INTRODUCTION

An important part of synthetic biology is the characterization of standardized biological parts. While we are nowhere near there yet, our differential equations model is a first step towards this goal. We decided to design a differential equations based model in the Matlab SimBiology interface.

METHODS

Our differential equations model uses Chemical Kinetic equations to predict the amount of reactant or product present after a period of time. The rate of reaction

$$A + B \longrightarrow C + D$$

is modelled using the equation

$$rate = k[A][B] .$$

k is the rate constant that determines how fast or slow a reaction will occur. [A] is the amount of the reactants present in the environment.

REACTIONS

The following reaction equations were employed to model our system.

$$LuxPQ + LuxU + p \xrightarrow{1.0E\text{-}6} LuxPQ + LuxU{:}p$$

$$LuxU{:}p + LuxO + p \xrightarrow{1.0E\text{-}6} LuxU{:}p + LuxO{:}p$$

$$LuxO{:}p{:}sigma54{:}Pqrr4 \rightarrow LuxO{:}p{:}sigma54{:}Pqrr4 + mRNA$$

$$mRNA \xrightarrow{0.0017} GFP \xrightarrow{0.1056}$$

$$GFP \xrightarrow{2.87E\text{-}4} null$$

$$AI\text{-}2 + LuxPQ \underset{1.0}{\overset{0.25}{\longleftrightarrow}} AI\text{-}2{:}LuxPQ$$

$$AI\text{-}2{:}LuxPQ + LuxU{:}p \xrightarrow{0.3} AI\text{-}2{:}LuxPQ + LuxU + p$$

$$LuxU{:}p \xrightarrow{0.09} LuxU + p$$

$$LuxO{:}p \xrightarrow{0.09} LuxO + p$$

$$Pqrr4 : sigma54 \underset{0.2}{\overset{0.002}{\longleftrightarrow}} Pqrr4 + sigma54$$

$$Sigma54{:}Pqrr4{:}LuxO{:}p \underset{1.0}{\overset{1.0}{\longleftrightarrow}} sigma54{:}Pqrr4 + LuxO{:}p$$

$$mRNA \xrightarrow{0.0048} null \xrightarrow{1.0}$$

The numbers above the arrows are rate constants.

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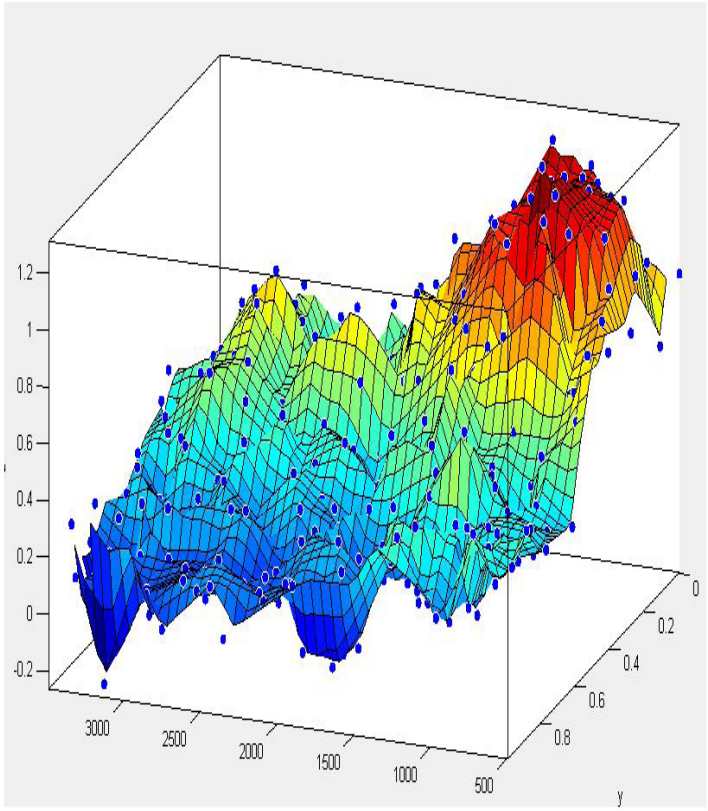
DIFFERENTIAL EQUATIONS BASED MODELLING



