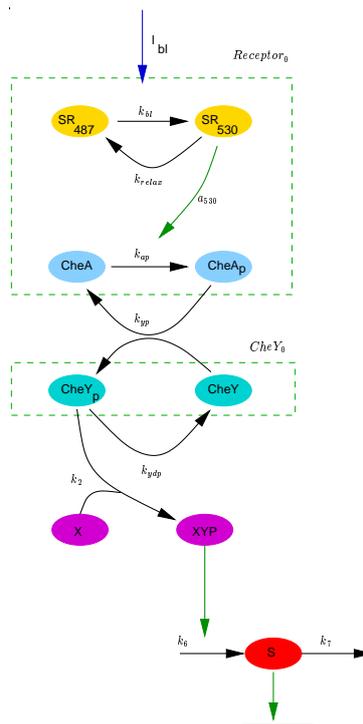


Model parameters and equations

1 Model a



name	value [molecules/cell]
$Receptor_0$	430
$[CheY_0]$	20000
$[X_0]$	90.9

name	value
k_{bl}	$0.241 \cdot 10^{-20}$
k_{relax}	1.54
a_{530}	$1 / [Receptor_0]$
k_{ap}	15.5
k_{yp}	0.0357
k_{ydp}	20
k_{21}	0.273
k_{22}	0.396
k_6	0.01268
k_7	$41 \cdot 10^{-6}$

Receptor SRII:

$$\begin{aligned}\frac{d[SR_{530}]}{dt} &= k_{bl} \cdot I_{bl} \cdot [SR_{487}] - k_{relax} \cdot [SR_{530}] \\ [Receptor_0] &= [SR_{487}] + [SR_{530}]\end{aligned}$$

Histidine Kinase CheA:

$$\begin{aligned}\frac{d[CheA_P]}{dt} &= k_{ap} \cdot [CheA] \cdot a_{530} \cdot [SR_{530}] \\ &\quad - k_{yp} \cdot [CheA_P] \cdot [CheY] \\ [Receptor_0] &= [CheA] + [CheA_P]\end{aligned}$$

Response Regulator CheY:

$$\begin{aligned}\frac{d[CheY_P]}{dt} &= k_{yp} \cdot [CheA_P] \cdot [CheY] - k_{ydp} \cdot [CheY_P] \\ &\quad - k_{21} \cdot [X] \cdot [CheY_P] + k_{22} \cdot [XY_P] \\ [CheY_0] &= [CheY] + [CheY_P]\end{aligned}$$

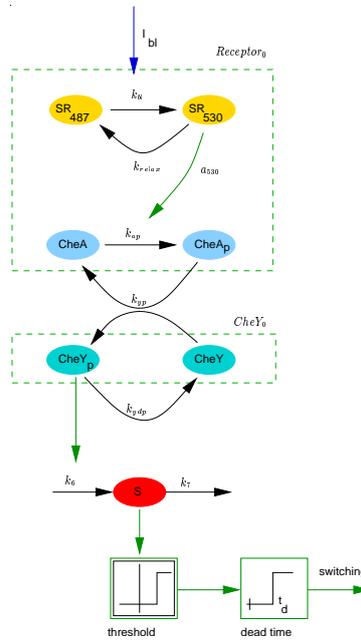
Switch mechanism:

$$\begin{aligned}\frac{d[XY_P]}{dt} &= +k_{21} \cdot [X] \cdot [CheY_P] - k_{22} \cdot [XY_P] \\ [X_0] &= [X] + [XY_P] \\ \frac{d[S]}{dt} &= k_6 \cdot [XY_P] - k_7 \cdot [S]\end{aligned}$$

Threshold:

$$\text{switch if } ([S] > 1)$$

2 Model b



name	value [molecules/cell]
$Receptor_0$	430
$[CheY_0]$	20000

name	value
k_{bl}	$0.241 \cdot 10^{-20}$
k_{relax}	1.54
a_{530}	$1 / Receptor_0$
k_{ap}	15.5
k_{yp}	0.0357
k_{ydp}	30
k_6	0.284
k_7	$23 \cdot 10^{-6}$
t_d	0.95

Receptor SRII:

$$\begin{aligned}\frac{d[SR_{530}]}{dt} &= k_{bl} \cdot I_{bl} \cdot [SR_{487}] - k_{relax} \cdot [SR_{530}] \\ [Receptor_0] &= [SR_{487}] + [SR_{530}]\end{aligned}$$

