

Dynamics of feedbacks in nonequilibrium biodiversity organizational scale

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[HTTPS://GITHUB.COM/MELIAN009/ECOEVON/TREE/MASTER/CCSS2024](https://github.com/MELIAN009/EcoEVON/tree/master/CCSS2024)

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Where are we now

NONEQUILIBRIUM

Feedbacks

Where are we gonna go

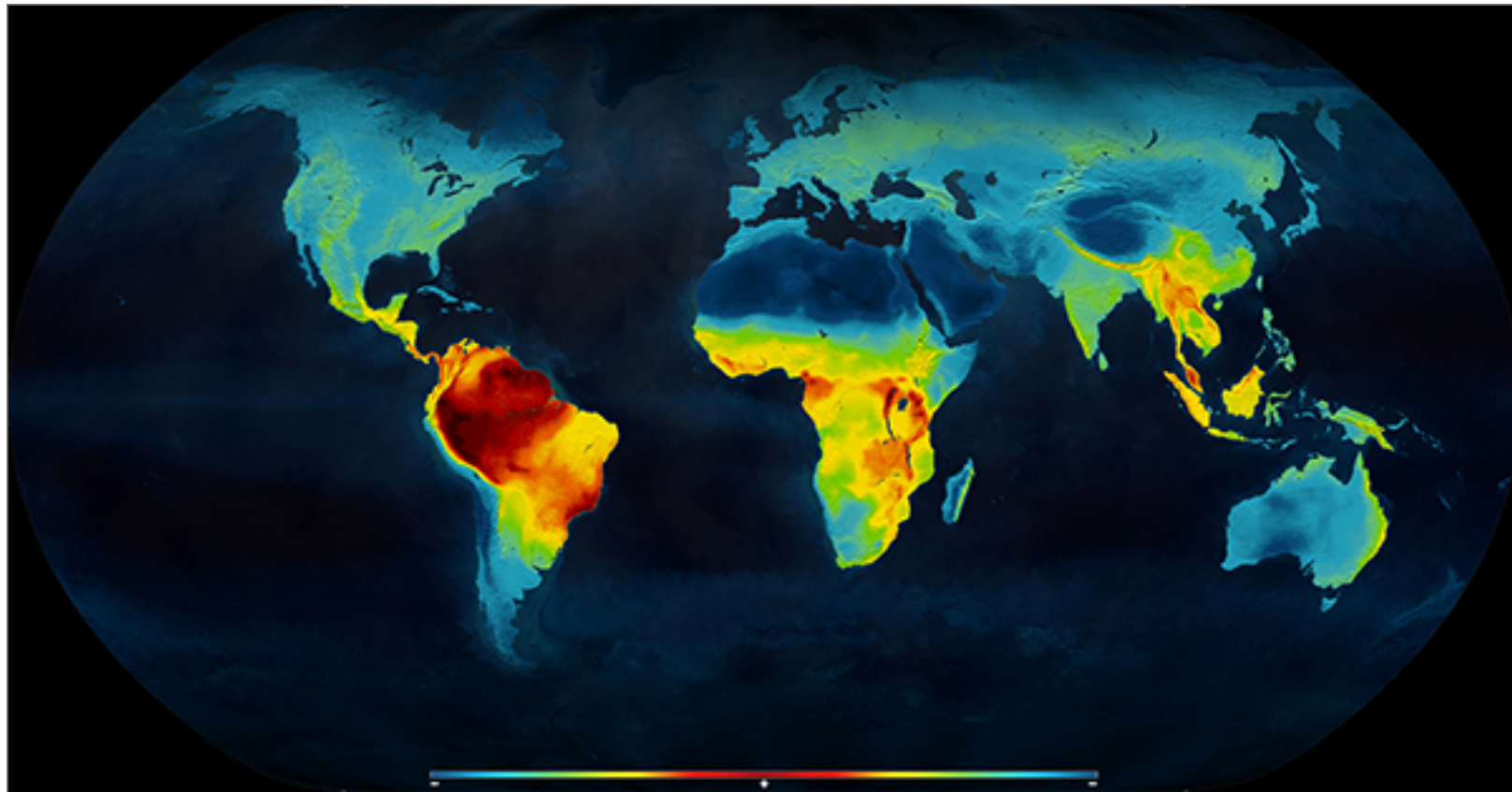
