Feedforward Control Systems

MADE BY

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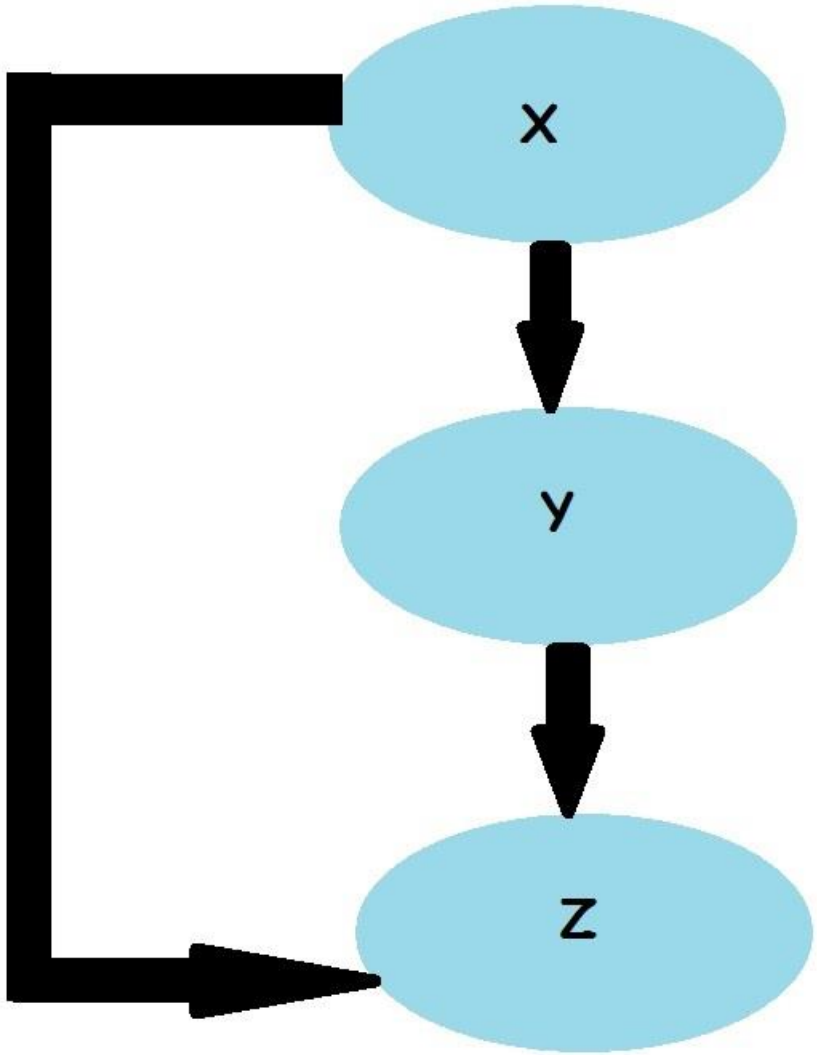
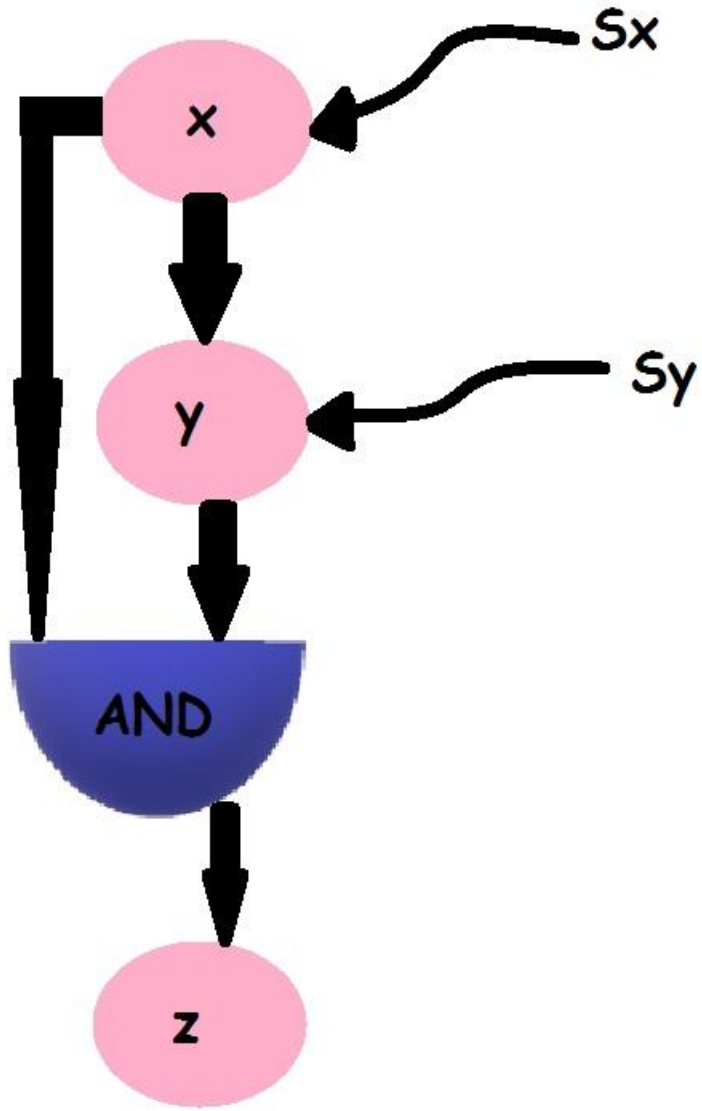
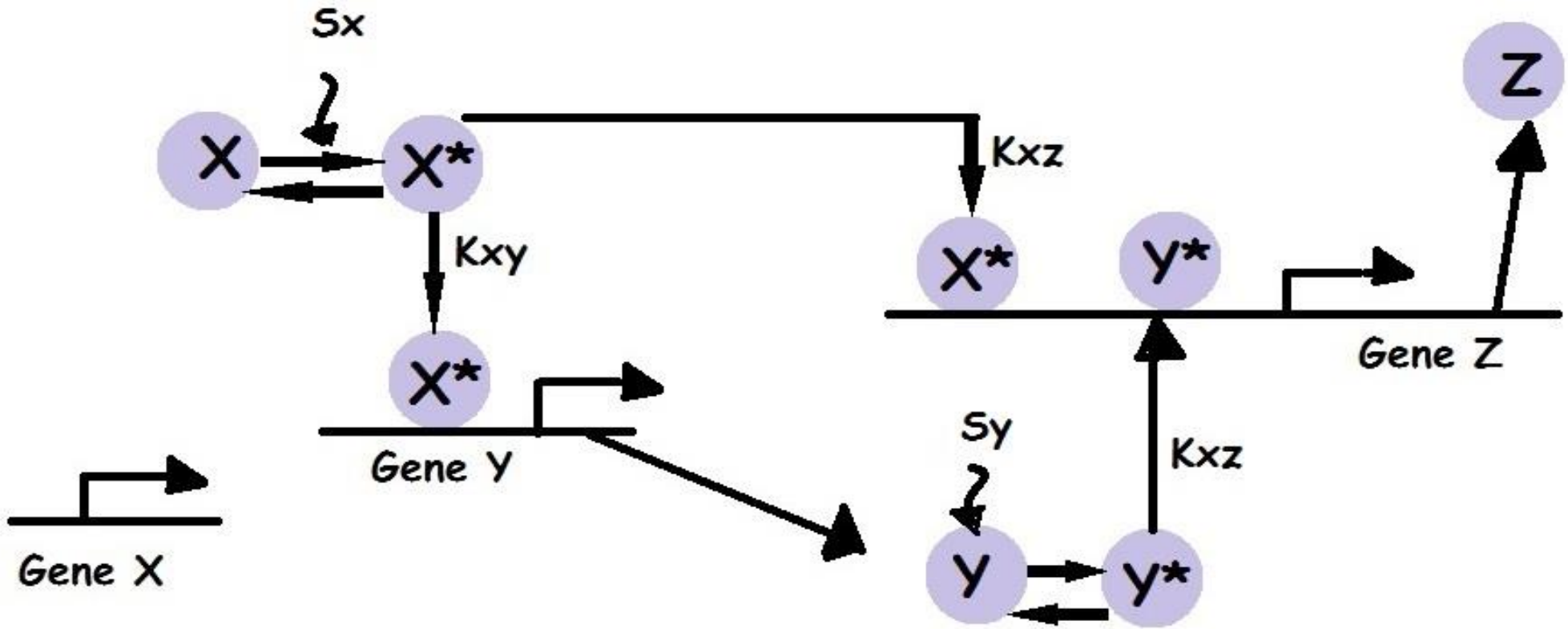
Coherent Feedforward Loop

