Reconciling mechanistic and functional perspectives on adaptation

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A major transition in evolutionary biology?

Less focus on evolution of "simple" traits; more focus on **evolution of "responses"** of individuals to their environment

Three main types of response strategies:

- adaptive choice of environment (habitat choice)
- adaptation to local environmental conditions (phenotypic/developmental plasticity)
- adaptive change of local environment (niche construction)

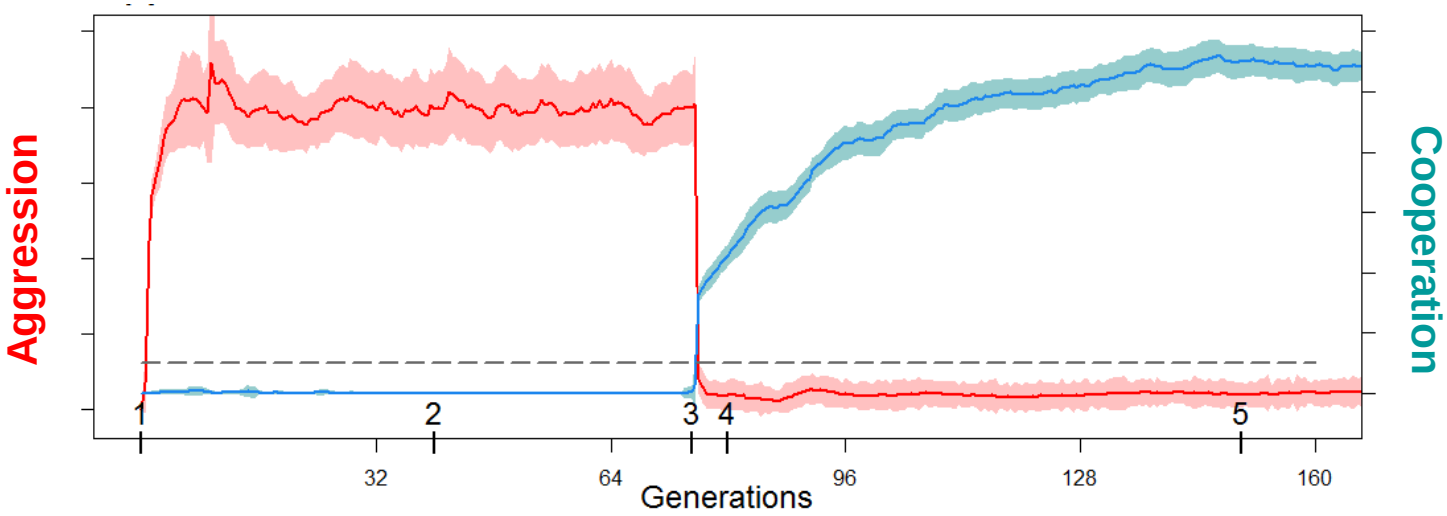
Does evolutionary theory need a rethink?

Responsiveness leads to **reciprocal causality** between organismal design and environmental structure, resulting in

- counter-intuitive evolutionary outcomes
- alternative stable states (often >100)
- non-equilibrium dynamics
- polymorphism (e.g. 'personalities')
- striking patterns of evolvability