Biodiversity organizational scale

Route to dimensionality

Where are we now



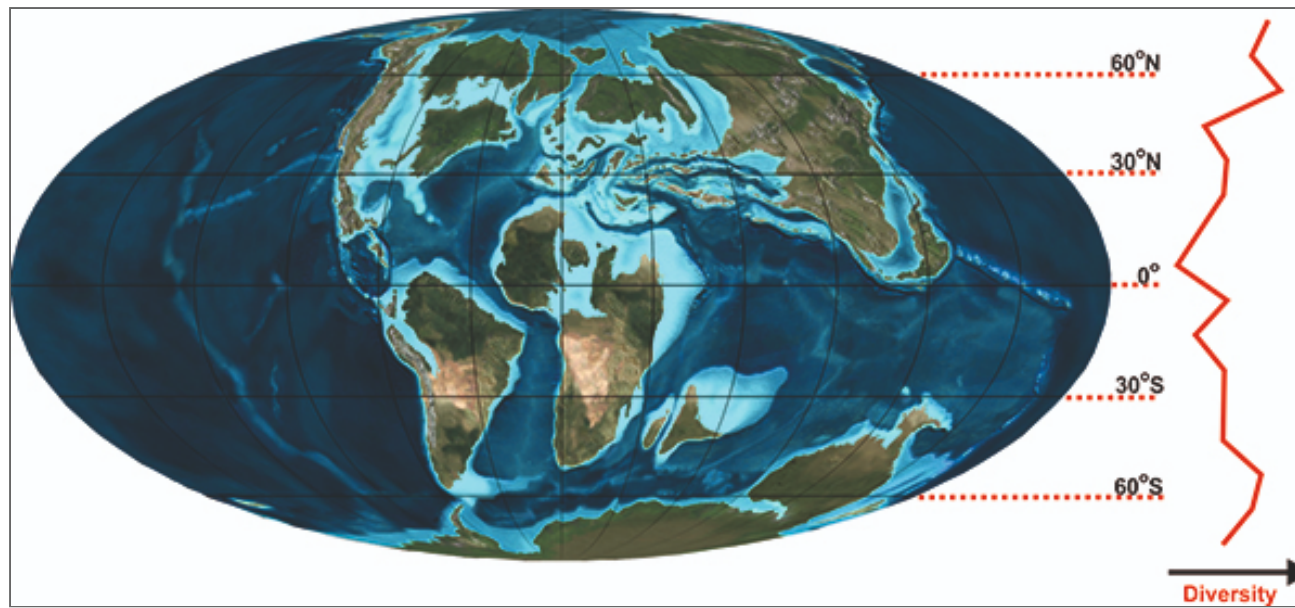
NONEQUILIBRIUM

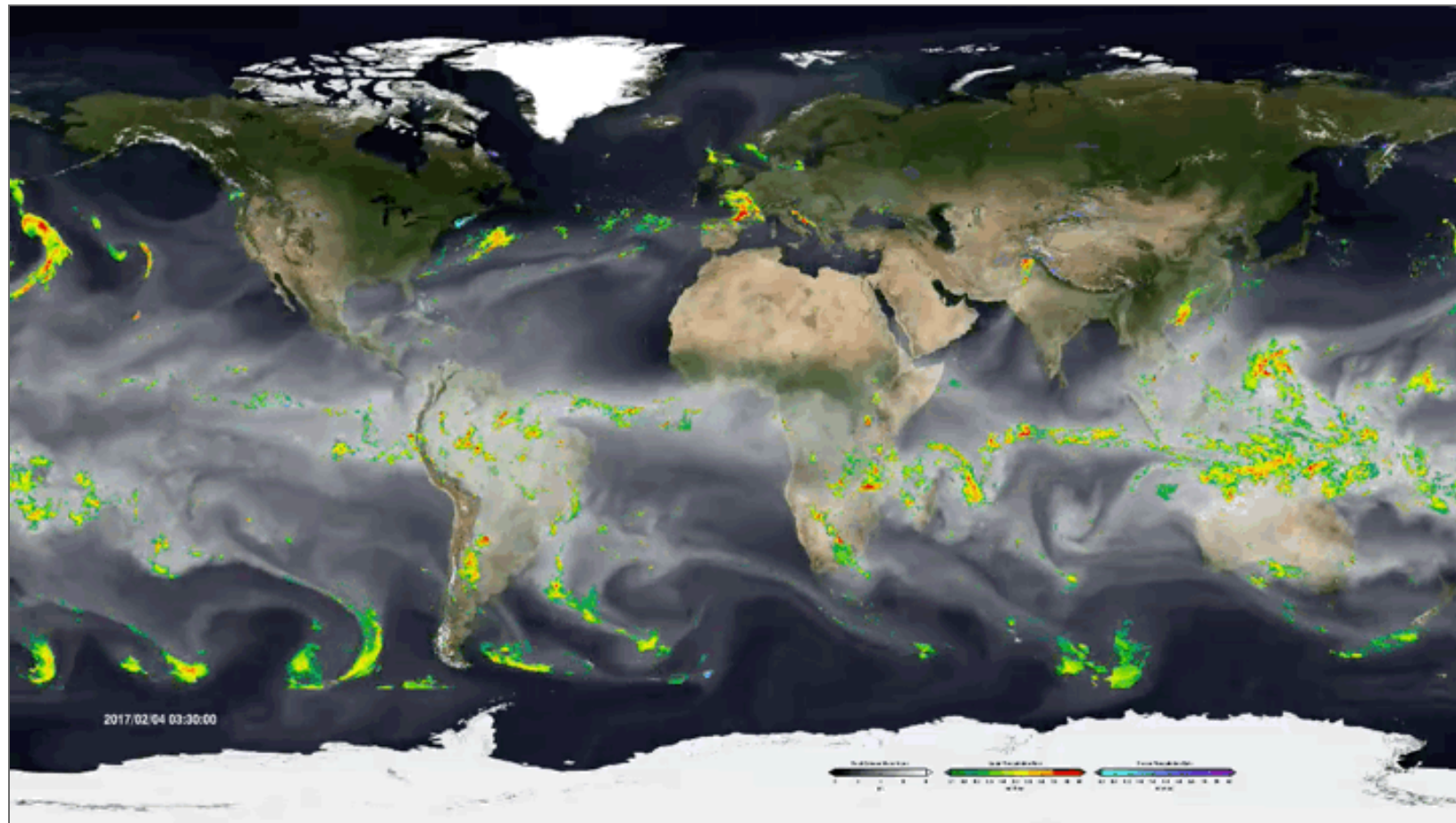



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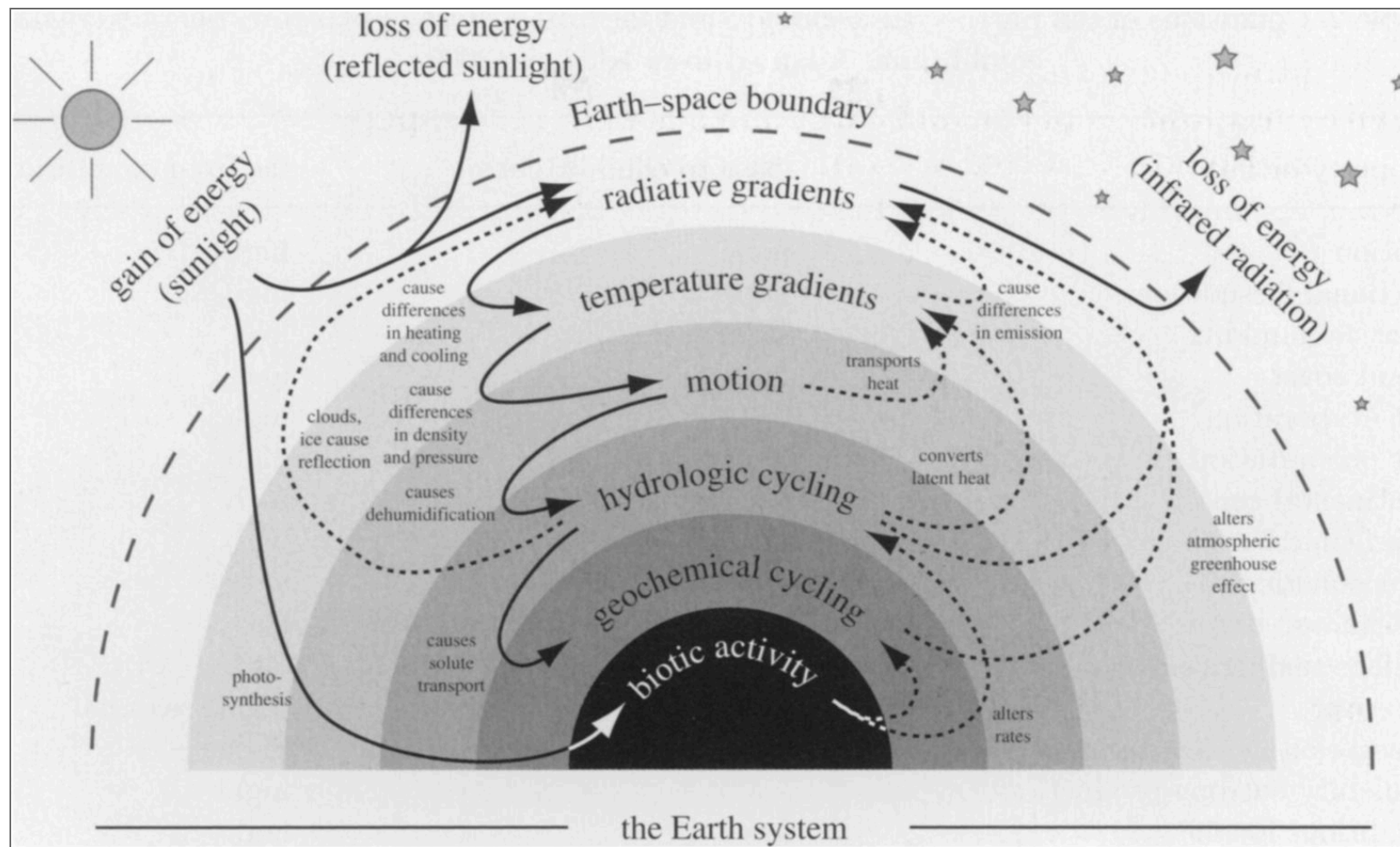
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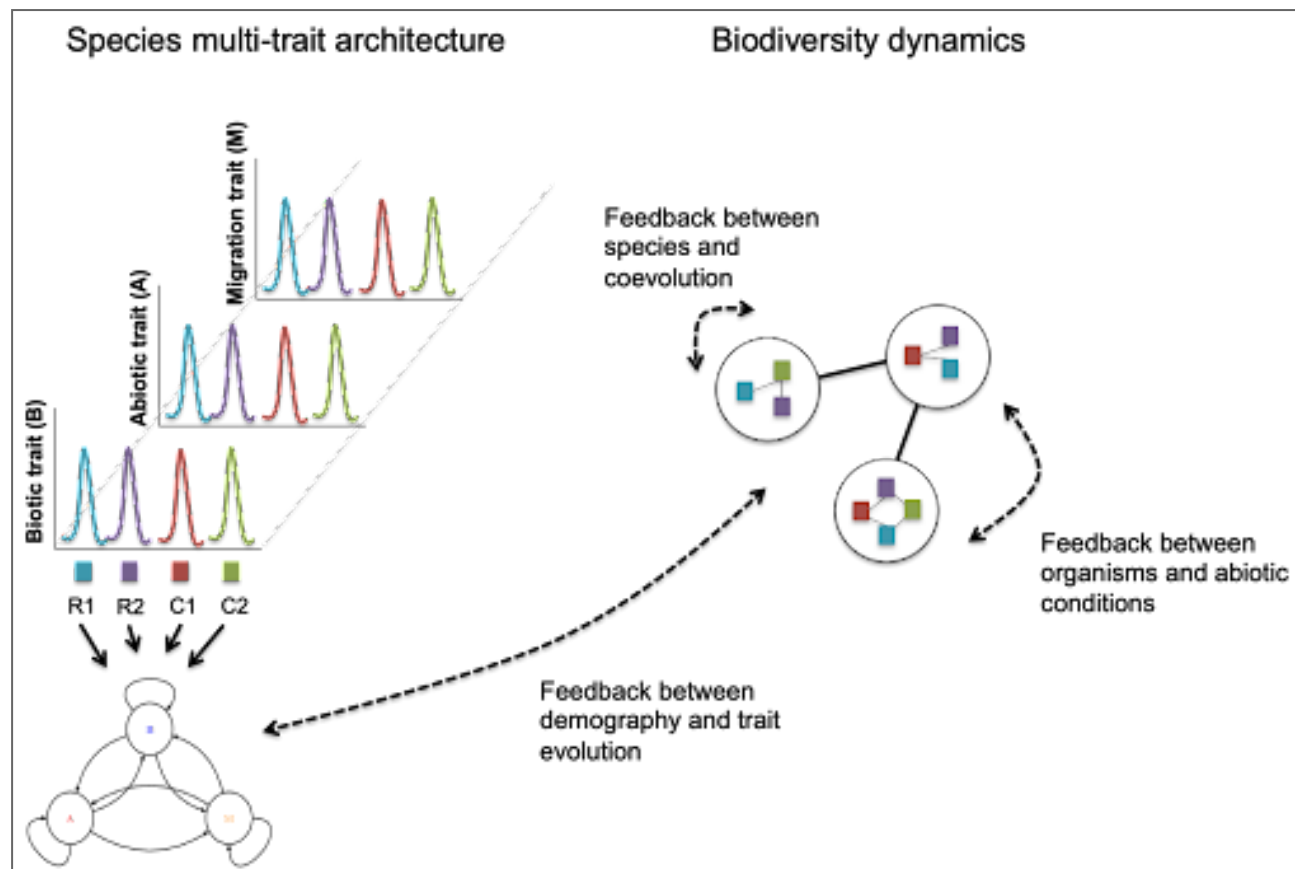




