BIOENG-320
Gene circuits
Week 1

Q1. Michaelis-Menten inhibition

As described in class, kinetic parameters are important for studying biological processes. Consider the following reaction scheme which represents the catalytic activity of an enzyme:

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} ES \xrightarrow{k_2} E + P$$

E: Enzyme; S: Substrate; ES: Enzyme-substrate complex; P: Product. Note: k_1 and k_{-1} correspond to the on-/off-rates and k_2 corresponds to the catalytic step for the transformation of the substrate to the product.

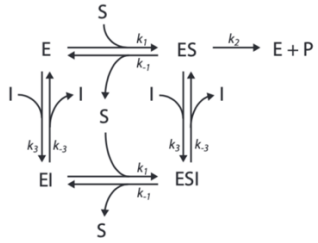
a) Derive an equation for product formation. Consider that a new constant known as the Michaelis-Menten constant (K_M) will be need to be present in this system and not the dissociated constant (K_d) defined as:

$$K_M = \frac{k_{-1} + k_2}{k_1}$$

Note: Steady state conditions could be considered only for the formation of the ES complex.

b) Draw the expected function for the product formation. Note: Y-axis corresponds to the formation rate (V). X-axis corresponds to substrate concentration.

c) In certain diseases, altered enzyme activities contribute to pathogenesis making them important protein targets of interest.
Several inhibition modes exist including:
Competitive – Inhibitor [I] competes with substrate (catalytic) binding site.
Uncompetitive – Inhibition occurs only when the ES complex is formed.
Non-Competitive – Inhibitor binds to other sites other than the catalytic site.
Identify which mode of inhibition is observed in the following scheme. Additionally, draw a representative scheme for the other two modes of inhibition.



Q2. Autorepression with Hill function

Consider the following dynamic system:

$$\frac{dX}{dt} = \frac{\beta}{1 + (X/K)^n} - \alpha X$$

Where X is the gene of interest, β is the production rate, α is the degradation rate, and n is the Hill coefficient.

a) Derive an expression for x(t) considering that the system is under a strong autorepression $(X/K)^n \gg 1$.

b) Compare the response time for the strongly regulated system against the unregulated system. ($t_{½\ \text{regulated}}$ / $t_{½\ \text{unregulated}}$)

c) Consider n = 1. How many times is the regulated system faster than the unregulated?