Community-level cohesion without cooperation

- Model
- Properties and behavior
- Community-level fitness
- Other cool stuff (role of ϵ and metaphor)

Model

$$\frac{dn}{dt} \propto n \left(\overset{\text{Harvest}}{\overset{\downarrow}{H}} - \overset{\text{Cost}}{\overset{\downarrow}{C}} \right)$$

How efficient you are at processing resources

Consider a community in a habitat where a single resource exists in N substrates… $i \in \{1 \ldots N\}$

$2^N - 1$ species

A B C D …

$$\vec{\sigma} = \{1, 1, 0, 1, \ldots\}$$

Each species is defined by the pathway it carries

Presence of substrate A

Absence of substrate C

σ_i

Total content of substrate ‘i’

$$\frac{dn_{\vec{\sigma}}}{dt} = \frac{1}{\tau_0 \chi_{\vec{\sigma}}} n_{\vec{\sigma}} \underbrace{\left(\overbrace{\sum_i \sigma_i \frac{R_i}{T_i}}^{\text{H}} - \overbrace{\chi_{\vec{\sigma}}}^{\text{C}} \right)}_{\Delta_{\vec{\sigma}}}$$

Maintenance cost

Number of individuals of species $\vec{\sigma}$

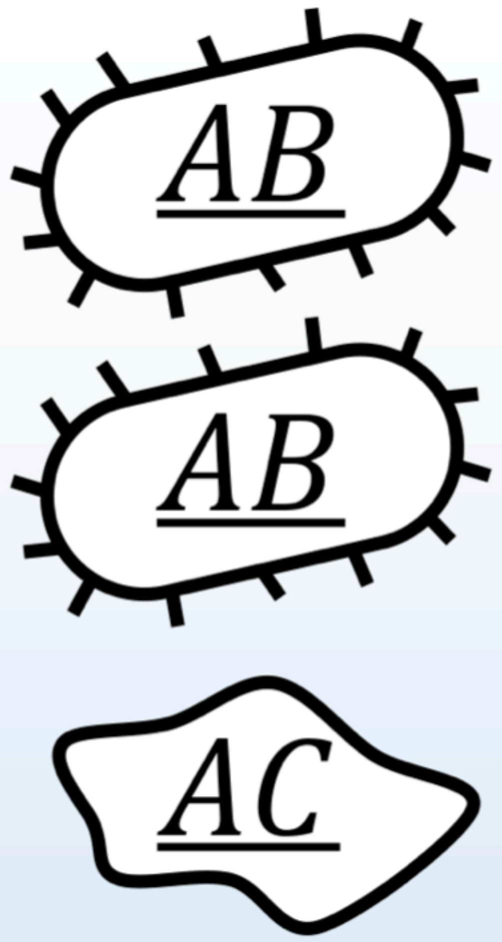
Biomas conversion factor

Resource ‘surplus’

Number of individuals capable of utilizing substrate ‘i’

*Note that T_i varies with t

In one time step…



R_A	$\underline{AB}$	$T_A = 3$	$\Delta_{\underline{AB}} = \frac{R_A}{3} + \frac{R_B}{2} - \chi_{\underline{AB}}$
R_B	$\underline{AB}$	$T_B = 2$	
R_C	$\underline{AC}$	$T_C = 1$	$\Delta_{\underline{AC}} = \frac{R_A}{3} + \frac{R_C}{1} - \chi_{\underline{AC}}$
Substrates	Community	Competitors for each substrate	Resource surplus $=$ Harvest $-$ Cost

Maintenance costs

The more pathways you carry, the less efficient you are at processing resources

Average cost per pathway (constant)