Histidine Kinase CheA:

$$\begin{aligned}\frac{d[CheA_P]}{dt} &= k_{ap} \cdot [CheA] \cdot a_{530} \cdot [SR_{530}] \\ &\quad - k_{yp} \cdot [CheA_P] \cdot [CheY] \\ [Receptor_0] &= [CheA] + [CheA_P]\end{aligned}$$

Response Regulator CheY:

$$\begin{aligned}\frac{d[CheY_P]}{dt} &= k_{yp} \cdot [CheA_P] \cdot [CheY] - k_{ydp} \cdot [CheY_P] \\ [CheY_0] &= [CheY] + [CheY_P]\end{aligned}$$

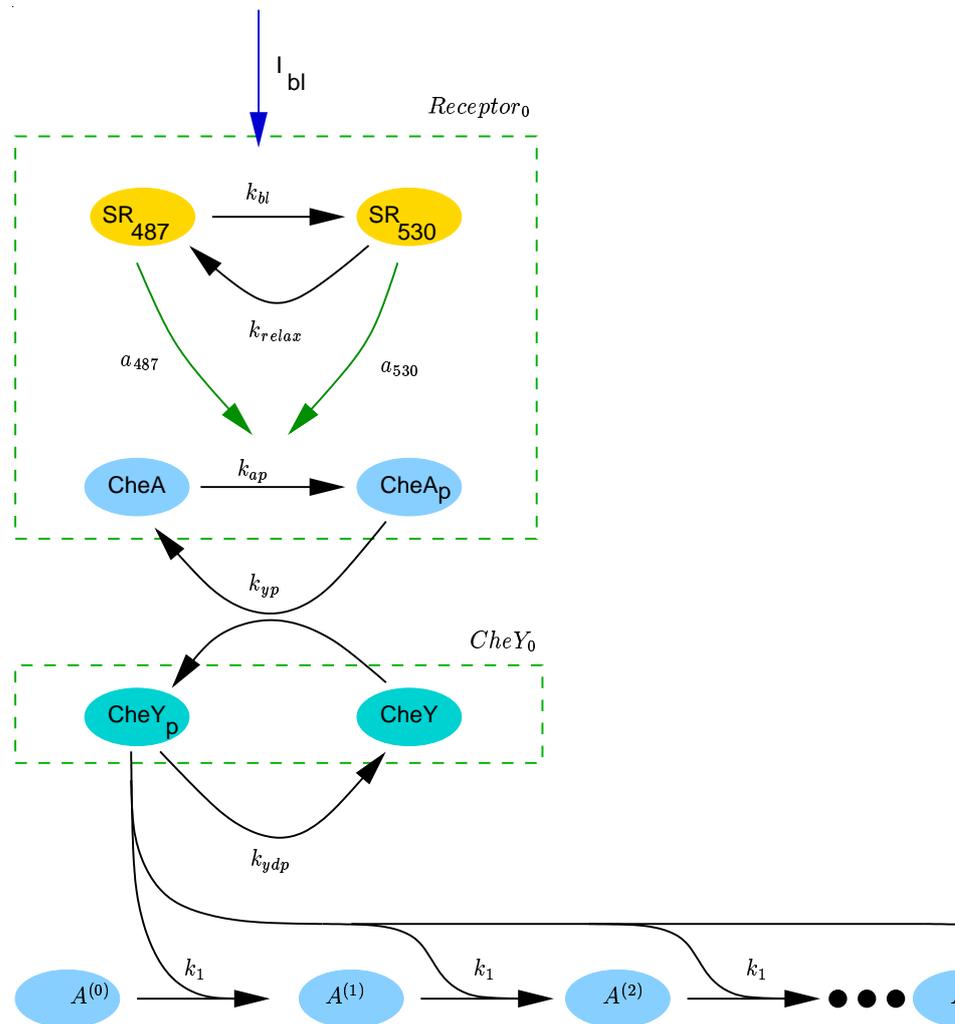
Switch mechanism:

$$\frac{d[S]}{dt} = k_6 \cdot [CheY_P] - k_7 \cdot [S]$$

Threshold:

switch if ($[S] > 1$) in t_d s

3 Model c



name	value [molecules/cell]
$Receptor_0$	430
$[CheY_0]$	20000
$[X_0]$	90.9
$A^{(0)}(t=0)$	1
$A^{(1...7)}(t=0)$	0
$B^{(0)}(t=0)$	0

name	value
k_{bl}	$0.241 \cdot 10^{-20}$
k_{relax}	1.54
a_{530}	$1/Receptor_0$
a_{487}	$0.001144/Receptor_0$
k_{ap}	15.5
k_{yp}	0.0357
k_{ydp}	30
k_1	1.888
k_2 (spontaneous)	0.0368
k_2 (blue light induced)	1.059

