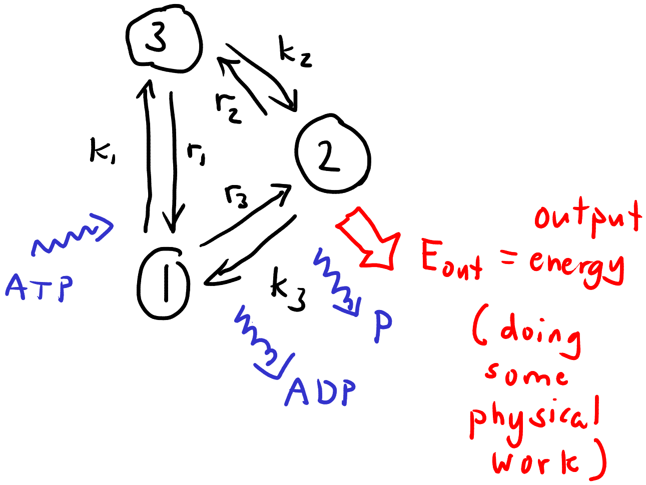

$t \to \infty$: $J_{31}(t), J_{23}(t), J_{12}(t) \longrightarrow \underset{\text{const.}}{J}$

stationary state current

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

D ↳ func. of rates > 0

$$\frac{k_1}{r_1} = e^{-\beta(H_3 - H_1 - \mu_{ATP})}$$

$-\mu_{ATP}$: E_{in} for photon

$$\frac{k_2}{r_2} = e^{-\beta(H_2 - H_3)}$$

$$\frac{k_3}{r_3} = e^{-\beta(H_1 - H_2 + \mu_{ADP} + \mu_P + E_{out})}$$

$\mu_{ADP} + \mu_P + E_{out}$: E_{out} for photon

$$\Rightarrow J = \frac{k_1 k_2 k_3}{D}\left(1 - e^{-\beta(\mu_{ATP} - \mu_{ADP} - \mu_P - E_{out})}\right)$$

$\mu_{ATP} - \mu_{ADP} - \mu_P \equiv \Delta\mu$

chemical pot. diff. for ATP hydrolysis reaction

= diff. in chem. pots. of inputs − outputs of reaction

$$\mu_{ATP} = \mu_{ATP,0} + k_B T \ln c_{ATP}$$

c_{ATP}: conc. of ATP in sol'n

$$\mu_{ADP} = \mu_{ADP,0} + k_B T \ln c_{ADP}$$

$$\mu_P = \ldots$$

$$\Rightarrow \Delta\mu = \overbrace{\mu_{ATP,0} - \mu_{ADP,0} - \mu_{P,0}}^{12\, k_B T} + k_B T \ln \frac{c_{ATP}}{c_{ADP}\, c_P}$$

$\Delta\mu \approx 21\text{-}29\ k_B T$ for modern cells across all life if $E_{out} < \Delta\mu \Rightarrow J > 0$ NESS

power budget: $\underset{\substack{\text{net}\\\text{power}\\\text{in}}}{\dot{W}} = \frac{1}{2}\sum_{nm} J_{nm} W_{nm}$

$$\underset{t\to\infty}{=} J(\Delta\mu - E_{out})$$

$$= P_{in} - P_{out}$$

where $P_{in} = J\Delta\mu \qquad P_{out} = J E_{out}$

efficiency: $\eta = \frac{P_{out}}{P_{in}} = \frac{E_{out}}{\Delta\mu}$

$P_{out} = J(E_{out})\,E_{out}$

typically $\approx 0.4 - 0.6$ for motor proteins

E_{out} = amount of work you put on the motor ("load")