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1. EQUATIONS

$$\begin{aligned}
EnvZ \quad \dot{x}_1 &= k_{ad}x_2 - k_{ap}x_1RL + k_{d2}x_4 - k_{b2}x_5x_1 - k_{b3} * x_6x_1 + k_{d3}x_7 \\
EnvZ - P \quad \dot{x}_2 &= k_{ap}x_1RL - k_{ad}x_2 + k_{d1}x_3 - k_{b1}x_6x_2 \\
EnvZ - P.OmpR \quad \dot{x}_3 &= -(k_{d1} + k_{pt})x_3 + k_{b1}x_6x_2 \\
EnvZ.OmpR - P \quad \dot{x}_4 &= k_{pt}x_3 - (k_{ph} + k_{d2})x_4 + k_{b2}x_5x_1 \\
OmpR - P \quad \dot{x}_5 &= k_{d2}x_4 - k_{b2}x_5x_1 \\
OmpR \quad \dot{x}_6 &= k_{d1}x_3 + k_{d3}x_7 - k_{b3}x_6x_1 - k_{b1}x_6x_2 \\
EnvZ.OmpR \quad \dot{x}_7 &= k_{ph}x_4 - k_{d3}x_7 + k_{b3}x_6x_1 \\
YcgF_{mRNA} \quad \dot{x}_8 &= k_1 - \gamma_{mRNA}x_8 \\
YcgF_{inactive} \quad \dot{x}_9 &= k_3x_8 - \gamma_2x_9 - 2k_{dim}x_9^2 \frac{BL^2}{\frac{1}{4} + (BL)^2} + 2k_{dis}x_{10} - \gamma_{Protein}x_9 \\
YcgF_{dimer} \quad \dot{x}_{10} &= 2k_{dim}x_9^2 \frac{BL^2}{\frac{1}{4} + (BL)^2} - k_{bind}x_{10}x_{12} - k_{dis}x_{10} + k_{ubind}x_{13} - \gamma_{Protein}x_{10} \\
YcgE_{RNA} \quad \dot{x}_{11} &= k_2 - \gamma_{mRNA}x_{11} \\
YcgE_{Protein} \quad \dot{x}_{12} &= k_4x_{11} - \gamma_2x_{12} - k_{bind}x_{10}x_{12} + k_{ubind}x_{13} - \gamma_{Protein}x_{12} \\
YcgE.YcgF_{complex} \quad \dot{x}_{13} &= -k_{ubind}x_{13} + k_{bind}x_{10}x_{12} \\
tRNA \quad \dot{x}_{14} &= k_t \frac{\left(\frac{x_5}{K1}\right)^2}{1 + \left(\frac{x_5}{K1}\right)^2} - (\gamma_1 + k_a)x_{14} + \gamma_{2p}x_{15} + 2k_{7p}x_{16} \left(\frac{\gamma_3}{k_{7m}}\right) \left(\frac{x_{14}}{\gamma_0 + x_{14}}\right)^2 \\
Aa - tRNA \quad \dot{x}_{15} &= k_a x_{14} - 2k_{7p}x_{16} \left(\frac{\gamma_3}{k_{7m}}\right) \left(\frac{x_{14}}{\gamma_0 + x_{14}}\right)^2 - \gamma_2 x_{15} \\
T7RNAP_{mRNA} \quad \dot{x}_{16} &= k_{7m} \left(1 - \frac{\left(\frac{x_{12}}{K1}\right)^2}{1 + \left(\frac{x_{12}}{K1}\right)^2}\right) - \gamma_3 x_{16} \\
T7RNAP \quad \dot{x}_{17} &= k_{7p}x_{16} \left(\frac{\gamma_3}{k_{7m}}\right) \left(\frac{x_{14}}{\gamma_0 + x_{14}}\right)^2 - \gamma_4 x_{17} \\
lacZ_{mRNA} \quad \dot{x}_{18} &= \alpha_M \left(1 - \frac{\left(\frac{x_{17}}{K5}\right)^2}{1 + \left(\frac{x_{17}}{K5}\right)^2}\right) - \gamma_M x_{18} \\
\beta - Galactosidase \quad \dot{x}_{19} &= \alpha_B x_{18} - \gamma_B x_{19} \\
dye \quad \dot{x}_{20} &= \alpha_A x_{19}
\end{aligned}$$

2. PARAMETERS

Parameter	Value	Unit	Name	Source
k_{ap}	0.1	$\frac{1}{s}$	EnvZ autophosphorelation rate	[?]
k_{ad}	0.001	$\frac{1}{s}$	EnvZ dephospholeration rate	[?]

