Bio-Model Selection System (BMSS): Models Documentation

Inducible System

Constant Inducer
- Single-equation
- Double-equation
- Double-equation with Protein Maturation Time

Inducer with Degradation
- Single-equation
- Double-equation
- Double-equation with Protein Maturation Time

Inducer with Delay
- Single-equation
- Double-equation
- Double-equation with Protein Maturation Time

Inhibition at High Concentrations
- Constant Inducer
- Inducer with Delay response

Combinational Effect
- Delay Degradation
- Degradation Delay

Constitutive System

Single-equation
- Single-equation
- Single-equation with Protein Maturation Time

Double-equation
- Double-equation
- Double-equation with Protein Maturation Time

Multiple Fixed RBS
- Multiple Single-equation Fixed RBS
- Multiple Single-equation Fixed RBS with Protein Maturation Time
- Multiple Double-equation Fixed RBS
- Multiple Double-equation Fixed RBS with Protein Maturation Time

Multiple Fixed Promoter
- Multiple Double-equation Fixed Promoter
- Multiple Double-equation Fixed Promoter with Protein Maturation Time

Logic Gates System

NOT gate
- NOT gate Single-equation
- NOT gate Single-equation with Protein Maturation Time
- NOT gate Double-equation
- NOT gate Double-equation with Protein Maturation Time

AND gate
- AND gate Double-equation
- AND gate Double-equation with Basal Leakiness at Input 1
- AND gate Double-equation with Basal Leakiness at Input 2
- AND gate Double-equation with Basal Leakiness at Output
- AND gate Double-equation with Basal Leakiness at Input 1 and Output
- AND gate Double-equation with Basal Leakiness at Input 1 and Output, with Protein Maturation Time

OR gate
- OR gate Double-equation
- OR gate Double-equation with Delay at Input 1
- OR gate Double-equation with Delay at Input 2
- OR gate Double-equation with Inducer Degradation at Input 1
- OR gate Double-equation with inducer degradation at Input 2
- OR gate Double-equation with Delay at Input 1 and Inducer Degradation at Input 2
- OR gate Double-equation with Inducer Degradation at Input 1 and Delay at Input 2
- OR gate Double-equation with Delay responses at Input 1 and 2
- OR gate Double-equation with Delay at Input 1 and Inducer Degradation at Input 2, and with Resources Competition
- OR gate Double-equation with Inducer Degradation at Input 1 and Delay at Input 2, and with Resources Competition
- OR gate Double-equation with Delay responses at Input 1 and 2, and with Resources Competition

Figure 1: Libraries of models developed for the three gene regulatory systems: Inducible, Constitutive and Logic gates. Single-equation and double-equation models refer to the lumped protein expression kinetics and two-step process (transcription and translation) representations respectively. The protein maturation time feature accounts for the maturation step undergone by nascent fluorescent proteins to start fluoresce.

Table 1: Mathematical Formulations for Inducible Promoter Systems

Model = 'ConstantInducer'
$$\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Inducer]^n}{[Inducer]^n + {K_{ind}}^n}\right) - deg_{mRNA}[mRNA]$$ $$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$$
Model = 'ConstantInducerKMat'
$$\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Inducer]^n}{[Inducer]^n + {K_{ind}}^n}\right) - deg_{mRNA}[mRNA]$$ $$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - K_{mature}[Pep]$$ $$\frac{d[Pep_m]}{dt} = K_{mature}[Pep] - deg_{Pep}[Pep_m]$$
Model = 'DegradationInducer'
$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$ $$\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Ind]^n}{[Ind]^n + {K_{ind}}^n}\right) - deg_{mRNA}[mRNA]$$ $$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$$
Model = 'DegradationInducerKMat'
$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$ $$\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Ind]^n}{[Ind]^n + {K_{ind}}^n}\right) - deg_{mRNA}[mRNA]$$ $$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - K_{mature}[Pep]$$ $$\frac{d[Pep_m]}{dt} = K_{mature}[Pep] - deg_{Pep}[Pep_m]$$
Model = 'DelayInducer'
$$\frac{d[Ind_e]}{dt} = -V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + {K_{trans}}^{n_{trans}}}\right)$$ $$\frac{d[Ind_i]}{dt} = V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + {K_{trans}}^{n_{trans}}}\right)$$ $$\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Ind_i]^n}{[Ind_i]^n + {K_{ind}}^n}\right) - deg_{mRNA}[mRNA]$$ $$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$$
Model = 'DelayInducerKMat'

$$\frac{d[Ind_e]}{dt} = -V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$$
$$\frac{d[Ind_i]}{dt} = V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$$
$$\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Ind_i]^n}{[Ind_i]^n + K_{ind}{}^n}\right) - deg_{mRNA}[mRNA]$$
$$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - K_{mature}[Pep]$$
$$\frac{d[Pep_m]}{dt} = K_{mature}[Pep] - deg_{Pep}[Pep_m]$$

