Enzyme rhythms in model rainer_1.speedy - spontaneous oscillations

Model name: rainer_1

o Optimisation problem
- Protein turnover time 1 s = 0.0167 min
- Perturbed parameter(s) : O2ext
- Perturbation frequency f : 1/s (period 1 s)
- Scored quantity: BM dilution
- Fitness-averaged fitness
- No posttranslational rhythms allowed
- Standard frequency considered f : 1/s (period 1 s)

o Model properties:
- inactive_enzymes: 0
- balanced_reference_state: 1
- consider_external_rhythm: 1
- adaptive_rhythm: 0
- spontaneous_rhythm: 1
- spontaneous_rhythm_at_omega: 1
- has_spontaneous_rhythm_and_inactive_enzymes: 0

o Beneficial self-induced oscillation found
- Maximum principal synergy found (in tested range) at frequency f =1.78/s (period 0.562 s)
- Maximum fitness found (in tested range) at frequency f =0.501/s (period 2 s)

o Fitness changes after external perturbation at frequency f=1/s
- Change by perturbation alone (xx): -9.34e-07

o Self-induced oscillations?
- Maximally self-induced oscillations (in tested range) at f = 1.78, principal synergy 0.0195
- Beneficial self-induced oscillations found at frequency f = 1/s (principal synergy = 0.0155)
- Predicted fitness change (self-induced, 2nd order, amplitude below 1/2 of mean) at frequency f =1: 6.62e-05
- Predicted maximal fitness change (self-induced, numeric opt, full amplitude constraints) at frequency f =0.501: 2.27e-07
WARNING: an external rhythm is given and a self-induced rhythm has been found

o Numerical calculation (responsive, f=1)
- Fitness change (fitness-averaged): 8.53e-05
- Fitness change (state-averaged): 8.53e-05

o Numerical calculation (self-induced rhythm, amplitude below 1/2 of mean, f=1)
- Fitness change (fitness-averaged) : 4.71e-06
- Fitness change (state-averaged): 4.73e-06

