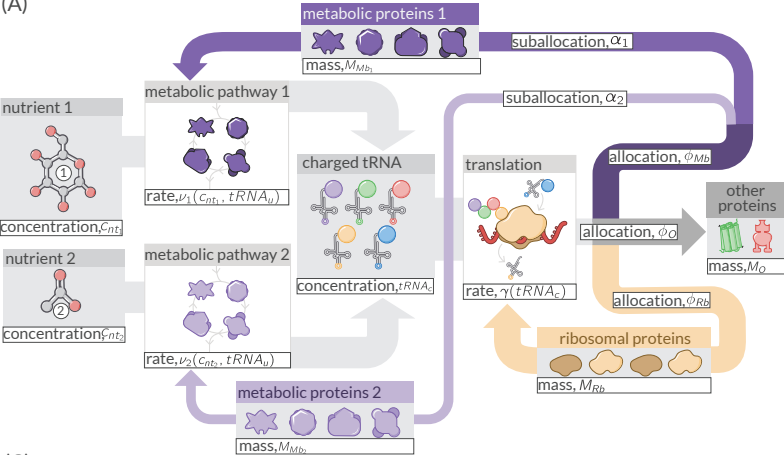


(A)



(C)

ppGpp regulatory circuit elements metabolic suballocation regulatory elements

tRNA dynamics

$$\begin{aligned} \frac{dtRNA_u}{dt} &= \underbrace{\kappa \left(\frac{tRNA_c}{tRNA_u} \right)}_{\text{transcription}} - \underbrace{\left(\frac{\nu_1(c_{nt1}, tRNA_u) M_{Mb1}}{M} + \frac{\nu_2(c_{nt2}, tRNA_u) M_{Mb2}}{M} \right)}_{\text{combined metabolism}} + \underbrace{\frac{\gamma(tRNA_c) M_{Rb}}{M} (1 - tRNA_u)}_{\text{translation and dilution}} \\ \frac{dtRNA_c}{dt} &= \underbrace{\left(\frac{\nu_1(c_{nt1}, tRNA_u) M_{Mb1}}{M} + \frac{\nu_2(c_{nt2}, tRNA_u) M_{Mb2}}{M} \right)}_{\text{combined metabolism}} - \underbrace{\frac{\gamma(tRNA_c) M_{Rb}}{M} (1 + tRNA_c)}_{\text{translation and dilution}} \end{aligned}$$

nutrient dynamics

$$\frac{dc_{nt_i}}{dt} = - \frac{\nu_i(c_{nt_i}, tRNA_u) M_{Mb_i}}{Y_i}$$

allocation and suballocation constraints

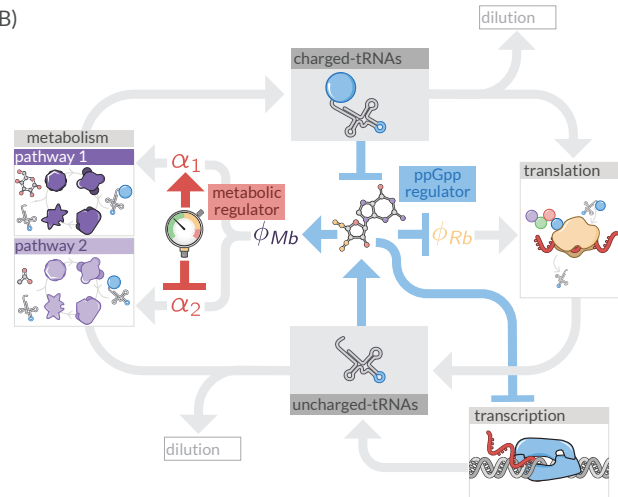
$$\phi_{Mb} = 1 - \phi_O - \phi_{Rb} \left(\frac{tRNA_c}{tRNA_u} \right); \alpha_2 = 1 - \alpha_1$$

flux-parity regulatory functions

$$\phi_{Rb} \left(\frac{tRNA_c}{tRNA_u} \right) = (1 - \phi_O) \frac{tRNA_c/tRNA_u}{1 + tRNA_c/tRNA_u}$$

$$\kappa \left(\frac{tRNA_c}{tRNA_u} \right) = \kappa_{max} \frac{tRNA_c/tRNA_u}{1 + tRNA_c/tRNA_u}$$

(B)



biomass dynamics

$$\begin{aligned} \frac{dM_{Rb}}{dt} &= \phi_{Rb} \left(\frac{tRNA_c}{tRNA_u} \right) \gamma(tRNA_c) M_{Rb} \\ \frac{dM_{Mb1}}{dt} &= \alpha_1 \left[1 - \phi_O - \phi_{Rb} \left(\frac{tRNA_c}{tRNA_u} \right) \right] \gamma(tRNA_c) M_{Rb} \\ \frac{dM_{Mb2}}{dt} &= \alpha_2 \left[1 - \phi_O - \phi_{Rb} \left(\frac{tRNA_c}{tRNA_u} \right) \right] \gamma(tRNA_c) M_{Rb} \\ \frac{dM_O}{dt} &= \phi_O \gamma(tRNA_c) M_{Rb} \end{aligned}$$

biochemical rate regulatory functions

$$\nu_i = \nu_{max_i} \left(\frac{tRNA_u}{tRNA_u + K_D} \right) \left(\frac{c_{nt,i}}{c_{nt,i} + K_{M_i}} \right)$$

$$\gamma(tRNA_c) = \gamma_{max} \left(\frac{tRNA_c}{tRNA_c + K_D} \right)$$