<u>Understanding Sweetness</u>

New Mexico
Supercomputing Challenge
Final Report
April 6, 2022

Team #56
St. Thomas Aquinas School

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Executive Summary

Type two diabetes is a serious problem for a lot of people, even people close to me. Type two diabetes is when your body stops using insulin correctly, and you can't process sugar as well. Type two diabetes is a big problem in modern day that needs to be solved.

My project is about how to regulate the blood sugar of a diabetic, and how things like carbohydrates and exercise affect it. If type two diabetes can be understood, then we can learn how to fix most people's diabetic problems.

Using the NetLogo Blood Sugar Regulation model I learned how the body would react to different foods and different amounts of exercise. In my blood sugar model I looked closer at how foods like donuts, high-carb, and foods like broccoli, low-carb, affected a diabetics blood sugar.

My model shows that the best way to help modern day diabetics is to eat low-carb meals and exercise regularly. This will prevent spikes and keep the blood sugar as low as possible. I am glad I was able to make a model that can act similar to how a real diabetic's blood sugar works. Learning about diabetes can help scientists defeat it once and for all.

Problem Definition

Type two diabetes is a serious problem for a lot of people, even people close to me. My mom, grandma and great grandparents all have or had diabetes. Chances are very high that I could get diabetes. That is why this project is important to me.

Type two diabetes is when your body stops using insulin correctly, and you can't process sugar as well. Some effects of diabetes are heart disease, stroke, and kidney disease (1). Then there are also eye problems, dental disease, nerve damage, and foot problems (2). Type two diabetes is a big problem in modern day that needs to be solved.

If type two diabetes can be understood, then we can learn how to fix most peoples diabetic problems. Using the netlogo blood sugar simulation (3) I can learn how the body will react to different foods and different amounts of exercise. With the original model I will use it as a base for my model. In my blood sugar model I will look closer at how foods like donuts and foods like broccoli will affect a diabetics blood sugar. Learning about diabetes can help scientists to defeat it once and for all.

Methodology

I started by learning and understanding the current Netlogo Blood Sugar Regulation Model. For my experiment I wanted to change the original model by making it easier for a controlled experiment. I wanted to focus more on the level of carbs and sugar in the food the person eats and what times they eat at. I wanted to focus on Exercise, Diet and meal choices and compare between normal and diabetic people. The original model had ways to model diabetic and non-diabetic people and exercise by using the metabolic rate slider. Except I thought the original model made it difficult to make a controlled experiment with the button for eating so I changed it to three set meals using the ticks. In the model every tick equals 7 minutes. In one day there are 1,440 minutes or 206 ticks per day. So if the model starts at dinner time then breakfast is at 111 ticks later, lunch is at 154 ticks later, and the next dinner is at 206 ticks later. Using the mod function and the ticks of the model and the meal times I made the 3 meals a day automatic. Then I made a chooser control for meal choices (see Appendix A), I had low-carb, normal, and high-carb meal options. Normal is the original meal setting of the model. Low-carb meal uses fewer calories for the meal spread over a longer time period. And high-carbs have more calories released over a shorter period of time. I also had the model end after two weeks also using the ticks (see code changes in Appendix B).

I played with the new model and tested and chose the metabolic rate value for exercise and non-exercise (see Table 1) and similarly chose the sensitivity of glucose, glucagon and insulin to represent diabetic vs non-diabetic (see Table 2). I also chose the meal size and length (see Table

3). Then I got help to design my experiment. I ran 3 simulation runs of each combination of diet, exercise and diabetes. So I had 36 total simulations (see Table 4). I exported the data as csv files (see Appendix C).

Table 1: Metabolic rate for Exercise and Non-Exercise

Variable	Metabolic Rate
Exercise	140
Non-Exercise	40

Table 2: Glucose, Insulin and Glucagon Sensitivity for Diabetic and Non-Diabetic

Variable	Glucose, Insulin, Glucagon Sensitivity
Diabetic	0.40
Non-Diabetic	0.90

Table 3: Meal size and length for low-carb, normal and high-carb choices

Variable	Meal size (kcal)	Meal length (ticks)
Low-Carb	6000	26 (~3 hours)
Normal	7000	17 (~2 hours)
High-Carb	8000	11 (~1 hour)

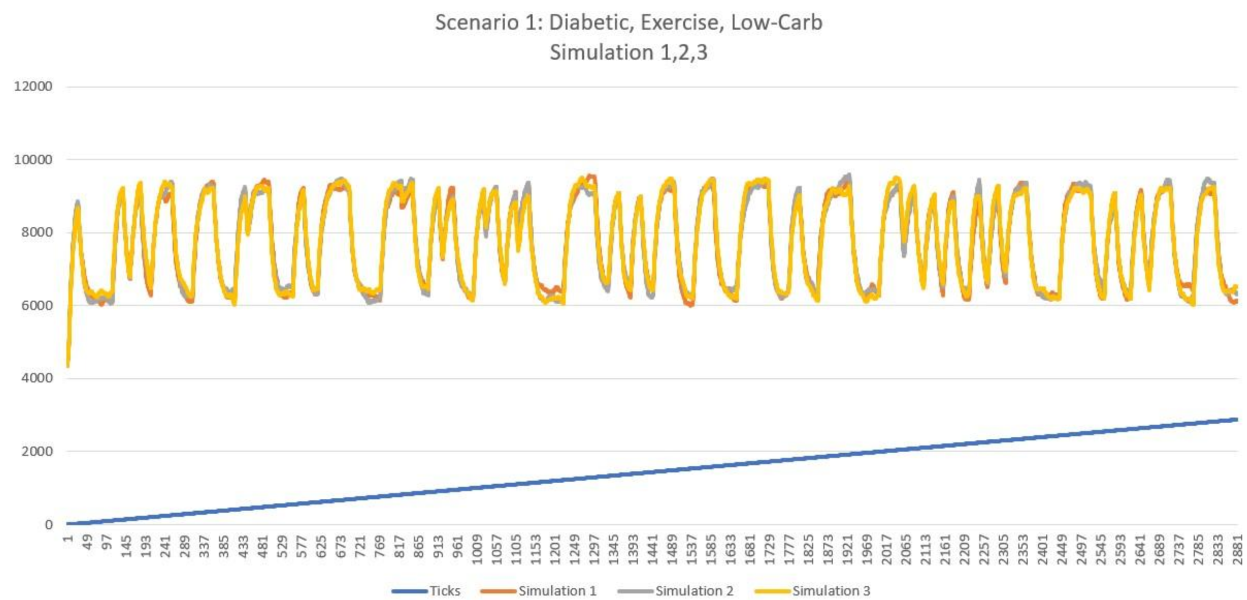
Table 4: Scenarios, each scenario was simulated 3 times