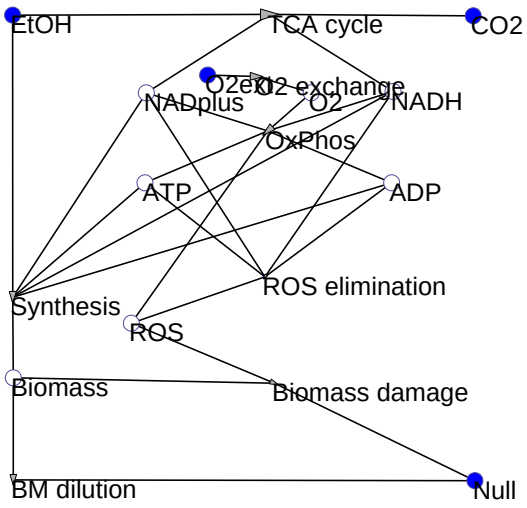


Figure 1: Network and reference flux

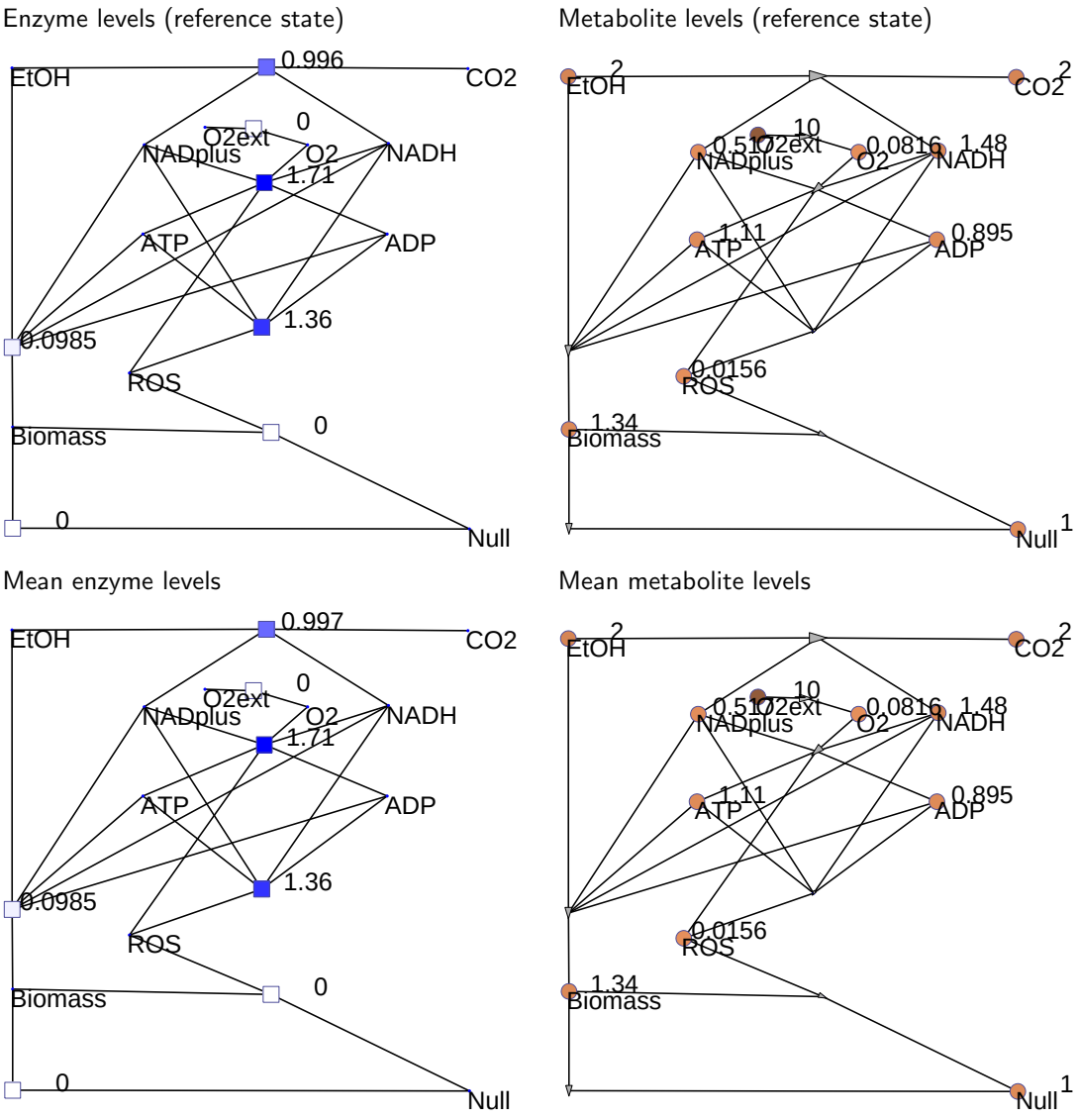


Figure 2: Reference state (top) and mean state during oscillation (bottom).