Parameter	Value	Unit	Name	Source
k_{b1}	0.5	$\frac{1}{s}$	binding rate EnvZ-P & OmpR	[?]
k_{d1}	0.5	$\frac{1}{s}$	unbinding rate EnvZ-P.OmpR	[?]
k_{b2}	0.05	$\frac{1}{s}$	binding rate EnvZ & OmpR-P	[?]
k_{d2}	0.5	$\frac{1}{s}$	unbinding rate EnvZ.OmpR-P	[?]
k_{b3}	0.5	$\frac{1}{s}$	binding rate EnvZ & OmpR	[?]
k_{d3}	5	$\frac{1}{s}$	unbinding rate EnvZ.OmpR	[?]
k_{ph}	0.05	$\frac{1}{s}$	dephosphorelation rate EnvZ.OmpR-P	[?]
k_{pt}	1.5	$\frac{1}{s}$	phosphotransfer rate	[?]
k_1	1.54e-3	$\frac{1}{s}$	max transcription rate tRNA	[?]
k_2	0.848e-3	$\frac{1}{s}$	max transcription rate tRNA	[?]
k_3	0.167	$\frac{1}{s}$	max translation rate T7RNAP	[?]
k_4	0.167	$\frac{1}{s}$	max translation rate T7RNAP	[?]
k_{dim}	0.008	$\frac{1}{s}$	dimerization rate YcgF	[?]
k_{dis}	0.0058	$\frac{1}{s}$	dissociation rate YcgF dimer	[?]
k_{bind}	100	$\frac{1}{s}$	binding rate YcgF dimer to YcgE	[?]
k_{ubind}	1	$\frac{1}{s}$	unbinding rate YcgF.YcgE	[?]
γ_{mRNA}	2.3105e-3	$\frac{1}{s}$	degradation mRNA YcgE/YcgF	[?]
$\gamma_{Protein}$	1.9254e-5	$\frac{1}{s}$	degradation rate Protein YcgE/YcgF	[?]
k_t	$\frac{46.67}{60}$	$\frac{nM}{s}$	max transcription rate tRNA	[?]
k_a	$\frac{0.08}{60}$	$\frac{1}{s}$	synthesis rate Aa-tRNA	[?]
k_{7p}	$\frac{1.5625}{60}$	$\frac{nM}{s}$	max transcription rate T7RNAP	[?]
k_{7m}	$\frac{268*0.05}{60}$	$\frac{1}{s}$	max translation rate T7RNAP	[?]
k_S	0.3	$\frac{1}{nM}$	AND Gate rate	[?]
γ_0	1	-	threshold Aa-tRNA	guessed
γ_1	$\frac{1}{60*60}$	$\frac{1}{s}$	degradation of tRNA	[?]
γ_2	$\frac{1}{40*60}$	$\frac{1}{s}$	degradation of Aa-tRNA	[?]

Parameter	Value	Unit	Name	Source
γ_3	$\frac{1}{4.4*60}$	$\frac{1}{s}$	degradation of T7RNAP mRNA	[?]
γ_4	$\frac{46.67}{40*60}$	$\frac{1}{s}$	degradation of T7RNAP	[?]
$K1$	5	nM	response param. OmpR-P,tRNA	guessed
$K3$	600	nM	response param. YcgE,T7RNAP	guessed
$K5$	$\frac{k7p}{4*\gamma_4}$	nM	response param T7RNAP,lacZ	guessed
α_M	$\frac{0.997}{60}$	$\frac{nM}{s}$	max transcription rate lacZ	[?]
α_B	$\frac{1.661e-5}{60}$	$\frac{1}{s}$	max translation rate lacZ	[?]
α_A	$\frac{20}{60}$	$\frac{1}{s}$	enzymatic reaction rate	[?]
γ_M	$\frac{0.411}{60}$	$\frac{1}{s}$	degradation lacZ mRNA	[?]
γ_B	$\frac{8.331e-4}{60}$	$\frac{1}{s}$	degradation β -Galactosidase	[?]

3. INITIAL DATA

Name	Variable	Initial Value	Comment	Source
$EnvZ$	x_1	$\frac{3500}{0.60221}$	3500 molecules per cell	[?]
$EnvZ - P$	x_2	0		
$EnvZ - P.OmpR$	x_3	0		
$EnvZ.OmpR - P$	x_4	0		
$OmpR - P$	x_5	0		
$OmpR$	x_6	$\frac{100}{0.60221}$	100 molecules per cell	[?]
$EnvZ.OmpR$	x_7	0		
$YcgF_{mRNA}$	x_8	$\frac{k_1}{\gamma_{mRNA}}$	steady state	
$YcgF_{inactive}$	x_9	$\frac{k_3}{\gamma_{Protein}} - \frac{k_1}{\gamma_{mRNA}}$	steady state	
$YcgF_{dimer}$	x_{10}	0		
$YcgE_{mRNA}$	x_{11}	$\frac{k_2}{\gamma_{mRNA}}$	steady state	
$YcgE$	x_{12}	$\frac{k_4}{\gamma_{Protein}} - \frac{k_2}{\gamma_{mRNA}}$	steady state	
$YcgE.YcgF$	x_{13}	0		

Name	Variable	Initial Value	Comment	Source
<i>tRNA</i>	x_{14}	0		
<i>Aa - tRNA</i>	x_{15}	0		
<i>T7RNAP_{mRNA}</i>	x_{16}	0		
<i>T7RNAP</i>	x_{17}	0		
<i>lacZ_{mRNA}</i>	x_{18}	0		
<i>β - Galactosidase</i>	x_{19}	0		
<i>dye</i>	x_{20}	0		

4. ANALYSIS

TBD

5. ATTRIBUTION

The red light sensor was modeled according to the paper “Hysteretic and graded responses in bacterial two-component signal transduction”

The model for our AND-Gate is based on the model of the iGEM team PKU Beijing 2009 for their AND-Gate1. We modified the equations such that the change in tRNA and Aa-tRNA does not include the degradation of the mRNA which caused negativity of some concentrations in our model.

The Expression of lacZ is an adaption of the model given by “Dynamics and bistability in a reduced model of the lac operon”

REFERENCES