Scenario	Simulation variables		
1	Diabetic	Exercise	Low-Carb
2	Diabetic	Exercise	Normal
3	Diabetic	Exercise	High-Carb
4	Diabetic	Non-Exercise	Low-Carb
5	Diabetic	Non-Exercise	Normal
6	Diabetic	Non-Exercise	High-Carb
7	Non-Diabetic	Exercise	Low-Carb
8	Non-Diabetic	Exercise	Normal
9	Non-Diabetic	Exercise	High-Carb
10	Non-Diabetic	Non-Exercise	Low-Carb
11	Non-Diabetic	Non-Exercise	Normal
12	Non-Diabetic	Non-Exercise	High-Carb

Results

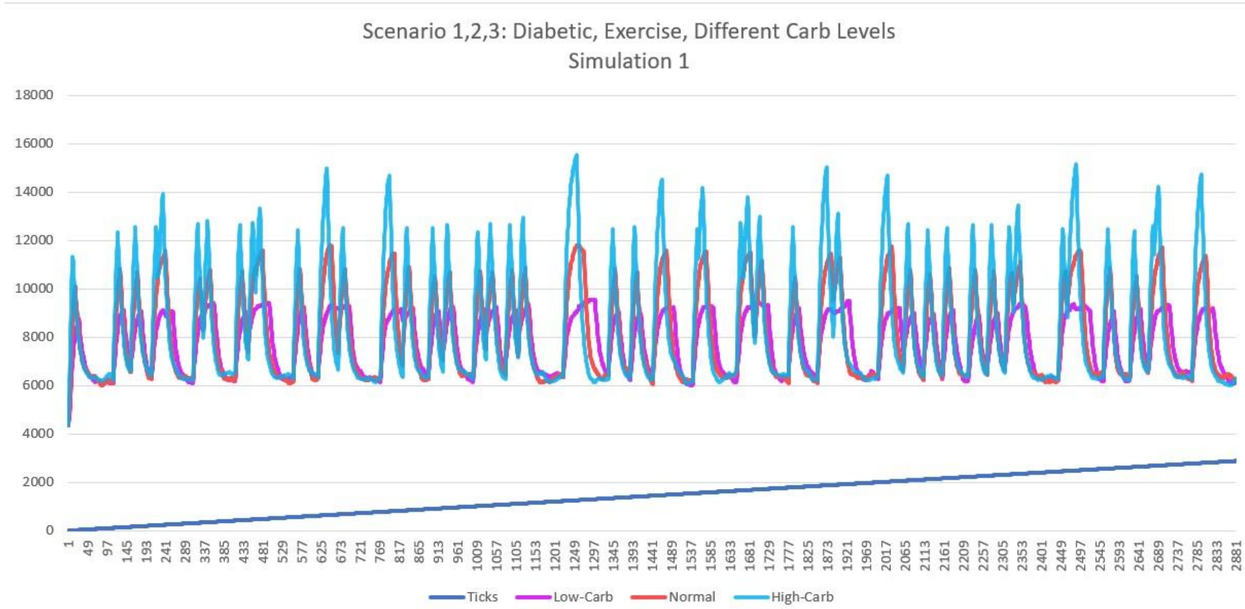
I explored the results by plotting the 3 runs of the first scenario. It showed that each simulation was different but very similar to each other and the blood sugar stayed within the same range through the 2 weeks of ticks (see Chart 1).

Chart 1: Diabetic, Exercise, Low-Carb comparing the 3 simulations



Next I explored the first simulation of the first 3 scenarios. It showed the effect of the 3 different meals, with higher spikes for high-carb and smallest spikes for low-carb (see Chart 2).

Chart 2: Scenarios 1, 2, 3 Diabetic, Exercise, Diet only 1st simulation



In order to analyze all of the data collected, I put all the csv files into 1 Microsoft Excel file with tabs for each csv using Python code (see Appendix D). Then I recorded and modified an Excel macro (see Appendix E) to put all of the data in the 36 tabs into 1 big table (see Appendix F). Then I learned how to do a pivot table in Excel.