Some examples from my own work…

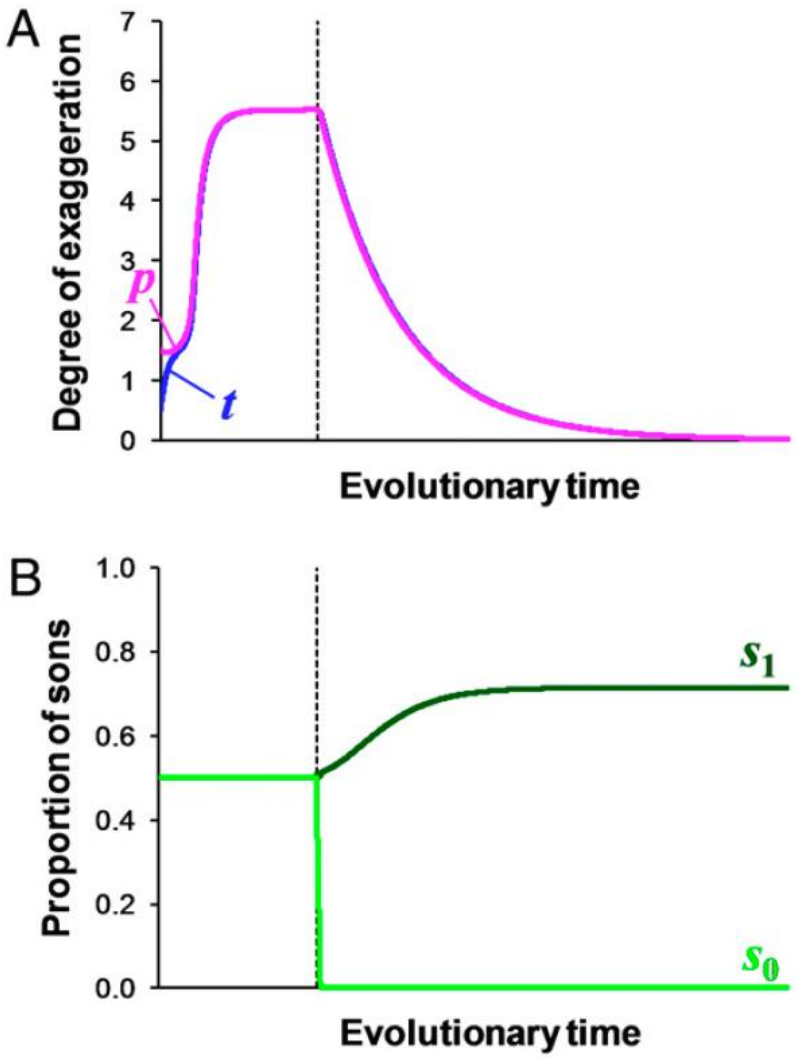
Example 1: Evolution of cooperation



Counterintuitive outcome: when responsiveness is taken into consideration, the evolution of productive cooperation is hampered rather than facilitated by kin structure…