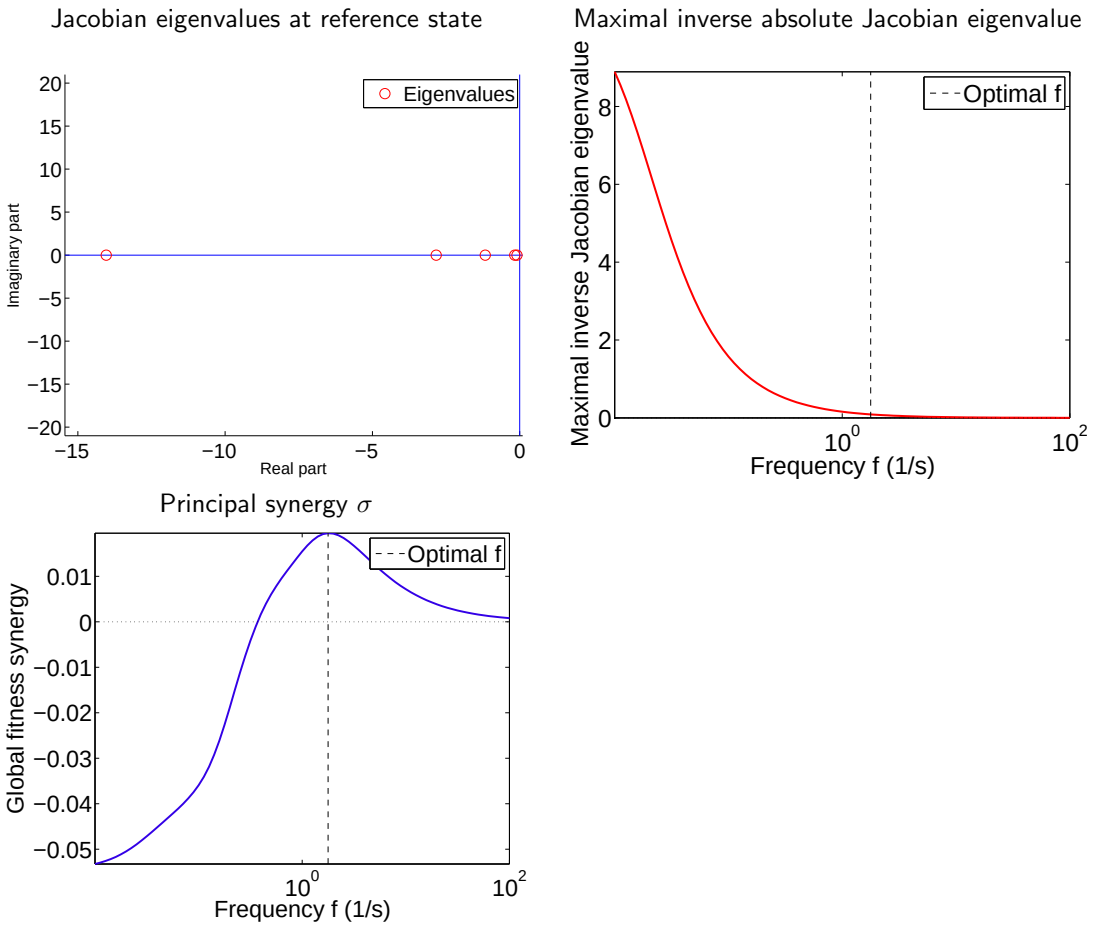
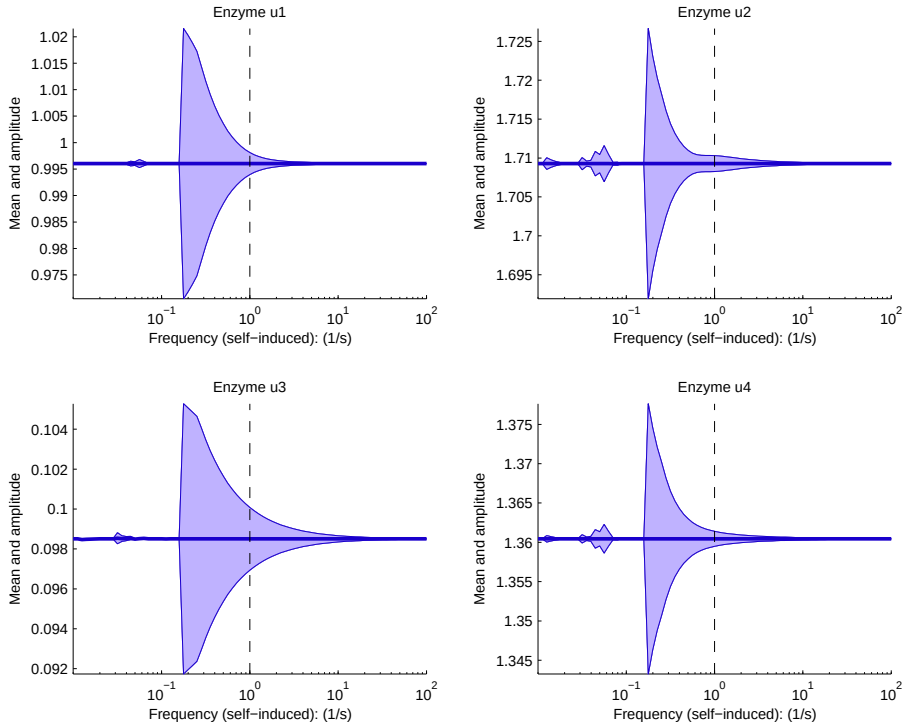
