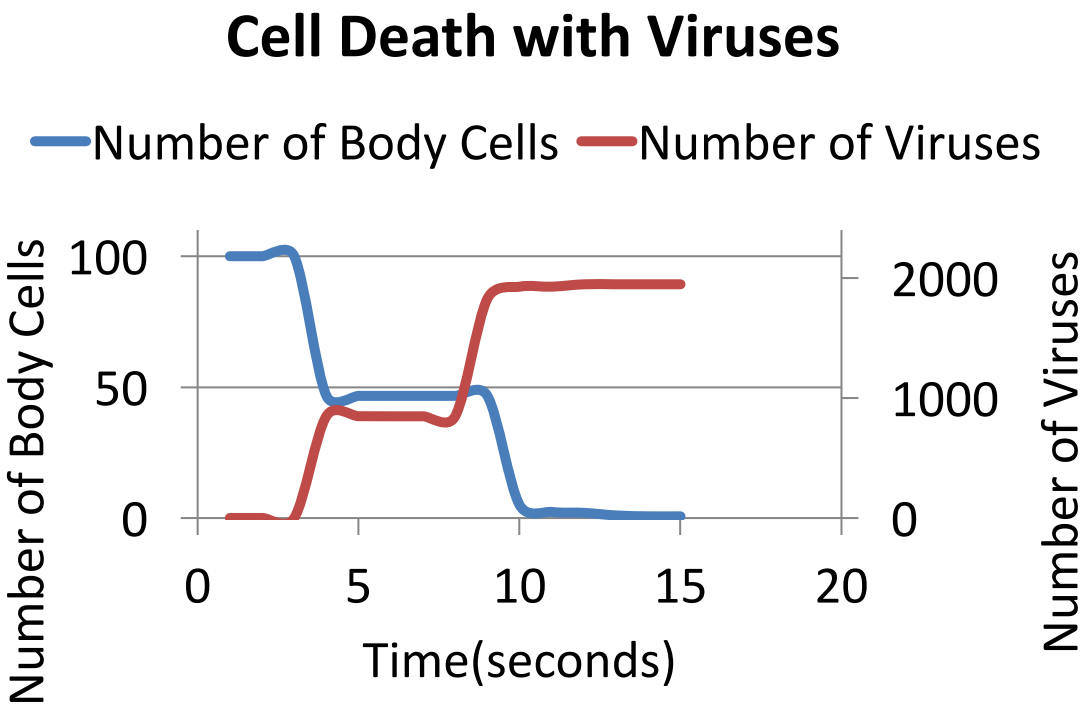
A bacteria infection

- A protected bacteria infection(with macrophages)

I will present each experiment in the following order.

Data/Observations: Experiment One

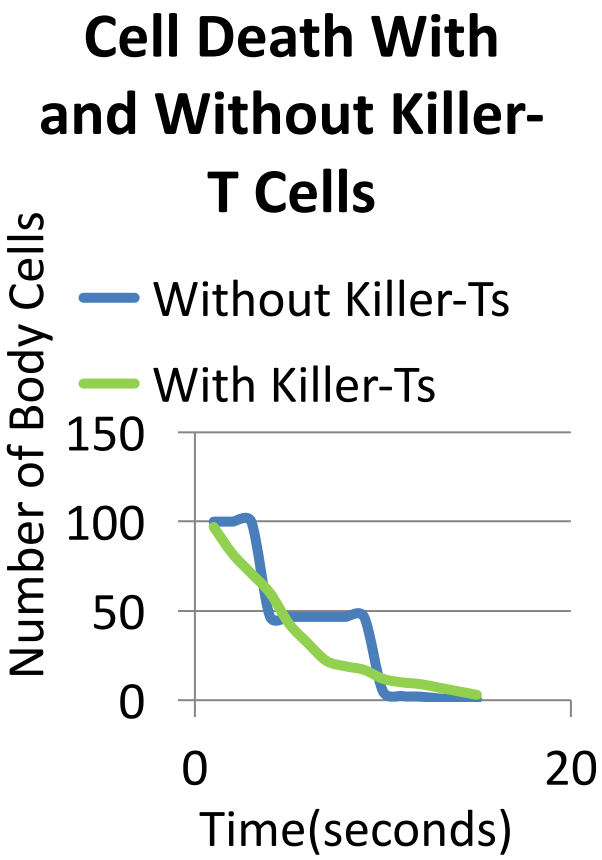
- In my first experiment, I simulated 100 body cells with one virus. The body cells had no protection from the virus.

