

# Dynamics of feedbacks in nonequilibrium biodiversity organizational scale

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<https://github.com/melian009/Ecoevon/tree/master/ccss2024>

## References

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Where are we now

NONEQUILIBRIUM

Feedbacks

Where are we gonna go

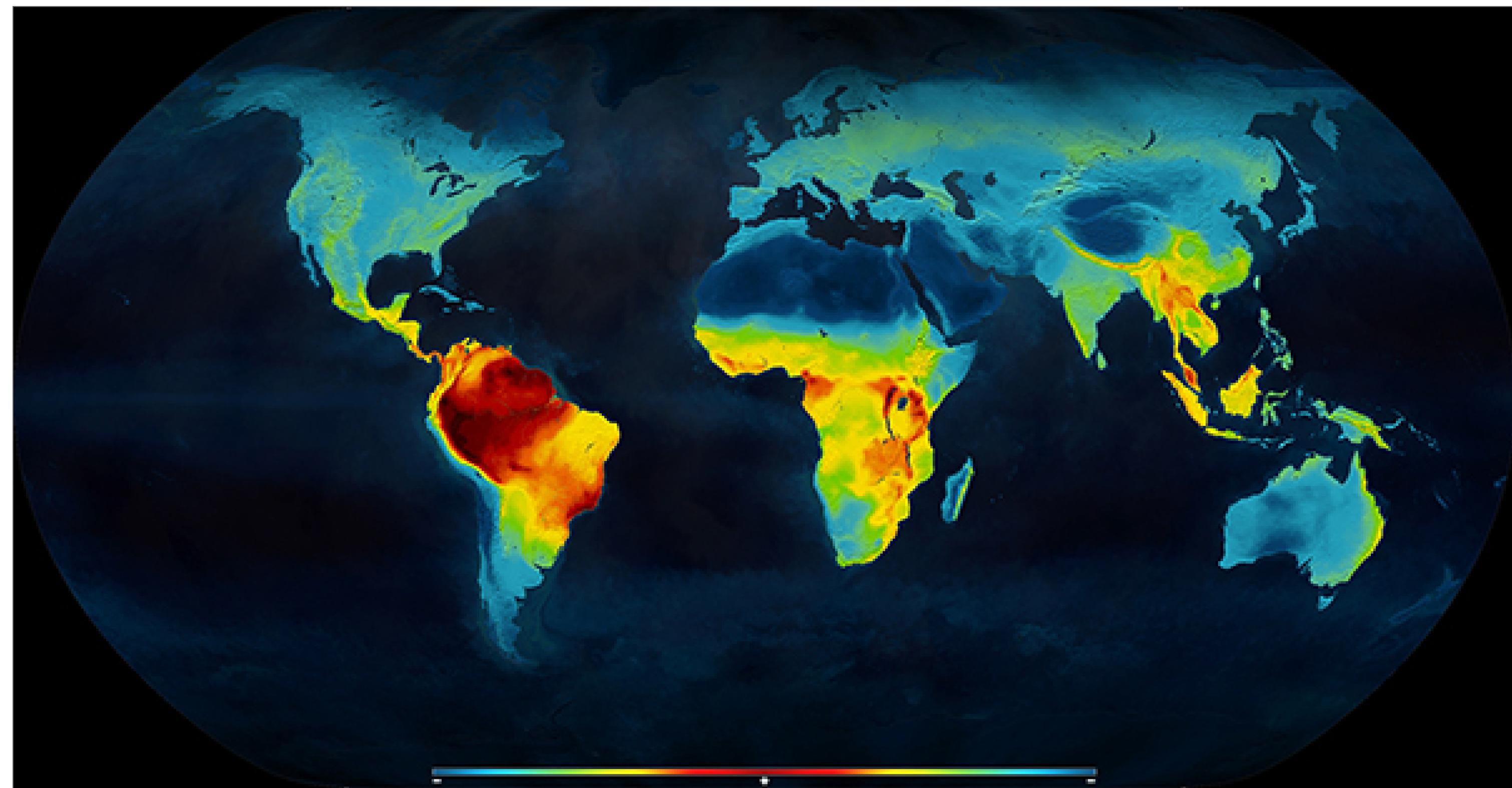
Biodiversity organizational scale

Route to dimensionality

Where are we now



## NONEQUILIBRIUM

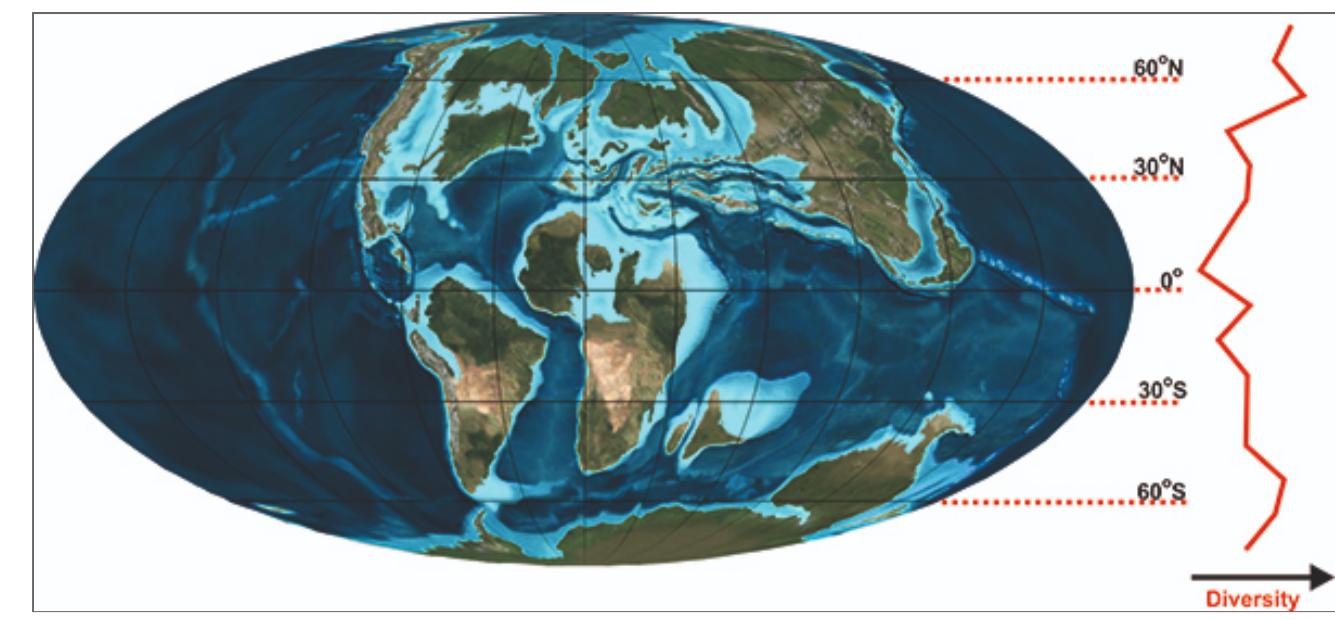


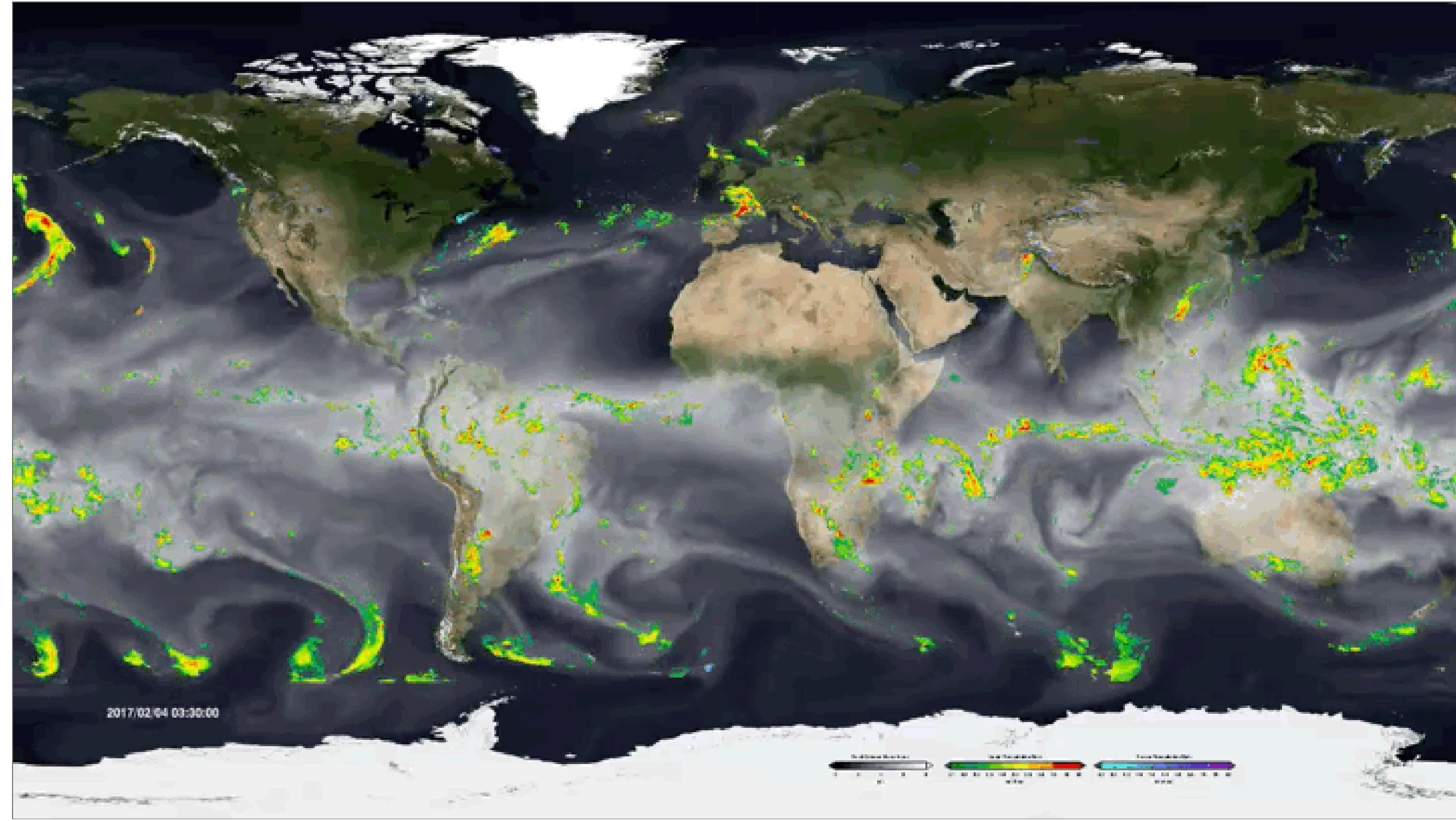
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Out[21]:

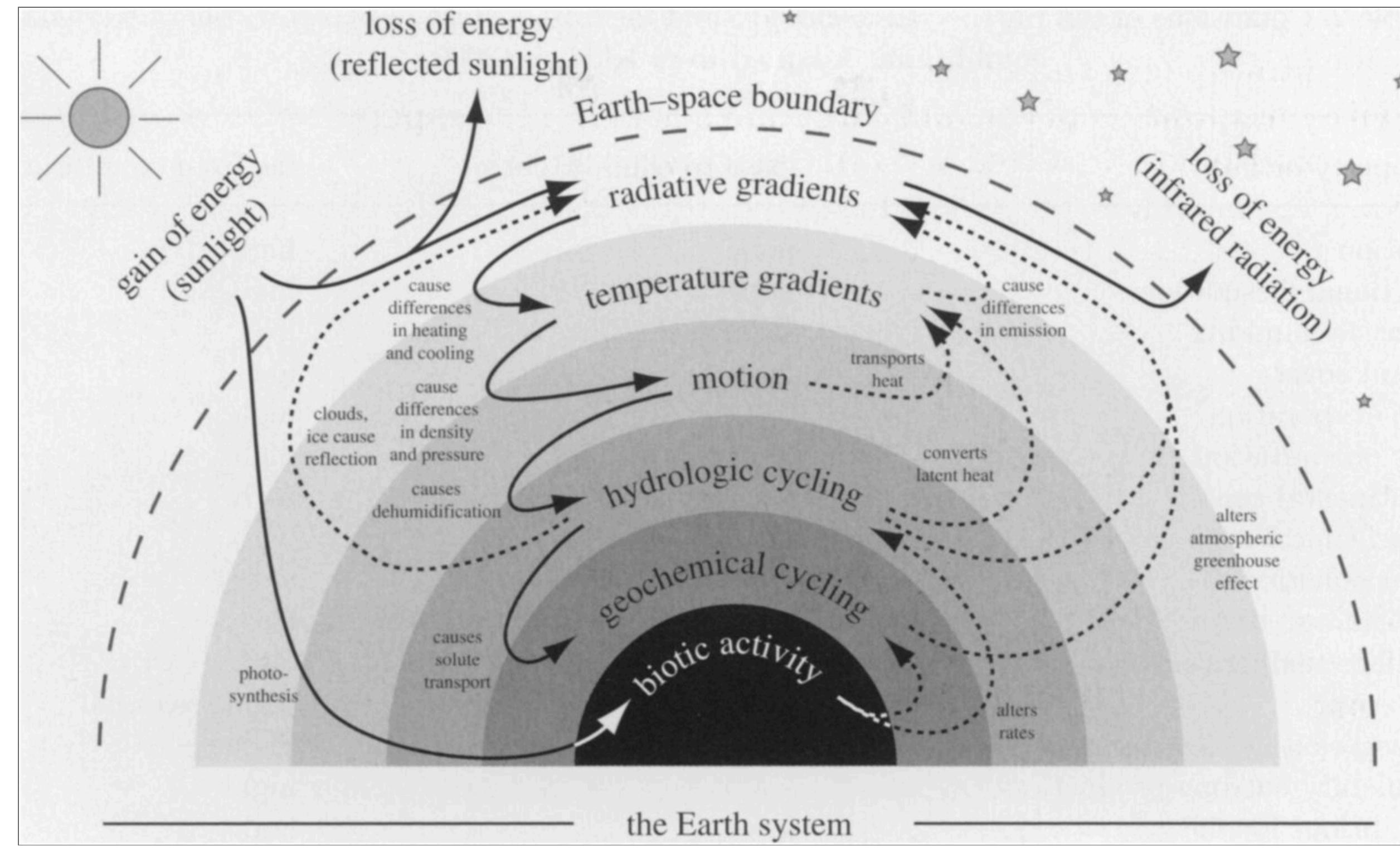
0.00 / 0.09

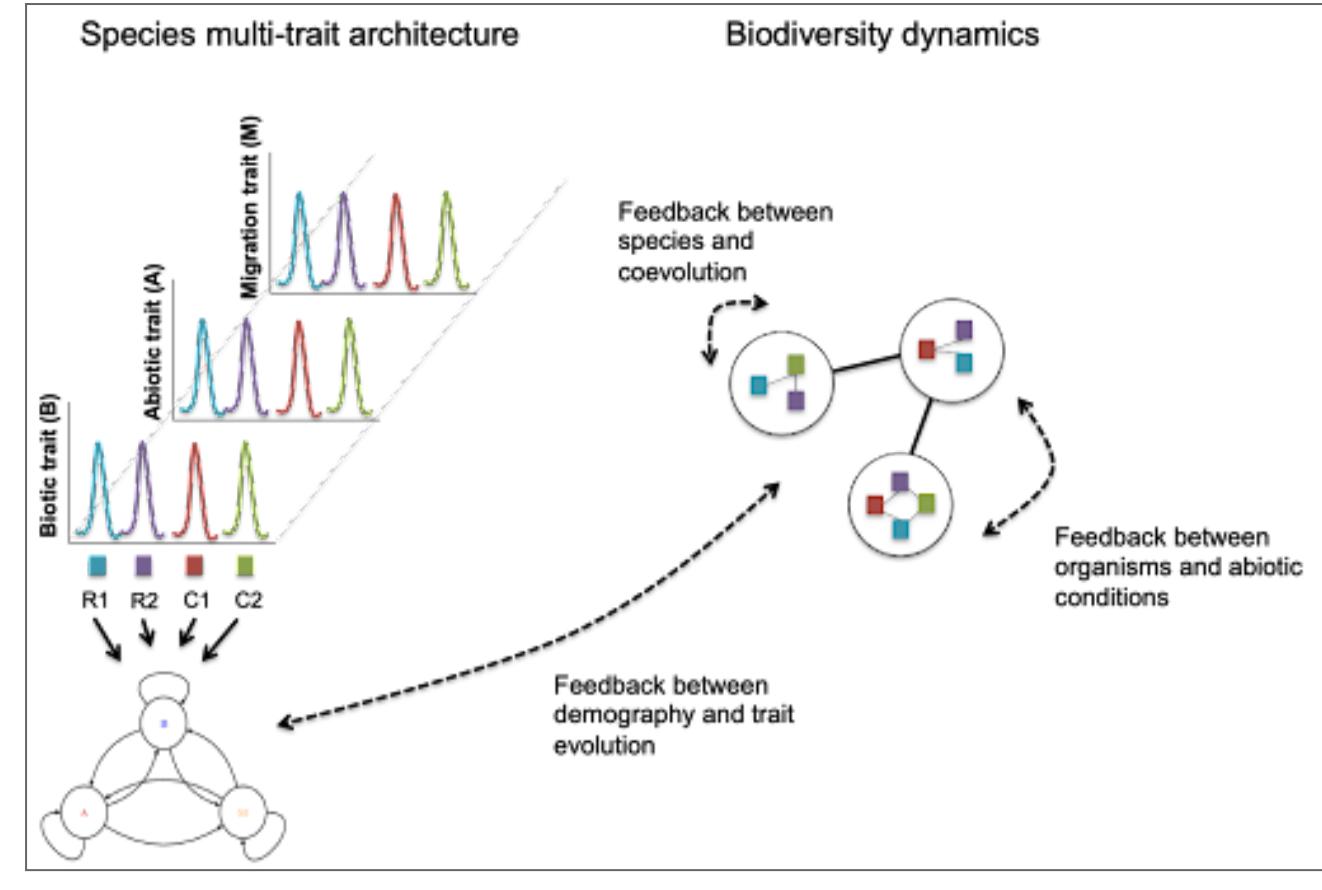




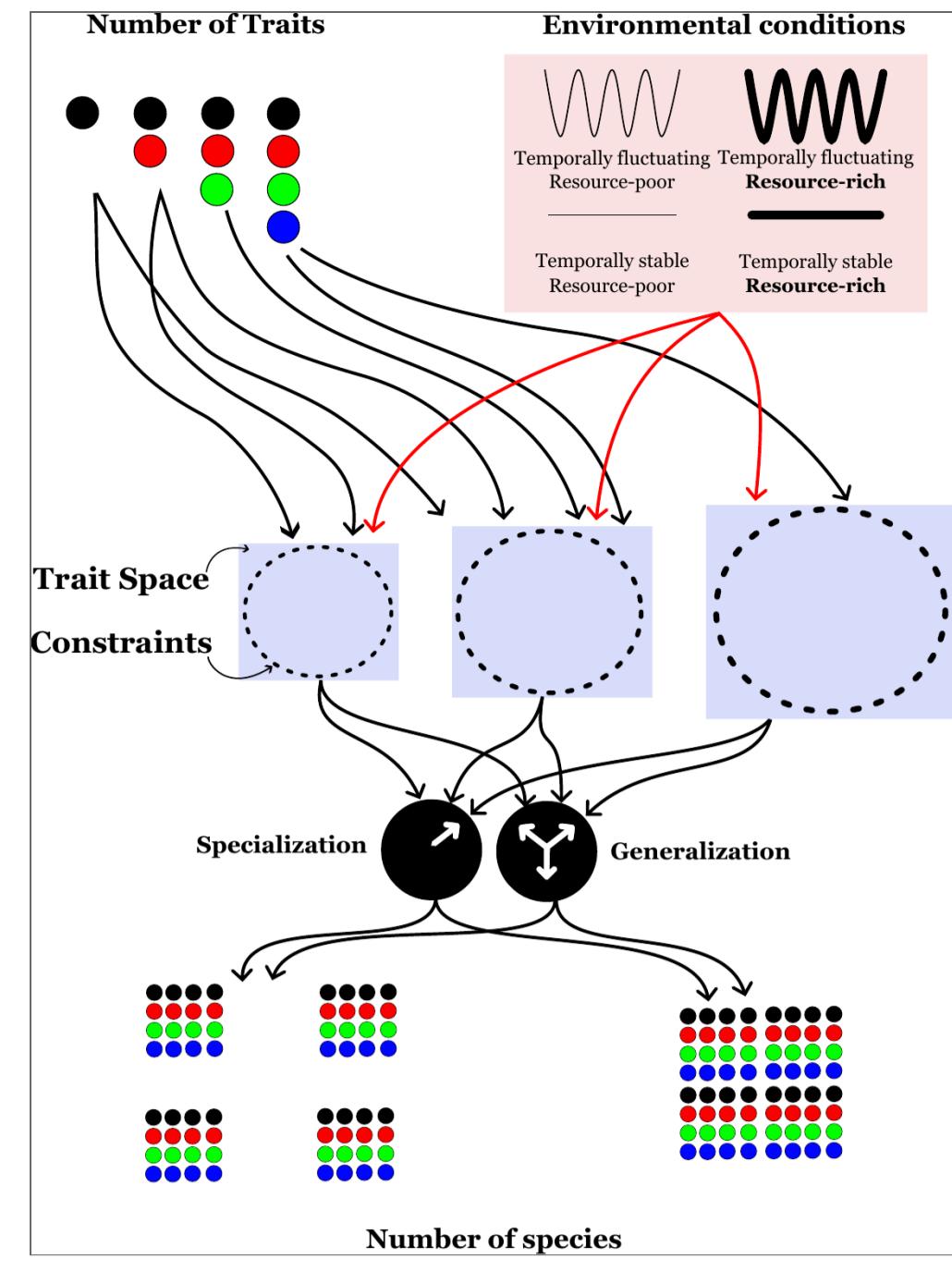