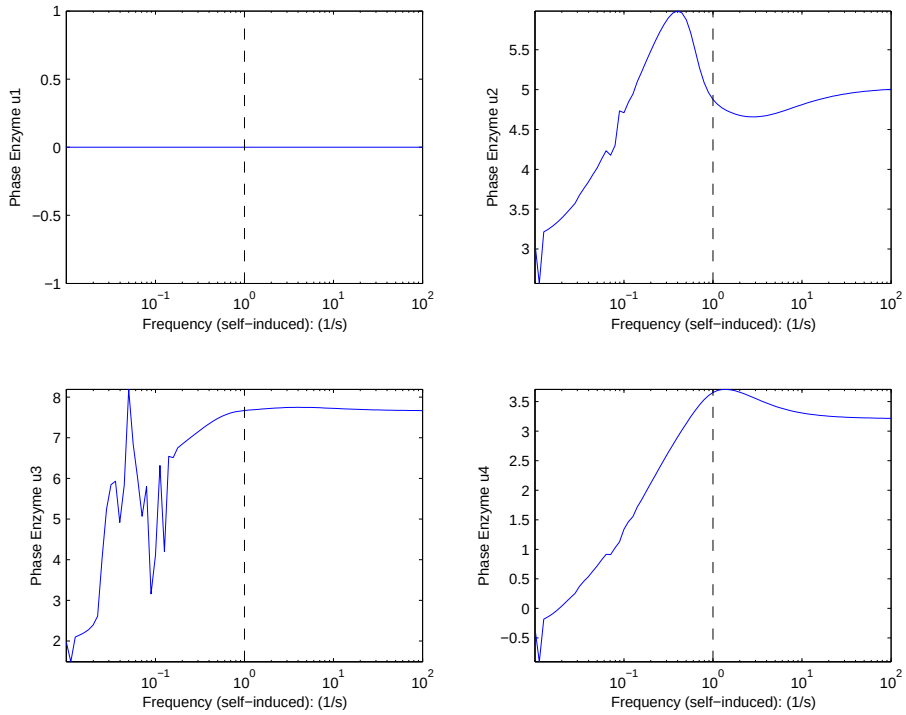