Receptor SRII:

$$\begin{aligned}\frac{d[SR_{530}]}{dt} &= k_{bl} \cdot I_{bl} \cdot [SR_{487}] - k_{relax} \cdot [SR_{530}] \\ [Receptor_0] &= [SR_{487}] + [SR_{530}]\end{aligned}$$

Histidine Kinase CheA:

$$\begin{aligned}\frac{d[CheA_P]}{dt} &= k_{ap} \cdot [CheA] \cdot (a_{530} \cdot [SR_{530}] + a_{487} \cdot [SR_{487}]) \\ &\quad - k_{yp} \cdot [CheA_P] \cdot [CheY] \\ [Receptor_0] &= [CheA] + [CheA_P]\end{aligned}$$

Response Regulator CheY:

$$\begin{aligned}\frac{d[CheY_P]}{dt} &= k_{yp} \cdot [CheA_P] \cdot [CheY] - k_{ydp} \cdot [CheY_P] \\ &\quad - \sum_{i=0}^6 k_1 \cdot [A^{(i)}] \cdot [CheY_P] \\ [CheY_0] &= [CheY] + [CheY_P]\end{aligned}$$

Switch mechanism:

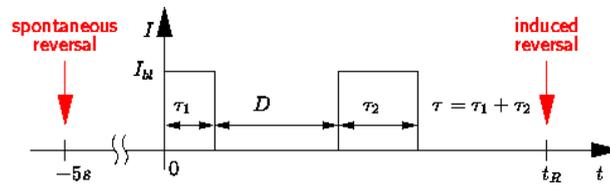
$$\begin{aligned}\frac{d[A^{(0)}]}{dt} &= -k_1 \cdot [A^{(0)}] \cdot [CheY_P] \\ \frac{d[A^{(i)}]}{dt} &= +k_1 \cdot [A^{(i-1)}] \cdot [CheY_P] - k_1 \cdot [A^{(i)}] \cdot [CheY_P] ; i = 1 \dots 6 \\ \frac{d[A^{(7)}]}{dt} &= +k_1 \cdot [A^{(6)}] \cdot [CheY_P] - k_2 \cdot [A^{(7)}] \\ \frac{d[B^{(0)}]}{dt} &= k_2 \cdot [A^{(7)}]\end{aligned}$$

Mean switching time:

$$t_R = \int_{t=0}^{\infty} k_2 \cdot [A^{(7)}] \cdot t \, dt$$

4 Experiments

Blue light with a wave length of $\lambda = 520nm$ was used for all experiments. The efficiency of the receptors for this kind of stimulus is approx. 16.4%. The efficiency is already taken into account in the reaction rate constant k_{bl} .



4.1 Single light pulses

At time $t=0$ (5s after the last spontaneous reversal) a light pulse of the duration τ and variable intensity I_{bl} is applied to a cell:

τ	I_{bl}
20ms	$2640 \cdot 10^{17} \dots 5530 \cdot 10^{17}$ [photons/s/m ²]
100ms	$522 \cdot 10^{17} \dots 5150 \cdot 10^{17}$ [photons/s/m ²]

4.2 Double light pulses with variable dark period

At time $t=0$ (5s after the last spontaneous reversal) a double light pulse is applied to a cell with:

τ_1	D	τ_2	I_{bl}
25ms	0...800ms	75ms	$2600 \cdot 10^{17}$ [photons/s/m ²]

4.3 Double light pulses with variable pulse ration

At time $t=0$ (5s after the last spontaneous reversal) a double light pulse is applied to a cell with:

τ_1	D	τ_2	I_{bl}
0...100ms	800ms	$(100 - \tau_1)$ ms	$1300 \cdot 10^{17}$ [photons/s/m ²]