Table 5: Pivot table summarizing all of the data collected, 36 simulations

	Column Labels							
	High-Carb		Low-Carb		Normal		Total Average of Glucose	Total Max of Glucose
Row Labels	Average of Glucose	Max of Glucose	Average of Glucose	Max of Glucose	Average of Glucose	Max of Glucose		
Diabetic	**8909**	**16795**	**8440**	**11825**	**8852**	**13425**	**8711**	**16795**
Exercise	8353	15564	7873	11825	8070	11914	8077	15564
Non-Exercise	9465	16795	9197	11063	9374	13425	9345	16795
Non-Diabetic	**3773**	**6601**	**3697**	**4955**	**3740**	**5295**	**3737**	**6601**
Exercise	3580	6091	3527	4955	3562	4979	3556	6091
Non-Exercise	3967	6601	3867	4670	3919	5295	3918	6601
Grand Total	**6341**	**16795**	**6251**	**11825**	**6064**	**13425**	**6224**	**16795**

In the pivot table (see Table 5) it shows how diabetics can’t be cured, but exercise and healthy foods definitely make a difference. Exercise and low-carb meals make a huge difference for diabetics but barely a difference for non-diabetic people. My model suggests that exercise reduces blood sugar better than food does.

Chart 3: Diabetics and Non-Diabetics with and without Exercise

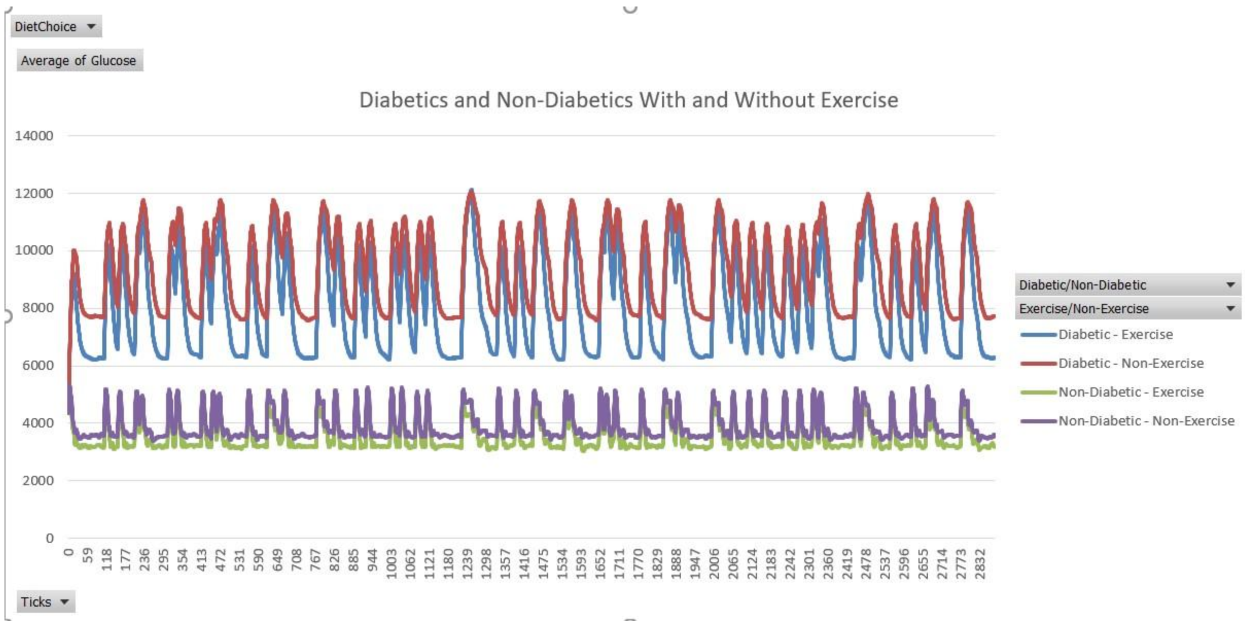
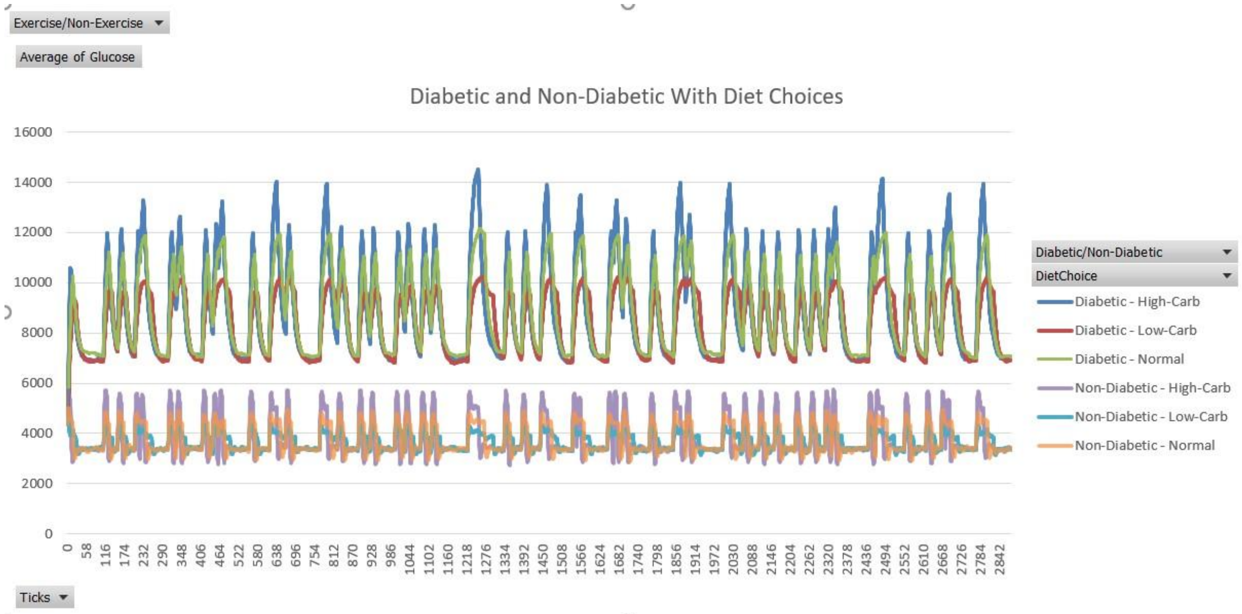


Chart 3 also supports my results of Exercise being better at lowering your sugars. The graph also shows that the Non-Exercise line goes higher than the Exercise line, and still makes no difference in the Non-Diabetic. For diabetics it is very dangerous for their sugars to go too high.