## Feedback





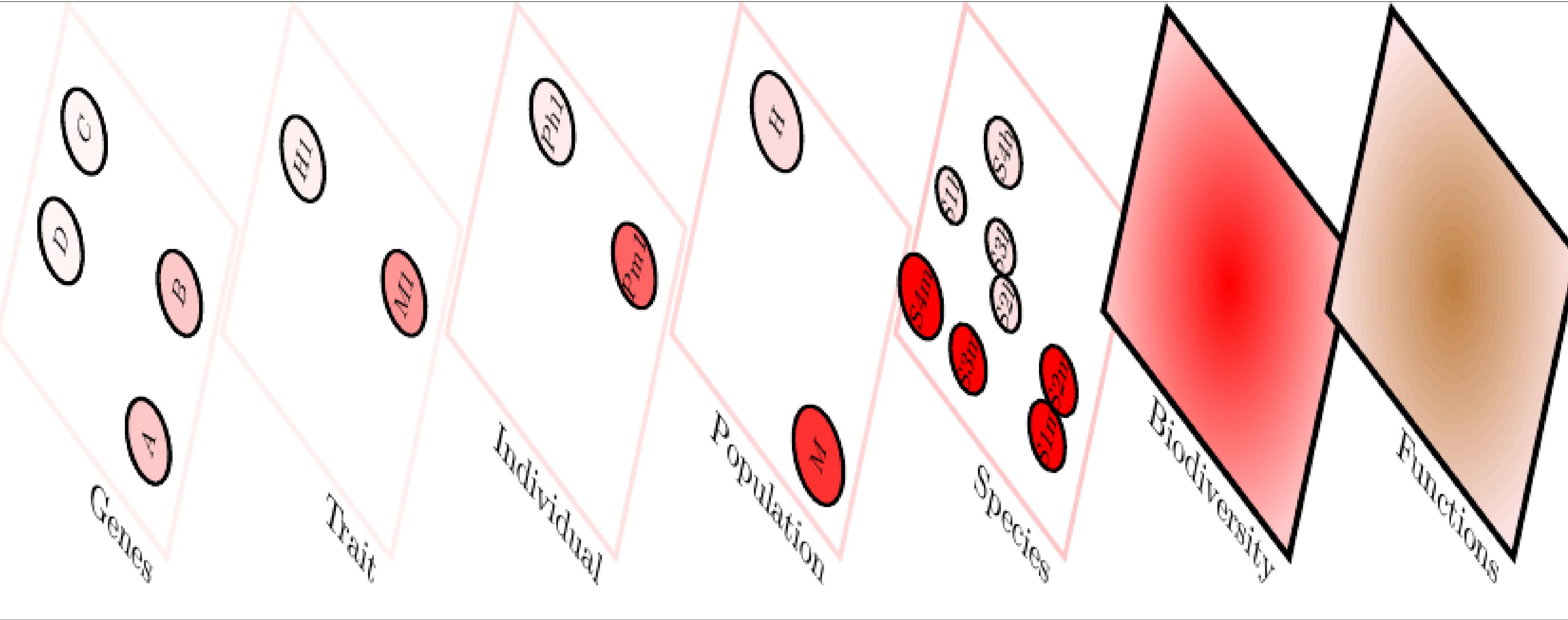
Where are we gonna go

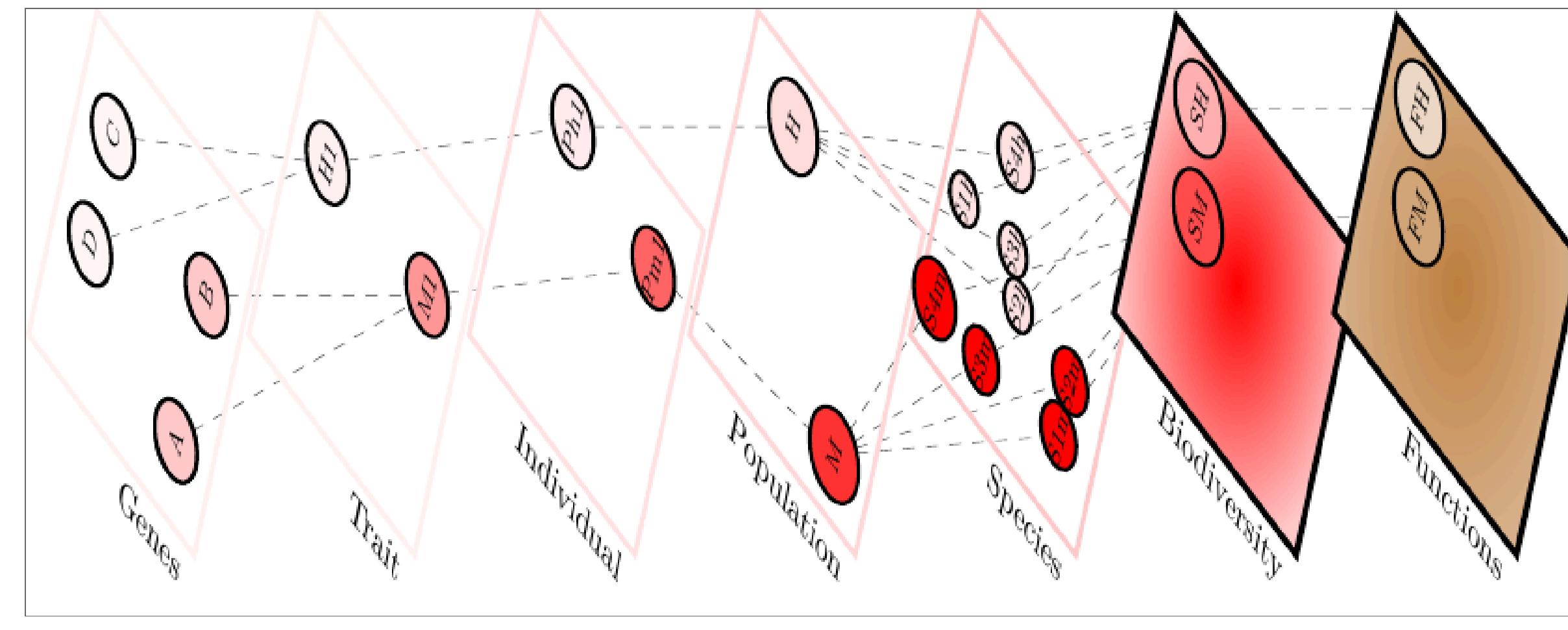


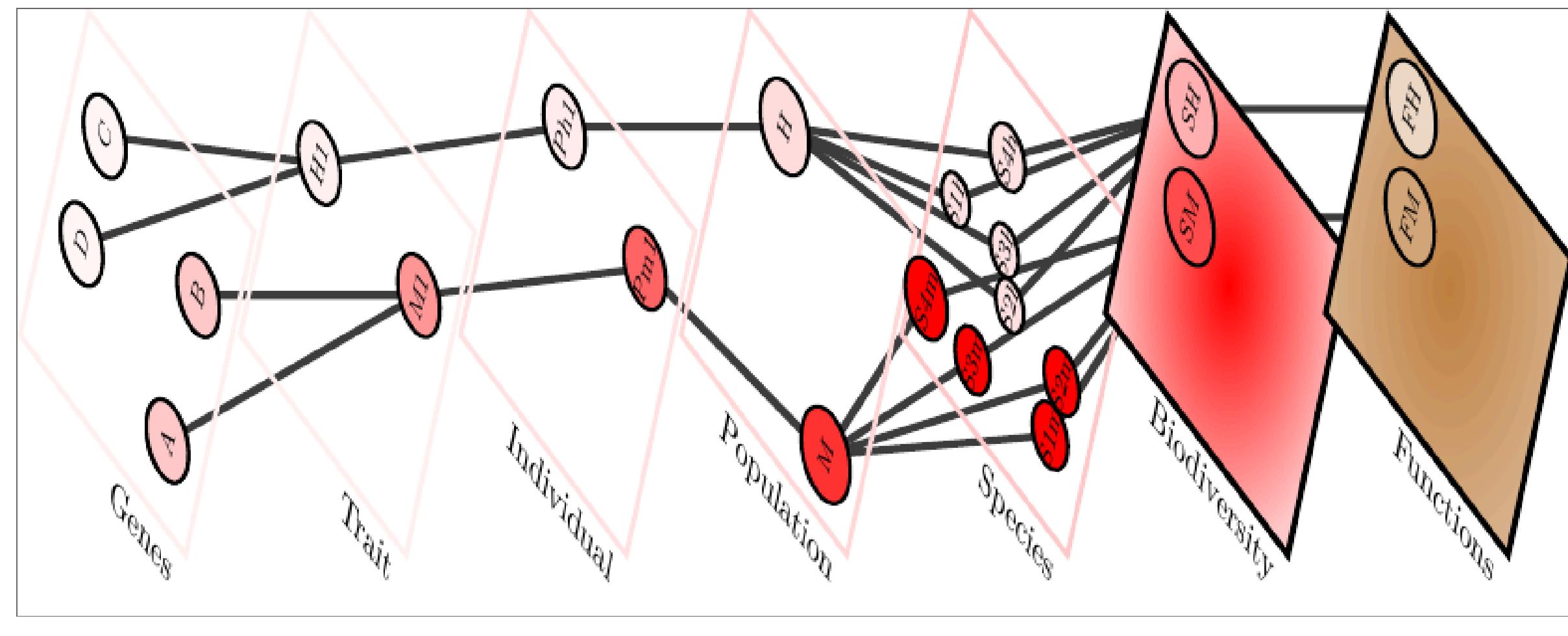
$$\Omega_{\text{BAM}} = \begin{bmatrix} V_B & C_{BA} & C_{BM} \\ C_{AB} & V_A & C_{AM} \\ C_{MB} & C_{MA} & V_M \end{bmatrix}$$