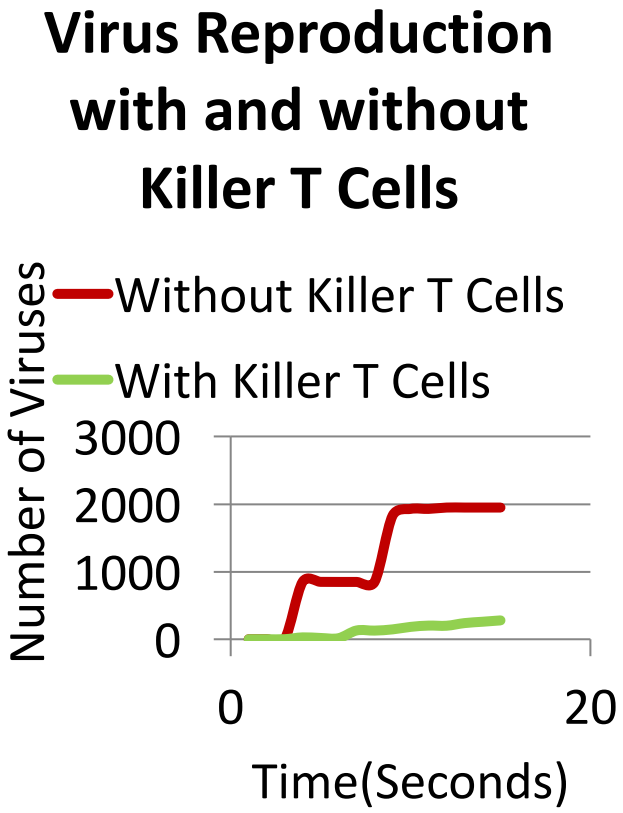


In this experiment, the number of body cells decreases rapidly, as the number of viruses go up(reproducing). By the end of 15 seconds, the population on body cells was dead and the number of viruses almost reached 2000.

Data/Observations: Experiment Two

- In this experiment, I simulated the same number of body cells and viruses except with 10 Killer-T cells. These cells are useful because there is a lot of time in this experiment for them to kill the infected cells, since the viruses take time to reproduce inside cells.



