CS CM 182 Lab 3

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I completed this written part of the homework, lab report, or exam entirely on my own.

Exercise 1 - equation of v fluxes from 1 to 6

$v_1 = \alpha S(t)$
$v_2 = \beta\, S(t)\, I(t) / N$
$v_3 = \gamma\, \mathrm{E}\, (\mathrm{t})$
$v_4 = \delta\, I(t)$
$v_5 = \lambda(t)\, Q(t)$
$v_6 = \mathrm{k(t)\, Q(t)}$

Exercise 2 - Epidemic analysis of COVID-19 in China by dynamical modeling

Background and Goal

The epidemic analysis of COVID-19 in China specifically focuses on five major cities in Hubei province, Mainland region excluding Hubei, Wuhan, Beijing, and Shanghai. Major public health regulations are enforced in these cities ever since the outbreak of the virus such as locking down measures, tracing close contacts, quarantining infected cases, promoting social consensus on self protection, for example, wearing face masks during the public area. The main problem of the discussion is the entire medical care and clinical research field is trying to understand the entire epidemic characteristics of the outbreak such as forecasting the inflection point, ending time and finding out different measures to restrain the spreading of COVID-19. However, one of the challenges during the formation of the model is the problem of overfitting within the model which is solely due to the less accurate data and parameters. As a result, the SEIR has been chosen to represent the effectiveness of different measures during the outbreak of the virus. The two main objectives of the model is to compare the effects of lock down of Hubei province based on the transmission dynamics in Wuhan and Beijing. Second, the model is designed to simulate the processes of transmission from infection source to human.

Method and Results

The SEIR model is entirely based on seven different states which are {S(t), P(t), E(t), I(t), Q(t), R(t), D(t)} = {susceptible cases, insusceptible cases, exposed cases, infectious cases, quarantined cases, recovered cases, closed cases}. Therefore, the total population N is represented as S+P+E+I+Q+R+D. Therefore six coefficients that represents the transfer rates under different scenario which are $\{\alpha, \beta, \gamma^{-1}, \delta^{-1}, \lambda(t), \kappa(t)\}$ = {protection rate, infection rate, average latent time, average quarantine time, cure rate, mortality rate}.The basic reproduction number of the virus is calculated by BRN = $\beta * \delta^{-1} * (1-\alpha)^{T}$ where T refers to the number of days. The results of the simulation show that average contact number is stable over time with certain differences depending on the region. The model does not account the fact of time delay due to lack of evidence.

In order to overcome the problem of overfitting, the model has also applied the simulating annealing algorithm which is basically prefix the latent time γ^{-1} and examine its influence on the other parameters such as initial values, population dynamics of both quarantined and infected cases. The results show that the initial values of exposed cases and infectious cases are increasing along with the latent time. This implies that each unprotected person has a great chance of being infected if he or she comes into contact with a COVID-19 patient.

The model also performs sensitivity analysis based on Wuhan's data which shows there is a positive correlation with the infection rate and the quarantine time and a negative correlation with the protection rate. There are several final remarks about the model results. First, the protection rate of Wuhan is significantly lower than other areas due to a mix of both susceptible and infectious cases. Second, the quarantine time for both Beijing and Shanghai are the shortest. Third, the estimated number of total infected cases in all five regions are large to indicate the virus has been spread out nationwide.

Personal Opinion

In my own opinion, I think the most valuable part of the analysis is when it discusses the forecast for the epidemic of COVID-19. The prediction is mainly about the inflection point, possible ending time and final total infected cases for the five cities above. Based on the collected data, the model has shown an optimistic estimation regarding the ending date of the disease. I think the predictions serve as a purpose of reference or reminders about the understanding about the epidemic of COVID-19. It just helps us as a community to better prepare ourselves in the future in order to prevent similar situations. One of the things that the model does not take into account is the time-delayed properties which refers to the patients needing a period of time to become infectious or recovered from the illness. I think these factors might affect the collected data in regards to the total infected people within the population due to the fact that it is hard to distinguish the exact number of both exposed and infectious cases. If the model has considered data that are up until now, the model will be more accurate and reliable.