Figure 3: Control analysis: fitness curvatures. Left: Frequency-dependent fitness curvature eigenvalues. Right: relative sizes and phases of the individual enzyme levels (components of the leading fitness curvature eigenvector).

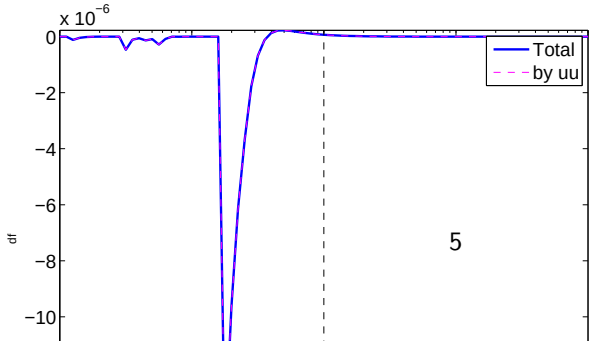
Protein level and enzyme activity (mean and amplitude)



Phase angles $[0, 2\,\pi]$



Fitness change



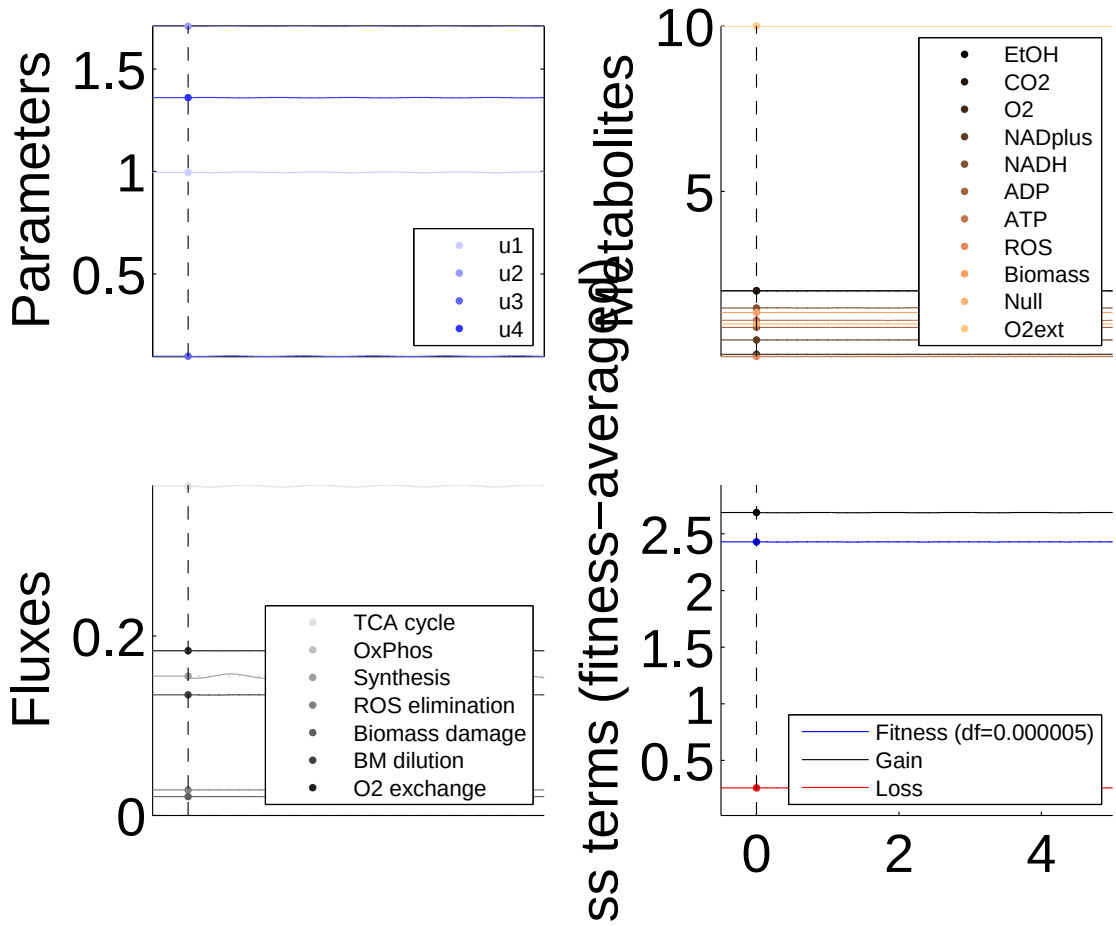


Figure 5: Numerical calculations: spontaneous oscillations. Perturbation frequency see first page.