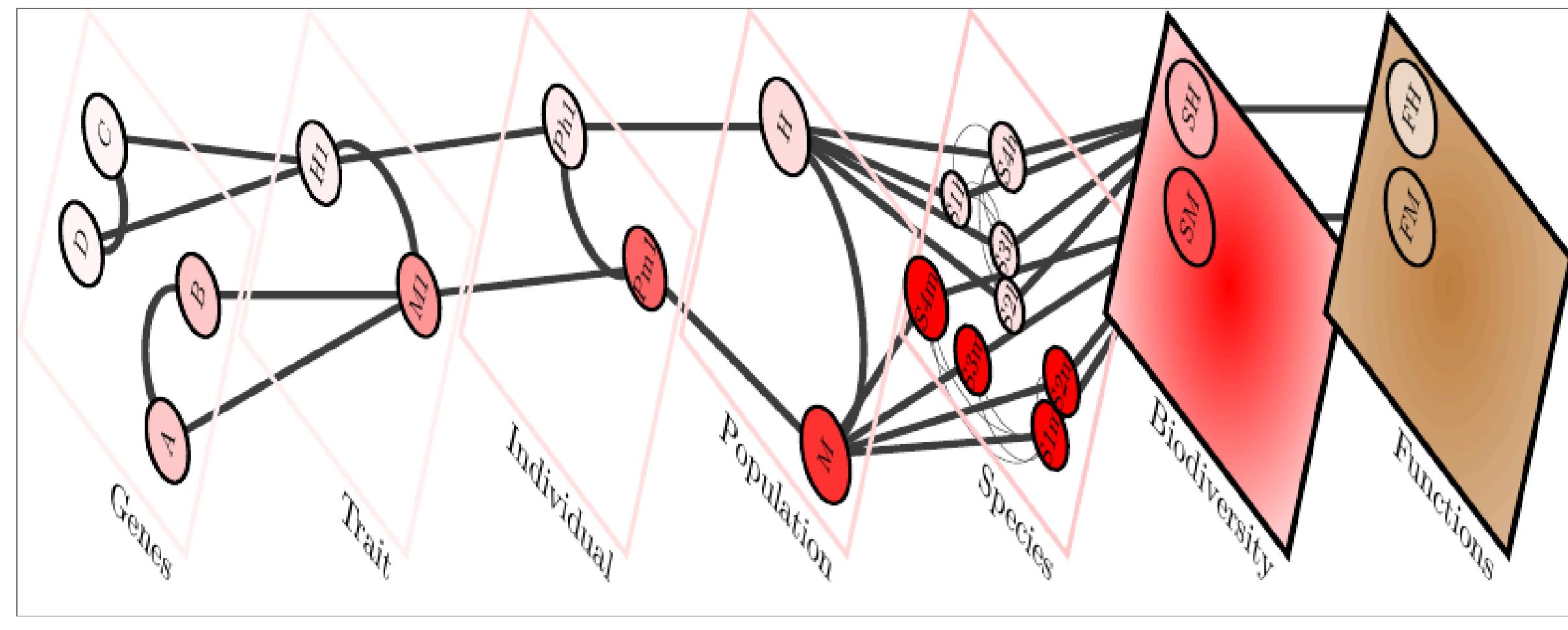
$$\mathbf{W}(\mathbf{z})_{ix}^t = \exp[-\gamma([\mathbf{r}_{ix}^t - \theta_{ix}^t]^T \Omega_{\text{BAM}}^{-1} [\mathbf{z}_{ix}^t - \theta_{ix}^t])]$$

$$\underbrace{\begin{bmatrix} W(\mathbf{z}_{E_{ix}}^t) \\ W(\mathbf{z}_{A_{ix}}^t) \\ \vdots \\ W(\mathbf{z}_{M_{ix}}^t) \end{bmatrix}}_{\tilde{\mathbf{w}}} = \underbrace{\begin{bmatrix} W(B_{ix}^t)^* \\ W(A_{ix}^t)^* \\ \vdots \\ W(M_{ix}^t)^* \end{bmatrix}}_{\mathbf{w}} \underbrace{\begin{bmatrix} V_B & C_{BA} & \dots & C_{BM} \\ C_{AB} & V_A & \dots & C_{AM} \\ \vdots & \vdots & \ddots & \vdots \\ C_{MB} & C_{MA} & \dots & V_M \end{bmatrix}}_{\Omega_{\text{BAM}}}^{-1} \underbrace{\begin{bmatrix} W(B_{ix}^t)^* \\ W(A_{ix}^t)^* \\ \vdots \\ W(M_{ix}^t)^* \end{bmatrix}}_{\mathbf{w}}$$



