# Stochastic simulation and chemical inference modules

1. **The Gillespie algorithm for stochastic simulation.**

   Download a copy of the original paper by Gillespie (*Exact Stochastic Simulation of Coupled Chemical Reactions*, D. T. Gillespie, J. Phys. Chem. **81** 2340 (1977)). Locate the file `GillespieMatlab.m`. Write down a description of the function of each variable in the M-file, and the line numbers corresponding to the steps in boxes 1-3 in Fig. 2 of the original paper.

2. **A simple stochastic chemical system.**

   We will first consider the following simple chemical system:

$$A \xrightarrow{k_1} B \tag{1}$$
$$B \xrightarrow{k_2} A, \tag{2}$$

   where $k_i$ are the rates of each reaction.

   (a) Write down the stochiometry matrix for this system.

   (b) Use `GillespieMatlab.m` to simulate this system for $k_1 = k_2$, $k_1 > k_2$ and $k_1 < k_2$. Plot the resulting stochastic trajectories to verify that the system behaves as expected.

3. **Gillespie simulation of the Monod model.**

   We will now look at a more complicated chemical system, used to model co-operative binding, which we shall see is useful in biological inference. Here, we have a protein which can exist in binding ($B$) or non-binding ($N$) states. The protein has $n$ sites, to which sugar molecules ($S$) may bind. However, the protein may only swap between $B$ and $N$ states when no sugars are bound to it. Sugar binding hence acts to "lock in" a particular state of the protein. This system is described by:

$$B_0 \xrightarrow{L} N_0 \tag{3}$$
$$N_0 \xrightarrow{1} B_0 \tag{4}$$
$$B_0 + S \xrightarrow{n} B_1 \tag{5}$$
$$B_1 \xrightarrow{K_R} B_0 + S \tag{6}$$
$$B_1 + S \xrightarrow{n-1} B_2 \tag{7}$$
$$B_2 \xrightarrow{2K_R} B_1 + S \tag{8}$$
$$N_0 + S \xrightarrow{n} N_1 \tag{9}$$
$$N_1 \xrightarrow{K_T} N_0 + S \tag{10}$$
$$N_1 + S \xrightarrow{n-1} N_2 \tag{11}$$
$$N_2 \xrightarrow{2K_T} N_1 + S \tag{12}$$

   (a) Write down the stochiometry matrix for this system. Don't forget that sugar molecules are reactants too! Why are some rates a function of $n$?

   (b) Use `GillespieSwain.m` to simulate this system for $K_R = 100$, $K_T = 10$, $L = 2$, $n = 1$. Explore the occupancy of the $B$ state as $S$ varies over orders of magnitude.

   (c) Simulate the system for $n = 2$. What do you notice about the behaviour at different sugar concentrations as $n$ changes?