Exercise 2 - Extra Credit Review- Artificial Intelligence Forecasting of Covid-19 in China

Compare and Contrast

Both the SEIR model and the artificial intelligence inspired models are used for forecasting of COVID-19 in order to estimate the size, lengths and ending of the virus in China. However, the AI model conducts a real time forecasting while the SEIR model is based on periodic collected data. The AI model aimed to forecast the total confirmed cases of COVID-19 in China over a four month period from January to February 2020. The model predicts that the epidemics of COVID-19 will end by the middle or end of April in China. In this specific analysis, the collected data has included the total number of accumulated and new confirmed cases across 31 provinces in China. As a result, the model is more reliable due to the fact that it has more access to available data. In the specific model, modified auto-encoders are used to predict the number of confirmed COVID-19 cases. The one special thing about these encoders is the number of nodes are increased from the input layer to the latent layer which is opposite from the classical version. A segment of times series which is 8 days has been chosen to serve as one sample. In each time series, a total of 128 segments has been taken as part of the training samples.

The model is involved with a recursive multiple forecasting during the experiment. The basic idea is the prediction from the previous time step was fed in as input for the next predicting step. For example, a predicted number of new confirmed cases at day one will be fed as input to predict the result of day two. Overall, the model predicted that the potential cumulative confirmed cases of COVID -19 was gonna reach 83,401 in China on April 10, 2020.

Personal opinion on effectiveness

Personally, I think the artificial intelligence model provides more aspects in regards to estimating the dynamics of transmission. Even though the SEIR model focuses on the purposes of targeting resources and evaluating impact of the intervention strategies, the majority of the results are based on certain assumptions and set parameters. As a result, the hypothesized parameters do not end up fitting the data that well and the forecasting might not be as accurate as possible. In contrast, the AI model is able to utilize real time data to predict the results during the outbreak of the virus. At the end, I think both models provide very insightful perspectives towards the current situation of the transmission of the disease. SEIR provides a more clear understanding of the causes and end results of the virus while the AI model gives a more numerical prediction about the virus.