Chart 4: Diabetic and Non-Diabetic with Diet Choices



In Chart 4 we can see that the low-carb meal is the best for not just diabetics, but it is also the best option for non-diabetic people. Although Exercise helped keep the average glucose a small number, it didn't help to keep the spikes from going high.

Conclusion

My model shows that the best way to help modern day diabetics is to eat low-carb meals and exercise regularly. This will prevent spikes and keep the blood sugar as low as possible, so these diabetics can stay healthy.

Using the simulations I was able to prove my belief that when a diabetic eats sugar it will make their blood sugar levels rise and if they eat healthy then it will keep their blood sugar lower. I also saw that when a type two diabetic does exercise it decreases their blood sugar.

I am glad I was able to make a model that can act similar to how a real diabetic’s blood sugar works. I see the similarities between my mother’s glucose monitor graphs and the graphs from the NetLogo simulations. Now I can always give the diabetics I know a way to control their sugars and be healthy. With these simulations I can prepare myself if I ever get diabetes and take better care of myself.

References

1. https://www.cdc.gov/diabetes/managing/manage-blood-sugar.html
2. https://www.niddk.nih.gov/health-information/diabetes/overview/what-is-diabetes
3. http://www.netlogoweb.org/launch#http://ccl.northwestern.edu/netlogo/models/models/Sample%20Models/Biology/Blood%20Sugar%20Regulation.nlogo
4. https://www.hsph.harvard.edu/nutritionsource/carbohydrates/carbohydrates-and-blood-sugar/
5. https://en.wikipedia.org/wiki/Blood_sugar_regulation
6. https://pubmed.ncbi.nlm.nih.gov/34959894/