Magnitude of cost fluctuations

$$\chi_{\vec{\sigma}} = \chi_0 |\vec{\sigma}| \left(1 + \epsilon \xi_{\vec{\sigma}}\right)$$

$$|\vec{\sigma}| \equiv \sum_i \sigma_i$$

$$\xi_{\vec{\sigma}} \sim N(0,1)$$

Neither specialists, nor generalists are systematically favored in competition

Properties

&

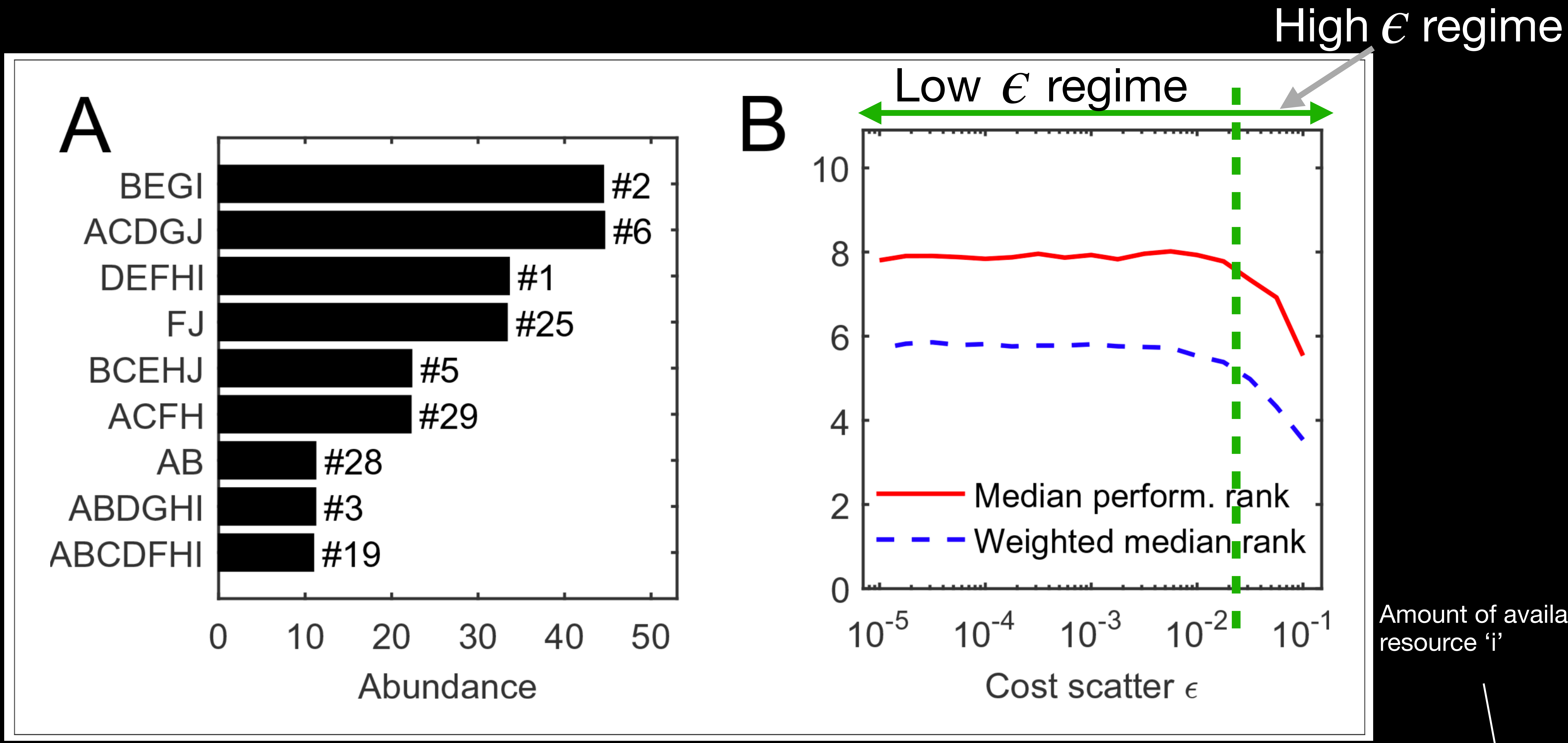
Behavior

- N = 10 substrates (1023 species)
- $\epsilon = 10^{-3}$
- What determines the species that survive?