<u>Exercise 3 - Two differential equations represent the models</u>

Let B equals to blood glucose

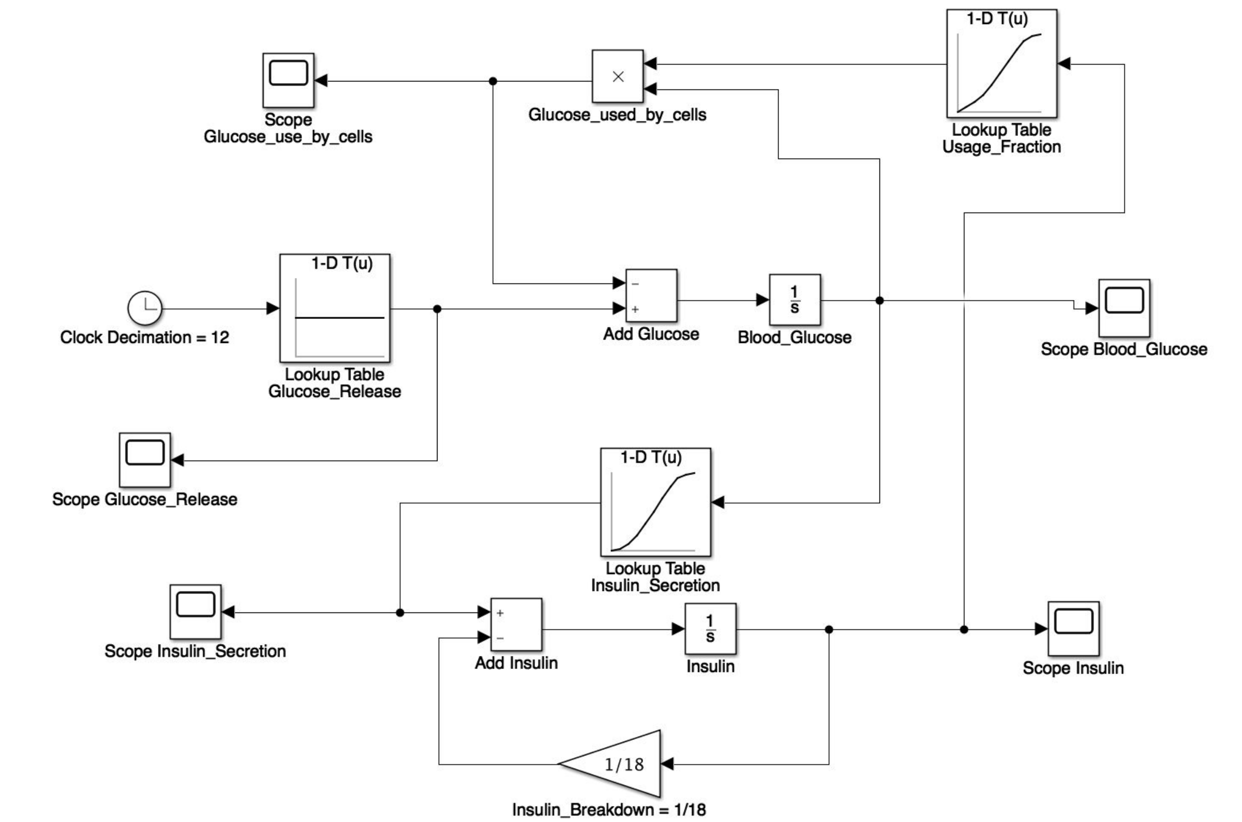
$$\frac{dG}{dt} = L_2(t) - L_1(I) * G$$

Let S equals to insulin

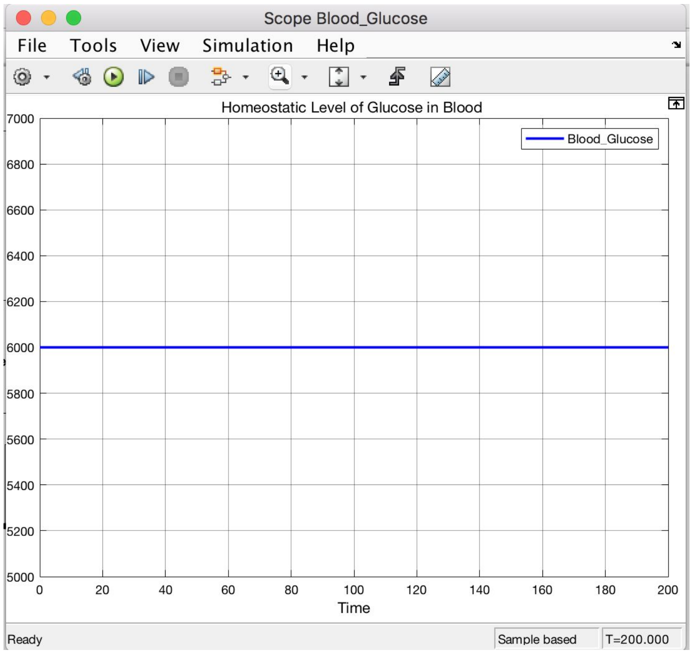
$$\frac{dI}{dt} = L_3(G) - \frac{I}{18}$$