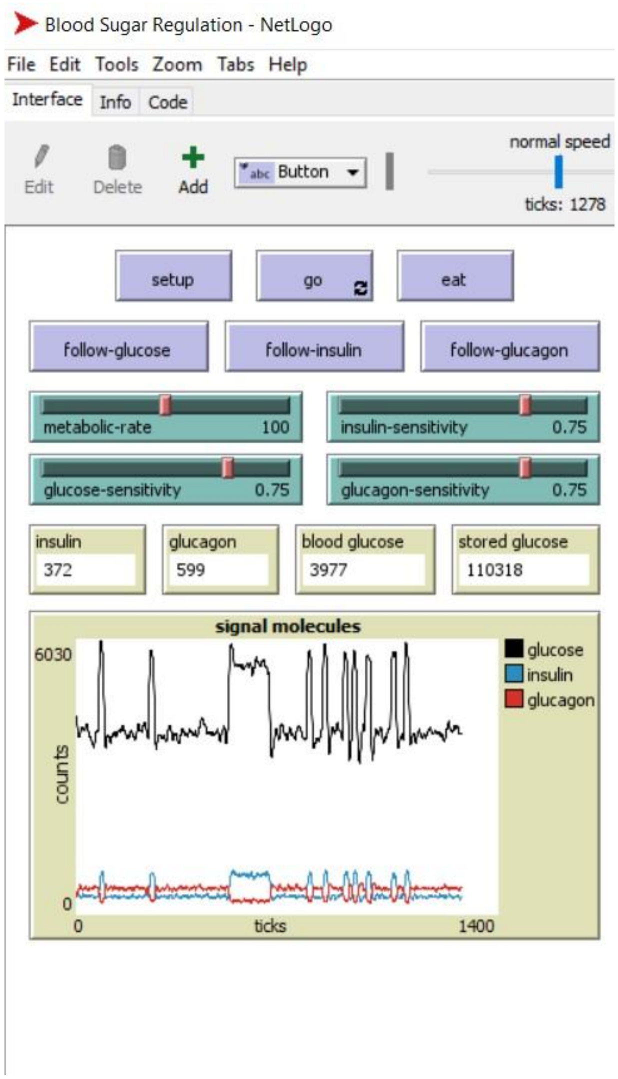
Acknowledgements

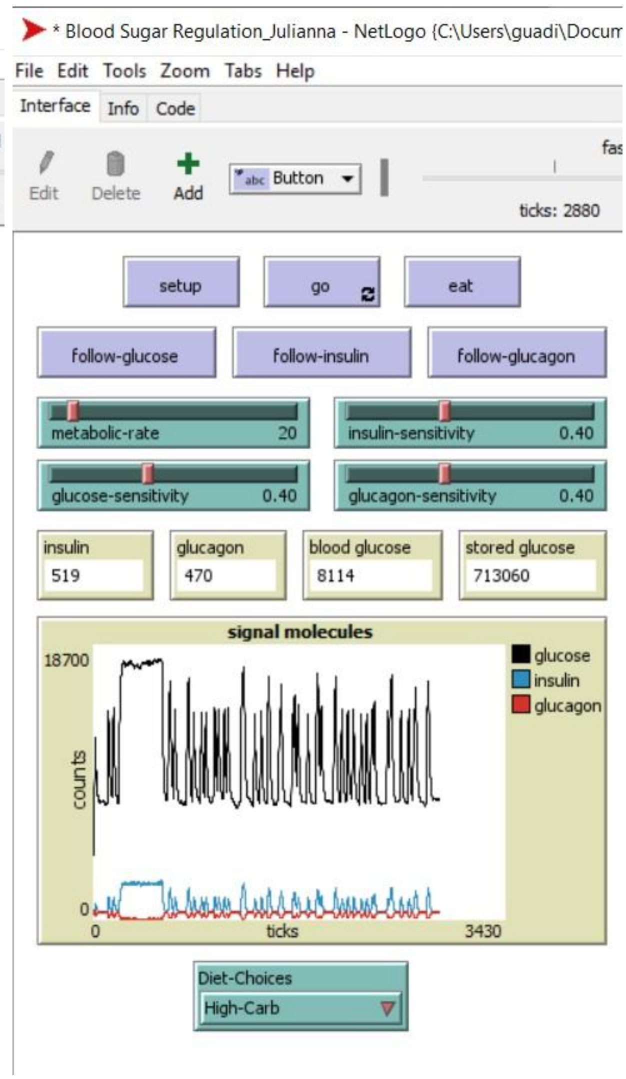
I would like to thank Mr. Vigil and my school for allowing me and motivating me to participate in the Supercomputing challenge.

I also would like to thank my mother and father for being there for me and helping me learn about NetLogo, Python and Excel.