Randomly set

Individual performance measure of species $\vec{\sigma}$ ➡ $$f_{\vec{\sigma}} \equiv \chi_0 \frac{|\vec{\sigma}|}{\chi_{\vec{\sigma}}} - 1 \approx -\epsilon\xi_{\vec{\sigma}}$$

How well does a species do if its alone in a typical environment



Amount of available resource 'i'

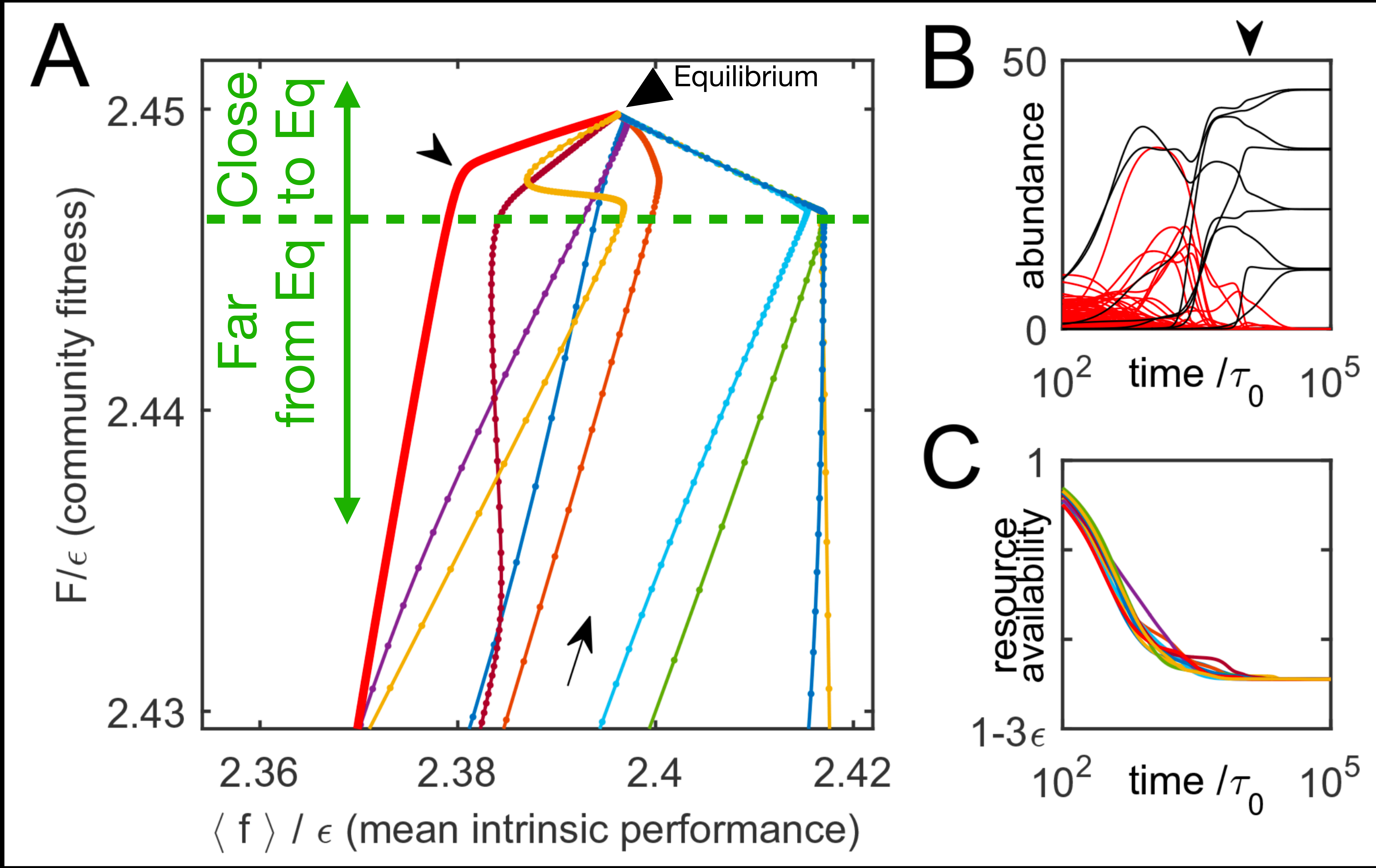
$f_{\vec{\sigma}}$ is correlated with the success of a species in a community, but not very well