Quiñones et al., Phil Trans 2016

Example 2: Conditional sex allocation

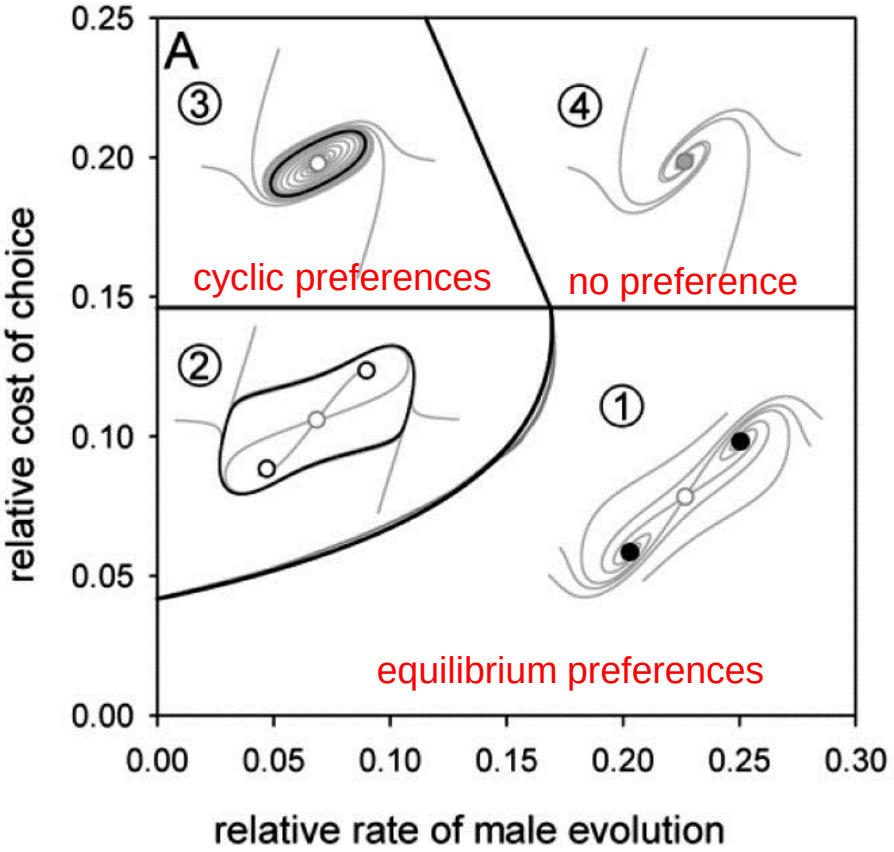


Reciprocal causality:

At first, attractive males overproduce sons, but in the longer term, conditional sex ratio strategies undermine the very process (sexual selection) driving their evolution…