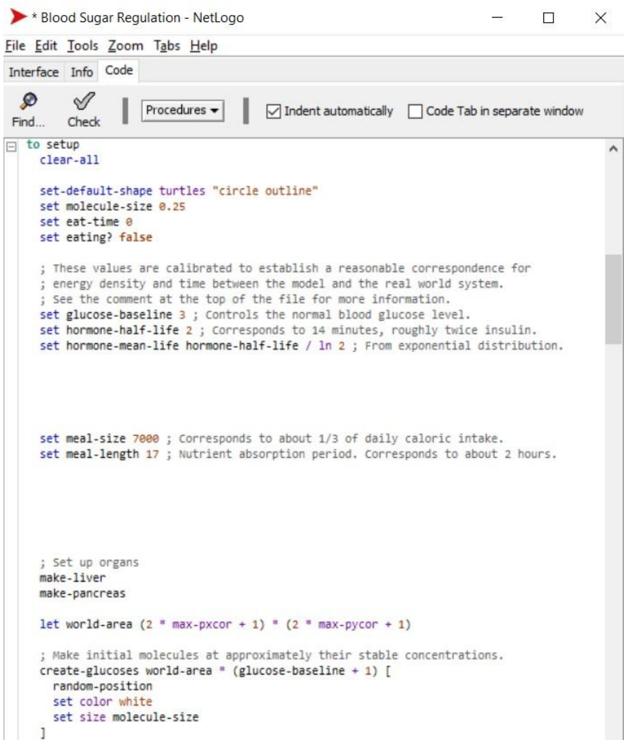
<u>Appendix</u>

Appendix A: NetLogo Blood Sugar Regulation model interface changes

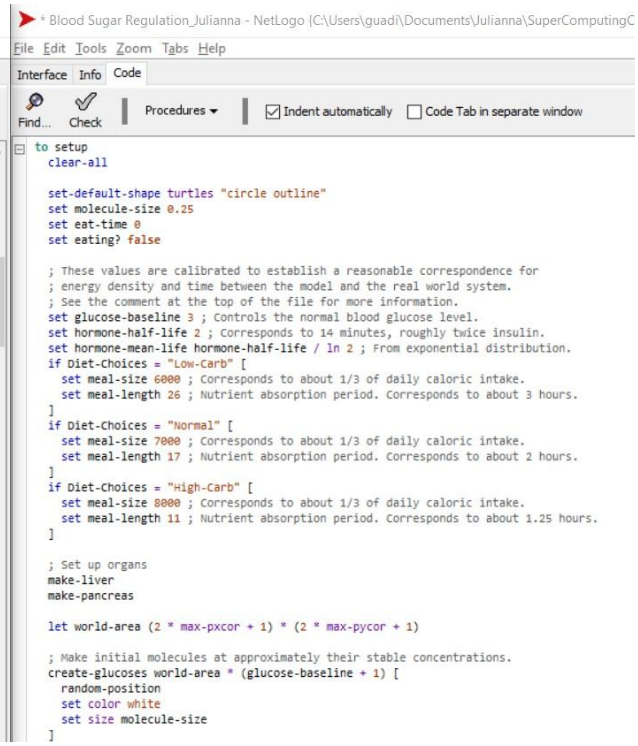




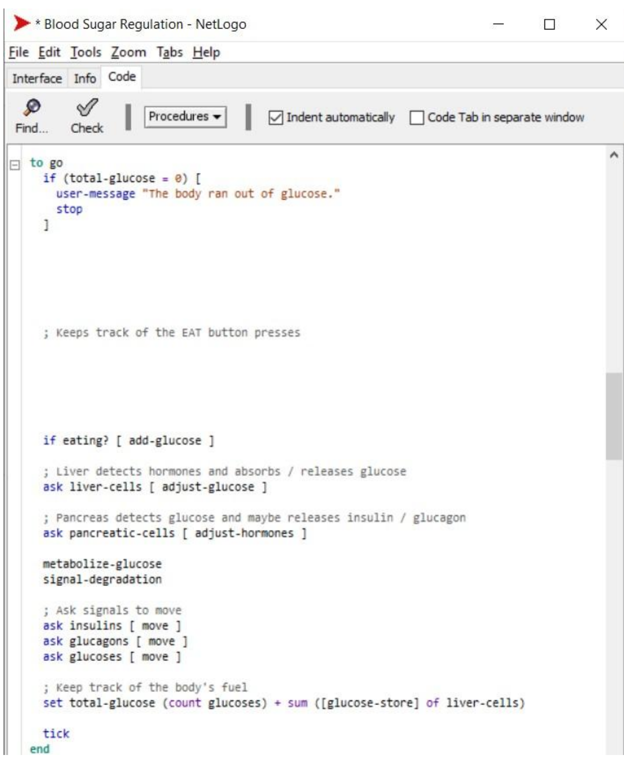
Appendix B: NetLogo Blood Sugar Regulation model code changes



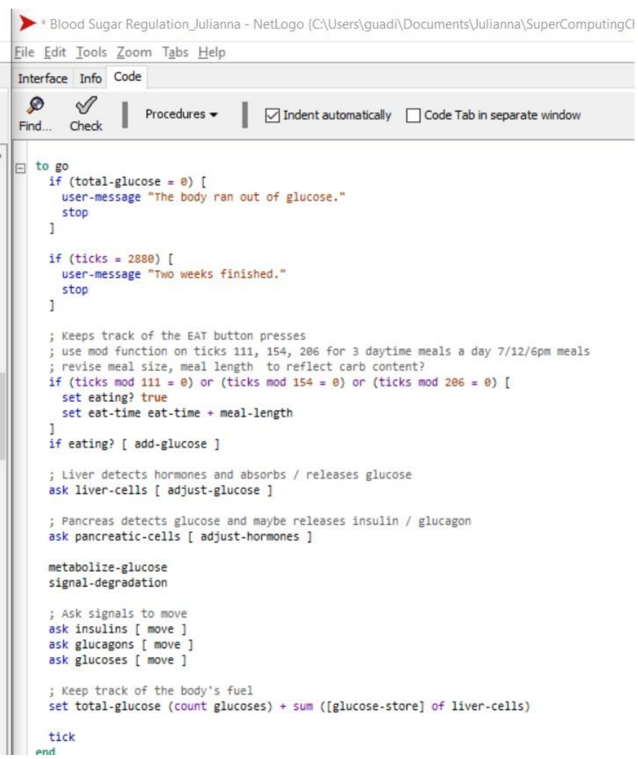

```
to setup
  clear-all

  set-default-shape turtles "circle outline"
  set molecule-size 0.25
  set eat-time 0
  set eating? false

  ; These values are calibrated to establish a reasonable correspondence for
  ; energy density and time between the model and the real world system.
  ; See the comment at the top of the file for more information.
  set glucose-baseline 3 ; Controls the normal blood glucose level.
  set hormone-half-life 2 ; Corresponds to 14 minutes, roughly twice insulin.
  set hormone-mean-life hormone-half-life / ln 2 ; From exponential distribution.




  set meal-size 7000 ; Corresponds to about 1/3 of daily caloric intake.
  set meal-length 17 ; Nutrient absorption period. Corresponds to about 2 hours.




  ; Set up organs
  make-liver
  make-pancreas

  let world-area (2 * max-pxcor + 1) * (2 * max-pycor + 1)

  ; Make initial molecules at approximately their stable concentrations.
  create-glucoses world-area * (glucose-baseline + 1) [
    random-position
    set color white
    set size molecule-size
  ]
```




```
to setup
  clear-all

  set-default-shape turtles "circle outline"
  set molecule-size 0.25
  set eat-time 0
  set eating? false

  ; These values are calibrated to establish a reasonable correspondence for
  ; energy density and time between the model and the real world system.
  ; See the comment at the top of the file for more information.
  set glucose-baseline 3 ; Controls the normal blood glucose level.
  set hormone-half-life 2 ; Corresponds to 14 minutes, roughly twice insulin.
  set hormone-mean-life hormone-half-life / ln 2 ; From exponential distribution.
  if Diet-Choices = "Low-Carb" [
    set meal-size 6000 ; Corresponds to about 1/3 of daily caloric intake.
    set meal-length 26 ; Nutrient absorption period. Corresponds to about 3 hours.
  ]
  if Diet-Choices = "Normal" [
    set meal-size 7000 ; Corresponds to about 1/3 of daily caloric intake.
    set meal-length 17 ; Nutrient absorption period. Corresponds to about 2 hours.
  ]
  if Diet-Choices = "High-Carb" [
    set meal-size 8000 ; Corresponds to about 1/3 of daily caloric intake.
    set meal-length 11 ; Nutrient absorption period. Corresponds to about 1.25 hours.
  ]

  ; Set up organs
  make-liver
  make-pancreas

  let world-area (2 * max-pxcor + 1) * (2 * max-pycor + 1)

  ; Make initial molecules at approximately their stable concentrations.
  create-glucoses world-area * (glucose-baseline + 1) [
    random-position
    set color white
    set size molecule-size
  ]
```




```
to go
  if (total-glucose = 0) [
    user-message "The body ran out of glucose."
    stop
  ]




  ; Keeps track of the EAT button presses




  if eating? [ add-glucose ]

  ; Liver detects hormones and absorbs / releases glucose
  ask liver-cells [ adjust-glucose ]

  ; Pancreas detects glucose and maybe releases insulin / glucagon
  ask pancreatic-cells [ adjust-hormones ]

  metabolize-glucose
  signal-degradation

  ; Ask signals to move
  ask insulins [ move ]
  ask glucagons [ move ]
  ask glucoses [ move ]

  ; Keep track of the body's fuel
  set total-glucose (count glucoses) + sum ([glucose-store] of liver-cells)

  tick
end
```




```
to go
  if (total-glucose = 0) [
    user-message "The body ran out of glucose."
    stop
  ]

  if (ticks = 2880) [
    user-message "Two weeks finished."
    stop
  ]

  ; Keeps track of the EAT button presses
  ; use mod function on ticks 111, 154, 206 for 3 daytime meals a day 7/12/6pm meals
  ; revise meal size, meal length  to reflect carb content?
  if (ticks mod 111 = 0) or (ticks mod 154 = 0) or (ticks mod 206 = 0) [
    set eating? true
    set eat-time eat-time + meal-length
  ]
  if eating? [ add-glucose ]

  ; Liver detects hormones and absorbs / releases glucose
  ask liver-cells [ adjust-glucose ]

  ; Pancreas detects glucose and maybe releases insulin / glucagon
  ask pancreatic-cells [ adjust-hormones ]

  metabolize-glucose
  signal-degradation

  ; Ask signals to move
  ask insulins [ move ]
  ask glucagons [ move ]
  ask glucoses [ move ]

  ; Keep track of the body's fuel
  set total-glucose (count glucoses) + sum ([glucose-store] of liver-cells)

  tick
end
```

