Chapter 11
MP Modelling of Glucose–Insulin Interactions in the Intravenous Glucose Tolerance Test

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ABSTRACT

The Intravenous Glucose Tolerance Test is an experimental procedure used to study the glucose-insulin endocrine regulatory system. An open problem is to construct a model representing simultaneously the entire regulative mechanism. In the past three decades, several models have appeared, but they have not escaped criticisms and drawbacks. In this paper, the authors apply the Metabolic P systems theory for developing new physiologically based models of the glucose-insulin system, which can be applied to the IVGTT. Ten data-sets obtained from literature were considered and an MP model was found for each, which fits the data and explains the regulations of the dynamics. Finally, each model is analysed to define a common pattern which explains, in general, the action of the glucose-insulin control system.

1. INTRODUCTION

Glucose is the primary source of energy for body cells. It is transported from the intestines or liver to body cells via the bloodstream, and is absorbed by the cells with the intervention of the hormone insulin produced by the pancreas. Blood glucose concentration is a function of the rate of glucose which enters the bloodstream, the glucose appearance, balanced by the rate of glucose which is removed from the circulation, the glucose disappearance. Normally, in mammals

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this concentration is tightly regulated as a part of metabolic homeostasis. Indeed, although several exogenous factors, like food intake and physical exercise, affect the blood glucose concentration level, the pancreatic endocrine hormones insulin and glucagon[1] keep this level in the range 70 – 110 mg/dl. When the blood glucose concentration level is high, the pancreatic β–cells release insulin which lowers that concentration by inducing the uptake of the excess glucose by the liver and other cells and by inhibiting hepatic glucose production. On the contrary, when the glucose level is low, the pancreatic α–cells release glucagon that results in increasing the blood glucose level by acting on liver cells and causing them to release glucose into the blood[2] (Figure 1).

If the plasma glucose concentration level is constantly out of the usual range, then we are in presence of blood glucose problems. In particular, when this level is constantly higher than the range upper bound (which is referred to as *hyperglycemia*), we are in presence of *Diabetes*: a dreadfully severe and pervasive illness which concerns a good number of structures in the body. Diabetes is classified into two main categories known as *type I* and *type II*, respectively. Type I, 5–10% of all categories of diabetes, results from autoimmune destruction of β-cells and the pancreas is no longer capable of making insulin. Therefore, daily insulin injections are necessary. Diabetes of type II refers to the remaining 90% and occurs when the pancreas produces insulin but cells fail to use it properly. In both the types of diabetes, the illness can lead to several complications like retinopathy, nephropathy, peripheral neuropathy and blindness. This motivates researches to study the glucose-insulin endocrine regulatory system. In particular, the glucose-insulin system has been the object of repeated mathematical modelling attempts. The majority of the proposed models were devoted to the study of the glucose-insulin dynamics by considering experimental data obtained by the *intravenous glucose tolerance test*, shortly *IVGTT*, and the *oral glucose tolerance test*, shortly *OGTT*. In these models, the insulin-glucose system is assumed to be com- posed of two linked subsystems modelling the insulin action and the glucose kinetics, respectively. Since the action of insulin is delayed with respect to plasma glucose, the subsystems of insulin action typically includes a delay.

Figure 1. The glucose homeostasis