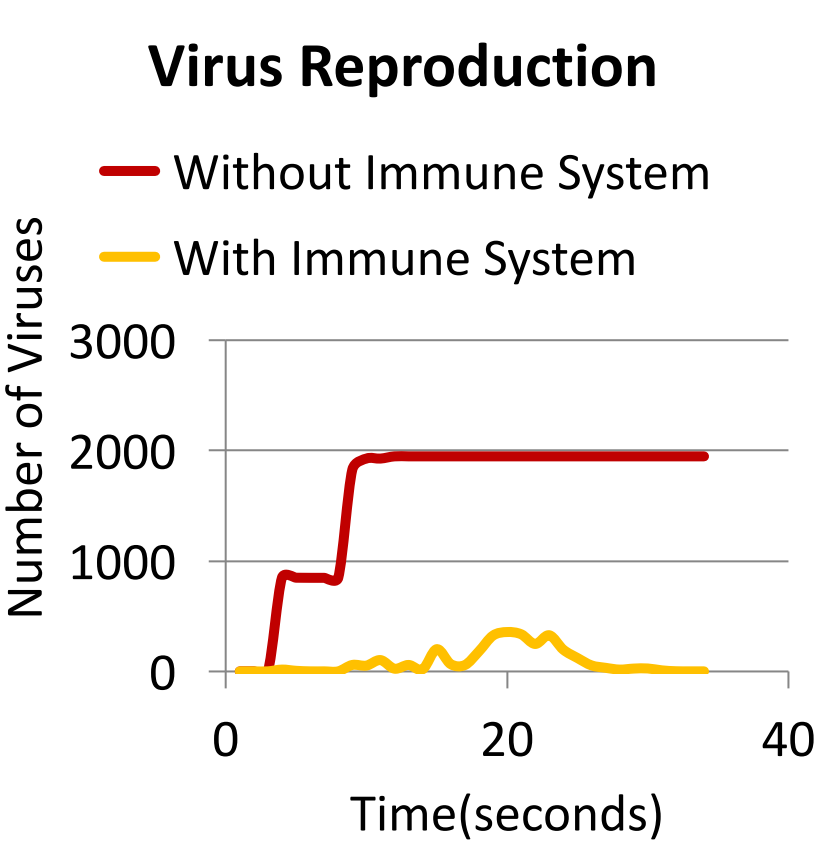


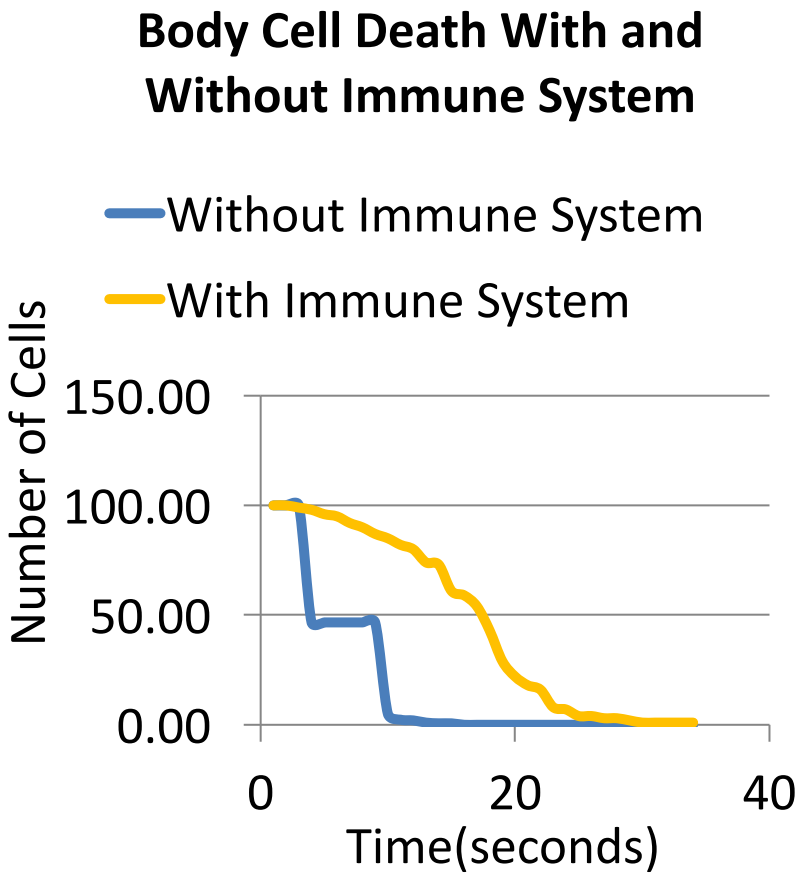
In this experiment, the impact of the Killer-T cells is big. In the first chart, (Cell Death With and Without Killer-T Cells) the impact is not large. The body cells without the Killer-T cells die in large amounts, whereas with the Killer-T cells, the death curve is much smoother. In a matter of 15 seconds, both numbers of body cells are gone.