Appendix C: Example of exported csv file from NetLogo

	A	B	C	D	E	F	G	H	I	J	K	L
1	export-plot data (NetLogo 6.2.2)											
2	Blood Sugar Regulation_Julianna.nlogo											
3	03/28/2022 19:22:56:111 -0600											
4												
5	MODEL SETTINGS											
6	glucose-se	insulin-sen	diet-choic	glucagon-s	metabolic-rate							
7	0.4	0.4	"Low-Carb	0.4	140							
8												
9	"signal molecules"											
10	x min	x max	y min	y max	autoplot?	current pe	legend ope	number of pens				
11	0	3430	0	10200	true	"glucose"	true	3				
12												
13	pen name	pen down?	mode	interval	color	x						
14	"glucose"	true	0	1	0	2880						
15	"insulin"	true	0	1	95	2880						
16	"glucagon'	true	0	1	15	2880						
17												
18	"glucose"				"insulin"				"glucagon"			
19	x	y	color	pen down?	x	y	color	pen down?	x	y	color	pen down?
20	0	4356	0	true	0	363	95	true	0	363	15	true
21	1	4428	0	true	1	280	95	true	1	555	15	true
22	2	4605	0	true	2	222	95	true	2	685	15	true
23	3	4815	0	true	3	200	95	true	3	730	15	true
24	4	5070	0	true	4	178	95	true	4	812	15	true
25	5	5330	0	true	5	144	95	true	5	833	15	true
26	6	5624	0	true	6	155	95	true	6	862	15	true
27	7	5954	0	true	7	175	95	true	7	842	15	true
28	8	6246	0	true	8	206	95	true	8	795	15	true

Chart Diabetic Exercise | Chart Diabetic Diet Choices | PivotTable | AllData | S1-R2.csv | **S1-R1.csv** | S1-R3.cs

Ready

Appendix D: Python code to merge all csv files into 1 Excel file

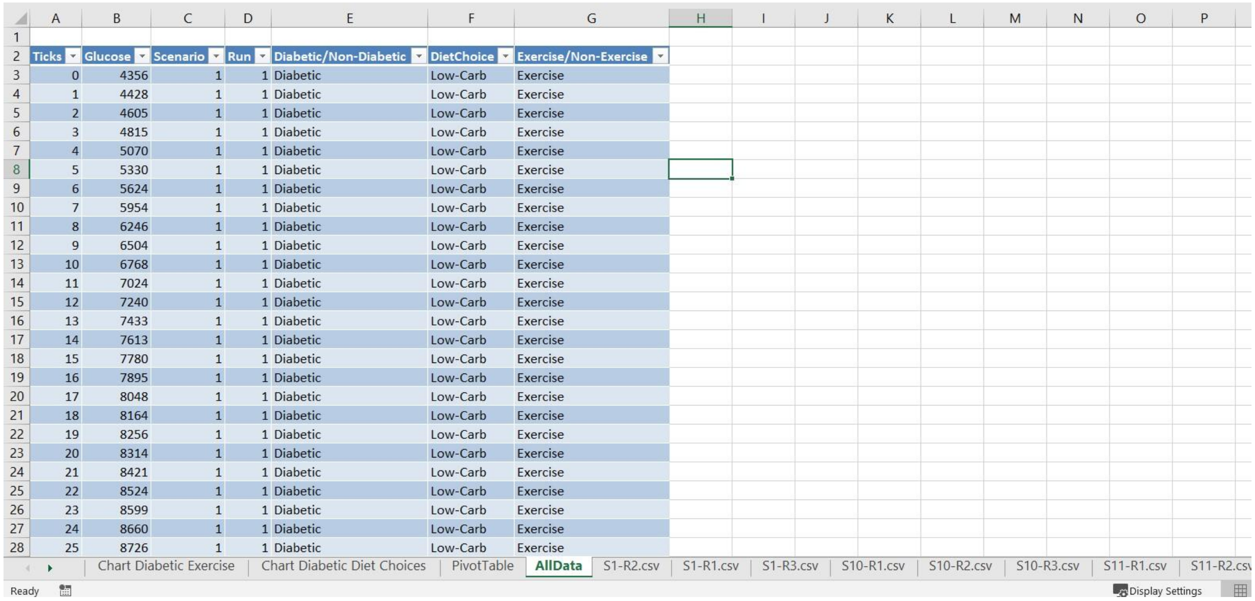
```python
# -*- coding: utf-8 -*-


# pip install pyexcel
# pip install pyexcel-xlsx
# pip install pyexcel-xlsxw

from pyexcel.cookbook import merge_all_to_a_book
import glob

import os
os.getcwd()
os.chdir('C:\ProgramData\Anaconda3')
csvFilePath = r"C:\Users\Documents\Julianna\SuperComputingChallenge2021-22\data\DataManipulation"


merge_all_to_a_book(glob.glob(csvFilePath + "\*.csv"), csvFilePath + "AllTogether.xlsx")
```