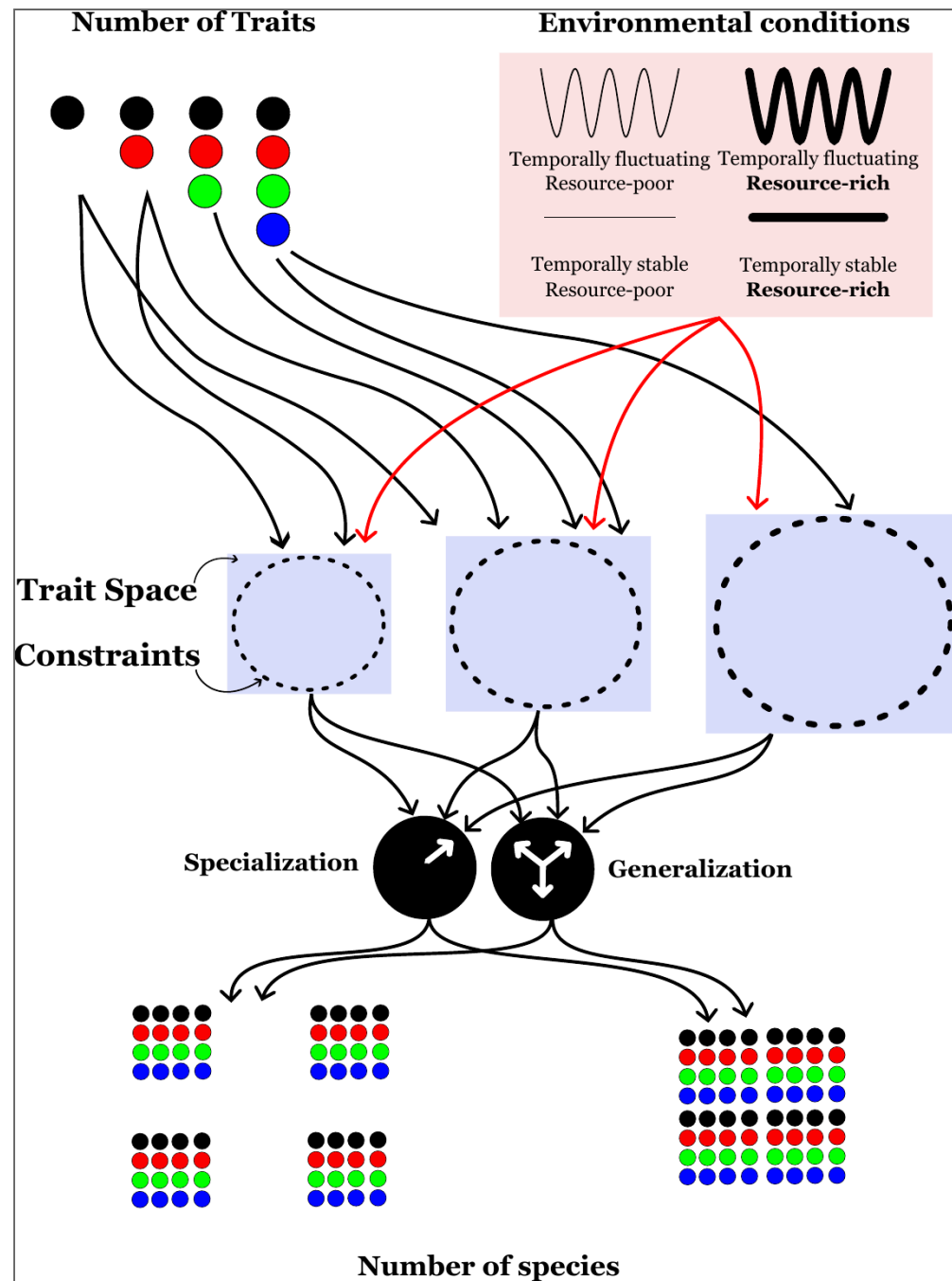


Feedback

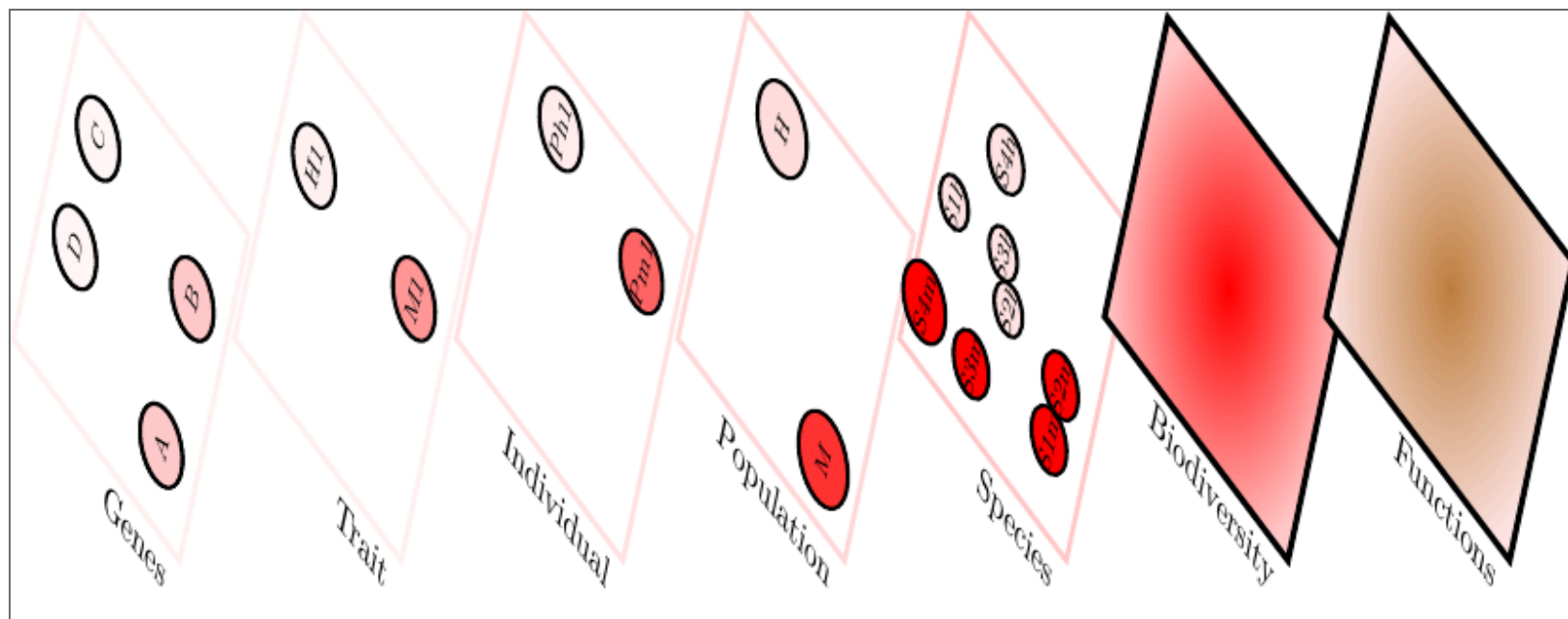


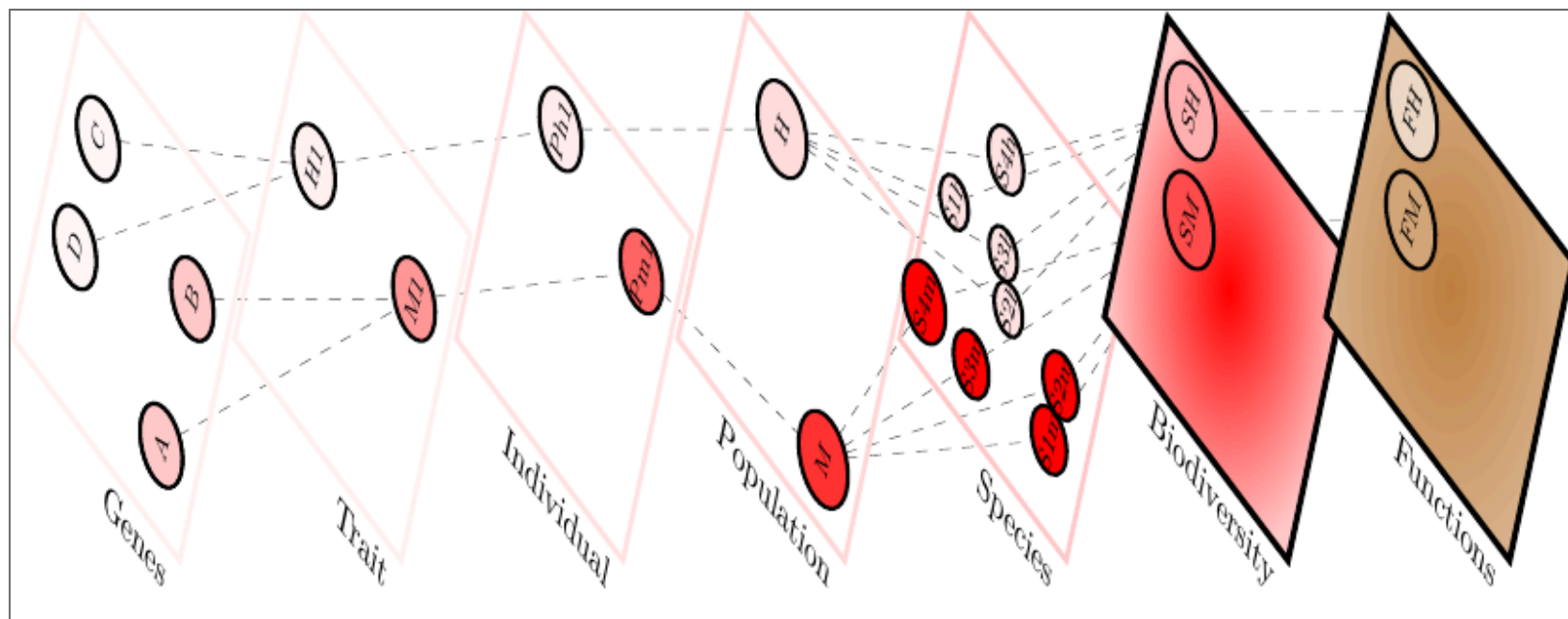


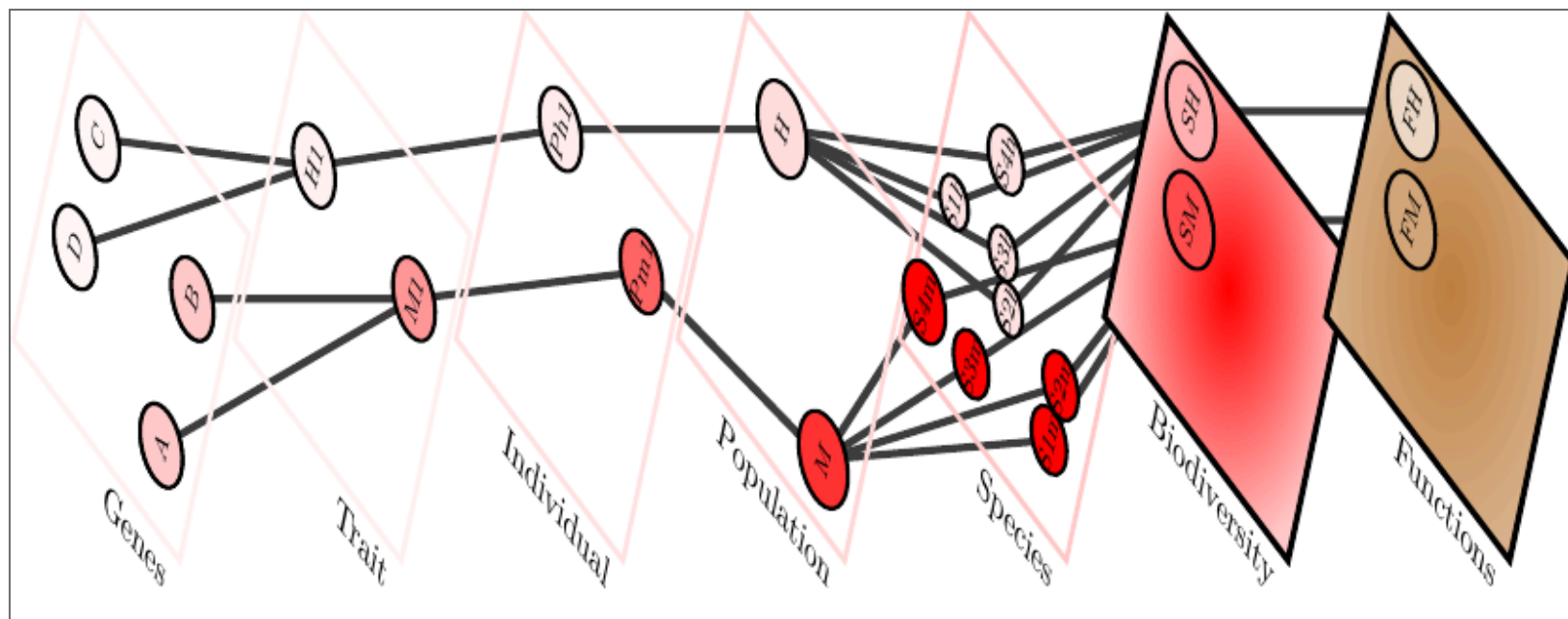
Where are we gonna go

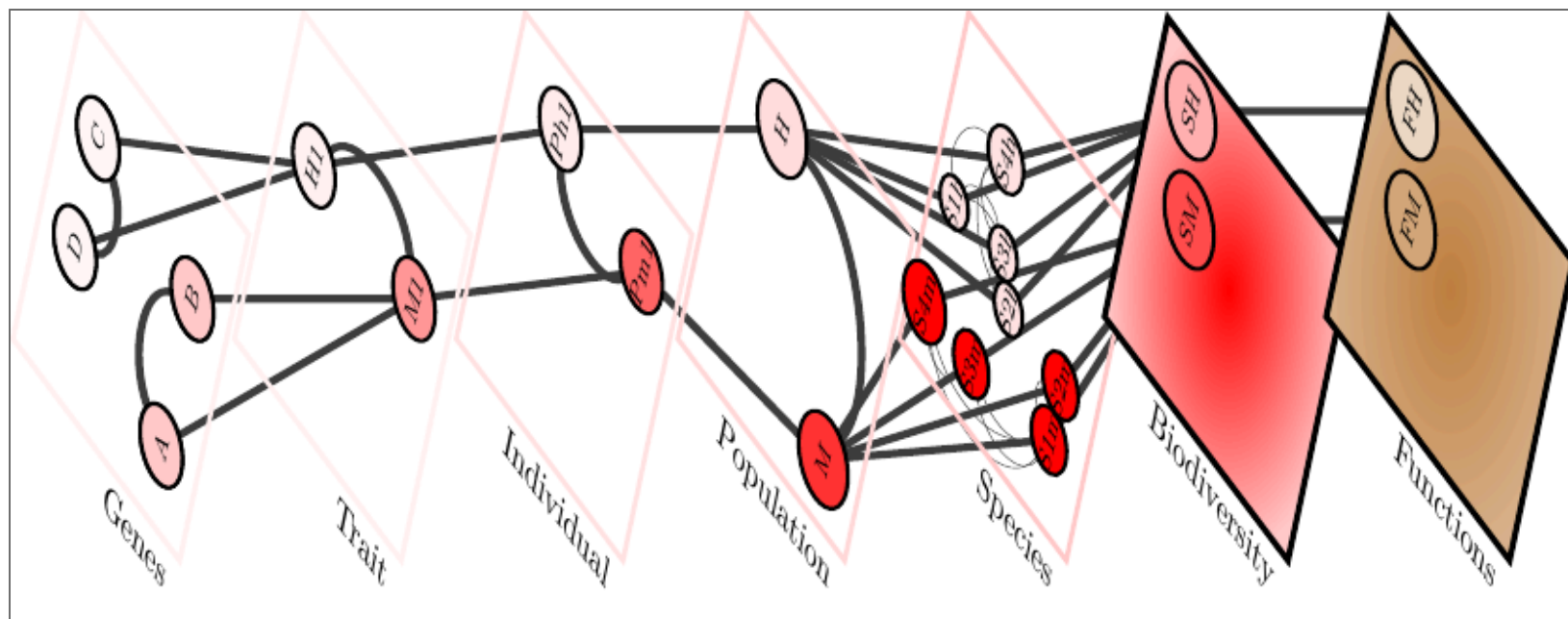


$$\begin{aligned}
\mathbf{\Omega}_{\text{BAM}} &= \begin{bmatrix} V_B & C_{BA} & C_{BM} \\ C_{AB} & V_A & C_{AM} \\ C_{MB} & C_{MA} & V_M \end{bmatrix} \\
\mathbf{W}(\mathbf{z})_{ix}^t &= \exp[-\gamma([\mathbf{z}_{ix}^t - \boldsymbol{\theta}_{ix}^t]^T \mathbf{\Omega}_{\text{BAM}}^{-1} [\mathbf{z}_{ix}^t - \boldsymbol{\theta}_{ix}^t])] \\
\underbrace{\begin{bmatrix} W(\mathbf{z}_{\mathbf{B}_{ix}}^t) \\ W(\mathbf{z}_{\mathbf{A}_{ix}}^t) \\ \vdots \\ W(\mathbf{z}_{\mathbf{M}_{ix}}^t) \end{bmatrix}}_{\mathbf{W}} &= \underbrace{\begin{bmatrix} W(B_{ix}^t)^* \\ W(A_{ix}^t)^* \\ \vdots \\ W(M_{ix}^t)^* \end{bmatrix}}_{\mathbf{W}}^T \underbrace{\begin{bmatrix} V_B & C_{BA} & \dots & C_{BM} \\ C_{AB} & V_A & \dots & C_{AM} \\ \vdots & \vdots & \ddots & \vdots \\ C_{MB} & C_{MA} & \dots & V_M \end{bmatrix}^{-1}}_{\mathbf{\Omega}_{\text{BAM}}} \underbrace{\begin{bmatrix} W(B_{ix}^t)^* \\ W(A_{ix}^t)^* \\ \vdots \\ W(M_{ix}^t)^* \end{bmatrix}}_{\mathbf{W}}
\end{aligned}$$