<u>**Exercise 4 - Homeostatic of glucose of in the blood**</u>

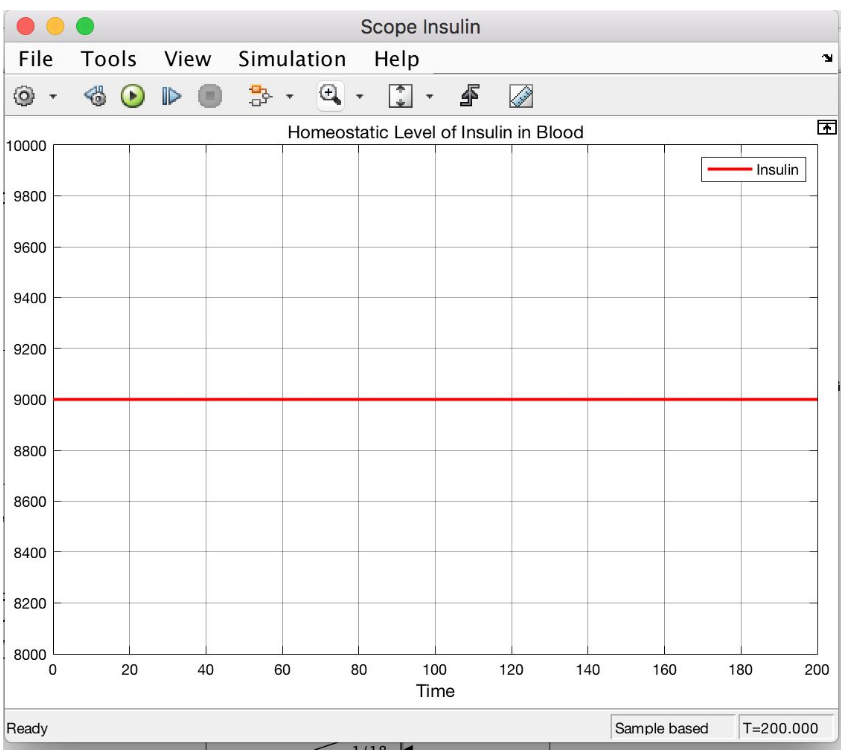
Simulink Diagram



1. The homeostatic level of glucose in the blood is 6000 concentration.

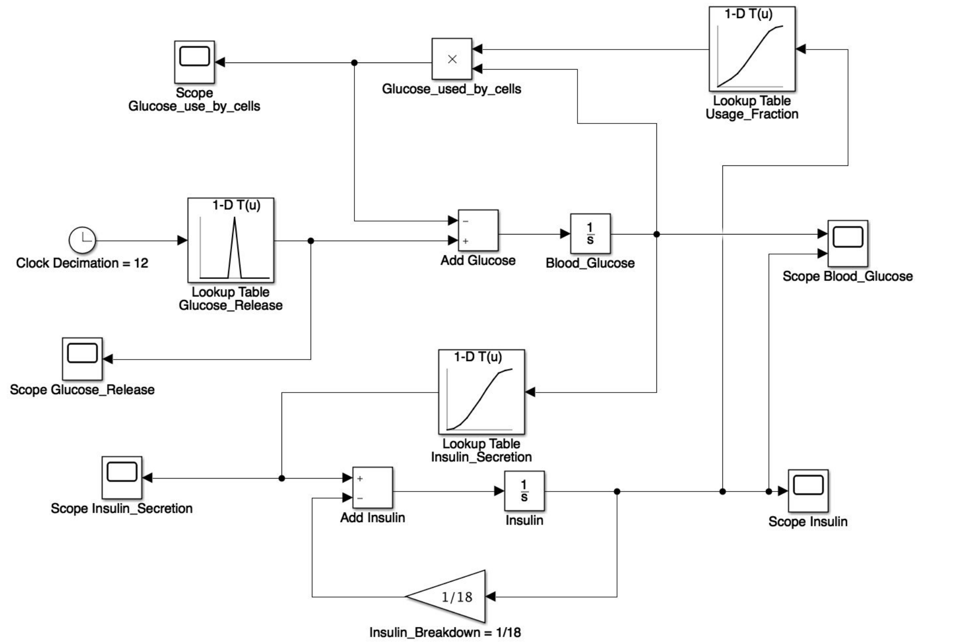


2. The homeostatic level of insulin in the blood is 9000 concentration.

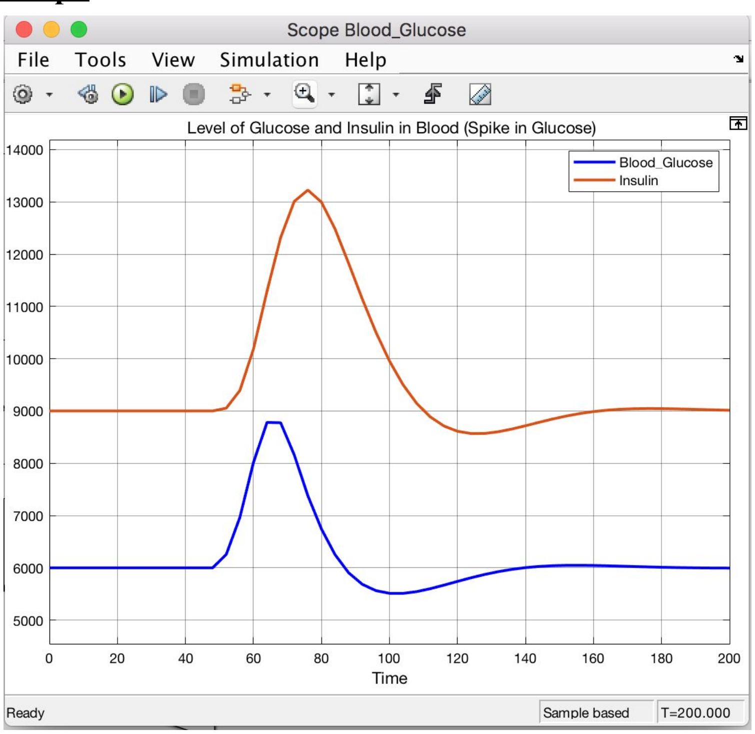


Exercise 5 - Eating candy bar

Simulink Diagram



Graph



<u>Answer</u>

The specific glucose release rate that I have chosen for the model :

