$$\frac{dA}{dt} = -k_1 * A$$

$$\frac{dA}{dt} = -k_{2f} * A + k_{2r} * B$$

$$\frac{dB}{dt} = k_{2f} * A - k_{2r} * B$$

Karin's

$$Ssk2 + ATP \xrightarrow{k_1^{MAP}} SskP + ADP$$

$$Ssk2P \xrightarrow{k_{-1}^{MAP}} Ssk2$$

$$Ssk2P + Pbs2 \xrightarrow{k_2^{MAP}} Ssk2 + Pbs2P$$

$$Pbs2P \xrightarrow{k_{-2}^{MAP}} Pbs2$$

$$Ssk2P + Pbs2P \xrightarrow{k_3^{MAP}} Ssk2 + Pbs2P_2$$

$$Pbs2P_2 \xrightarrow{k_3^{MAP}} Pbs2P$$

$$Hog1 + Pbs2P_2 \xrightarrow{k_4^{MAP}} Hog1P + Pbs2P$$

$$Hog1P \xrightarrow{k_v - 4^{MAP}} Hog1$$

$$Hog1P + Pbs2P_2 \xrightarrow{k_5^{MAP}} Hog1P_{2cyt} + Pbs2P$$

$$Hog1P_{2cyt} \xrightarrow{k_{-5}^{MAP}} Hog1P$$

$$Hog1P_{2cyt} \xrightarrow{k_{trans}} Hog1P_{2nuc}$$

$$Hog1P_{2nuc} \xrightarrow{k_{dephos}} Hog1_{nuc}$$

$$Hog1_{nuc} \xrightarrow{k_{trans1}} Hog1$$

$$Hog1 \xrightarrow{k_{trans2}} Hog1_{nuc}$$

$$Hog1_{nuc} \xrightarrow{k_{trans2}} Hog1_{nuc}$$

Paper's

$$Ssk2 + ATP \xrightarrow{k_1^{MAP}} SskP + ADP$$

$$Ssk2P \xrightarrow{k_2^{MAP}} Ssk2$$

$$Pbs2 + ATP \xrightarrow{k_2^{MAP}} ADP + Pbs2P$$

$$Pbs2P \xrightarrow{k_2^{MAP}} Pbs2$$

$$Pbs2P + ATP \xrightarrow{k_3^{MAP}} Pbs2P_2 + ADP$$

$$Pbs2P_2 \xrightarrow{k_3^{MAP}} Pbs2P_2 + ADP$$

$$Pbs2P_2 \xrightarrow{k_3^{MAP}} Pbs2P_2$$

$$Hog1 + ATP \xrightarrow{k_4^{MAP}} Hog1P + ADP$$

$$Hog1P \xrightarrow{k_V - 4^{MAP}} Hog1$$

$$Hog1P \xrightarrow{k_V - 4^{MAP}} Hog1P_{2cyt} + ADP$$

$$Hog1P_{2cyt} \xrightarrow{k_{trans}} Hog1P_{2cyt} + ADP$$

$$Hog1P_{2cyt} \xrightarrow{k_{trans}} Hog1P_{2cyt}$$

$$Hog1P_{2cyt} \xrightarrow{k_{trans}} Hog1$$

$$Hog1 \xrightarrow{k_{trans}} Hog1$$

$$Hog1 \xrightarrow{k_{trans}} Hog1$$

$$Hog1 \xrightarrow{k_{trans}} Hog1$$

$$Hog1 \xrightarrow{k_{trans}} Hog1$$

$$V_1^{MAP} = k_1^{MAP} * Ssk2 * Ssk1$$

$$v_1^{MAP} = k_1^{MAP} * Ssk2 * Ssk1$$

$$v_1^{MAP} = k_1^{MAP} * Ssk2 * Pbs2$$

$$v_2^{MAP} = k_2^{MAP} * Ssk2 * Pbs2$$

$$v_3^{MAP} = k_2^{MAP} * Ssk2 + Pbs2P$$

$$v_3^{MAP} = k_3 * Pbs2P_2$$

$$v_4^{MAP} = k_3^{MAP} * Ssk2P * Pbs2P$$

$$v_3^{MAP} = k_{-3} * Pbs2P_2$$

$$v_4^{MAP} = k_4^{MAP} * Hog1 * PbsP_2$$

$$v_4^{MAP} = k_4^{MAP} * Hog1P * Pbs2P_2$$

$$v_4^{MAP} = k_5 * Hog1P * Pbs2P_2$$

$$v_{-4}^{MAP} = k_{-5} * Hog1P_{2cyt}$$

$$v_{trans} = k_{trans} * Hog1$$

Karin's

$$\frac{dSsk2}{dt} = -v_1^{MAP} + v_{-1}^{MAP} + v_2^{MAP} + v_3^{MAP}$$