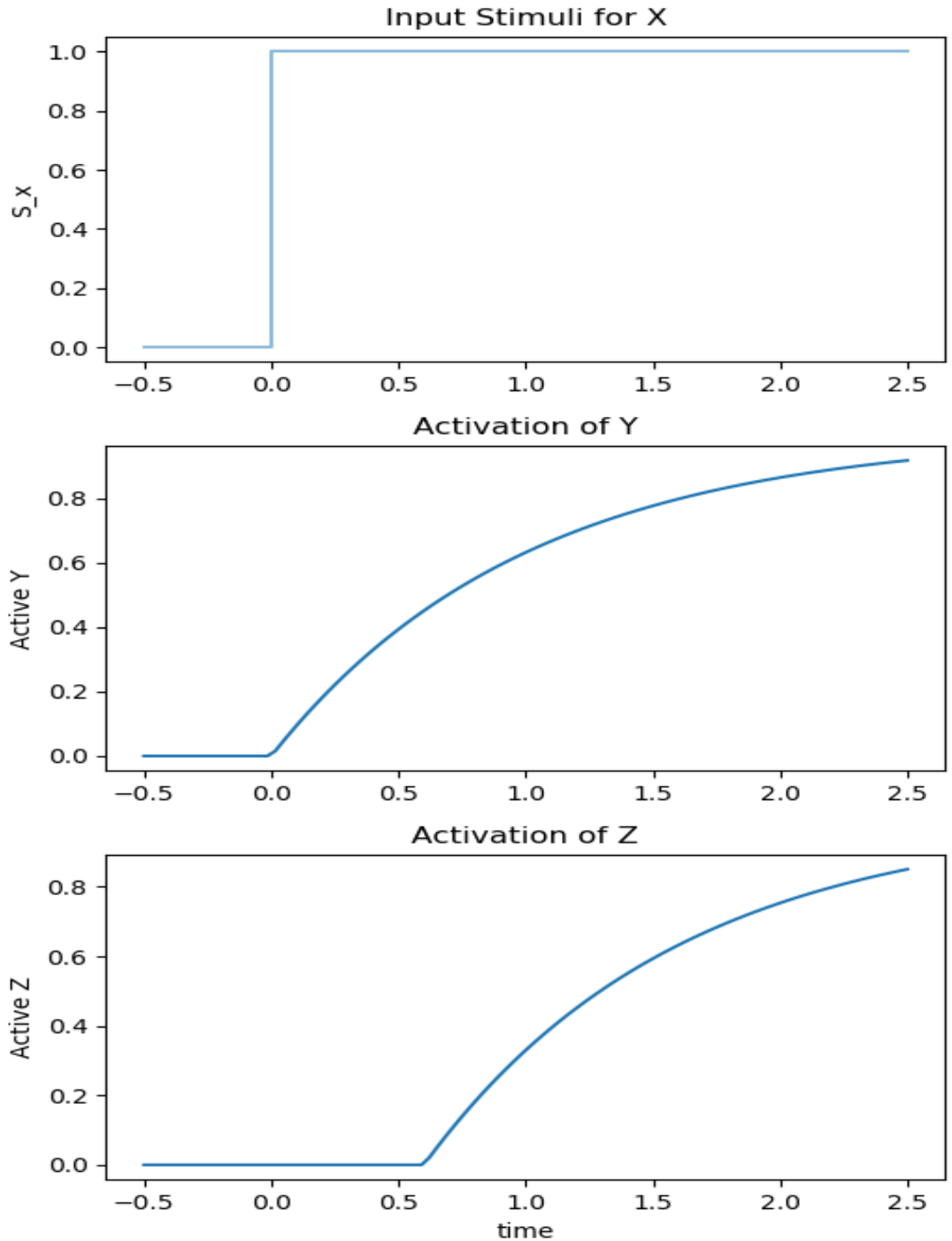


Coherent Feedforward Loop with an AND Input Function



Molecular Interactions in Coherent Feedforward Loop




Input Stimuli for X
S_x
1.0
0.8
0.6
0.4
0.2
0.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
Activation of Y
Active Y
0.8
0.6
0.4
0.2
0.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
Activation of Z
Active Z
0.8
0.6
0.4
0.2
0.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
time

Model Equations

$$\frac{\mathrm{d}Y}{\mathrm{d}t} = \beta_y \, \theta(X^* > K_{xy}) - \alpha_y \, Y$$

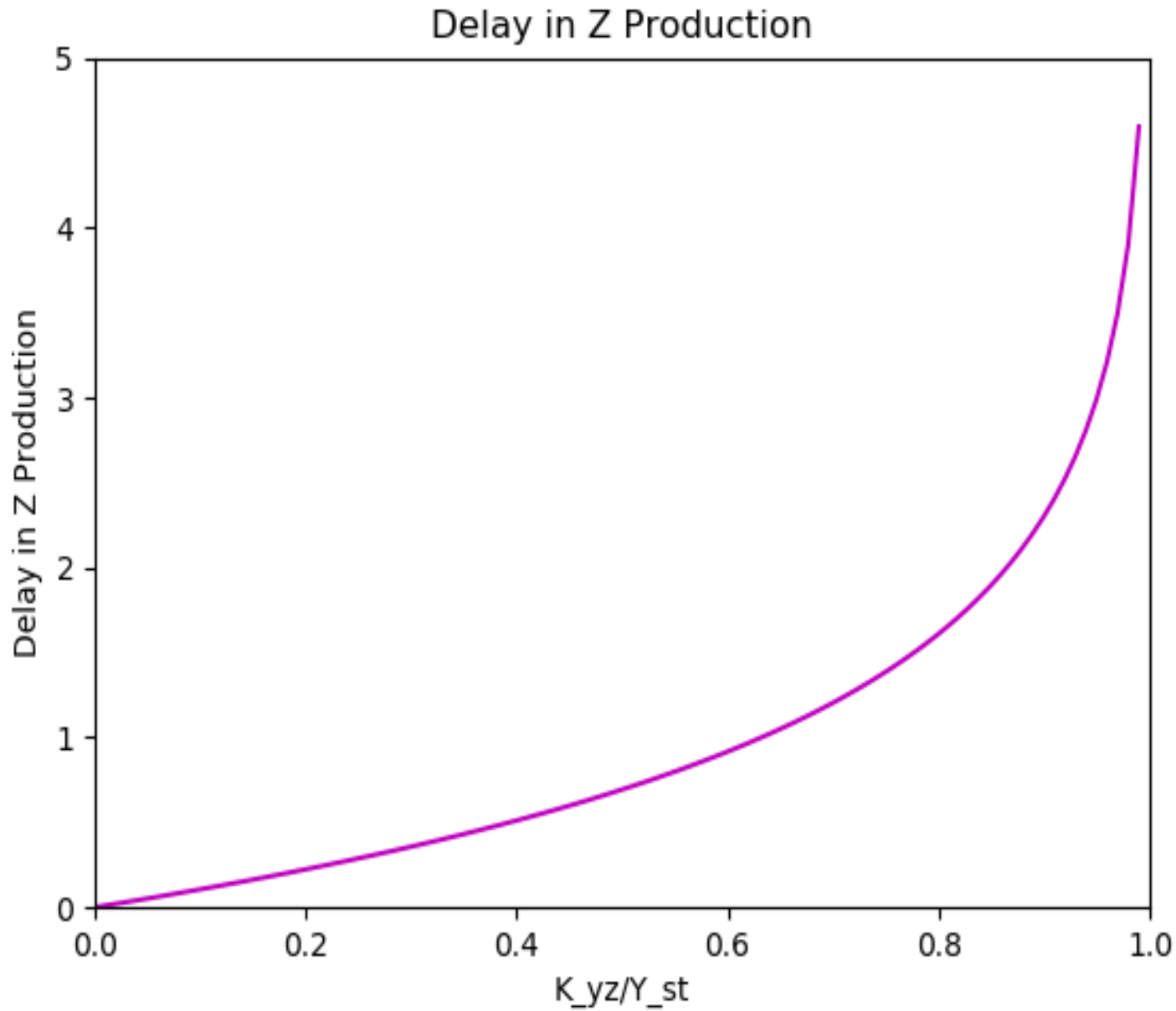
$$\frac{\mathrm{d}Z}{\mathrm{d}t} = \beta_z \, \theta(X^* > K_{xz})\theta(Y^* > K_{yz}) - \alpha_z \, Z$$