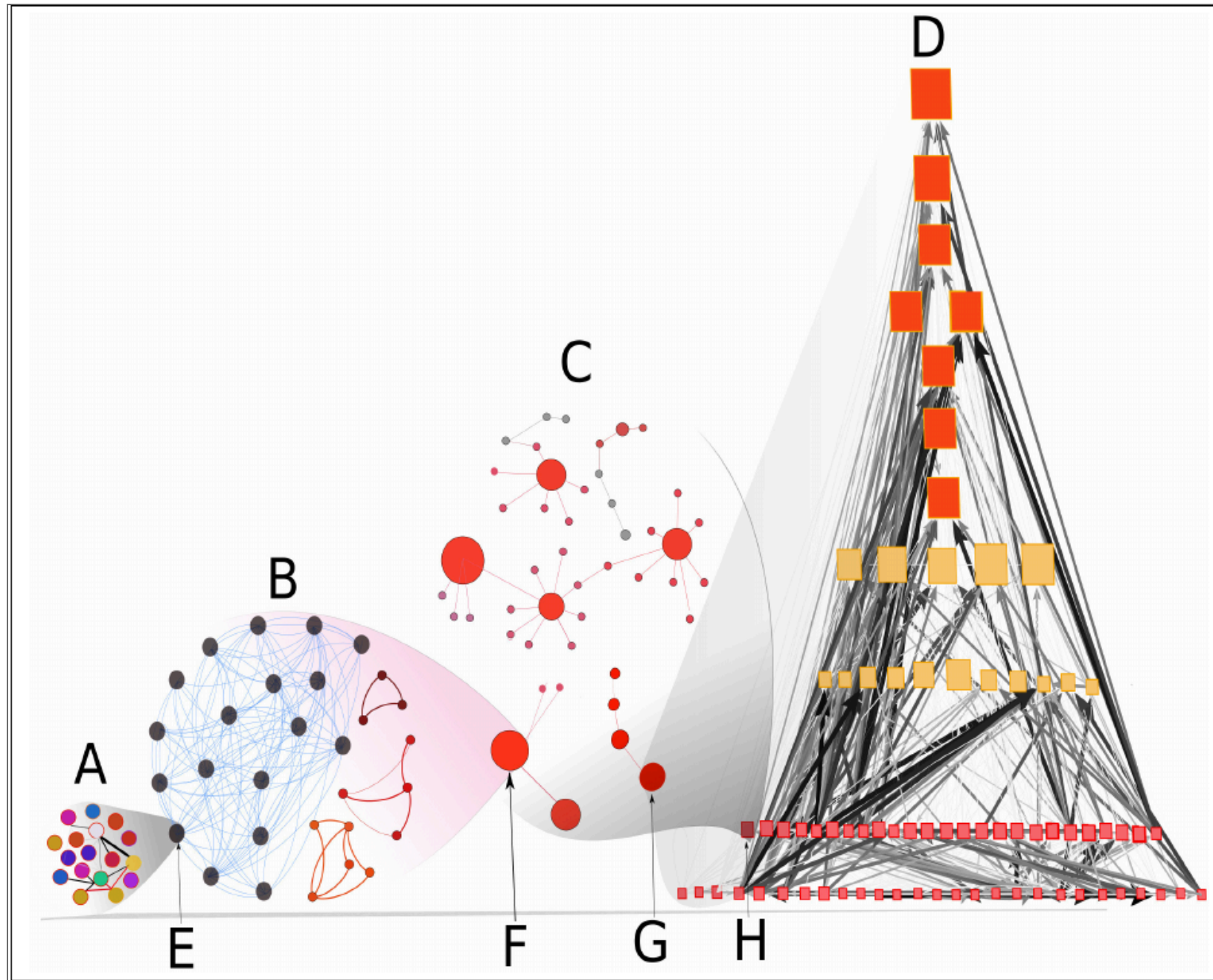


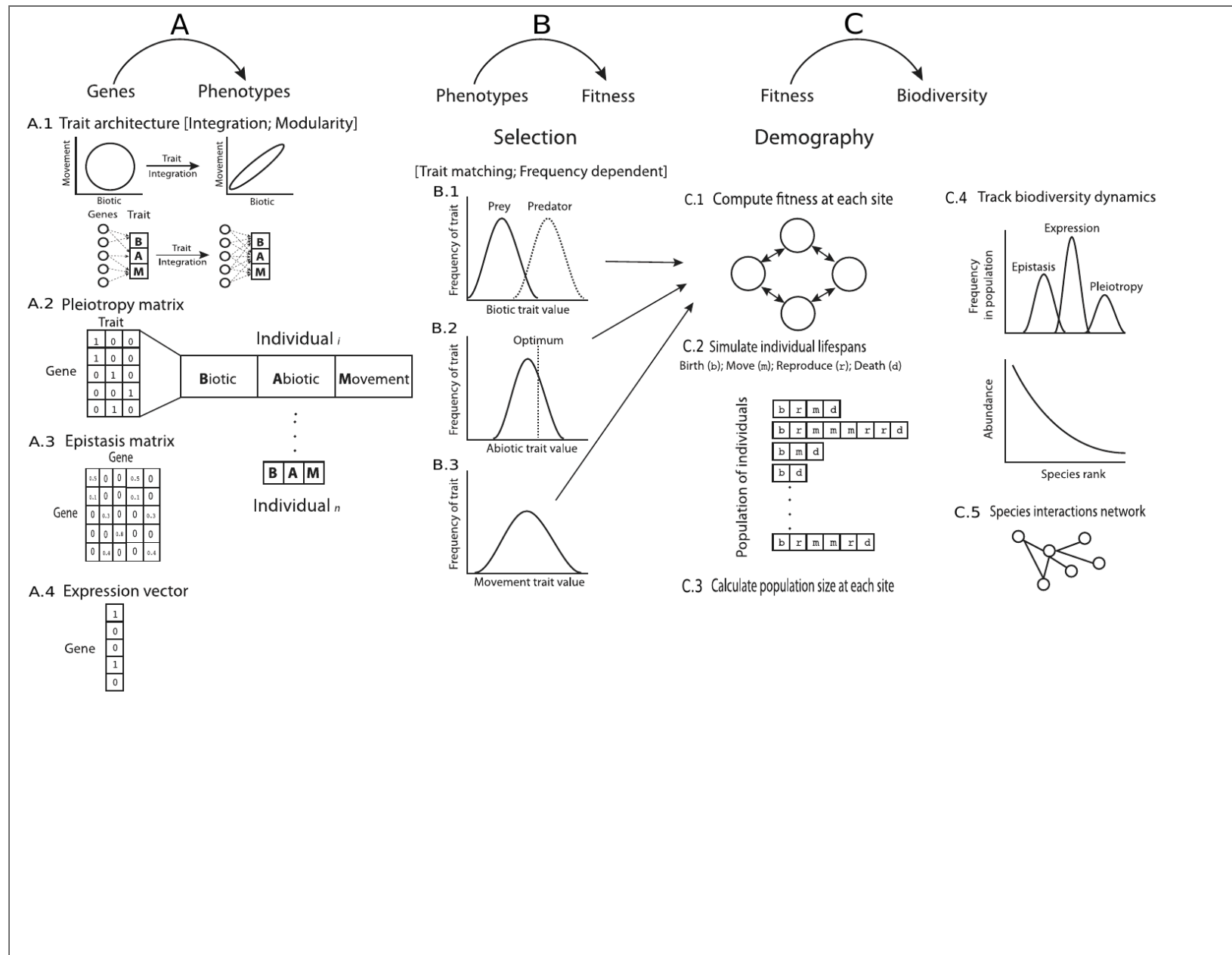




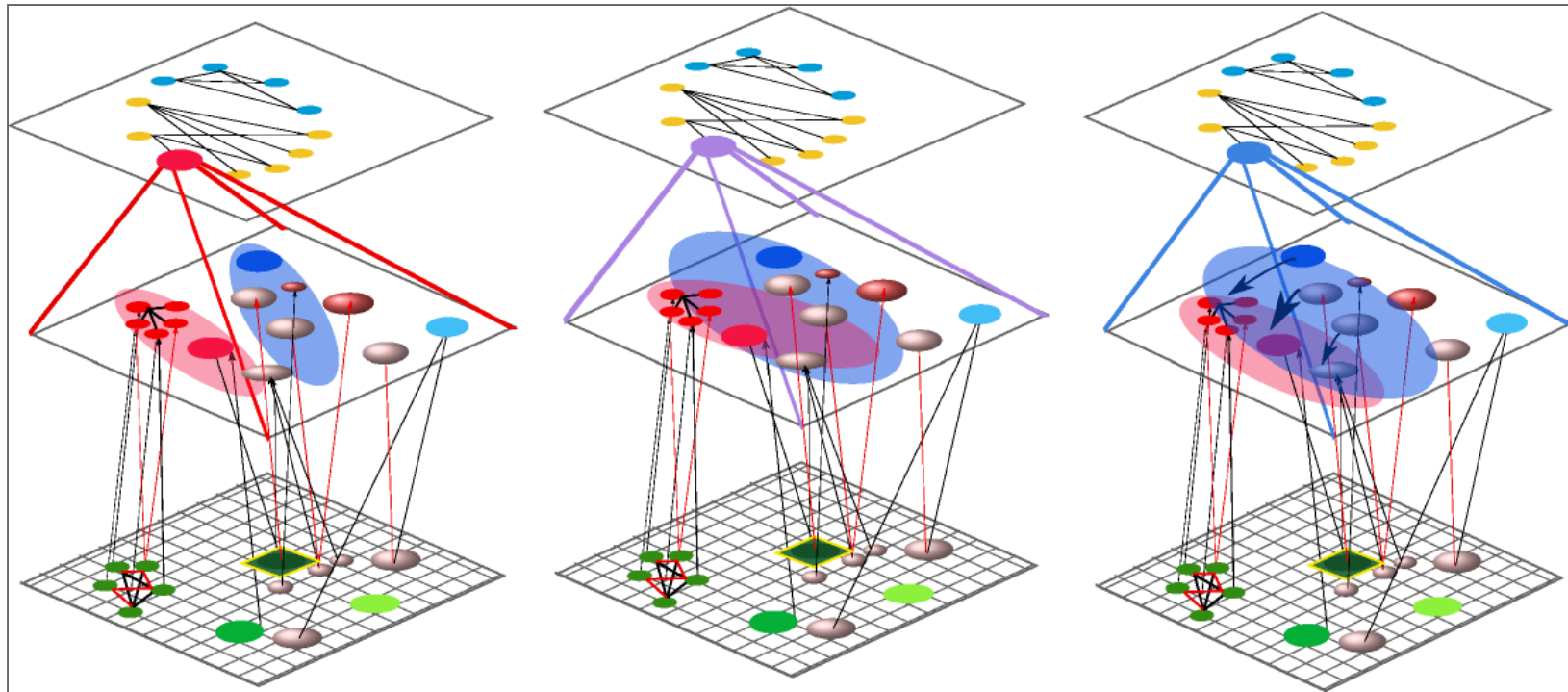
$$\partial_t \rho(\mathbf{z}, \mathbf{t}) = -\nabla_{\mathbf{z}} [\nabla_{\mathbf{z}} \mathbf{F}(\mathbf{z}, \mathbf{y}_{\mathbf{t}}) \rho(\mathbf{z}, \mathbf{t})] - r(\mathbf{z}, \mathbf{y}_{\mathbf{t}}) \rho(\mathbf{z}, \mathbf{t}) \\ + \int_{\Omega} \int_{\Omega} M(\mathbf{z} | \mathbf{z}', \mathbf{z}'') \mathbf{B}(\mathbf{z}', \mathbf{z}'') \rho(\mathbf{z}', \mathbf{t}) \rho(\mathbf{z}'', \mathbf{t}) d^d \mathbf{z}' d^d \mathbf{z}''$$