$$\frac{dSsk2P}{dt} = v_1^{MAP} - v_{-1}^{MAP} - v_2^{MAP} - v_3^{MAP}$$

$$\frac{dPbs2}{dt} = -v_2^{MAP} + v_{-2}^{MAP}$$

$$\frac{dPbs2P}{dt} = v_2^{MAP} - v_{-2}^{MAP} - v_3^{MAP} + v_{-3}^{MAP} + v_4^{MAP}$$

$$\frac{dPbs2P_2}{dt} = v_3^{MAP} - v_{-3}^{MAP} - v_4^{MAP} + v_5^{MAP} + v_5^{MAP}$$

$$\frac{dHog1}{dt} = -v_4^{MAP} + v_{-4}^{MAP} + v_{trans1} - v_{trans2}$$

$$\frac{dHog1P}{dt} = v_4^{MAP} - v_{-4}^{MAP} - v_5^{MAP} + v_{-5}^{MAP}$$

$$\frac{dHog1P_{2cyt}}{dt} = v_5^{MAP} - v_{-5}^{MAP} - v_{trans}$$

$$\frac{dHog1P_{2nuc}}{dt} = v_{trans} - v_{dephos}$$

$$\frac{dHog1_{nuc}}{dt} = -v_{trans1} + v_{dephos} + v_{trans2}$$

$$\frac{dSsk2}{dt} = -v_1^{MAP} + v_{-1}^{MAP}$$

$$\frac{dSsk2P}{dt} = v_1^{MAP} - v_{-1}^{MAP}$$

$$\frac{dPbs2P}{dt} = -v_2^{MAP} + v_{-2}^{MAP}$$

$$\frac{dPbs2P}{dt} = v_2^{MAP} - v_{-2}^{MAP} - v_3^{MAP} + v_{-3}^{MAP}$$

$$\frac{dPbs2P_2}{dt} = v_3^{MAP} - v_{-3}^{MAP} - v_{-3}^{MAP}$$

Paper

 $\frac{dHog1}{dt} = -v_4^{MAP} + v_{-4}^{MAP} + v_{trans1} - v_{trans2}$

 $\frac{d Hog 1P}{dt} = v_4^{MAP} - v_{-4}^{MAP} - v_5^{MAP} + v_{-5}^{MAP}$

 $\frac{dHog1P_{2cyt}}{dt} = v_5^{MAP} - v_{-5}^{MAP} - v_{trans}^{MAP}$

 $\frac{dHog1P_{2nuc}}{dt} = v_{trans} - v_{dephos}$

 $\frac{dHog1_{nuc}}{dt} = -v_{trans1} + v_{dephos} + v_{trans2}$

(1)
$$\operatorname{Sln}_{1} \xrightarrow{k_{1}^{TCS}} \operatorname{Sln}_{1} P$$

(2)
$$\operatorname{Sln}_{1}P + \operatorname{Ypd}_{1} \xrightarrow{\frac{k_{2}^{TCS}}{k_{2}^{TCS}}} \operatorname{Sln}_{1} + \operatorname{Ypd}_{1}P$$

$$\mathrm{Ypd}_1\mathrm{P} + \mathrm{Ssk}_1 \xrightarrow{k_3^{TCS}} \mathrm{Ypd}_1 + \mathrm{Ssk}_1\mathrm{P}$$

$$(4) Ssk_1P \xrightarrow{k_4^{TCS}} Ssk_1$$

$$\begin{split} \frac{dVolume}{dt} &= -v_0^{TCS} \\ \frac{dSln1}{dt} &= -v_1^{TCS} + v_2^{TCS} \\ \frac{dSln1P}{dt} &= v_1^{TCS} - v_2^{TCS} \\ \frac{dYpd1}{dt} &= -v_2^{TCS} + v_3^{TCS} \\ \frac{dYpd1P}{dt} &= v_2^{TCS} - v_3^{TCS} \\ \frac{dSsk1}{dt} &= -v_3^{TCS} + v_4^{TCS} \\ \frac{dSsk1P}{dt} &= v_3^{TCS} - v_4^{TCS} \\ \end{split}$$

$$v0 = k0 * Receptor$$

 $v1 = k1 * MAPKKK * Receptor$
 $v2 = k2 * MAPKKKP * Phosphotase$
 $v3 = k3 * MAPKK * MAPKKKP$
 $v4 = k4 * MAPKKP * Phosphotase$
 $v5 = k5 * MAPK * MAPKKP$
 $v6 = k6 * MAPKP * Phosphotase$

