An Introduction to Mathematical Modeling in the Life Sciences

Final Project Idea (V1.0)

Zhen-Yu Liu (刘振宇) Yuanpei College 1700017853

Subject:

Mathematical modeling of the glucose-insulin homeostatic control system

Reason: (same as Project Idea V0.0)

The glucose-insulin system is one of the clearest and simplest examples of homeostatic control in the organism. Many researchers have investigated the physiological mechanisms of the feedback regulation of blood glucose level and insulin secretion. However, due to the increasing importance of identifying insulin resistance, there is a strong need to have a reliable mathematical model for this system. Besides providing clinical protocols to compute insulin sensitivity of the patient, mathematical models the system may also generally allowing a more accurate knowledge of the regulatory mechanisms underlying glucose–insulin homeostasis.

Since the research in our laboratory focuses on the development and homeostasis of mammalian pancreas, especially the islet, we frequently conduct experiments about glucose tolerance and insulin sensitivity. Our researches always adopt the traditional biological perspective. I think it would be very helpful if we try to analyze the blood glucose-insulin homeostasis using mathematical modeling.

Anticipations:

In Project Idea V0.0 we have mentioned that there are already some mathematical models for this system, the *Minimal Model* (MM model) in the late seventies, the *DDE model* in 2000, and the *Single Delay Model* (SDM) in 2007. However, these models were presented decades ago and did not fit well with experimental data under pathologic conditions such as hypoglycemia and diabetes. Recent research had provided new insights on this topic. The results of recent researches demonstrate that chaos is a common feature in complex biological systems. Chaotic dynamics also provided a successful method for investigating glucose-insulin system and explain its behavior in pathologic conditions[1]. Furthermore, recent publications on this topic mostly adopt a three-dimension ODE system[1,2]:

$$\frac{dx}{dt} = f_1(x, y, z)$$

$$\frac{dy}{dt} = f_2(x, y, z)$$

$$\frac{dz}{dt} = f_3(x, y, z)$$

where x(t) is insulin concentration, y(t) is blood glucose concentration and z(t) is the population density of β cells. It seems that the introduction of the population density of β cells was a better choice to optimize model performance. This was different from our assumptions in Idea V0.0, where we plan to introduce z as the intake of glucose into somatic cells.

For the final project we intended to reconstruct the 3D chaotic system in reference [1] and explore its behaviors under physiological and pathological conditions. We might also complete our ideas in V0.0 to compare why population density of β cells is a better variable for the system.

Reference:

[1] Shabestari, P. S., Panahi, S., Hatef, B. et al. A new chaotic model for glucose-insulin regulatory system. Chaos Solitons & Fractals, 112, 44-51. (2018).

[2] Rajagopal, K., Bayani, A., Jafari, S. et al. Chaotic dynamics of a fractional order glucose-insulin regulatory system. Front Inform Technol Electron Eng (2019).