Model = 'SingleConstantInducer'

$$\frac{d[Pep]}{dt} = syn_{Pep}\left(\frac{[Inducer]^n}{[Inducer]^n + K_{ind}{}^n}\right) - deg_{Pep}[Pep]$$

Model = 'SingleDegradationInducer'

$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$
$$\frac{d[Pep]}{dt} = syn_{Pep}\left(\frac{[Ind]^n}{[Ind]^n + K_{ind}{}^n}\right) - deg_{Pep}[Pep]$$

Model = 'SingleDelayInducer'

$$\frac{d[Ind_e]}{dt} = -V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$$
$$\frac{d[Ind_i]}{dt} = V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$$
$$\frac{d[Pep]}{dt} = syn_{Pep}\left(\frac{[Ind_i]^n}{[Ind_i]^n + K_{ind}{}^n}\right) - deg_{Pep}[Pep]$$

Model = 'ConstantIndInhibition'

$$\frac{d[mRNA]}{dt} = K_{Leak} + syn_{mRNA}\left(\frac{[Inducer]^n}{[Inducer]^n + K_{ind}{}^n}\right)\left(1 - K_{inhmax}\left(\frac{[Inducer]^{n_{inh}}}{[Inducer]^{n_{inh}} + K_{inh}{}^{n_{inh}}}\right)\right) - deg_{mRNA}[mRNA]$$
$$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$$

Model = 'DelayIndInhibition'

$$\frac{d[Ind_e]}{dt} = -V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$$
$$\frac{d[Ind_i]}{dt} = V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$$
$$\frac{d[mRNA]}{dt} = K_{Leak} + syn_{mRNA}\left(\frac{[Ind_i]^n}{[Ind_i]^n + K_{ind}{}^n}\right)\left(1 - K_{inhmax}\left(\frac{[Ind_e]^{n_{inh}}}{[Ind_e]^{n_{inh}} + K_{inh}{}^{n_{inh}}}\right)\right) - deg_{mRNA}[mRNA]$$
$$\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$$

Model = 'DelayDegradationInducer'
$\frac{d[Ind_e]}{dt} = -V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$ $\frac{d[Ind_i]}{dt} = V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right) - deg_{Ind}[Ind_i]$ $\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Ind_i]^n}{[Ind_i]^n + K_{ind}{}^n}\right) - deg_{mRNA}[mRNA]$ $\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$
Model = 'DegradationDelayInducer'
$\frac{d[Ind_e]}{dt} = -deg_{Ind}[Ind_e] - V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$ $\frac{d[Ind_i]}{dt} = V_m\left(\frac{[Ind_e]^{n_{trans}}}{[Ind_e]^{n_{trans}} + K_{trans}{}^{n_{trans}}}\right)$ $\frac{d[mRNA]}{dt} = syn_{mRNA}\left(\frac{[Ind_i]^n}{[Ind_i]^n + K_{ind}{}^n}\right) - deg_{mRNA}[mRNA]$ $\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$

Table 2: Mathematical Formulations for Constitutive Promoter Systems

Model = 'ConstDouble'
$\frac{d[mRNA]}{dt} = syn_{mRNA} - deg_{mRNA}[mRNA]$ $\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - deg_{Pep}[Pep]$
Model = 'ConstDoubleKMat'
$\frac{d[mRNA]}{dt} = syn_{mRNA} - deg_{mRNA}[mRNA]$ $\frac{d[Pep]}{dt} = syn_{Pep}[mRNA] - K_{mature}[Pep]$ $\frac{d[Pep_m]}{dt} = K_{mature}[Pep] - deg_{Pep}[Pep_m]$
Model = 'ConstSingle'
$\frac{d[Pep]}{dt} = syn_{Pep} - deg_{Pep}[Pep]$
Model = 'ConstSingleKMat'
$\frac{d[Pep]}{dt} = syn_{Pep} - K_{mature}[Pep]$ $\frac{d[Pep_m]}{dt} = K_{mature}[Pep] - deg_{Pep}[Pep_m]$
Model = 'MultiDoubleFixRBS'

$$\frac{d[mRNAX]}{dt} = syn_{mRNAX} - deg_{mRNA}[mRNAX]$$
$$\frac{d[PepX]}{dt} = syn_{Pep}[mRNAX] - deg_{Pep}[PepX]$$
$$for\ X = 1,2, \ldots 6$$