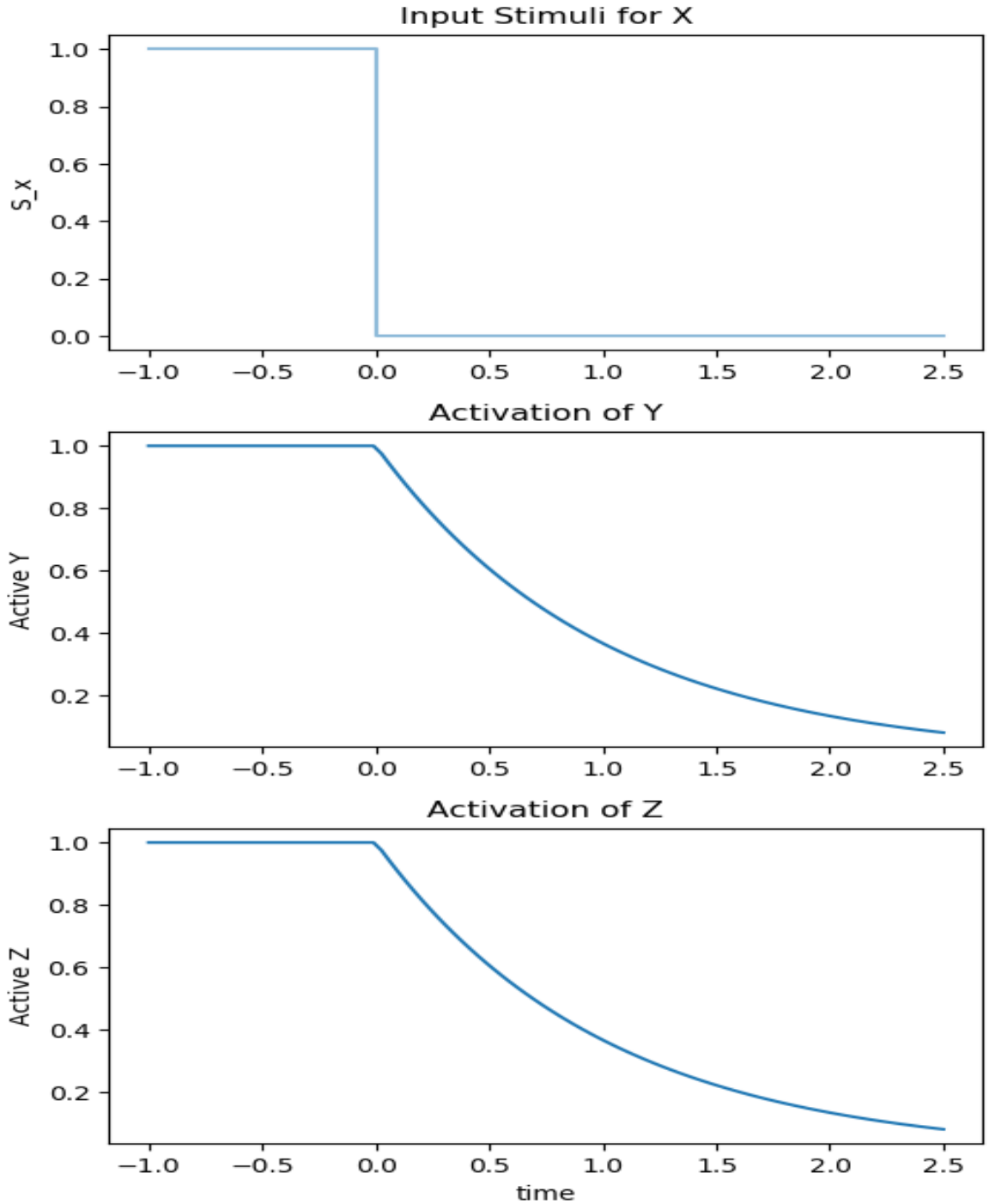
$$Y^*(t) = Y_s t(1 - e^{-\alpha_y \, t})$$

