Systems Biology Tutorial 5: MCA

In this tutorial, we will explore MCA with a simple 2-step pathway:

$$\mathrm{S} \;\underset{}{\overset{\boxed{1}}{\rightleftharpoons}}\; \mathrm{X} \;\underset{}{\overset{\boxed{2}}{\rightleftharpoons}}\; \mathrm{P}$$

The rate equations for the reactions are given by:

$$v_1 = k_{1\mathrm{f}}\left(s - \frac{x}{K_{\mathrm{eq1}}}\right)$$

$$v_2 = \frac{\dfrac{V_{\mathrm{f2}}}{K_{\mathrm{x}}}\left(x - \dfrac{p}{K_{\mathrm{eq2}}}\right)}{1 + \dfrac{x}{K_{\mathrm{x}}} + \dfrac{p}{K_{\mathrm{p}}}}$$

A Mathematica notebook for this pathway is available as Tut5.nb. Inspect this file, note that it also has values for the kinetic parameters and initial values for the variable concentrations.

1. Perform a time simulation for $0 \leq \mathrm{t} \leq 10$. Plot the concentration of x vs. time. Plot the rates of both reactions vs. time. What are the values of the steady-state concentration of x and the flux J?

2. Calculate C^J_{v1} and C^J_{v2} using perturbation control analysis. To do this, increase k1f (or V2f respectively) by 1% from its original value and note the new flux. Calculate the flux-control coefficient using the formula you learnt in the MCA lecture.

3. Do the flux control coefficients for the model sum to 1? If not, explain the difference.

4. By how many percent would $v2$ change upon a 1% increase in K_x? Calculate the elasticity of the enzyme using the analytical derivative.

5. Increase the K_x by 1% and obtain a new model simulation. Determine the %-change in the flux at the new steady state (R^J_{Kx}). Does the change in the flux agree with the change in the activity of enzyme 2?

6. Determine the elasticities of e^{v1}_x and e^{v2}_x at steady state using the analytical method of Tut 3. Calculate the flux control coefficients using your answers. Do the flux control coefficients sum to 1? How do they compare to the flux control coefficients that we determined in Question 2?

7. Use the partitioned response $C^J_{\mathrm{v1}}\epsilon^{\mathrm{v1}}_x + C^J_{\mathrm{v2}}\epsilon^{\mathrm{v2}}_x$ to show that a 1% change in the concentration of x will not affect the flux (i.e. test the flux connectivity theorem).