Fawcett et al., PNAS 2011

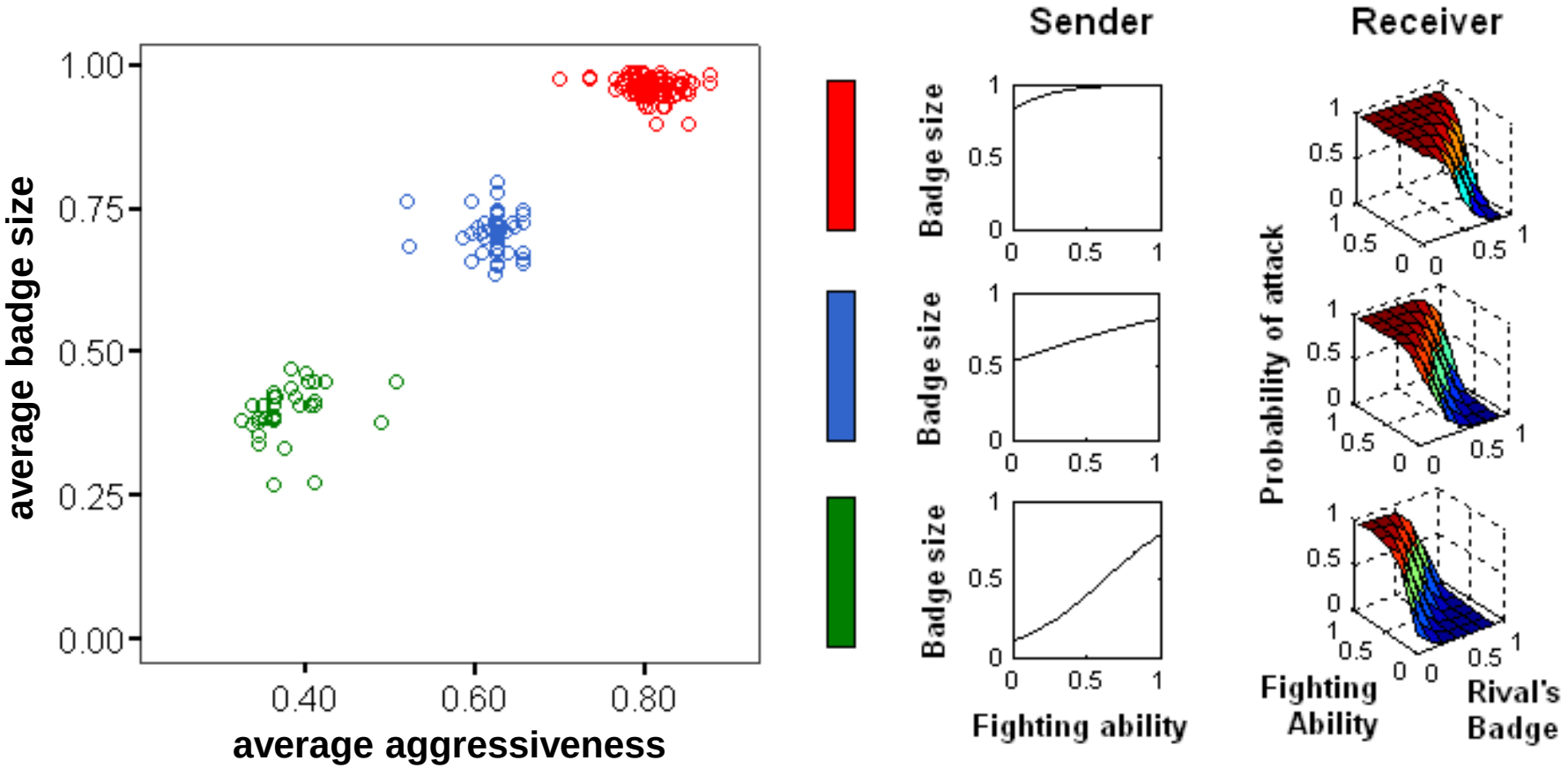
Example 3: Conditional ornamentation



Non-equilibrium dynamics: conditional ornamentation can lead to evolutionary oscillations, and away from equilibrium populations have very different properties than standard theory predicts…