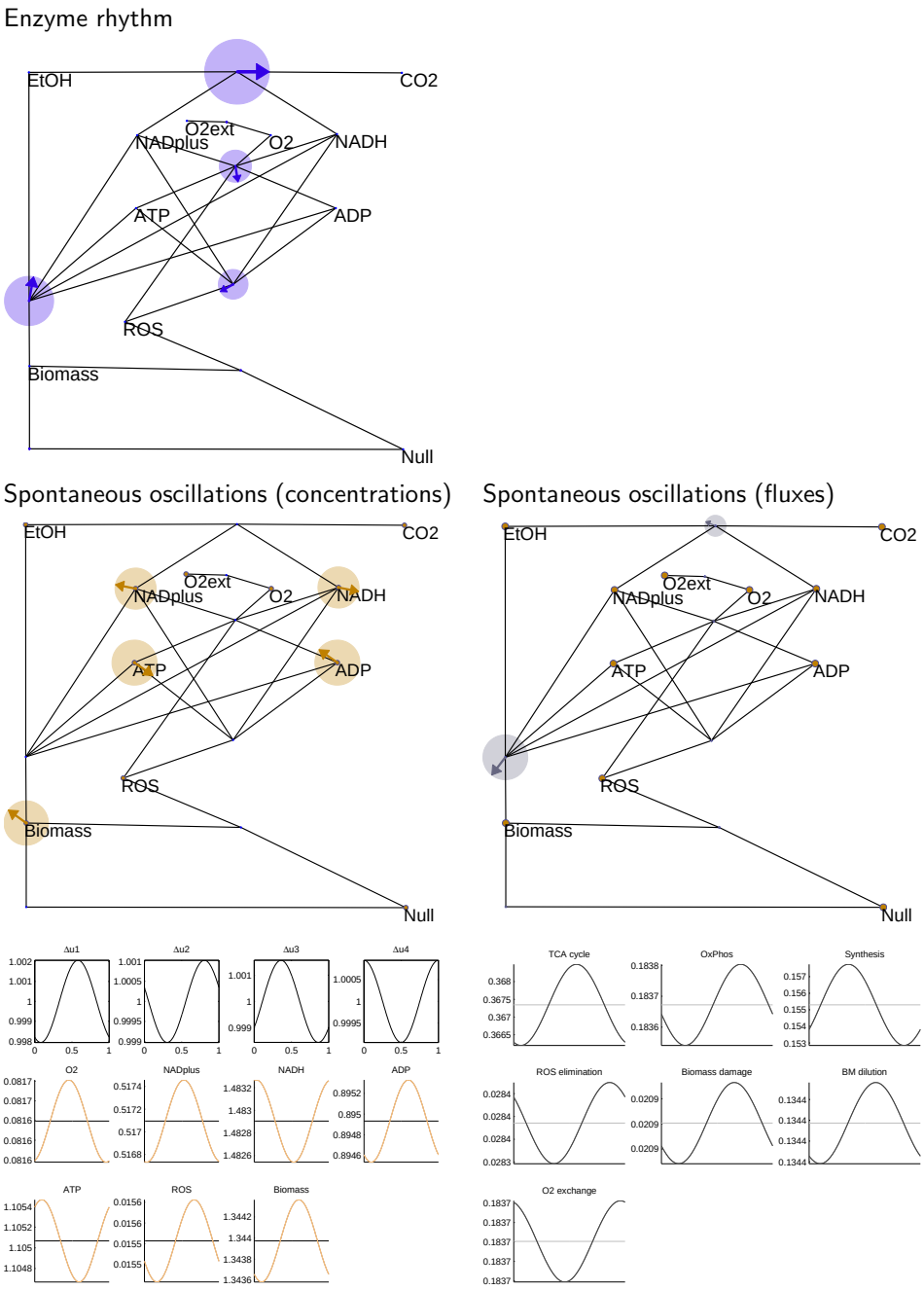


Figure 6: Spontaneous oscillations (local expansion; arrows: absolute changes). Perturbation frequency see first page.