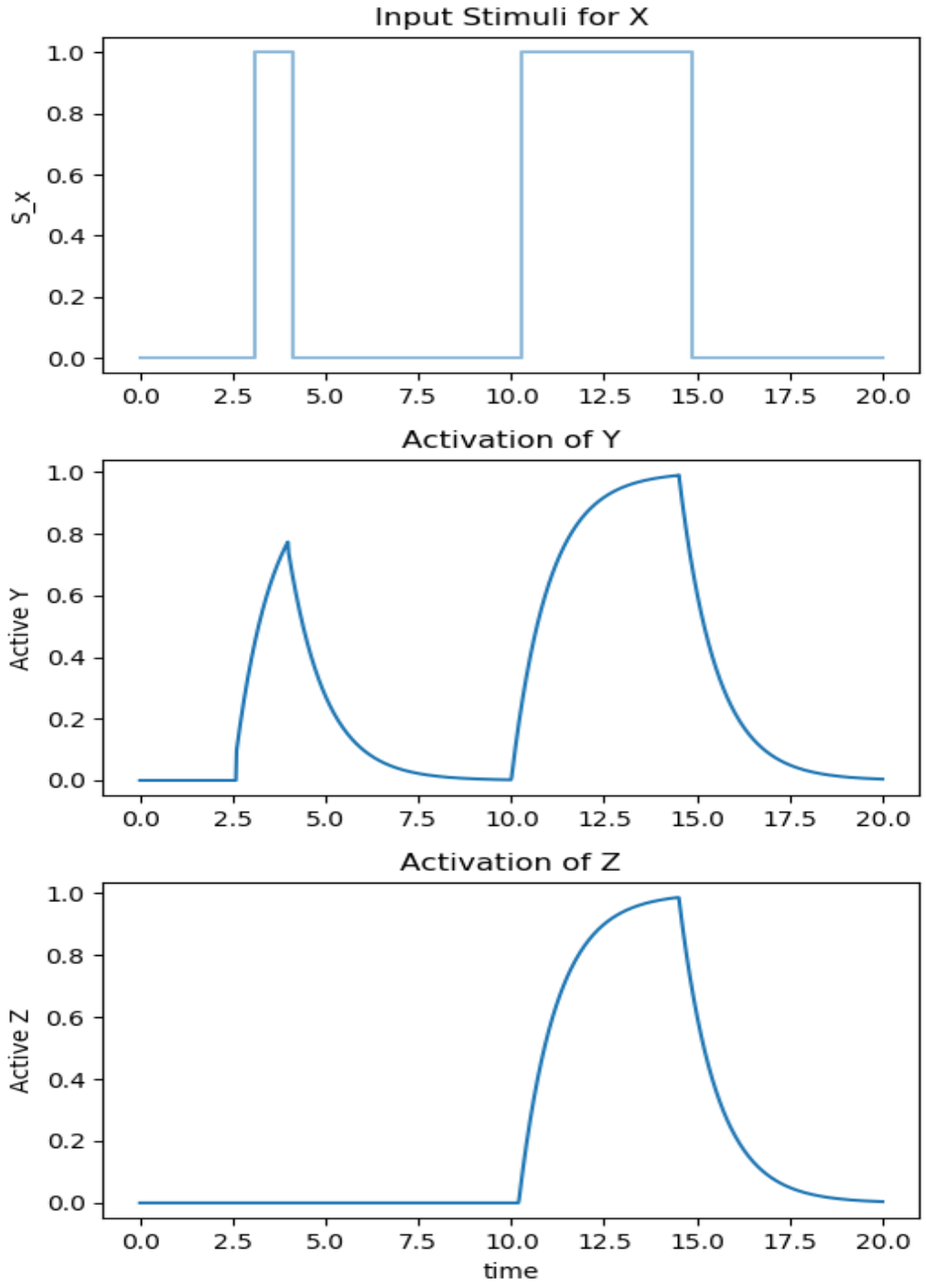
$$Y^*(T_{on}) = Y_s t(1 - e^{-\alpha_y \, T_{on}}) = K_{yz}$$

