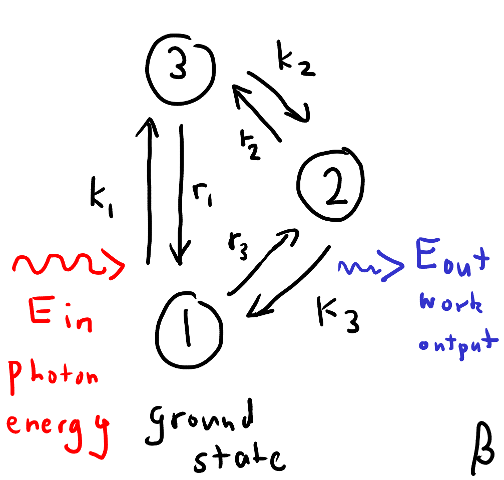
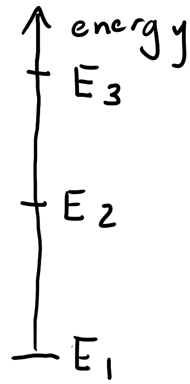
Simple model of light-sensitive protein

excited state





$$\beta = \frac{1}{k_B T}$$

$$\frac{\Omega_{nm}}{\Omega_{mn}} = e^{-\beta(E_n - E_m - \underbrace{W_{nm}}_{\text{work added into sys.}})}$$

$$\frac{k_1}{r_1} = e^{-\beta(E_3 - E_1 - \underbrace{E_{in}}_{W_{31}})}$$

$$\frac{k_2}{r_2} = e^{-\beta(E_2 - E_3)}$$

$$\frac{k_3}{r_3} = e^{-\beta(E_1 - E_2 + E_{out})}$$

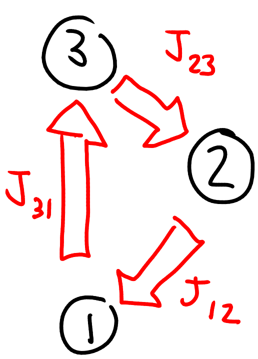
r_1 = spontaneous fluorescence
typically fast
$\sim [ps - ns]^{-1}$

k_2 = rearrangement of protein after photon absorption
(lose some energy to heat $E_3 \to E_2$)

$\frac{k_2}{r_1} \sim 0.1 - 0.7$ for photoproteins

fraction of "successful" absorptions

$$= \frac{k_2}{r_1 + k_2} = \frac{k_2/r_1}{1 + k_2/r_1}$$



Stationary state: $0 = \sum_m J^s_{nm}$

$$0 = J^s_{12} - J^s_{31}$$

$$0 = J^s_{23} - J^s_{12}$$

$$0 = J^s_{31} - J^s_{23}$$

$$J^s_{12} = J^s_{23} = J^s_{31} = J$$

const.

$$J = J^s_{12} = k_3 p^s_2 - r_3 p^s_1$$

$$J = J^s_{23} = k_2 p^s_3 - r_2 p^s_2$$

$$J = J^s_{31} = k_1 p^s_1 - r_1 p^s_3$$

$$p^s_1 + p^s_2 + p^s_3 = 1$$

algebra $\Rightarrow$ $J = \dfrac{k_1 k_2 k_3 - r_1 r_2 r_3}{F}$

$F \to$ expr. involving k_i + r_i

$F > 0$ always

$$J = \frac{k_1 k_2 k_3}{F}\left(1 - \frac{r_1\, r_2\, r_3}{k_1\, k_2\, k_3}\right)$$

$$= \frac{k_1 k_2 k_3}{F}\left(1 - e^{-\beta(E_{in} - E_{out})}\right)$$

$E_{in} > E_{out}$: $J > 0$ NESS (clockwise around loop)

earlier: $E_{in} = E_{out} = 0 \Rightarrow J = 0$ ESS