Model = ‘MultiDoubleFixRBSKMat’

$$\frac{d[mRNAX]}{dt} = syn_{mRNAX} - deg_{mRNA}[mRNAX]$$
$$\frac{d[PepX]}{dt} = syn_{Pep}[mRNAX] - K_{mature}[PepX]$$
$$\frac{d[PepX_m]}{dt} = K_{mature}[PepX] - deg_{Pep}[PepX_m]$$
$$for\ X = 1,2, \ldots 6$$

Model = ‘MultiSingleFixRBS’

$$\frac{d[PepX]}{dt} = syn_{PepX} - deg_{Pep}[PepX]$$
$$for\ X = 1,2, \ldots 6$$

Model = ‘MultiSingleFixRBSKMat’

$$\frac{d[PepX]}{dt} = syn_{PepX} - K_{mature}[PepX]$$
$$\frac{d[PepX_m]}{dt} = K_{mature}[PepX] - deg_{Pep}[PepX_m]$$
$$for\ X = 1,2, \ldots 6$$

Model = ‘MultiDoubleFixPromoter’

$$\frac{d[mRNAX]}{dt} = syn_{mRNA} - deg_{mRNA}[mRNAX]$$
$$\frac{d[PepX]}{dt} = syn_{PepX}[mRNAX] - deg_{Pep}[PepX]$$
$$for\ X = 1,2, \ldots 6$$

Model = ‘MultiDoubleFixPromoterKMat’

$$\frac{d[mRNAX]}{dt} = syn_{mRNA} - deg_{mRNA}[mRNAX]$$
$$\frac{d[PepX]}{dt} = syn_{PepX}[mRNAX] - K_{mature}[PepX]$$
$$\frac{d[PepX_m]}{dt} = K_{mature}[PepX] - deg_{Pep}[PepX_m]$$
$$for\ X = 1,2, \ldots 6$$

Table 3: Mathematical Formulations for Logic Gate Systems (NOT, AND, and OR gates)

Model = 'NOTgate'

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state) - deg_{mRNA}[mRNA1]$$

$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$

$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}\left(1 - K_{maxrep}\left(\frac{[Pep1]}{Pep_{max}}\right)\right) - deg_{mRNA}[mRNA2]$$

$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$

Model = 'NOTgateKMat'

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state) - deg_{mRNA}[mRNA1]$$

$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$

$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}\left(1 - K_{maxrep}\left(\frac{[Pep1]}{Pep_{max}}\right)\right) - deg_{mRNA}[mRNA2]$$

$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - K_{mature}[Pep2]$$

$$\frac{d[Pep2_m]}{dt} = K_{mature}[Pep2] - deg_{Pep}[Pep2_m]$$

Model = 'NOTgateSingle'

$$\frac{d[mRNA1]}{dt} = syn_{mRNA}(1 - K_{maxrep}(state)) - deg_{mRNA}[mRNA1]$$

$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$

Model = 'NOTgateSingleKMat'

$$\frac{d[mRNA1]}{dt} = syn_{mRNA}(1 - K_{maxrep}(state)) - deg_{mRNA}[mRNA1]$$

$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - K_{mature}[Pep1]$$

$$\frac{d[Pep1_m]}{dt} = K_{mature}[Pep1] - deg_{Pep}[Pep1_m]$$

Model = 'ANDgate'

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1]}{Pep1_{max}}\right)\left(\frac{[Pep2]}{Pep2_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ANDgateBLeak1'

$$\frac{d[mRNA1]}{dt} = K_{Leak} + syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1]}{Pep1_{max}}\right)\left(\frac{[Pep2]}{Pep2_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ANDgateBLeak2'

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = K_{Leak} + syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1]}{Pep1_{max}}\right)\left(\frac{[Pep2]}{Pep2_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ANDgateBLeak3'

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = K_{Leak} + syn_{mRNA3}\left(\frac{[Pep1]}{Pep1_{max}}\right)\left(\frac{[Pep2]}{Pep2_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = ‘ANDgateBLeak13’

$$\frac{d[mRNA1]}{dt} = K_{Leak1} + syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = K_{Leak} + syn_{mRNA3}\left(\frac{[Pep1]}{Pep1_{max}}\right)\left(\frac{[Pep2]}{Pep2_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = ‘ANDgateBLeak13KMat’

$$\frac{d[mRNA1]}{dt} = K_{Leak1} + syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = K_{Leak} + syn_{mRNA3}\left(\frac{[Pep1]}{Pep1_{max}}\right)\left(\frac{[Pep2]}{Pep2_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - K_{mature}[Pep3]$$
$$\frac{d[Pep3_m]}{dt} = K_{mature}[mRNA3] - deg_{Pep}[Pep3_m]$$

Model = ‘ORgate’