Van Doorn & Weissing, AmNat 2006

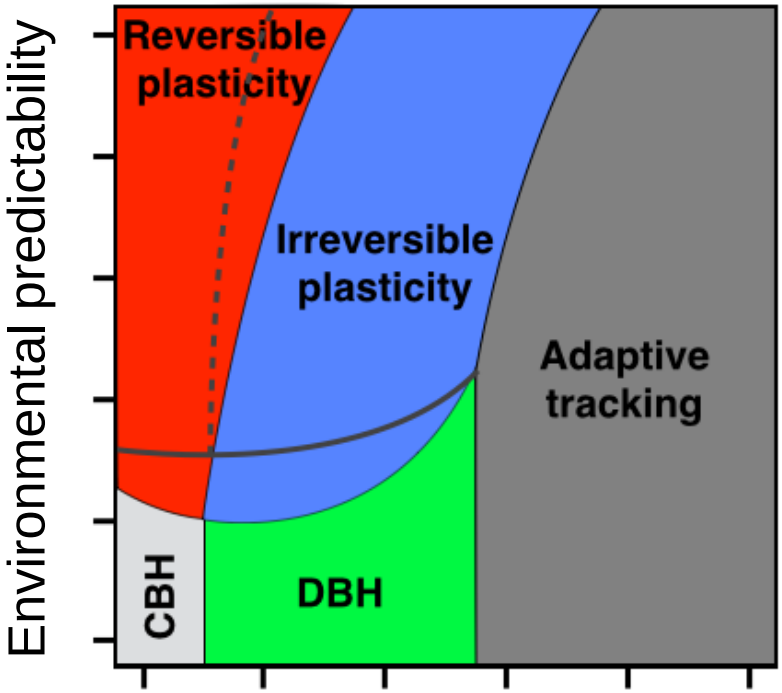
Example 4: Evolution of information use

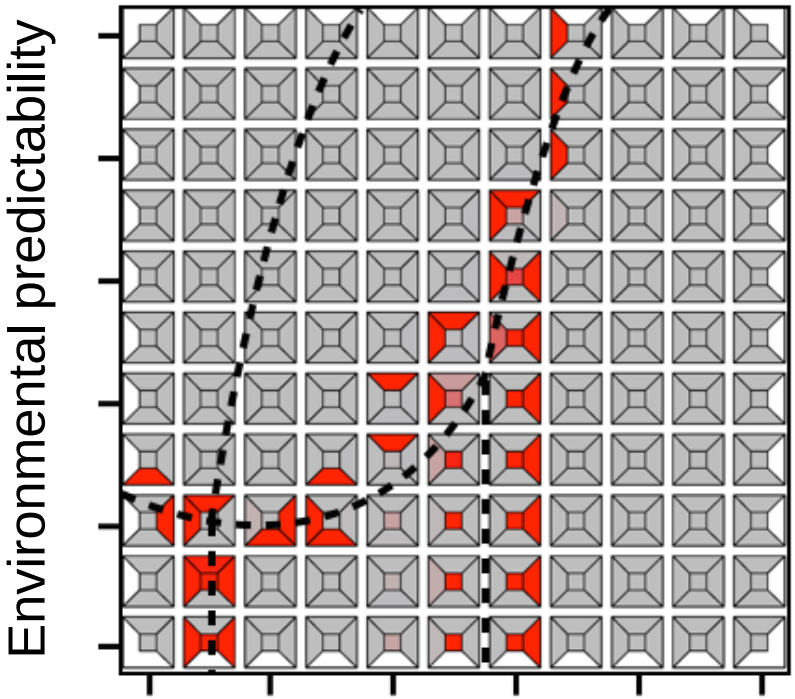


Polymorphism: more often than not, the evolution of inference, (social) learning and communication leads to the emergence of coexisting strategies…

Botero et al., Evolution 2010
Mendez Salinas & Weissing 2018

Example 5: Evolutionary tipping points

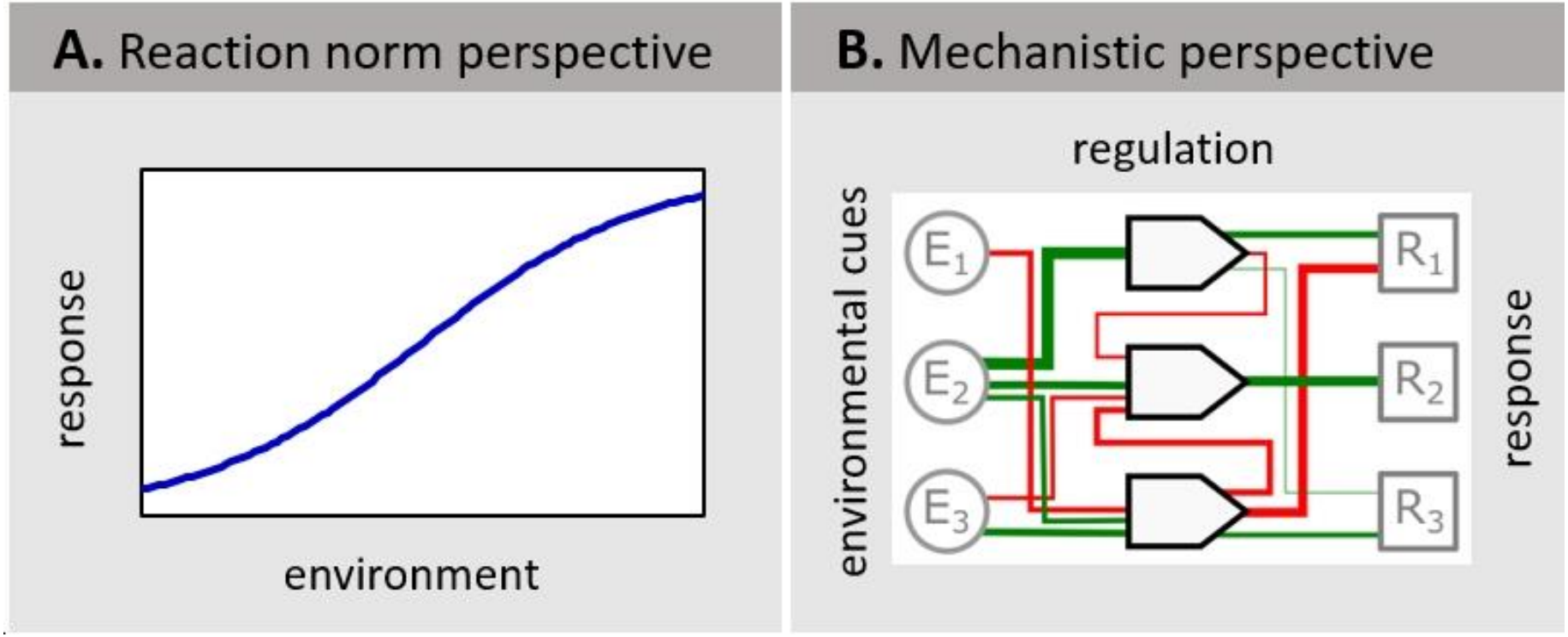




Evolutionary rescue: the mode of adaptation strongly affects evolvability, the potential to adapt to environmental change…