Glucose_Release

Time [min]	0.00	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0	120.0
Rate	198	198	198	198	198	600	198	198	198	198	198

The reason I choose this rate is to demonstrate the sudden increase of glucose at time = 60.0 seconds

As we eat the candy bar and our body is digesting it, the level of blood glucose in our blood increases and eventually reaches a max point to come back down. Based on the graph, the level of glucose in our blood creates an increasing trough shape in the chart. At the same time, insulin also follows the same pattern as the level of glucose, first rise and fall back down to reach the homeostatic level in the blood. However, the insulin falls slower than glucose.The reason for the delay of fall in insulin is because it takes time to inform the pancreas about the secretion of insulin in order to get rid of the extra glucose in our blood. When our system senses there is a high blood sugar, it sends a message to the pancreas to promote insulin release. Then, insulin stimulates glucose uptake from blood. After that, the extra glucose is being stored in the tissue cells. As the insulin promotes the glucose uptake in the cell, the level of glucose falls faster than insulin in order to lower blood sugars. Since secretion of insulin starts later, it takes longer to return back to homeostatic level compared with glucose.

<u>Exercise 6 - Produce little or no insulin</u>

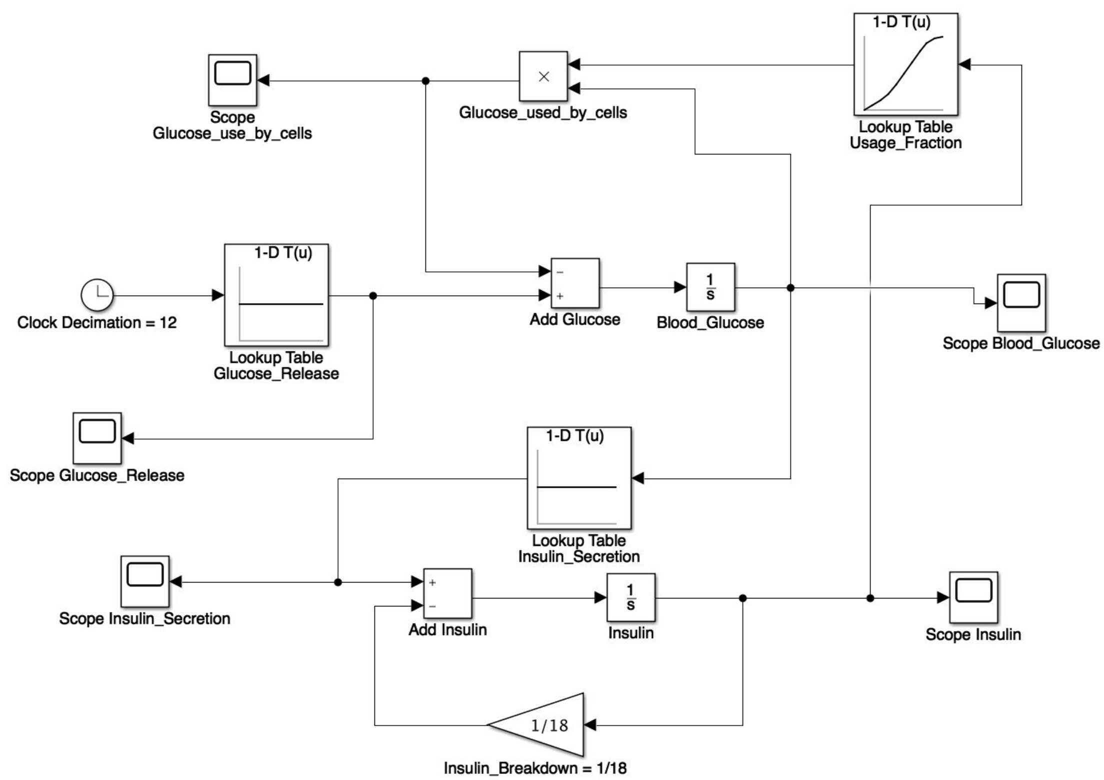
<u>Based from the following glucose release rate and insulin secretion rate</u>