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$

$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = ‘ORgateDelay’

$$\frac{d[Ind_e]}{dt} = -\left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[Ind_i]}{dt} = \left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind_i](state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = ‘ORgate_Delay’

$$\frac{d[Ind_e]}{dt} = -\left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[Ind_i]}{dt} = \left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind_i](state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = ‘ORgateDegradation’

$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind](state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}(state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1]+[Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ORgate_Degradation'

$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}(state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind](state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1]+[Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ORgateDelayDegradation'

$$\frac{d[Ind_e]}{dt} = -\left(\frac{[Ind_e]}{[Ind_e]+K_m}\right)[Ind_e]$$
$$\frac{d[Ind_i]}{dt} = \left(\frac{[Ind_e]}{[Ind_e]+K_m}\right)[Ind_e]$$
$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind_i](state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind](state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1]+[Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ORgateDegradationDelay'

$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$

$$\frac{d[Ind_e]}{dt} = -\left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$

$$\frac{d[Ind_i]}{dt} = \left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind](state1) - deg_{mRNA}[mRNA1]$$

$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$

$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind_i](state2) - deg_{mRNA}[mRNA2]$$

$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$

$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$

$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = ‘ORgateDelayDelay’

$$\frac{d[Ind_{e1}]}{dt} = -\left(\frac{[Ind_{e1}]}{[Ind_{e1}] + K_{m1}}\right)[Ind_{e1}]$$

$$\frac{d[Ind_{i1}]}{dt} = \left(\frac{[Ind_{e1}]}{[Ind_{e1}] + K_{m1}}\right)[Ind_{e1}]$$

$$\frac{d[Ind_{e2}]}{dt} = -\left(\frac{[Ind_{e2}]}{[Ind_{e2}] + K_{m2}}\right)[Ind_{e2}]$$

$$\frac{d[Ind_{i2}]}{dt} = \left(\frac{[Ind_{e2}]}{[Ind_{e2}] + K_{m2}}\right)[Ind_{e2}]$$

$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind_{i1}](state1) - deg_{mRNA}[mRNA1]$$

$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$

$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind_{i2}](state2) - deg_{mRNA}[mRNA2]$$

$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$

$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$

$$\frac{d[Pep3]}{dt} = syn_{Pep}[mRNA3] - deg_{Pep}[Pep3]$$

Model = ‘ORgateDelayDegradeResCompete’

$$\frac{d[Ind_e]}{dt} = -\left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[Ind_i]}{dt} = \left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind_i](state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind](state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep3}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ORgateDegradeDelayResCompete'

$$\frac{d[Ind]}{dt} = -deg_{Ind}[Ind]$$
$$\frac{d[Ind_e]}{dt} = -\left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[Ind_i]}{dt} = \left(\frac{[Ind_e]}{[Ind_e] + K_m}\right)[Ind_e]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind](state1) - deg_{mRNA}[mRNA1]$$
$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind_i](state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep3}[mRNA3] - deg_{Pep}[Pep3]$$

Model = 'ORgateDelayDelayResCompete'

$$\frac{d[Ind_{e1}]}{dt} = -\left(\frac{[Ind_{e1}]}{[Ind_{e1}] + K_{m1}}\right)[Ind_{e1}]$$
$$\frac{d[Ind_{i1}]}{dt} = \left(\frac{[Ind_{e1}]}{[Ind_{e1}] + K_{m1}}\right)[Ind_{e1}]$$
$$\frac{d[Ind_{e2}]}{dt} = -\left(\frac{[Ind_{e2}]}{[Ind_{e2}] + K_{m2}}\right)[Ind_{e2}]$$
$$\frac{d[Ind_{i2}]}{dt} = \left(\frac{[Ind_{e2}]}{[Ind_{e2}] + K_{m2}}\right)[Ind_{e2}]$$
$$\frac{d[mRNA1]}{dt} = syn_{mRNA1}[Ind_{i1}](state1) - deg_{mRNA}[mRNA1]$$

$$\frac{d[Pep1]}{dt} = syn_{Pep}[mRNA1] - deg_{Pep}[Pep1]$$
$$\frac{d[mRNA2]}{dt} = syn_{mRNA2}[Ind_{i2}](state2) - deg_{mRNA}[mRNA2]$$
$$\frac{d[Pep2]}{dt} = syn_{Pep}[mRNA2] - deg_{Pep}[Pep2]$$
$$\frac{d[mRNA3]}{dt} = syn_{mRNA3}\left(\frac{[Pep1] + [Pep2]}{Pep_{max}}\right) - deg_{mRNA}[mRNA3]$$
$$\frac{d[Pep3]}{dt} = syn_{Pep3}[mRNA3] - deg_{Pep}[Pep3]$$