$$T_{on} = \frac{1}{\alpha_y} log(\frac{1}{1 - \frac{K_{yz}}{Y_{st}}})$$

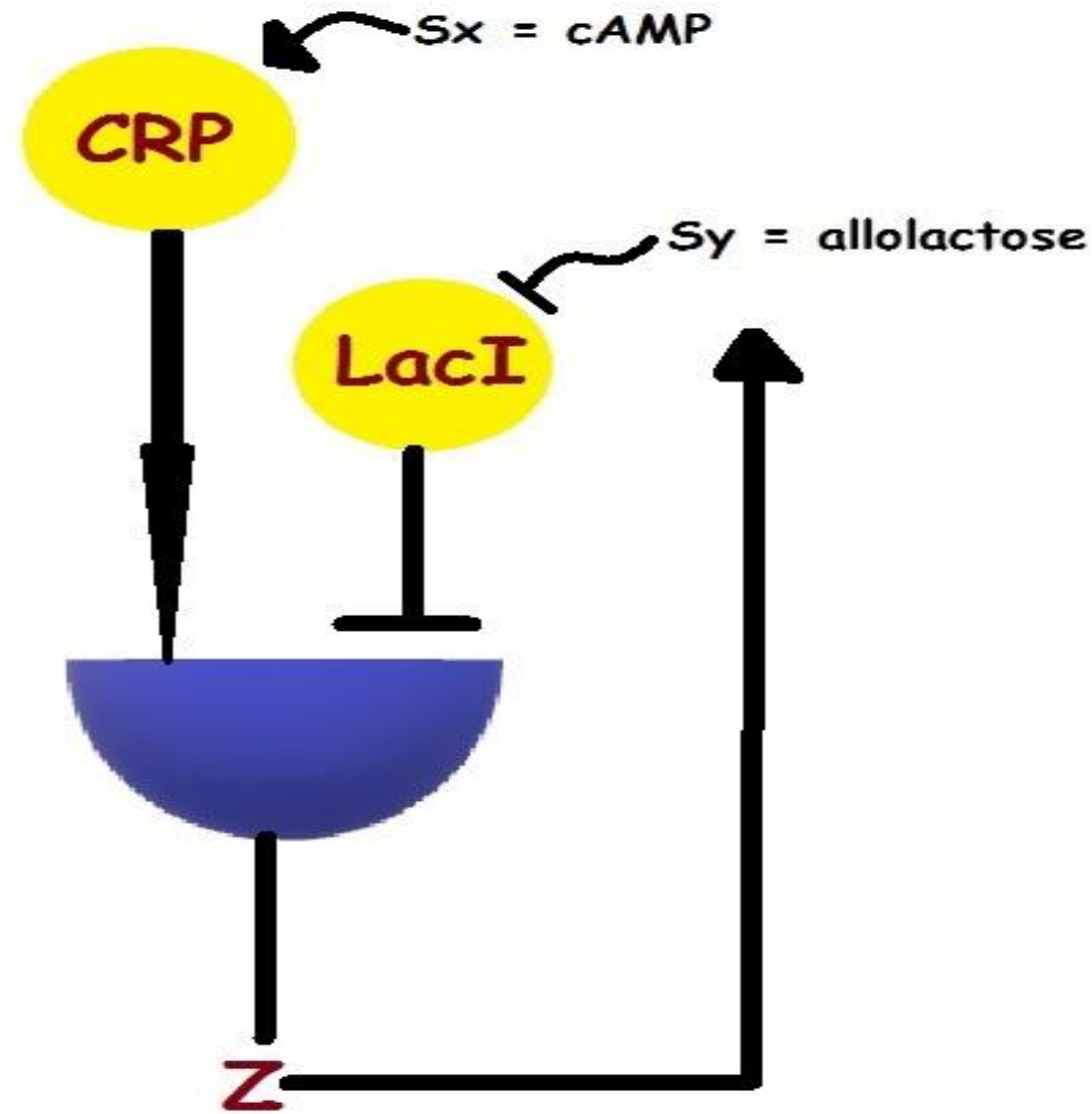
$$Y_{st} = \frac{\beta_y}{\alpha_y}$$


Delay in Z Production
Delay in Z Production
K_yz/Y_st
0
1
2
3
4
5
0.0
0.2
0.4
0.6
0.8
1.0

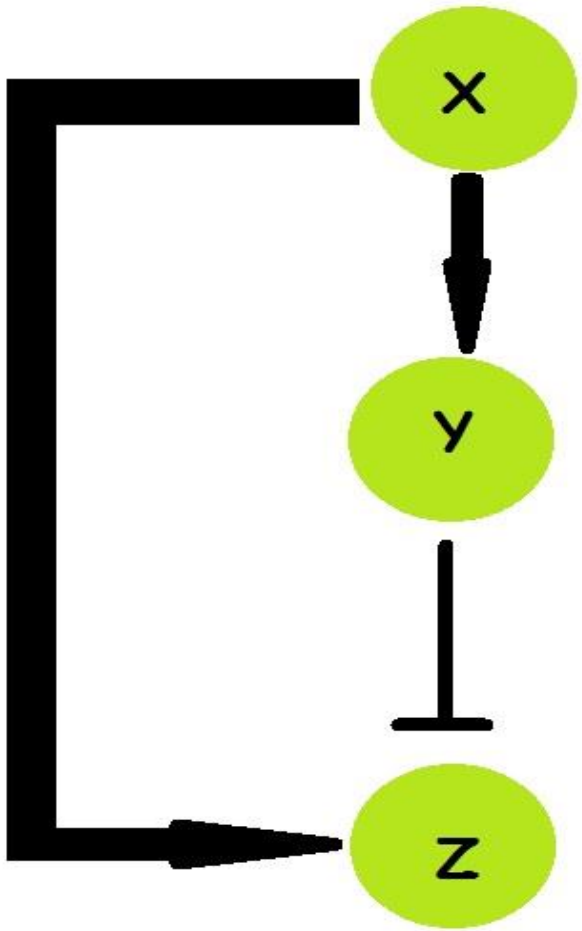

Input Stimuli for X
S_x
1.0
0.8
0.6
0.4
0.2
0.0
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
Activation of Y
Active Y
1.0
0.8
0.6
0.4
0.2
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
Activation of Z
Active Z
1.0
0.8
0.6
0.4
0.2
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
time


Input Stimuli for X
S_x
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Activation of Y
Active Y
Activation of Z
Active Z
time