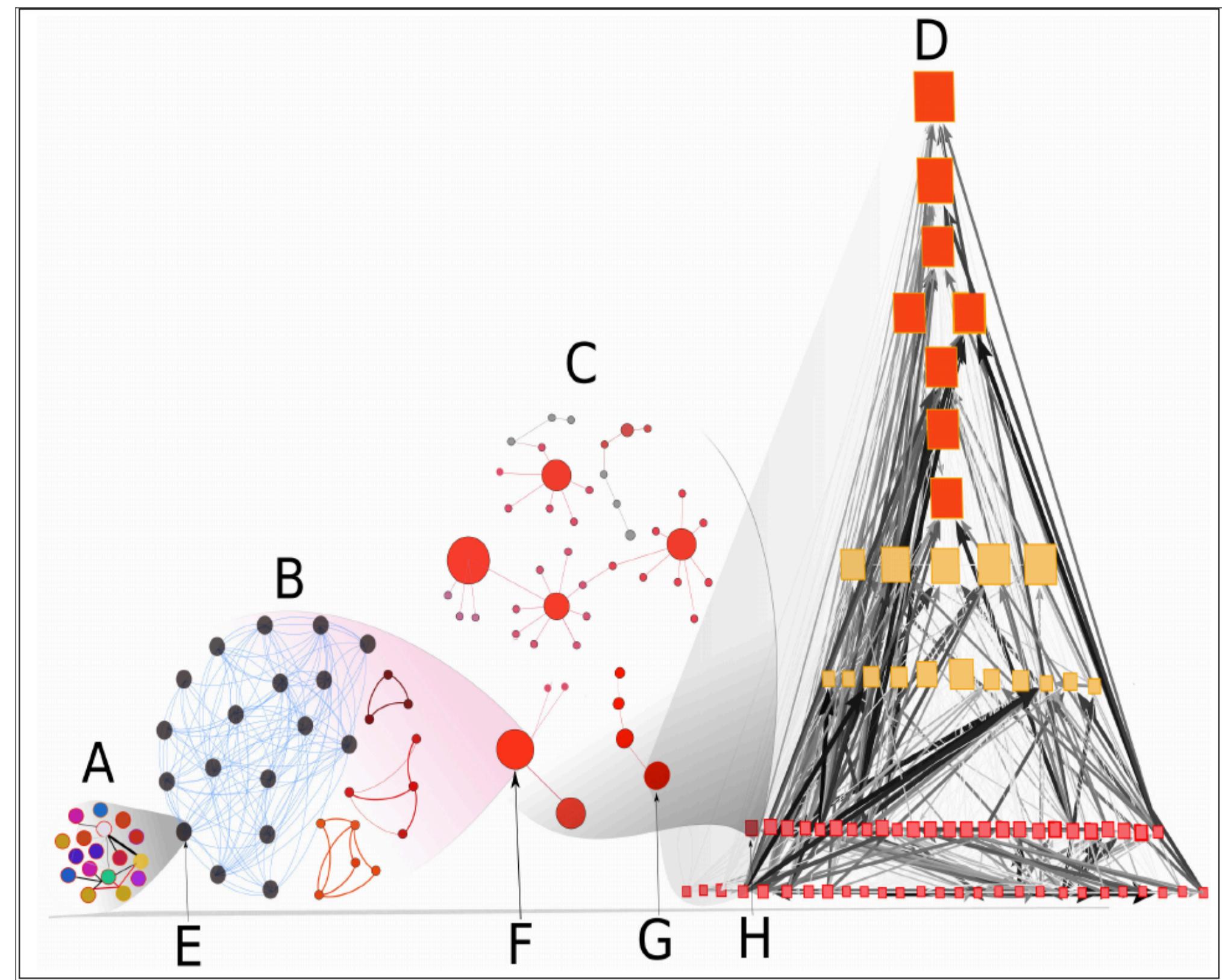


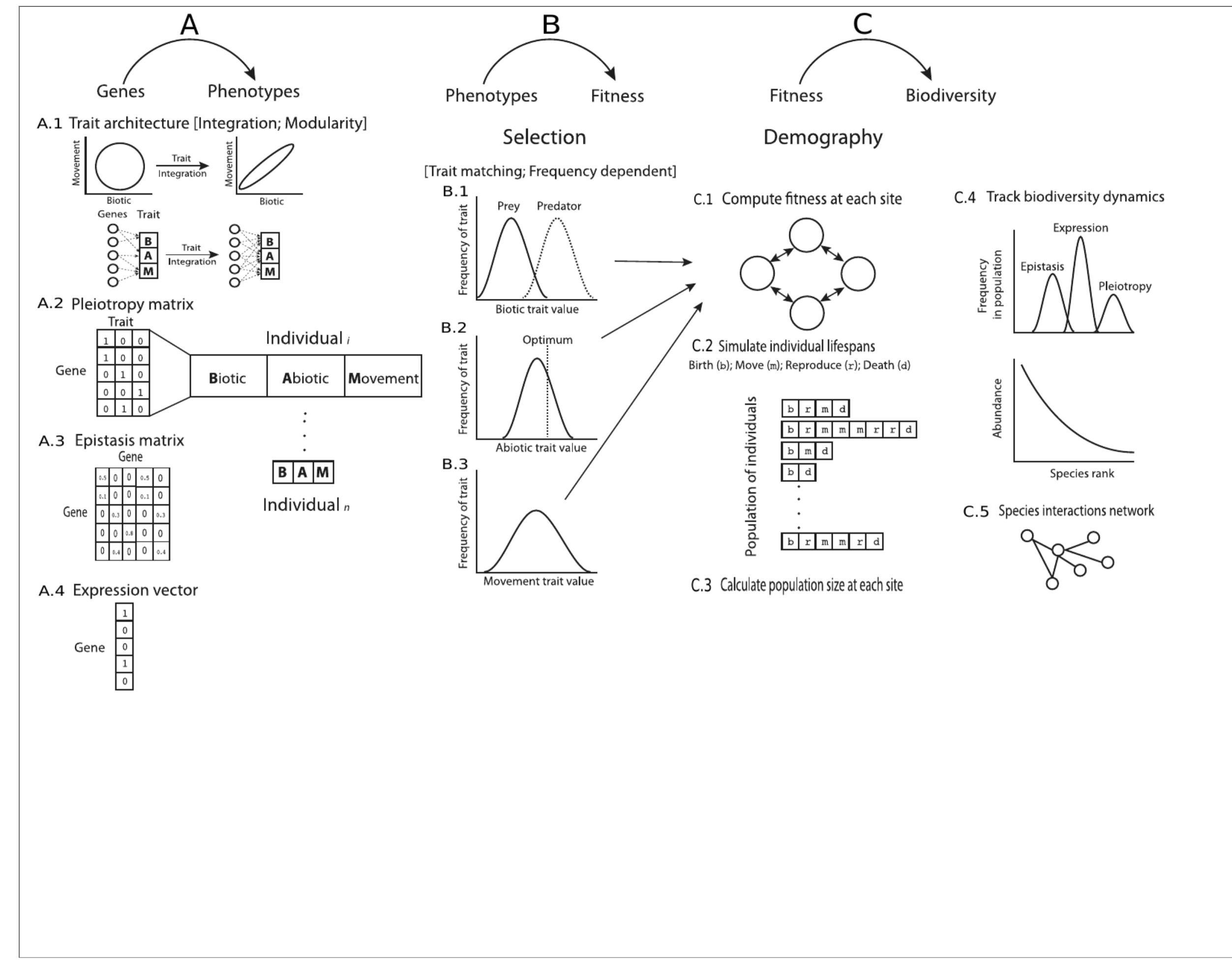




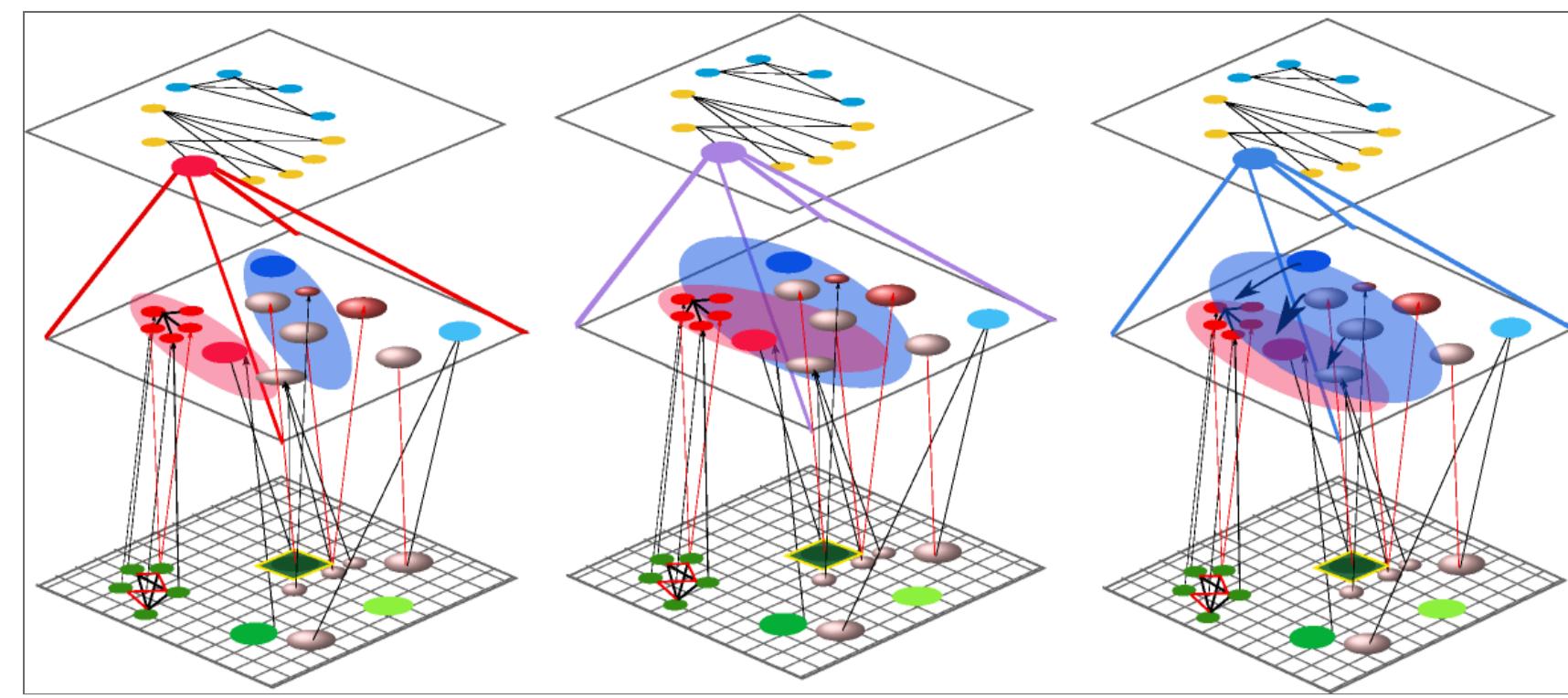
$$\begin{aligned}\partial_t \rho(\mathbf{z}, \mathbf{t}) = & -\nabla_{\mathbf{z}} [\nabla_{\mathbf{z}} \mathbf{F}(\mathbf{z}, \mathbf{y}_t) \rho(\mathbf{z}, \mathbf{t})] - r(\mathbf{z}, \mathbf{y}_t) \rho(\mathbf{z}, \mathbf{t}) \\ & + \int_{\Omega} \int_{\Omega} M(\mathbf{z} | \mathbf{z}', \mathbf{z}'')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