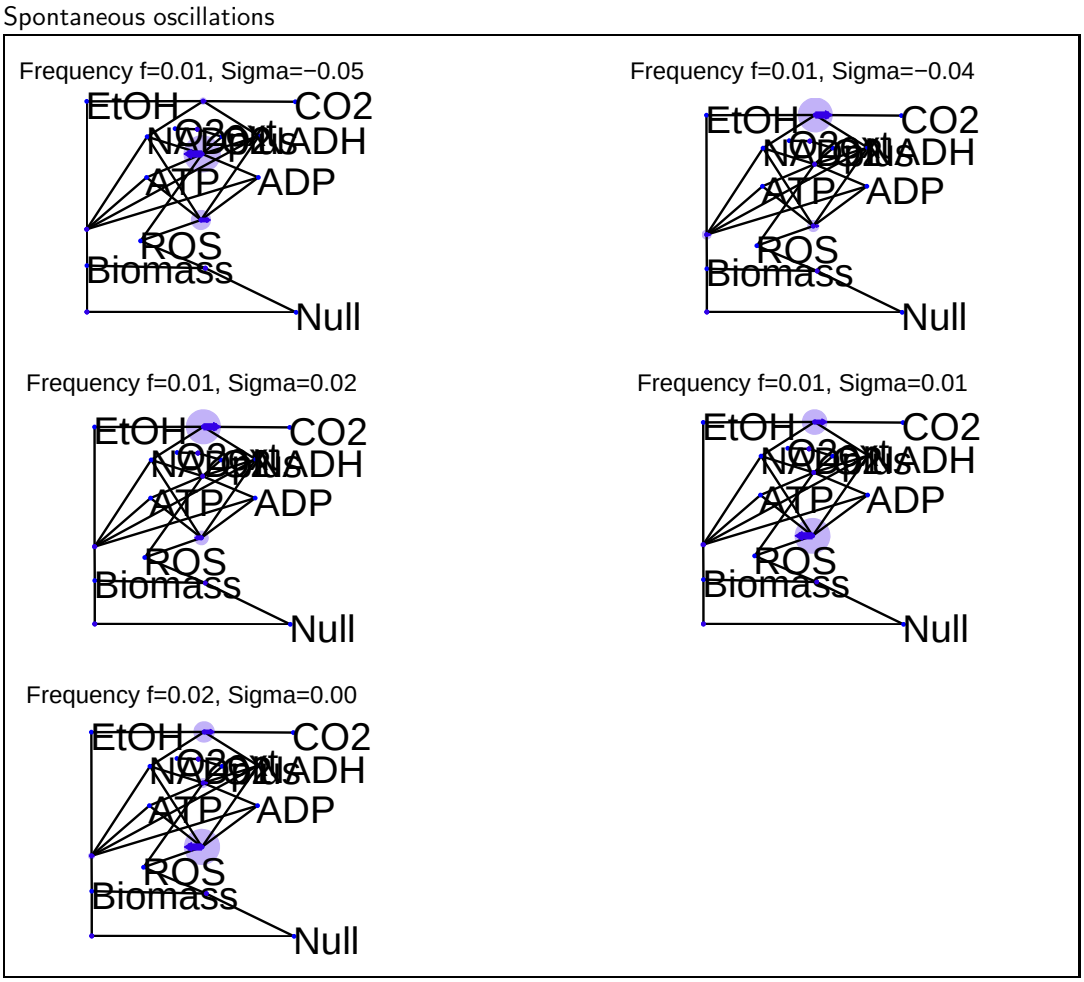


Figure 7: Spontaneous oscillations (or tendencies towards them) for various circular frequencies ω. If the maximal fitness curvatures λ is positive, the rhythm is beneficial (local expansion; arrows: absolute changes).