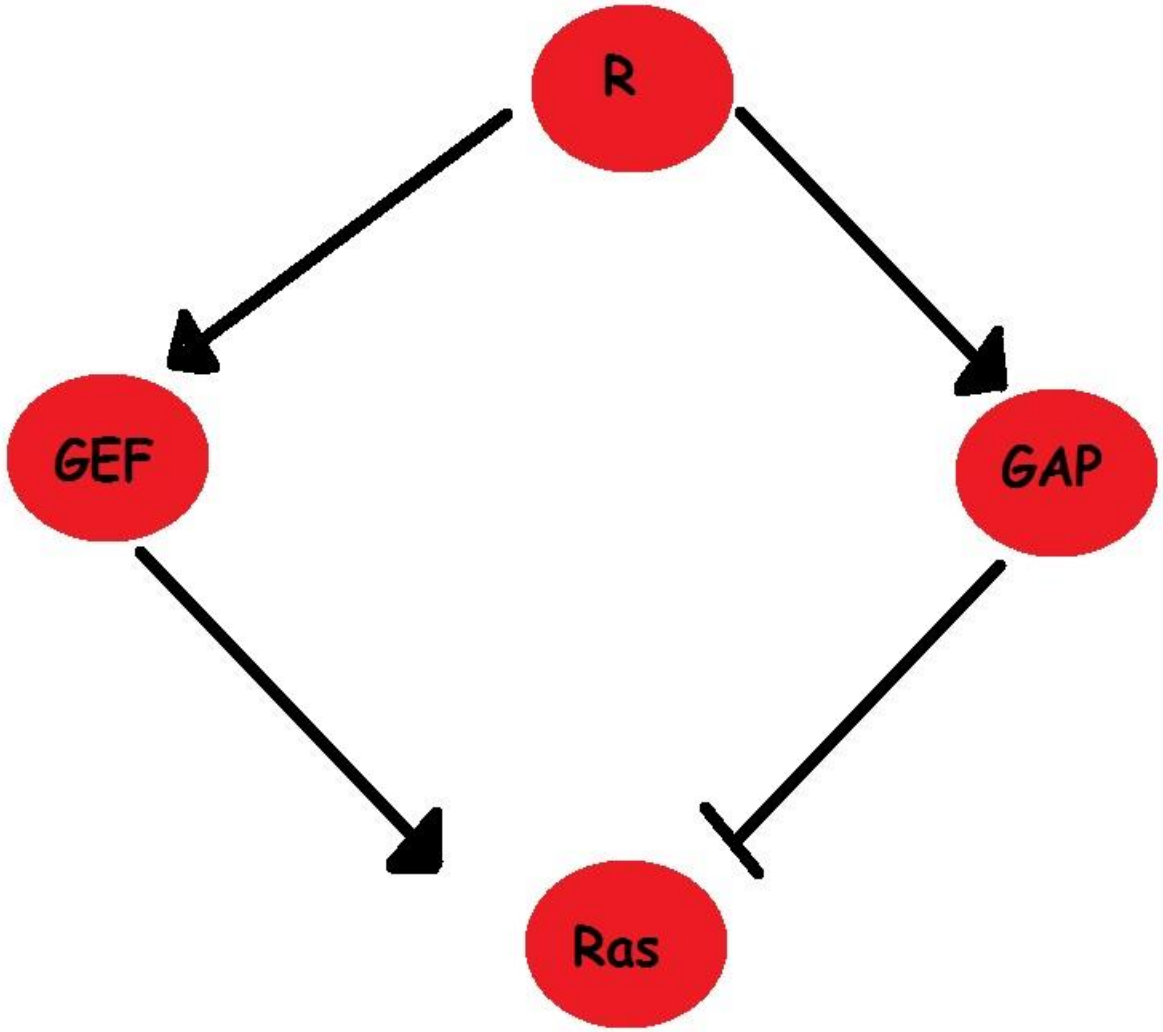
The Lac Operon



Incoherent Feedforward Loop



Incoherent Feedforward Control of Activated Ras



Incoherent Feedforward Control Governs Adaptation of Activated Ras in a Eukaryotic Chemotaxis Pathway
Kosuke Takeda1, **Danying Shao**2, **Micha Adler**3, **Pascale G. Charest**1, **William F. Loomis**1, **Herbert Levine**2, **Alex Groisman**3, **Wouter-Jan Rappel**2, and **Richard A. Firtel**1,

Model Equations

$$\frac{\mathrm{d}R_1}{\mathrm{d}t} = k_{R1}(cAMP + r_1)(R_1^{tot} - R_1) - k_{-R1}R_1$$

$$\frac{\mathrm{d}R_2}{\mathrm{d}t} = k_{R2}(cAMP + r_2)(R_2^{tot} - R_2) - k_{-R2}R_2$$

