Genesis of Ecto-symbiotic features based on Commensalistic Syntrophy

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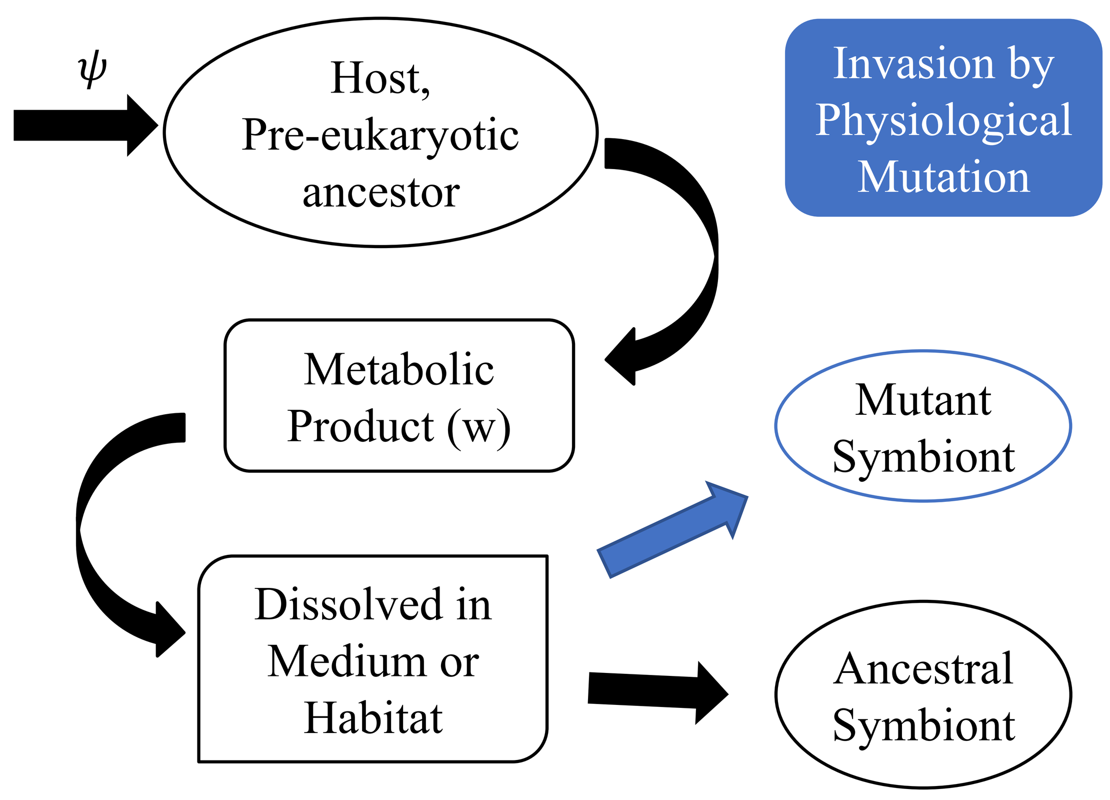
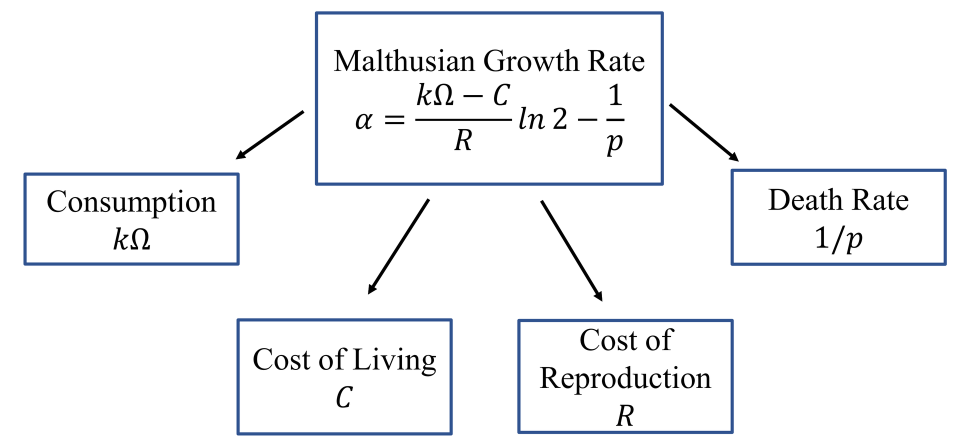
Problem