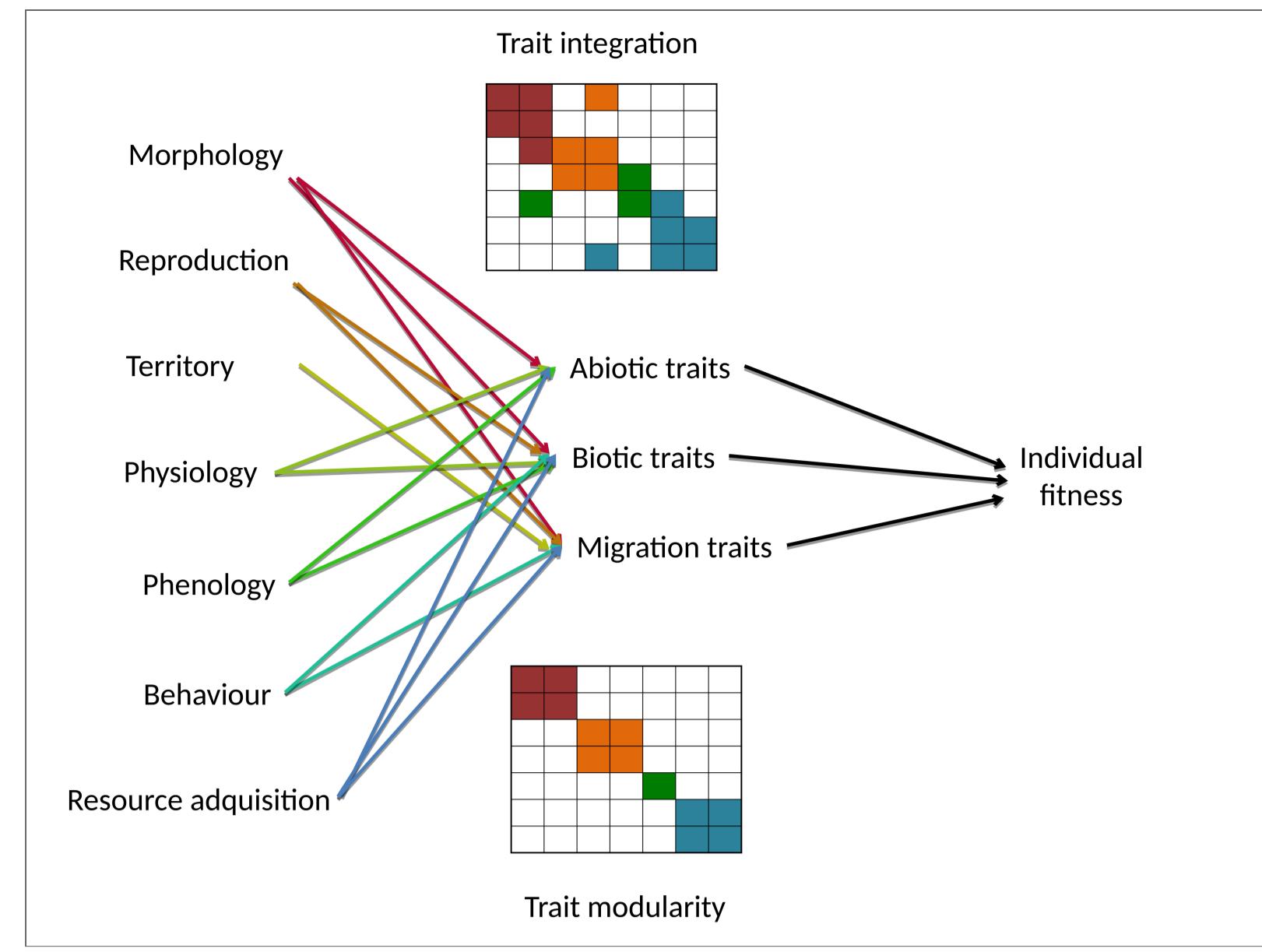
## Biodiversity organizational scale





## 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

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

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

## 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,  $\theta_a$  is the optimal value used as the mean of a normal distribution,  $\sigma^2$  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

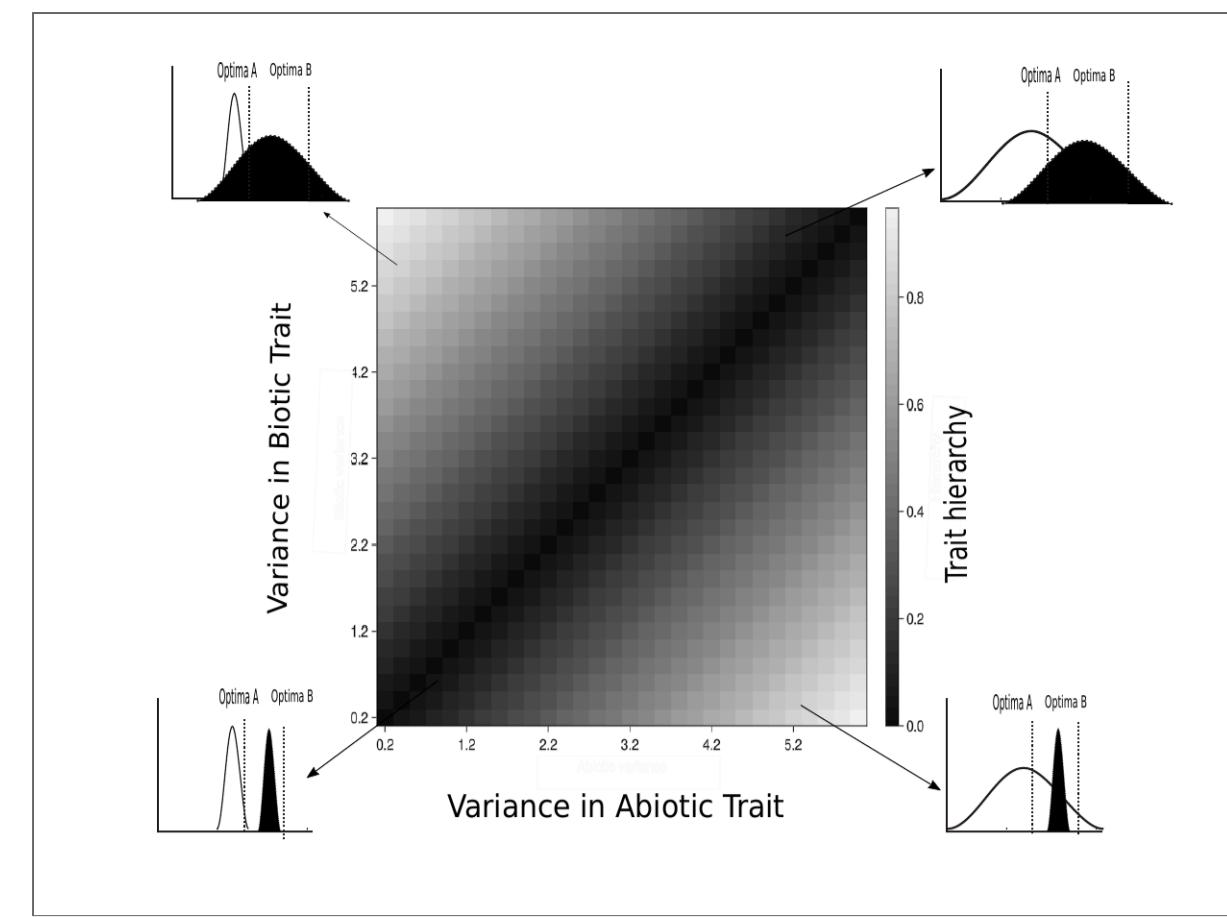
$$s_{z_b^i z_b^j}(x,t) = (1 - D(z_b^i z_b^j)_{(x,t)}) \times |c_{z_b^i z_b^j}| \times sign(c_{z_b^i z_b^j}) \quad (7)$$