Appendix E: Excel Macro VBA code to combine data into 1 table

(General) | MakeBigTable

```
Sub MakeBigTable()

    Dim DataCSV As Worksheet
    Dim PositionOfR As Integer
    Dim Diabetes, DietChoice, MetabolicRate As String

    For Each DataCSV In ThisWorkbook.Worksheets
        If InStr(DataCSV.Name, ".csv") > 0 Then
            ThisWorkbook.Worksheets(DataCSV.Name).Range("A20:B2900").Copy
            ThisWorkbook.Worksheets("AllData").Range("A2").End(xlDown).Offset(1, 0).PasteSpecial
            Application.CutCopyMode = False
            PositionOfR = InStr(DataCSV.Name, "R")
            ThisWorkbook.Worksheets("AllData").Range("C2").End(xlDown).Offset(1, 0).Value = Mid(DataCSV.Name, 2, PositionOfR - 3)
            ThisWorkbook.Worksheets("AllData").Range("D2").End(xlDown).Offset(1, 0).Value = Mid(DataCSV.Name, PositionOfR + 1, 1)
            If ThisWorkbook.Worksheets(DataCSV.Name).Range("A7").Value = 0.4 Then
                Diabetes = "Diabetic"
            Else
                Diabetes = "Non-Diabetic"
            End If
            If ThisWorkbook.Worksheets(DataCSV.Name).Range("C7").Value = """Low-Carb""" Then
                DietChoice = "Low-Carb"
            ElseIf ThisWorkbook.Worksheets(DataCSV.Name).Range("C7").Value = """Normal""" Then
                DietChoice = "Normal"
            Else
                DietChoice = "High-Carb"
            End If
            If ThisWorkbook.Worksheets(DataCSV.Name).Range("E7").Value = 140 Then
                MetabolicRate = "Exercise"
            Else
                MetabolicRate = "Non-Exercise"
            End If
            ThisWorkbook.Worksheets("AllData").Range("E2").End(xlDown).Offset(1, 0).Value = Diabetes
            ThisWorkbook.Worksheets("AllData").Range("F2").End(xlDown).Offset(1, 0).Value = DietChoice
            ThisWorkbook.Worksheets("AllData").Range("G2").End(xlDown).Offset(1, 0).Value = MetabolicRate
            Range(ThisWorkbook.Worksheets("AllData").Range("C2").End(xlDown), _
                ThisWorkbook.Worksheets("AllData").Range("C2").End(xlDown).Offset(0, 4)).Select
            Selection.AutoFill Destination:=Range(ThisWorkbook.Worksheets("AllData").Range("C2").End(xlDown), _
                ThisWorkbook.Worksheets("AllData").Range("A2").End(xlDown).Offset(0, 6))
        End If
    Next DataCSV

End Sub
```

Appendix F: Final table with all the data in Excel



Ticks	Glucose	Scenario	Run	Diabetic/Non-Diabetic	DietChoice	Exercise/Non-Exercise
0	4356	1	1	Diabetic	Low-Carb	Exercise
1	4428	1	1	Diabetic	Low-Carb	Exercise
2	4605	1	1	Diabetic	Low-Carb	Exercise
3	4815	1	1	Diabetic	Low-Carb	Exercise
4	5070	1	1	Diabetic	Low-Carb	Exercise
5	5330	1	1	Diabetic	Low-Carb	Exercise
6	5624	1	1	Diabetic	Low-Carb	Exercise
7	5954	1	1	Diabetic	Low-Carb	Exercise
8	6246	1	1	Diabetic	Low-Carb	Exercise
9	6504	1	1	Diabetic	Low-Carb	Exercise
10	6768	1	1	Diabetic	Low-Carb	Exercise
11	7024	1	1	Diabetic	Low-Carb	Exercise
12	7240	1	1	Diabetic	Low-Carb	Exercise
13	7433	1	1	Diabetic	Low-Carb	Exercise
14	7613	1	1	Diabetic	Low-Carb	Exercise
15	7780	1	1	Diabetic	Low-Carb	Exercise
16	7895	1	1	Diabetic	Low-Carb	Exercise
17	8048	1	1	Diabetic	Low-Carb	Exercise
18	8164	1	1	Diabetic	Low-Carb	Exercise
19	8256	1	1	Diabetic	Low-Carb	Exercise
20	8314	1	1	Diabetic	Low-Carb	Exercise
21	8421	1	1	Diabetic	Low-Carb	Exercise
22	8524	1	1	Diabetic	Low-Carb	Exercise
23	8599	1	1	Diabetic	Low-Carb	Exercise
24	8660	1	1	Diabetic	Low-Carb	Exercise
25	8726	1	1	Diabetic	Low-Carb	Exercise