- Eukaryogenesis by symbiogenesis is a much-appreciated unified theory providing explanation to the origin of eukaryotes and mitochondria.
- The initial conditions for the formation of multi-species intimate associations from unicellular organisms that were previously capable of independent existence are yet unclear. We provide a theoretical analysis of a hypothesis on the origin of such symbiogenetic associations.

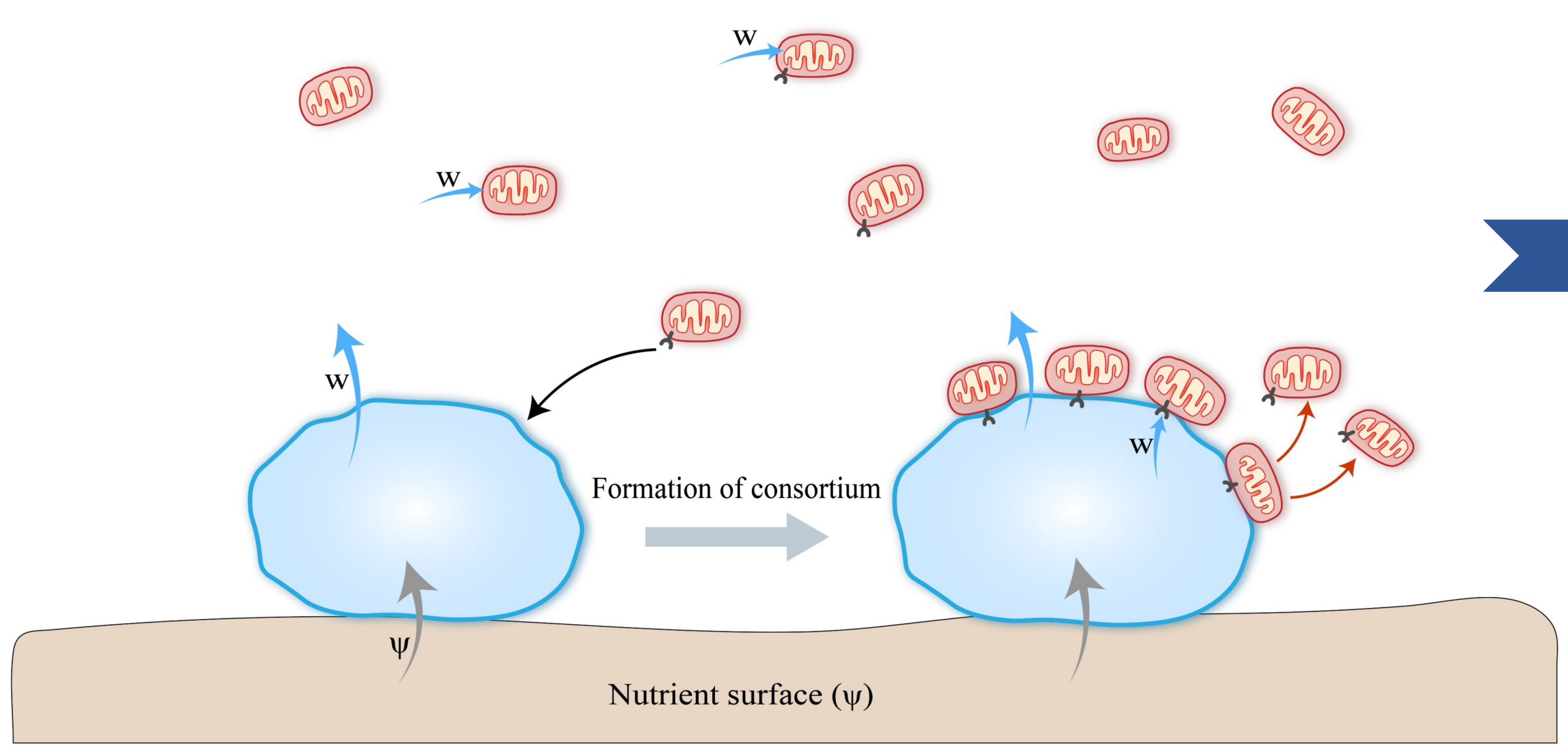


Methods

- Ageless and pseudomonas-like organisms
- Host cannot phagocytose



Model



Schematic diagram of the resident-mutant coevolutionary system with host (blue) and symbiont (red) species.

- Density based dynamics of the resident-mutant coevolutionary system:

Free-living Host:
$$\dot{x} = x\left(\frac{k_X\Psi - C_X}{R_X} ln\, 2 - \frac{1}{p_X} - a_1(x+z)\right) - \frac{\beta x u}{h}$$

Free-living Resident Symbiont:
$$\dot{y} = y\left(\frac{k_Y\frac{w}{V} - C_Y}{R_Y} ln\, 2 - \frac{1}{p_Y} - a_2(y+u)\right)$$

Consortium:
$$\dot{z} = z\left(\frac{k_X\Psi - C_X}{R_X} ln\, 2 - \frac{1}{p_X} - a_1(x+z)\right) + \frac{\beta x u}{h}$$

Free-living Mutant Symbiont:
$$\dot{u} = u\left(\frac{k_Y\frac{w}{V} - C_U}{R_U} ln\, 2 - \frac{1}{p_Y} - a_2(y+u)\right) - \beta x u + \chi z$$

Metabolite Concentration:
$$\dot{w} = k_X\Psi x + (1 - k_Y h)k_X\Psi z - k_Y\frac{w}{V}(y+u)$$

- Host is unaffected
- $C_Y < C_U$ & $R_Y < R_U$

β - Rate of interaction between hosts and free-living mutant symbionts
h - Average of symbionts on a host surface
χ - Rate of addition of mutant symbionts back to the free-living state from consortia
V - Volume of habitat/medium (dilution effect)
a_i - Competition ($i = 1, 2$)

Results

- Local asymptotical stability analysis of the four ecologically feasible fixed points:

E_0 : Trivial Equilibrium

E_1 : Resident Equilibrium

E_2 : Evolutionary Substitution

E_3 : Polymorphism/Coexistence

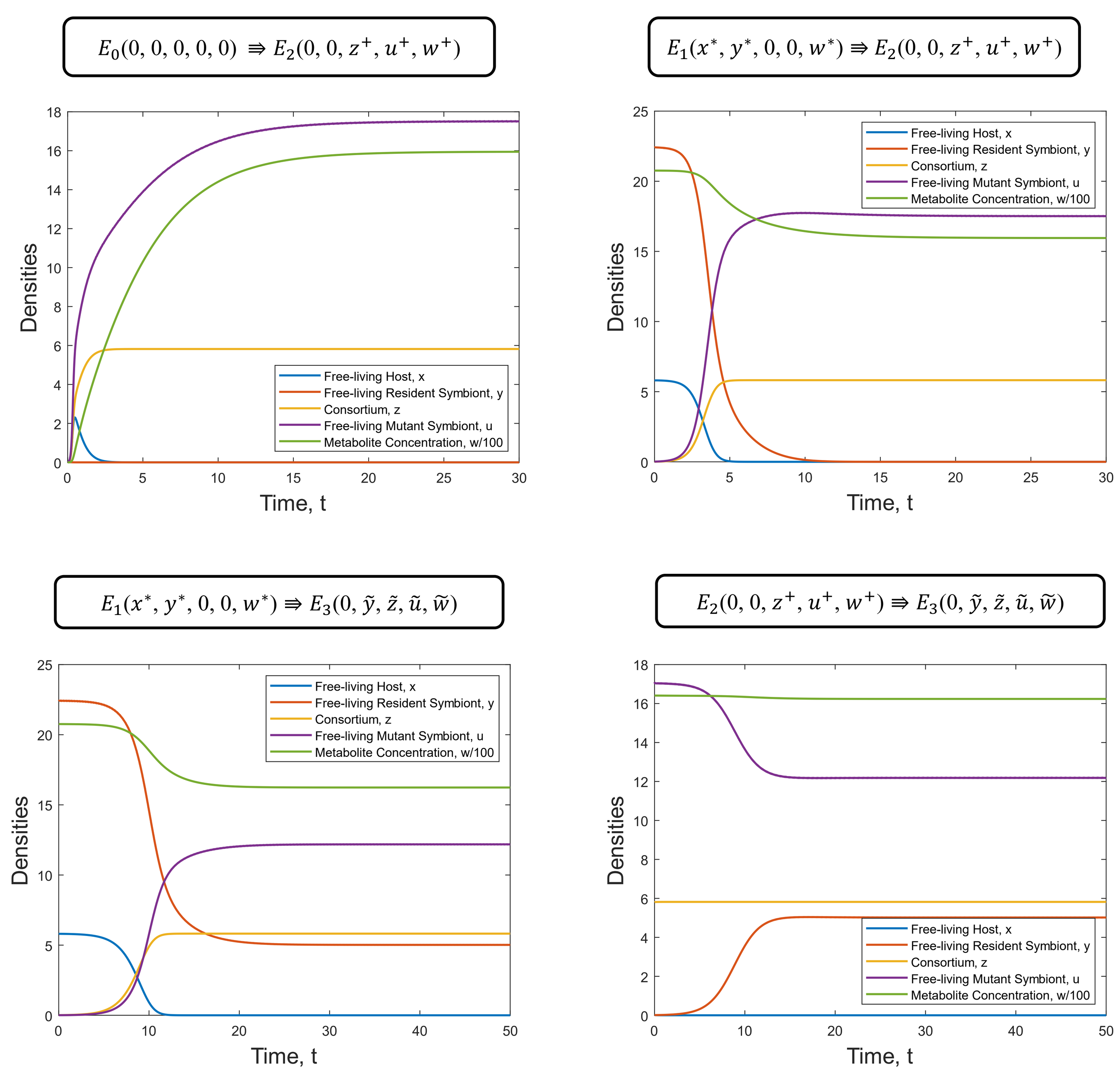
Sufficient conditions for evolutionary substitution and subsequent fixation of multi-species associations or consortia:

- Invading phenotype has lower cost of living to reproduction

$$\frac{C_U}{R_U} < \frac{C_Y}{R_Y}$$

- Perfect vertical transmission and high possibility of horizontal transmission

$$\chi > \frac{k_X\psi(1 - k_Y h)(ln\, 2)(R_U - R_Y)}{R_U R_Y}$$



Take-away info

- **Vertical transmission** of symbionts is crucial and could have evolved at a very early stage of **eukaryote evolution**. Ecological fixation of consortia happens with the assumption that an offspring of a **consortium** has the ecto-symbionts.
- **Evolutionary substitution** happens when the cost of living to reproduction of the mutant phenotype is less than that of the resident phenotype of the symbiont and there is high possibility of horizontal transmission.
- Substitution of the resident phenotype of the symbiont by the mutant phenotype eventually means the **emergence and stability or fixation of the symbiotic merger (consortia)** in the ecological system, hence opening the door to **endo-symbiosis**.

More details in preprint:

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MARIE SKŁODOWSKA-CURIE ACTIONS

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