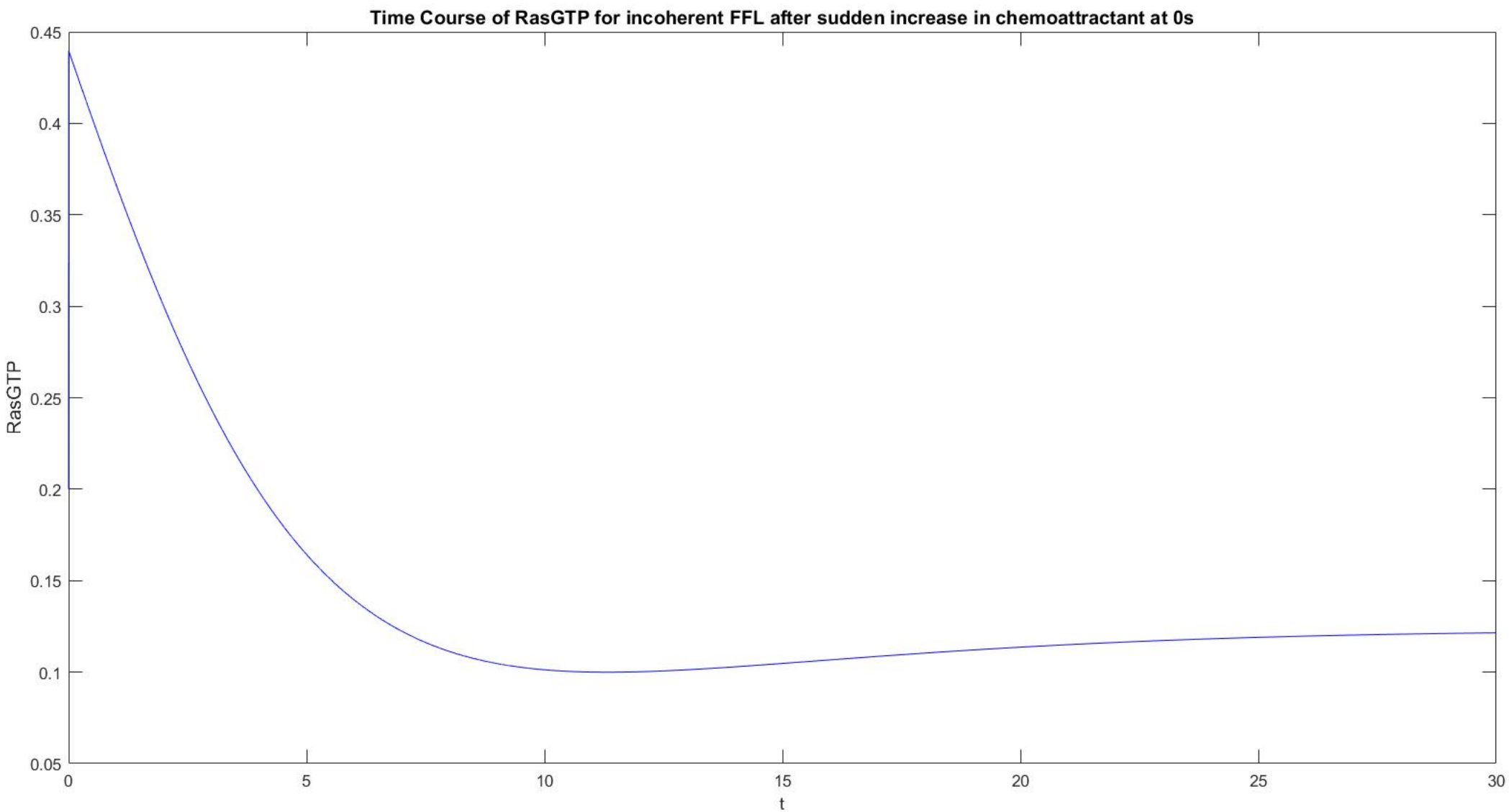
$$R = R_1 + R_2$$

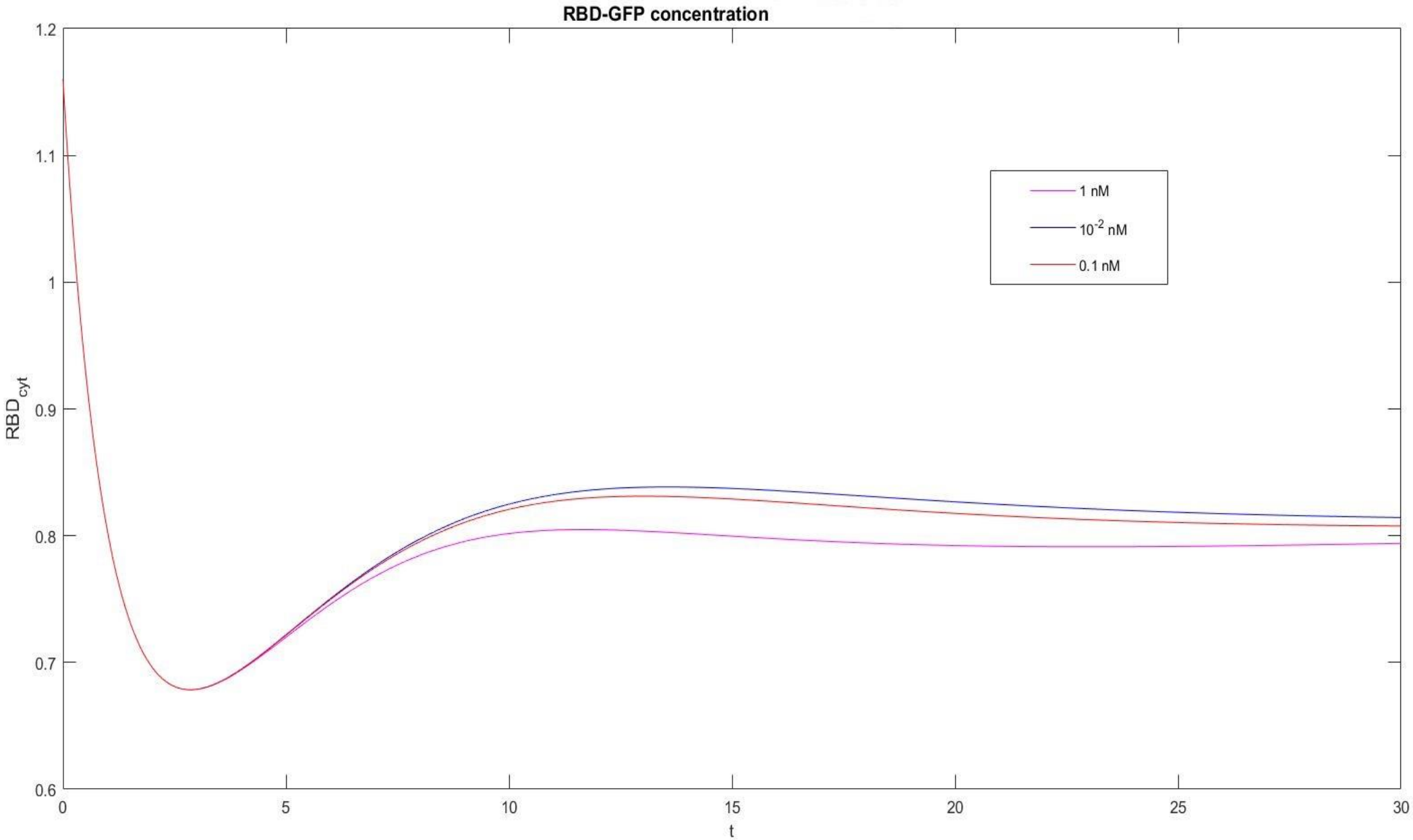
$$\frac{\mathrm{d}GEF}{\mathrm{d}t} = k_{GEF}R - k_{-GEF}GEF$$

$$\frac{\mathrm{d}GAP}{\mathrm{d}t} = k_{GAP}R - k_{-GAP}GAP$$

$$\frac{\mathrm{d}Ras^{GTP}}{\mathrm{d}t} = k_{Ras}GEF(Ras^{tot} - Ras^{GTP}) - k_{-Ras}GAPRas^{GTP}$$

$$\frac{\mathrm{d}RBD^{cyt}}{\mathrm{d}t} = k_{RBD}^{off}(RBD^{tot} - RBD^{cyt}) - k_{-RBD}^{on}Ras^{GTP}RBD^{cyt}$$


Time Course of RasGTP for incoherent FFL after sudden increase in chemoattractant at 0s
RasGTP
t
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5
10
15
20
25
30


RBD-GFP concentration
1.2
1.1
1
0.9
0.8
0.7
0.6
RBD_cyt
0
5
10
15
20
25
30
t
1 nM
10^-2 nM
0.1 nM