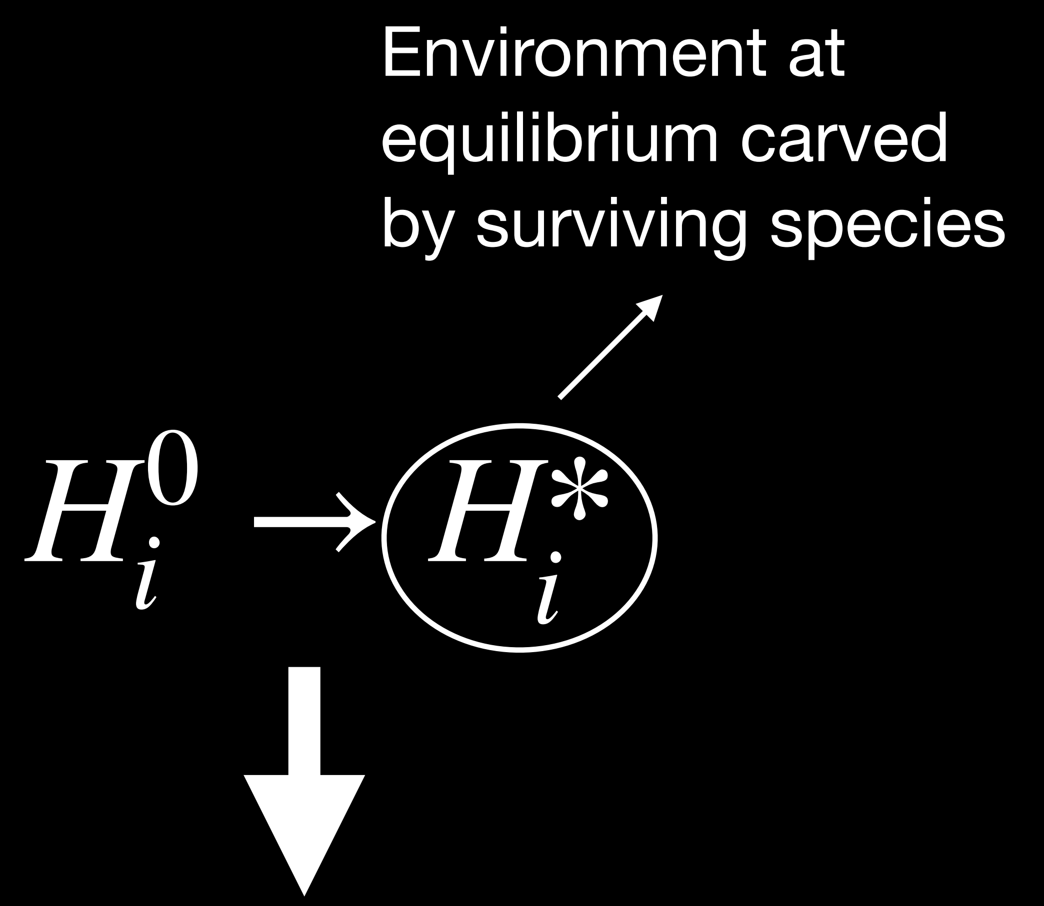
$$H_i \equiv \frac{R_i}{T_i}$$

The success of a species is context dependent

Demand of resource 'i'

Lyapunov function F : a quantity that is increasing on any trajectory of the system.





Relevance of $f_{\vec{\sigma}}$ decreases

Community-level Fitness

What is F ?

A simple case:

$$max(F) \rightarrow min\left(\sum_i \log H_i\right) \rightarrow min(R_i/T_i) \rightarrow$$

The winning community is the one that is most efficient at depleting all substrates simultaneously

$$H_i \equiv \frac{R_i}{T_i}$$

$F \equiv$ Community-level Fitness

Can F predict the outcome of community coalescence?

What I would like to do in less than 2 months

Effective cohesion of coalescing communities is a general result, not limited to a modeling framework

- Find $f_{\vec{\sigma}}$ (easy?)
- Find a numeric equivalent of F: Something that measures how well resources are simultaneously consumed.
- Compare to find that F is a better predictor than $f_{\vec{\sigma}}$.
- Members of a co-evolved community with a history of coalescence tend to have more persistence upon interaction with a ‘naive’ community that has never been exposed to such events.