In the second chart,(Virus Reproduction with and without Killer T Cells), the impact is huge. Without the Killer-T Cells, the virus population grows to almost 2000 after a matter of 15 seconds, whereas with the Killer-T cells, the number of viruses only reaches less than 500. So, the addition of Killer-T cells vastly decreases the number of viruses.

Data/Observations: Experiment Three

- This experiment is the main experiment of the entire project; it demonstrates the effect of the entire immune system to protect body cells and destroy viruses. (See research slide for types of simulated cells). Discussion is on the next slide.



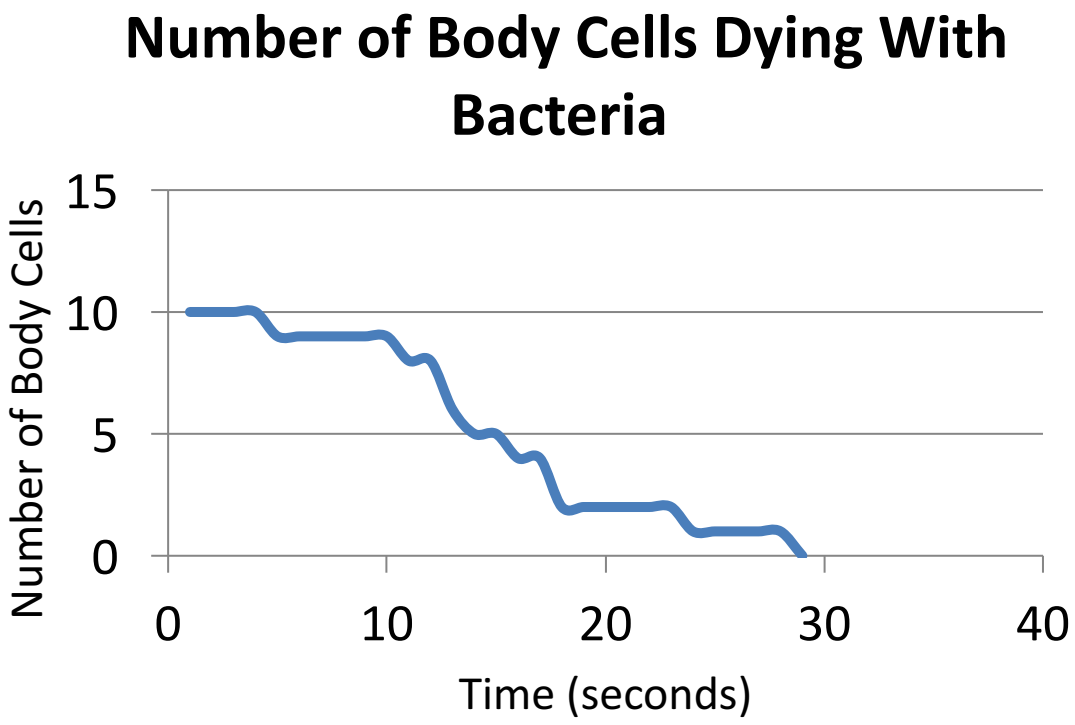


Data/Observations: Experiment Three Discussion

- In these results, the effect was the most significant. The chart on the right shows the death of body cells with (red) and without(blue) the immune system. The impact of the immune system shows that the cells without the immune system died significantly before the cells with the immune system did. In the chart on the left, the effect is also extremely large. The viruses without the immune system replicated much more than the viruses with the immune system. In fact, the viruses with the immune system were destroyed after awhile. So, the immune system impacted the body cells and the viruses the most. (**See charts**)