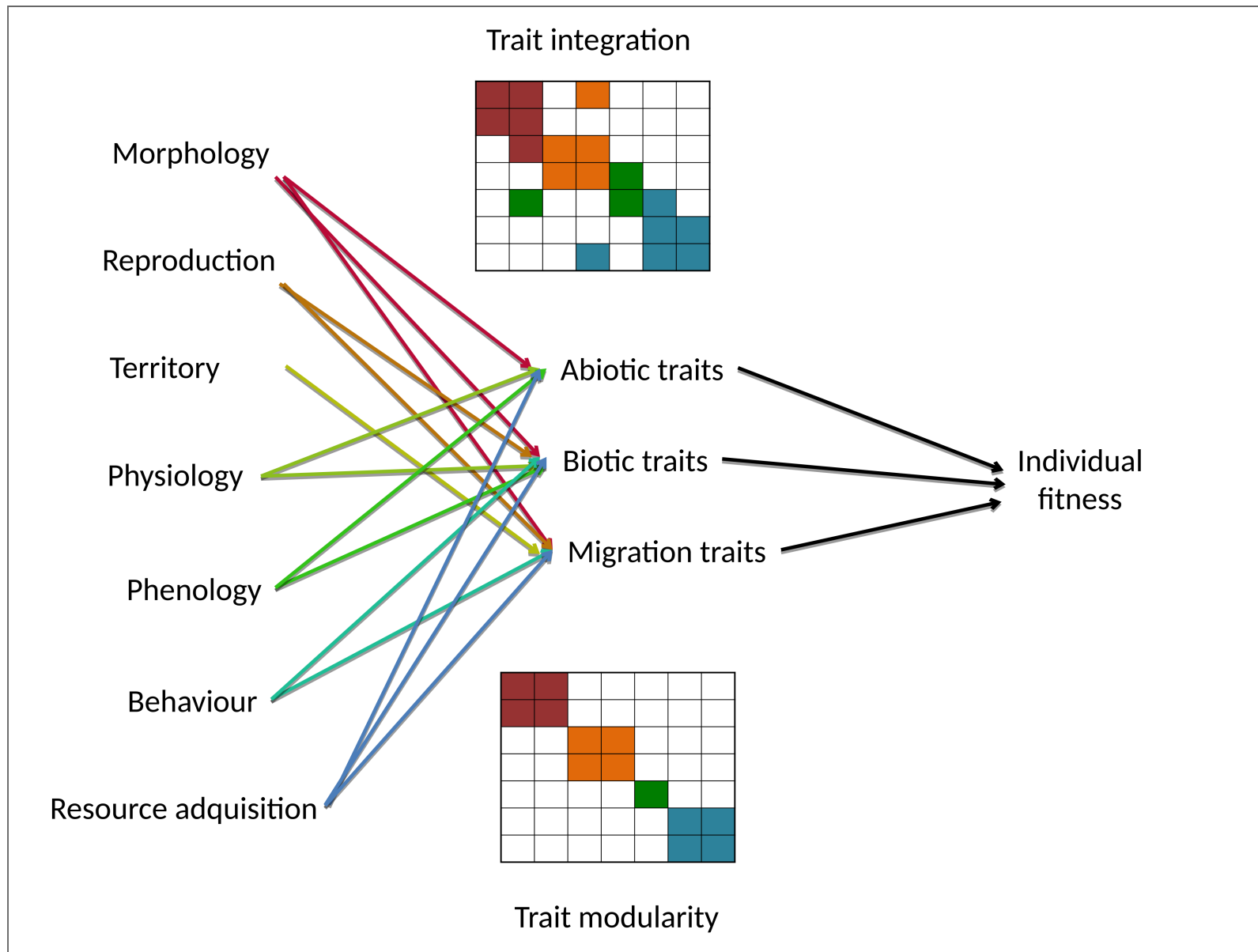
Biodiversity organizational scale





Route to Dimensionality





Complex traits: GPA

$$z_j^i(x, t) = f(\mathbf{L})(x, t), f : \mathbb{R}^m \rightarrow \mathbb{R}^z \quad (1)$$

In this formulation, an individual's i phenotype in site x and time t is given by

$$\mathbf{Z}^i_{(x, t)} = f(\mathbf{L}) = \mathbf{D}[f(\mathbf{L})] = \mathbf{B}\mathbf{Y}, \quad (2)$$

$$\mathbf{Z}^i_{(x, t)} = \mathbf{B}^T \mathbf{E} \mathbf{Y} \quad (3)$$

Abiotic trait

$$D(z_a^i)_{(x,t)} = |0.5 - cdf(\mathcal{N}(\theta_a, \sigma^2), z_a^i)|, \quad (4)$$

where $D(z_a^i)$ is the distance of abiotic trait of individual i to its optimum, θ_a is the optimal value used as the mean of a normal distribution, σ^2 is the variance of the normal distribution, and z_a^i is the value of the abiotic trait i and cdf is cumulative distribution function. The fitness of the abiotic trait of individual i is then given by

$$W(z_a^i)_{(x,t)} = 1 - D(z_a^i)_{(x,t)} \quad (5)$$

Biotic trait

$$D(z_b^i z_b^j)(x, t) = |0.5 - cdf(\mathcal{N}(z_b^i, \sigma^2), z_b^j)|. \quad (6)$$

The strength of an interaction is a function of species-species coefficient and the phenotypic distance between the two individuals

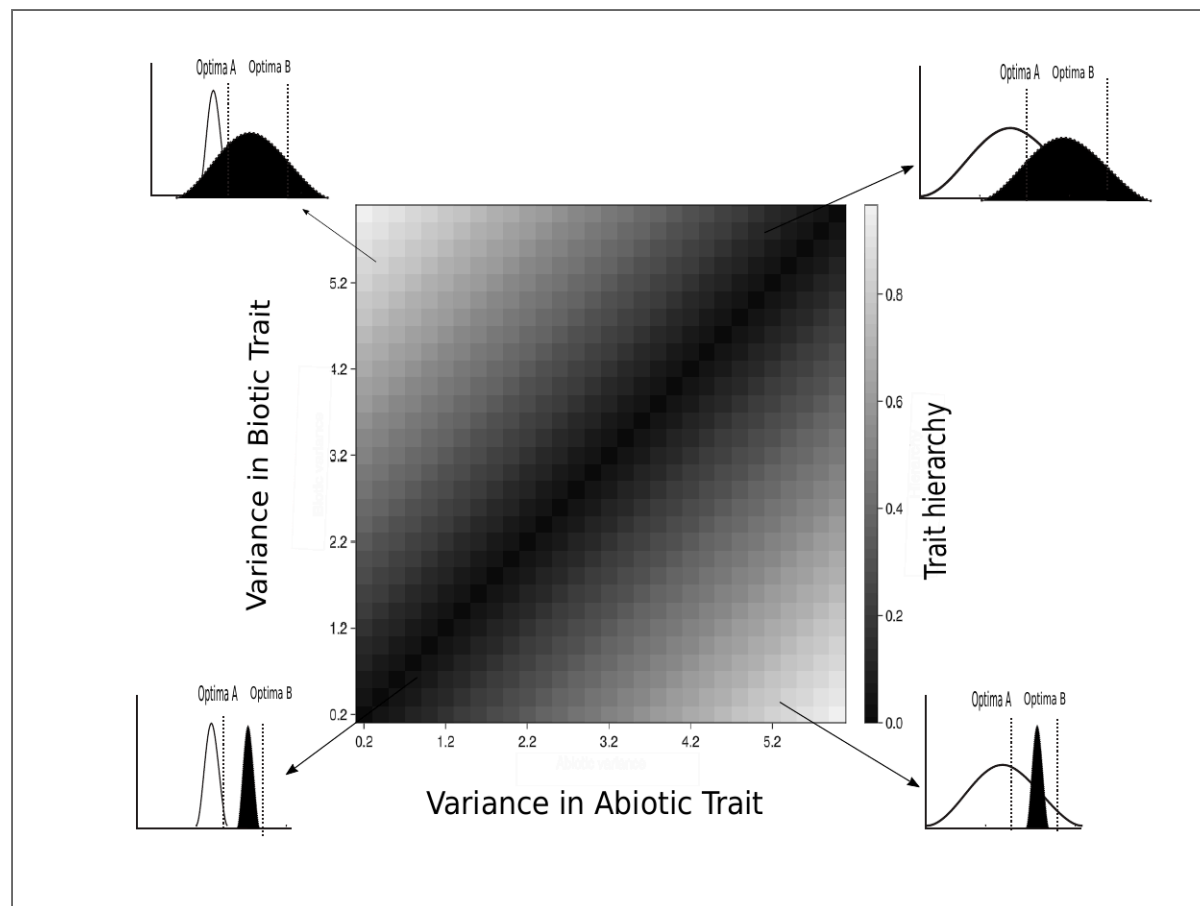
$$s_{z_b^i z_b^j}(x, t) = (1 - D(z_b^i z_b^j)(x, t)) \times |c_{z_b^A z_b^B}| \times \text{sign}(c_{z_b^A z_b^B}) \quad (7)$$