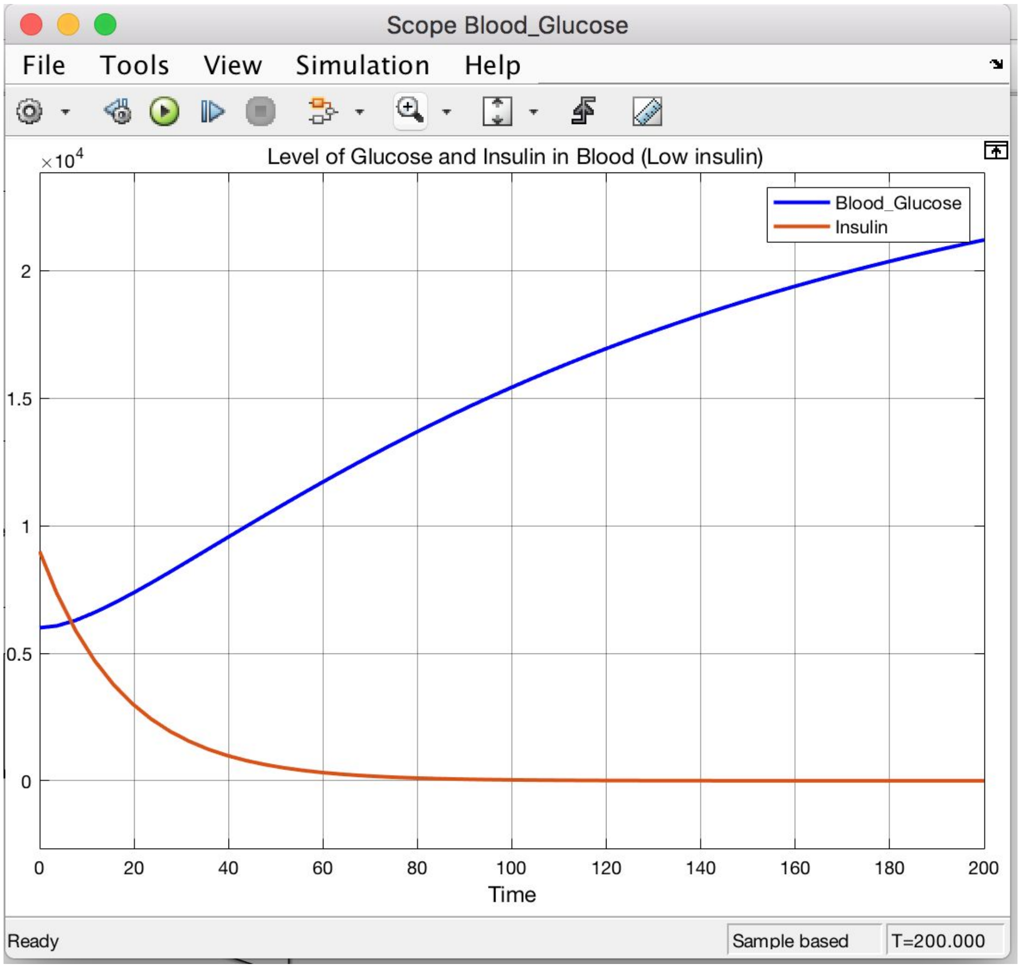
Glucose_Release

Time [min]	0.00	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0	120.0
Rate	198	198	198	198	198	198	198	198	198	198	198

Insulin_Secretion

Time [min]	1000	2000	3000	4000	5000	6000	7000	8000	9000	1000 0	1100 0
Rate	0	0	0	0	0	0	0	0	0	0	0





Answers

The level of insulin in blood starts to slowly decrease and eventually reach zero since we are trying to model the situation when the beta cells of the pancreas produce little to no insulin. The reason that it decreases slowly is because it takes time for the body to respond to the decrease in secretion of insulin. As the insulin in blood slowly decreases, the glucose in blood slowly increases at first, and then reaches the maximum point of slightly above 2.5 concentration as time goes on. The reason that it increases slowly is because the level of insulin is slowly decreasing in response to that.

Some of the negative health effects associated with high level of blood glucose is risk of stroke, extreme thirst, sweet-smelling breath, risk of heart disease, fatigue, lack of energy, pancreas malfunction, excessive urination, damaged blood vessels, nerve damage, foot problems, loss consciousness, visual disturbances, cataracts, glaucoma, risk of infections, high blood pressure and gastroparesis.

Citations

Hu, Z., Ge, Q., Li, S., & Xiong, M. (2020). Artificial Intelligence Forecasting of Covid-19 in China. *Artificial Intelligence Forecasting of Covid-19 in China*. Retrieved from https://arxiv.org/pdf/2002.07112.pdf