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THE REACTION PATHWAYS DIAGRAM

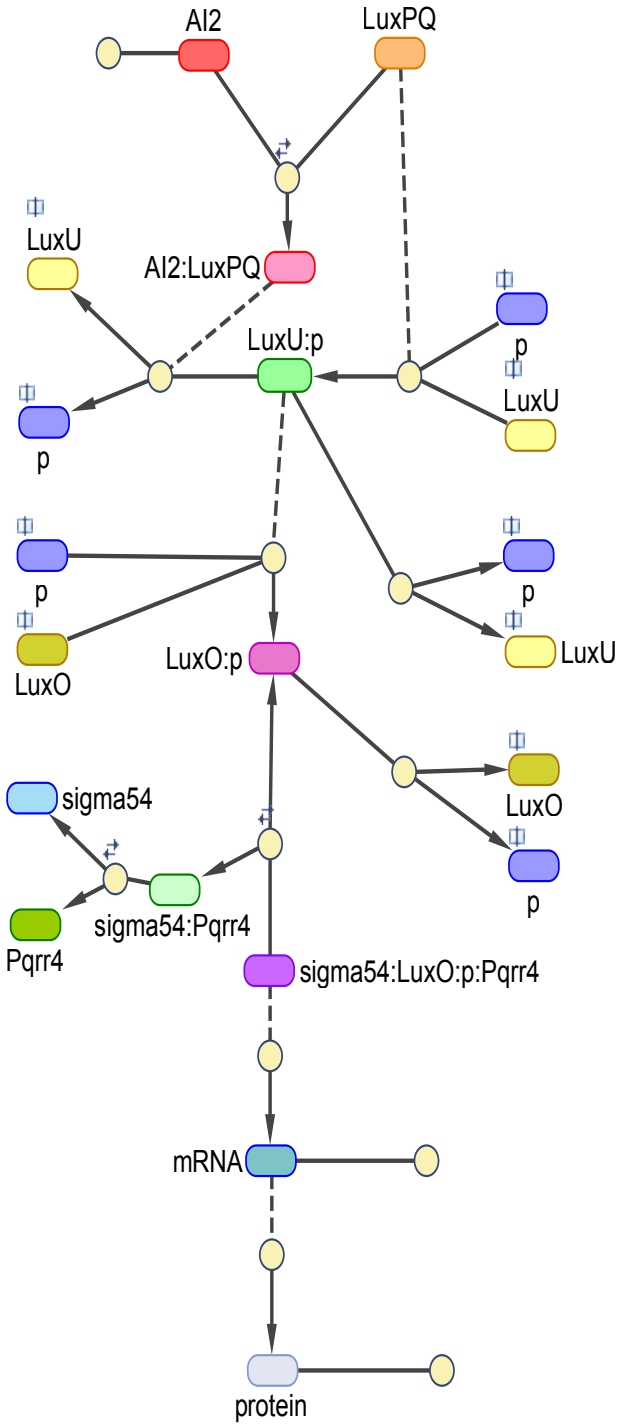

Fig 1: This SimBiology diagram maps the connections between the reactants and the products.

EFFECT OF VARYING THE LEVEL OF AI-2 ON THE DEGRADATION OF GFP

AI-2 is the molecule of input to the system which produces different expression levels of GFP. Therefore we decided to test the effects of different levels of AI-2 on our system.