$$\frac{dReceptor}{dt} = -v0$$

$$\frac{dMAPKKKP}{dt} = v1 - v2$$

$$\frac{dMAPKKP}{dt} = v3 - v4$$

$$\frac{dMAPKF}{dt} = v5 - v6$$

$$\frac{dMAPKKK}{dt} = -dMAPKKKP$$

$$\frac{dMAPKKK}{dt} = -dMAPKKKP$$

$$\frac{dMAPKK}{dt} = -dMAPKKP$$

$$\frac{dMAPK}{dt} = -dMAPKF$$

$$\frac{dMAPK}{dt} = -dMAPKF$$

$$\frac{dPhosphotase}{dt} = 0$$

$$v_{1}^{MAP} = k_{1}^{MAP} * Ssk2 * Ssk1$$

$$v_{1}^{MAP} = k_{1}^{MAP} * Ssk2 * Ssk1$$

$$v_{-1}^{MAP} = k_{-1}^{MAP} * Ssk2P$$

$$v_{2}^{MAP} = k_{2}^{MAP} * Ssk2 * Pbs2$$

$$v_{-2}^{MAP} = k_{-2} * Pbs2P$$

$$v_{3}^{MAP} = k_{3}^{MAP} * Ssk2P * Pbs2P$$

$$v_{-3}^{MAP} = k_{-3} * Pbs2P_{2}$$

$$v_{-4}^{MAP} = k_{4}^{MAP} * Hog1 * PbsP_{2}$$

$$v_{-4}^{MAP} = k_{-4} * Hog1P$$

$$v_{5}^{MAP} = k_{5} * Hog1P * Pbs2P_{2}$$

$$v_{-5}^{MAP} = k_{-5} * Hog1P_{2}$$

$$\frac{dSsk1}{dt} = -v_{0}^{MAP}$$

$$\frac{dSsk2}{dt} = -v_{1}^{MAP} + v_{-1}^{MAP}$$

$$\frac{dSsk2P}{dt} = v_{1}^{MAP} - v_{-1}^{MAP}$$

$$\frac{dPbs2P}{dt} = v_{2}^{MAP} - v_{-2}^{MAP} - v_{3}^{MAP} + v_{-3}^{MAP}$$

$$\frac{dPbs2P}{dt} = v_{3}^{MAP} - v_{-3}^{MAP} - v_{-3}^{MAP}$$

$$\frac{dHog1}{dt} = -v_{4}^{MAP} + v_{-4}^{MAP}$$

$$\frac{dHog1P}{dt} = v_{4}^{MAP} - v_{-4}^{MAP} - v_{-5}^{MAP} + v_{-5}^{MAP}$$

$$\frac{dHog1P}{dt} = v_{5}^{MAP} - v_{-5}^{MAP} - v_{-5}^{MAP}$$

$$vts = kts_1 * Hog_1P_{2nuc}$$

$$vex = kex * mRNA_{nuc}$$

$$vrd = kts * mRNA_{cyt}$$

$$vtl = ktl * mRNA_{cyt}$$

$$vpd = kpd * Protein$$

$$\frac{dmRNA_{nuc}}{dt} = vts - vex$$

$$\frac{dmRNA_{cyt}}{dt} = vex - vrd$$

$$\frac{dProtein}{dt} = vtl - vpd$$

$$f(E, S, ES)$$

[H2](t), [O2](t), [H2O](t), [C](t), [CO2](t)

$$y(t) = \begin{pmatrix} [H_2](t) \\ [O_2](t) \\ [H_2O](t) \\ [C](t) \\ [CO_2](t) \end{pmatrix}$$

$$\dot{y} \equiv rac{dy}{dt} = \left(egin{array}{c} rac{d[H_2]}{dt} \\ rac{d[O_2]}{dt} \\ rac{d[H_2O]}{dt} \\ rac{d[C]}{dt} \\ rac{d[CO_2]}{dt} \end{array}
ight)$$

$$\dot{y} = \Gamma V$$

$$\dot{y} \equiv \frac{dy}{dt} = \begin{pmatrix} \frac{d[H_2]}{dt} = -k1 * [H_2]^2 * [O_2] \\ \frac{d[O_2]}{dt} = -k1 * [H_2]^2 * [O_2] - k2 * [C] * [O_2] \\ \frac{d[H_2O]}{dt} = 2 * k1 * [H_2]^2 * [O_2] \\ \frac{d[C]}{dt} = -k2 * [C] * [O_2] \\ \frac{d[CO_2]}{dt} = k2 * [C] * [O_2] \end{pmatrix}$$