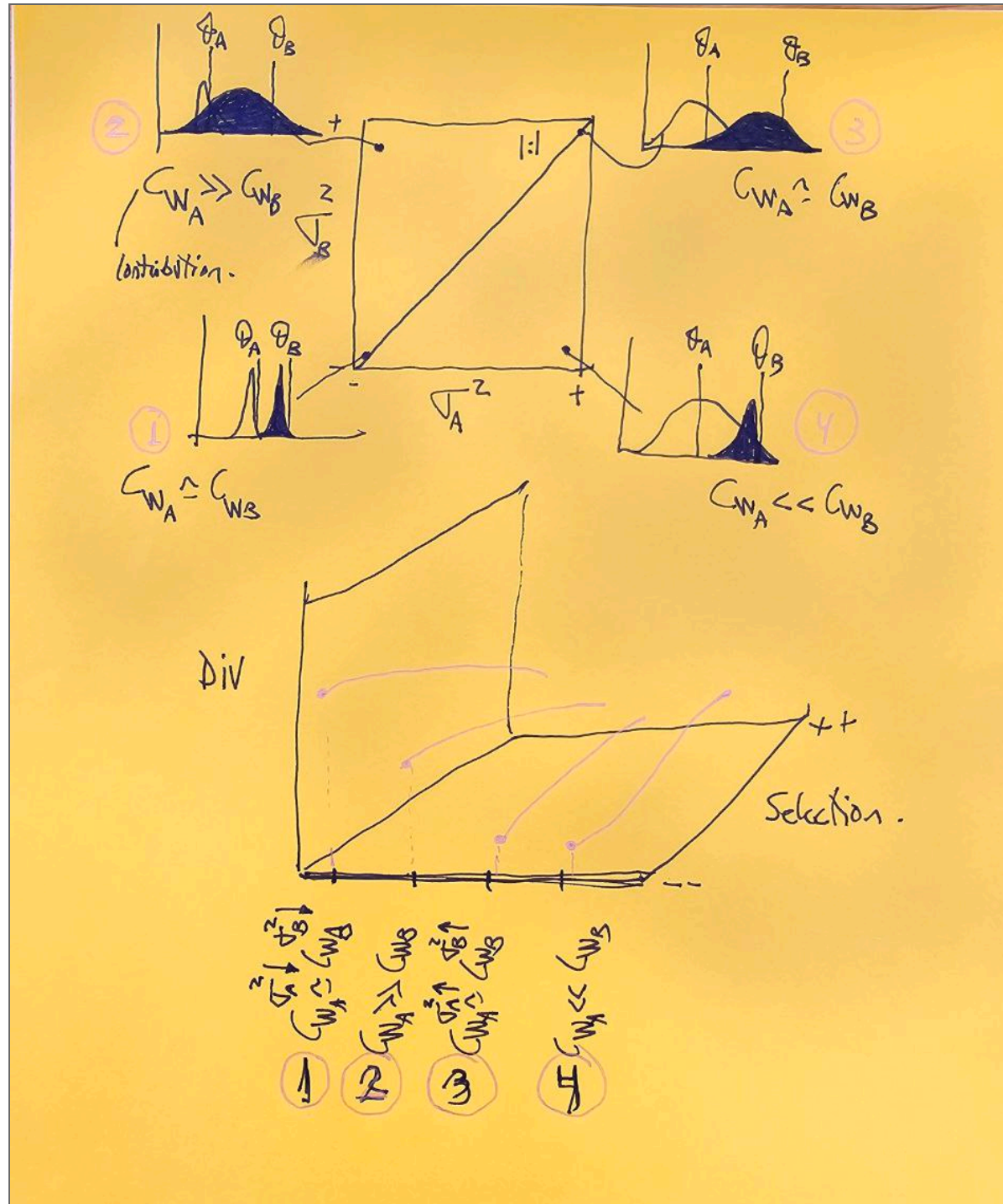
Fitness

$$W(Z^i)_{(x,t)} = W(z_a^i)_{(x,t)} + s_{z_b^i z_b^j}(x,t), \quad (8)$$

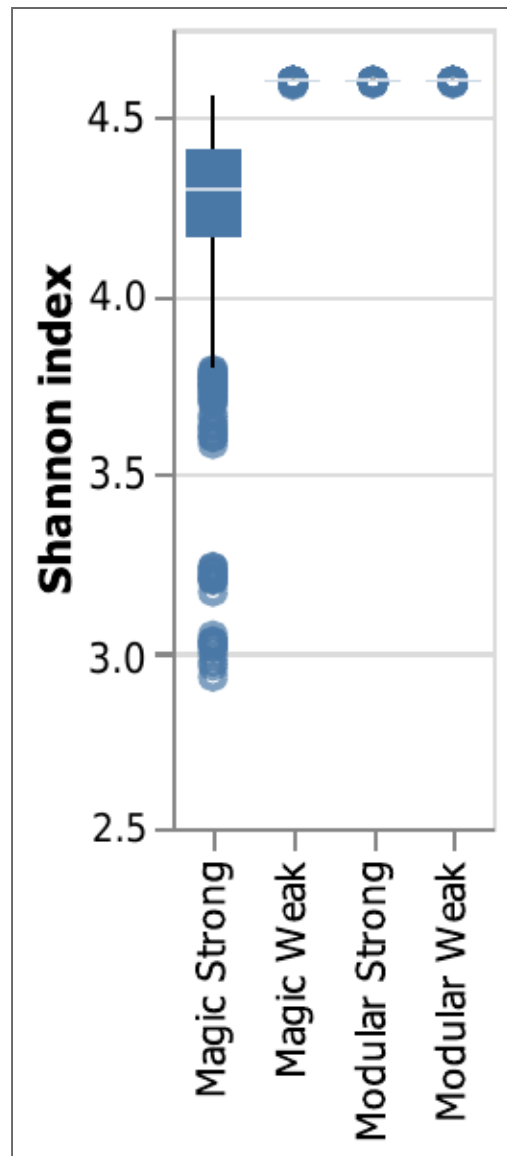
and the fitness function takes into account the selection coefficient as

$$W(Z^i)_{(x,t)} = 1 - ((1 - W(Z^i)_{(x,t)}) \times s_A) \quad (9)$$









Take home message

Where are we now

- gap in understanding bb-ba-ab-aa-interactions accounting for nonequilibrium and feedbacks at many spatiotemporal scales

Where are we gonna go

- GPA connecting complex traits to biotic-abiotic feedbacks and diversity patterns
- The route to dimensionality integrating BOS to feedbacks