Other cool stuff

ϵ & metaphor

Other interesting stuff

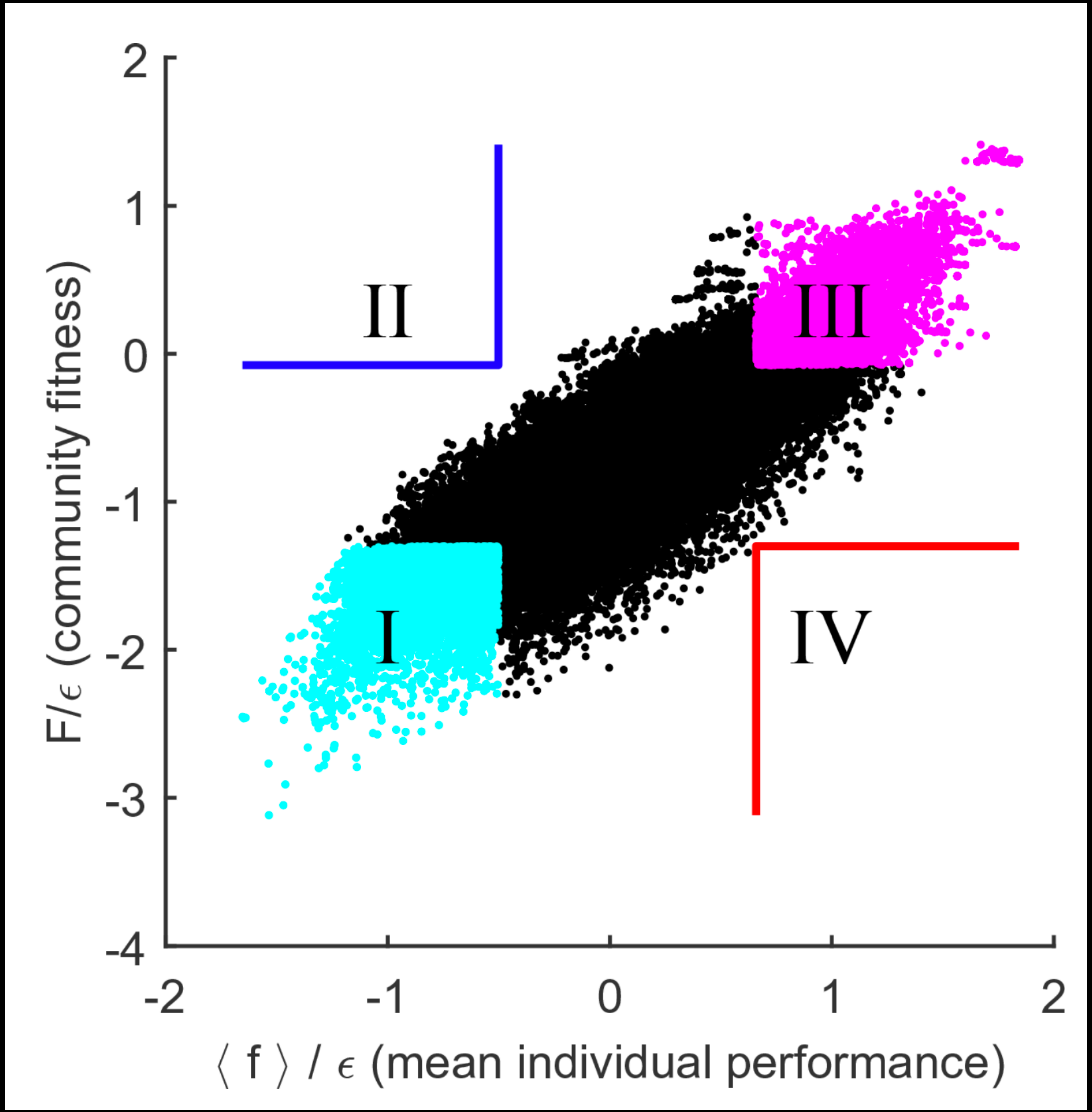
“The role of ϵ is to tune the relative importance of intrinsic vs environment-dependent factors in determining a species fate”