$$\Gamma = \begin{pmatrix} H_2 & O_2 & H_2O & C & CO_2 \\ R1: & -2 & -1 & 2 & 0 & 0 \\ R2: & 0 & -1 & 0 & -1 & 1 \end{pmatrix}$$

$$\Gamma = \begin{pmatrix} R1 & R2 \\ H_2 & -2 & 0 \\ O_2 & -1 & -1 \\ H_2O & 2 & 0 \\ C & 0 & -1 \\ CO_2 & 0 & 1 \end{pmatrix}$$

$$V = \begin{pmatrix} k_1 * [H_2]^2 * [O_2] \\ k_2 * [C] * [O_2] \end{pmatrix}$$

$$\dot{y} = \Gamma * V = \begin{pmatrix} R1 & R2 \\ H_2 & -2 & 0 \\ O_2 & -1 & -1 \\ H_2O & 2 & 0 \\ C & 0 & -1 \\ CO_2 & 0 & 1 \end{pmatrix} * \begin{pmatrix} R1: & k1 * [H_2]^2 * [O_2] \\ R2: & k2 * [C] * [O_2] \end{pmatrix} = \begin{pmatrix} \frac{d[H_2]}{dt} = -2 * k1 * [H_2]^2 * [O_2] \\ \frac{d[O_2]}{dt} = -k1 * [H_2]^2 * [O_2] - k2 * [C] * [O_2] \\ \frac{d[H_2O]}{dt} = 2 * k1 * [H_2]^2 * [O_2] \\ \frac{d[C]}{dt} = -k2 * [C] * [O_2] \\ \frac{d[CO_2]}{dt} = k2 * [C] * [O_2] \end{pmatrix}$$

$$rate_{R1} = -\frac{1}{2} * \frac{d[H_2]}{dt} = -\frac{d[O_2]}{dt} = +\frac{1}{2} * \frac{d[H_2O]}{dt}$$

$$rate_{R1} = k_1 [H_2]^2 [O_2]$$

Enzymatic reaction

$$\dot{y} = \Gamma * V = \begin{pmatrix} R1 & R2 & R3 \\ S & -1 & +1 & 0 \\ E & -1 & +1 & +1 \\ SE & +1 & -1 & -1 \\ P & 0 & 0 & +1 \end{pmatrix} * \begin{pmatrix} R1 : & k_1 * E * S \\ R2 : & k_2 * ES \\ R3 : & k_3 * ES \end{pmatrix} = \begin{pmatrix} \frac{dS}{dt} = -k_1 * E * S + k_2 * ES \\ \frac{dE}{dt} = -k_1 * E * S + (k_2 + k_3) * ES \\ \frac{dES}{dt} = k_1 * E * S - (k_2 + k_3) * ES \\ \frac{dP}{dt} = k_3 * ES \end{pmatrix}$$

Gene expression

$$\dot{y} = \Gamma * V = \begin{pmatrix} R1 & R2 & R3 & R4 \\ G & 0 & 0 & 0 & 0 \\ M & +1 & 0 & -1 & 0 \\ P & 0 & +1 & 0 & -1 \end{pmatrix} * \begin{pmatrix} R1 : & k_1 * G \\ R2 : & k_2 * M \\ R3 : & k_3 * M \\ R4 : & k_4 * P \end{pmatrix} = \begin{pmatrix} \frac{dG}{dt} = 0 \\ \frac{dM}{dt} = k_1 * G - k_3 * M \\ \frac{dP}{dt} = k_2 * M - k_4 * P \end{pmatrix}$$

Gene regulation

$$\dot{y} = \Gamma * V = \begin{pmatrix} R1 & R2 & R3 \\ S & -1 & +1 & 0 \\ E & -1 & +1 & +1 \\ SE & +1 & -1 & -1 \\ P & 0 & 0 & +1 \end{pmatrix} * \begin{pmatrix} R1 : & k_1 * E * S \\ R2 : & k_2 * ES \\ R3 : & k_3 * ES \end{pmatrix} = \begin{pmatrix} \frac{dS}{dt} = -k_1 * E * S + k_2 * ES \\ \frac{dE}{dt} = -k_1 * E * S + (k_2 + k_3) * ES \\ \frac{dES}{dt} = k_1 * E * S - (k_2 + k_3) * ES \\ \frac{dP}{dt} = k_3 * ES \end{pmatrix}$$