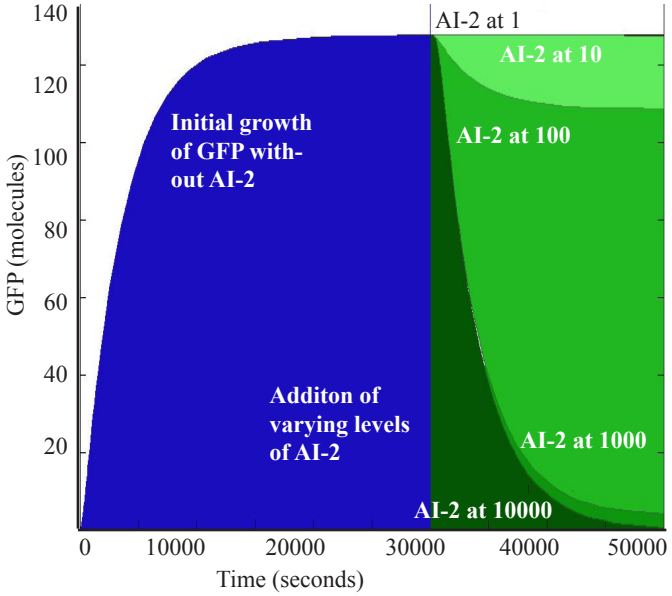

Fig 2: The rate of GFP degradation for different AI-2 levels with respect to time (LuxPQ at 100).

At AI-2 levels of 1 and 10, the amount of GFP remains constant due to lack of [AI-2:LuxPQ] complex to carry out the de-phosphorylation of LuxU. At 100 AI-2 molecules, we start to see some degradation of GFP due to increase in the [AI-2:LuxPQ] phosphotase. However, as the binding of AI-2 to LuxPQ is not 100%, not all of 100 AI-2 are bound to LuxPQ molecules, and therefore the GFP degradation does not reach zero. Finally, beyond AI-2 levels of 1000, we see a significant decrease in GFP, almost reaching zero. This phenomenon possibly suggests that the AI-2 level have to be at least an order of magnitude higher than the level of LuxPQ in order to see a significant difference between system on and off.

EFFECT OF VARYING THE LEVEL OF LUXPQ ON THE DEGRADATION OF GFP

The level of variation of LuxPQ in our system determines the response of the system to AI-2. For the optimization of the system's response the amount of LuxPQ present in the cell is important.

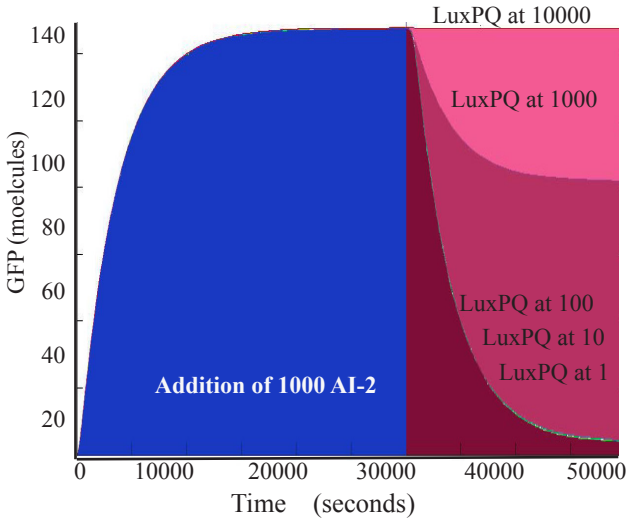

Fig 3: The rate of GFP degradation for different LuxPQ levels with respect to time.

GFP degradation rate remains relatively constant from one LuxPQ to 100 LuxPQ. This may be due to the amplifying effect of LuxPQ phosphatase activity. Since one LuxPQ has the potential to de-phosphorylate a large amount of LuxU, having more LuxPQ around does not necessarily translate into faster de-phosphorylation of LuxU. Beyond 1,000 LuxPQ, however, the GFP degradation rate starts to fall. The reason behind this phenomenon could be that because the binding of AI-2 to LuxPQ is not 100%, not all of 1,000 LuxPQ are bound to 1,000 AI-2 molecules. Since the remaining unbound LuxPQ acts as a kinase, this leads to increased phosphorylation of LuxU compared to when no unbound LuxPQ is present. Increased amounts of LuxU:p means that there are more than enough LuxU:p and LuxO:p to initiate the production of GFP, and therefore the degradation rate of GFP is slow or zero.