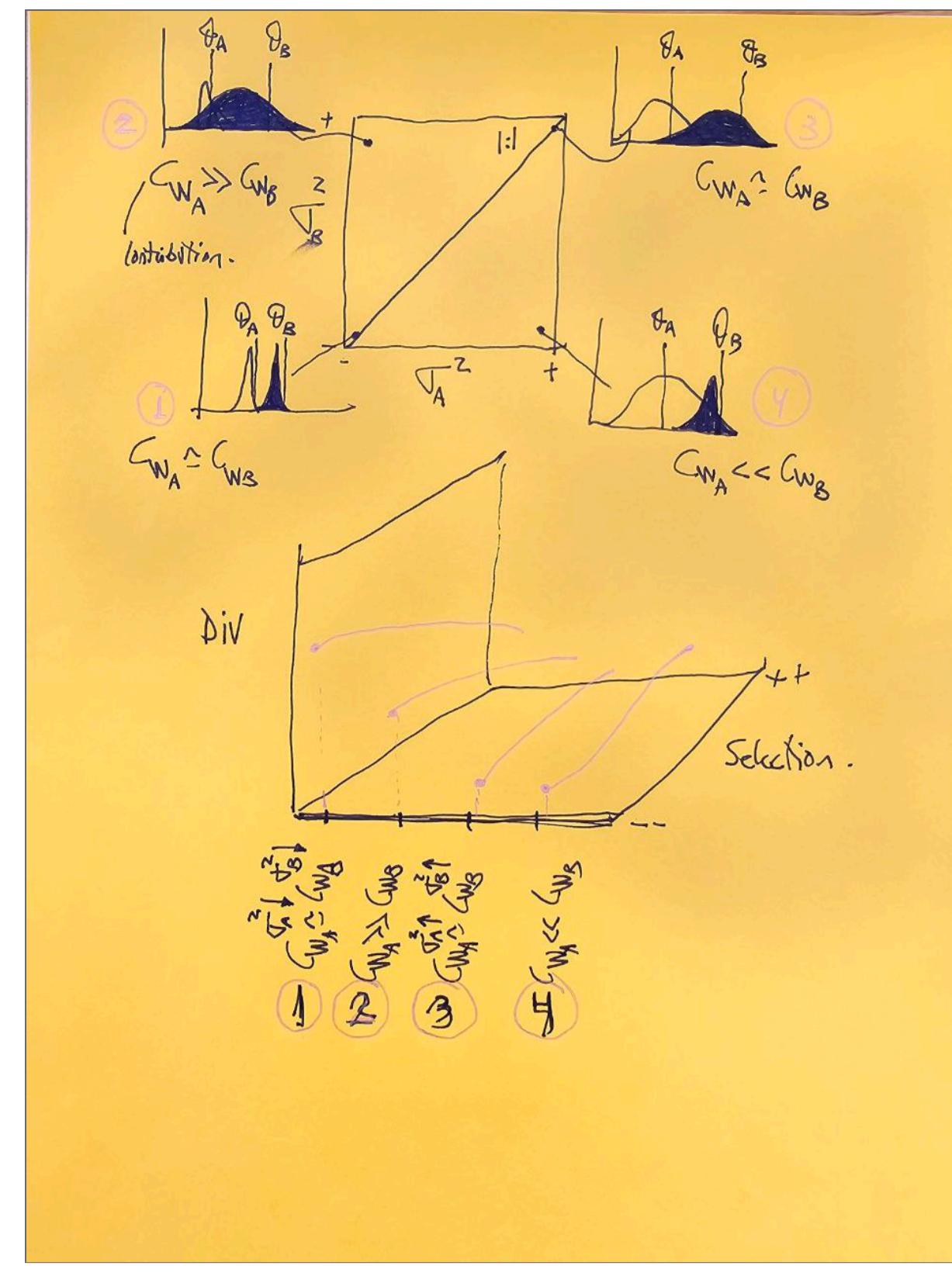
## Fitness

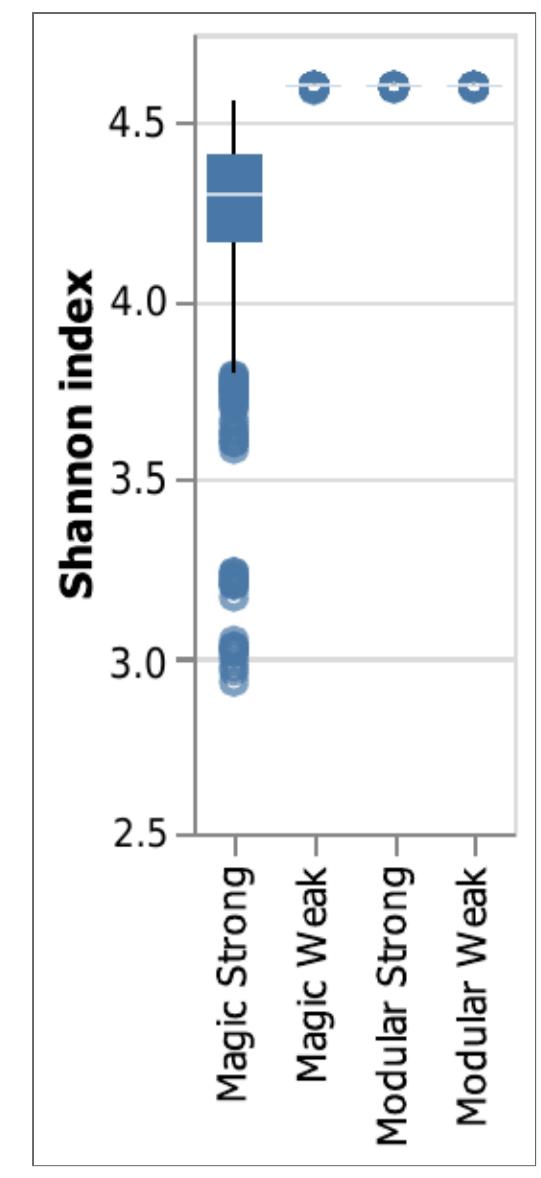
$$W(Z^i)(x, t) = W(z_a^i)(x, t) + s_{z_b^i z_b^j}(x, t), \quad (8)$$

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