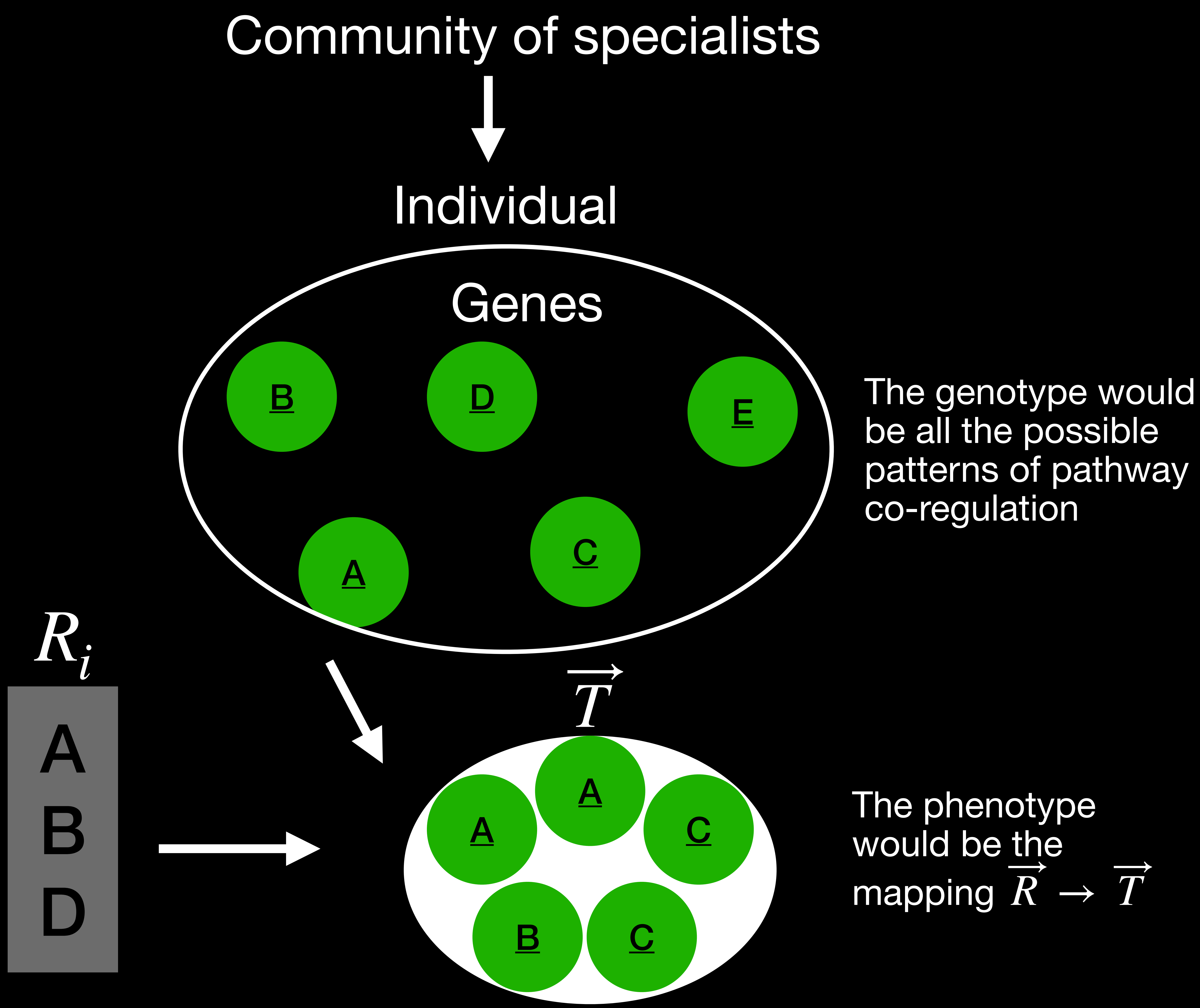
Low ϵ

regime where the genetically inhomogeneous assembly of species increasingly acts ’as a whole’

High ϵ

largely individualistic regime





Model for adaptive evolution of a single organism striving to better adjust its response $\vec{T}$ to the environment $\vec{R}$

The end