Data/Observations: Experiment 4

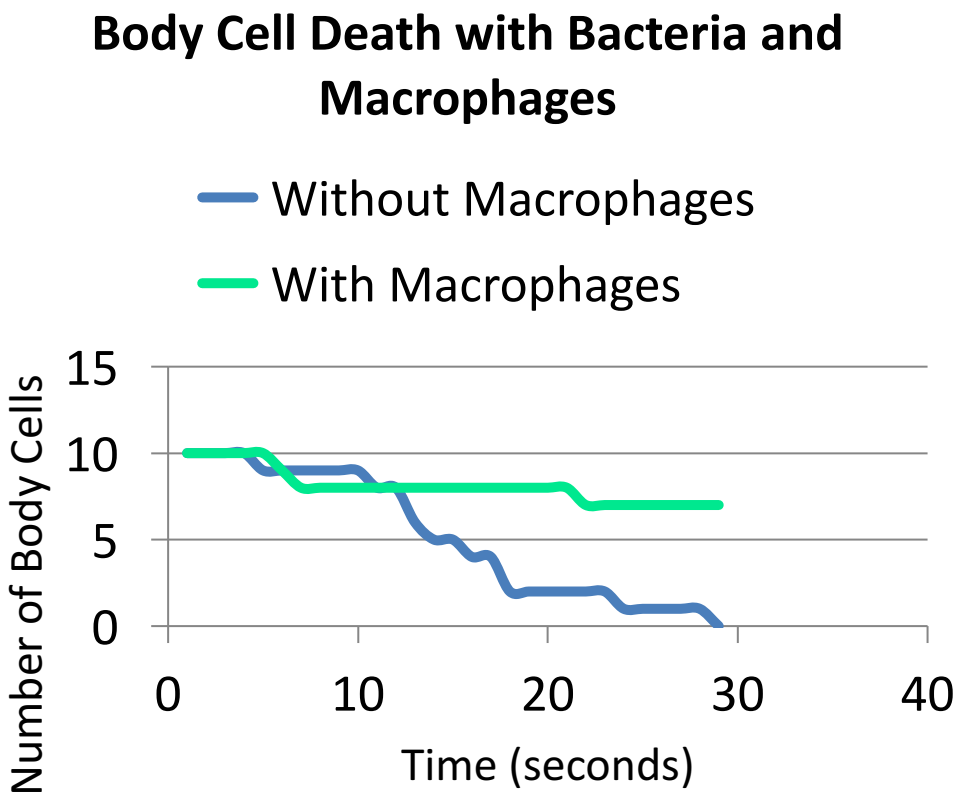
- In this experiment, I used 10 body cells and 1 bacteria, with nothing protecting the bacteria. (Since the bacteria kill much slower, I used only 10)



In this experiment, the body cells died smoother and slower, all body cells died after 30 seconds.

Data/Observations: Experiment 5

- In this experiment, I used the same number of body cells and bacteria, except I added 10 macrophages. This addition is useful because macrophages can eat bacteria.



In this experiment, the impact was also significant. After a matter of 30 seconds, the body cells with the macrophages were saved, and in the test without the macrophages, all the body cells died.

Conclusion

The simulation reflected aspects of the immune system effectively, based on known behaviors of the immune system.

In this simulation:

- Body cells died when exposed to viruses without an immune system to protect them
- Killer-T cells modestly protected the body cells from viruses by reducing viral numbers
- Adding back the whole immune system effectively protected the body cells
- Bacteria killed body cells with toxins
- The simulated immune system was able to protect cells from bacterial toxins and save body cells

Works Cited

- http://www.diabetes.co.uk/
- Your Amazing Immune System: How it Protects Your Body, compiled by the Japanese Society for Immunology. Wiley-Blackwell 2009. pp. 1-71
- Burillo-Kirch, C, Microbes: Discover an Unseen World. Nomad Press 2015, pp 1-114

- Special Thanks to Dr. Loida Viera-Hutchins, Pediatric Immunology, University of Utah

- To check out my program, go to http://www.cs.utah.edu/~suresh/scienceproject/sciencefair.html