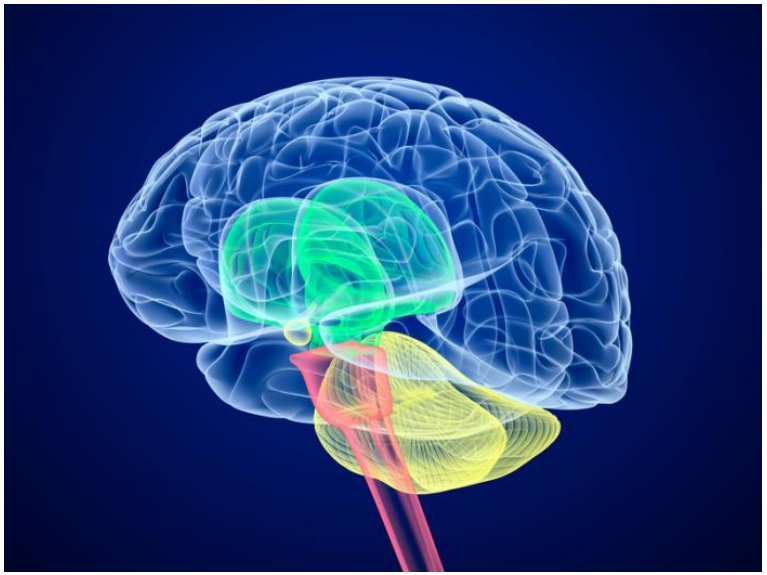
Botero et al., PNAS 2014

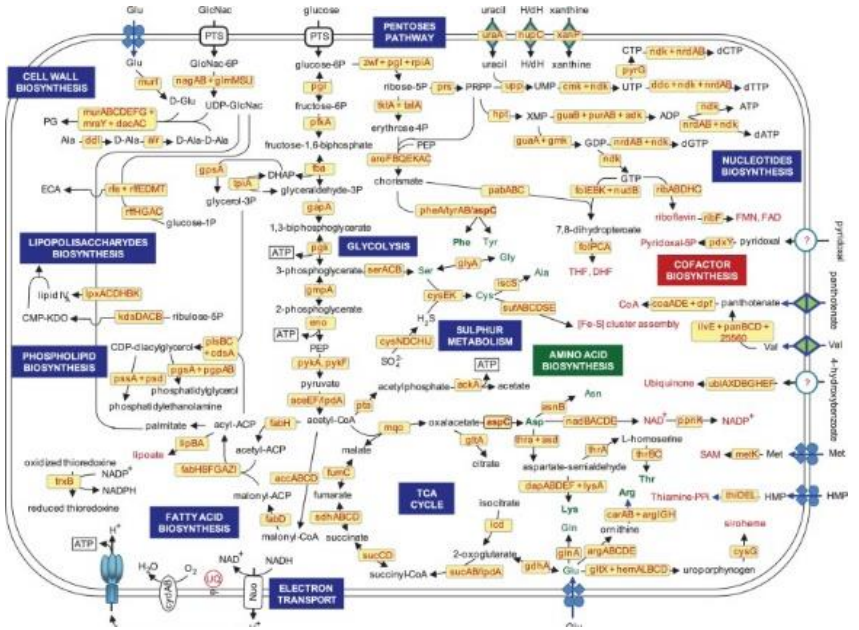
How to model the evolution of response strategies?



- traditional approach: view conditional strategies (e.g. norms of reaction) as target of selection
- mechanistic approach: view regulatory networks underlying these strategies as target of selection

Eco-evo theory of adaptive responses





Arguments for the **neglect of mechanisms** by current eco-evo theory:

- mechanistic models are ‘messy’, difficult to analyse, and do not allow general conclusions
- constraints imposed by mechanisms will be removed by natural selection

Toward a mechanism-based evo-eco theory

My approach:

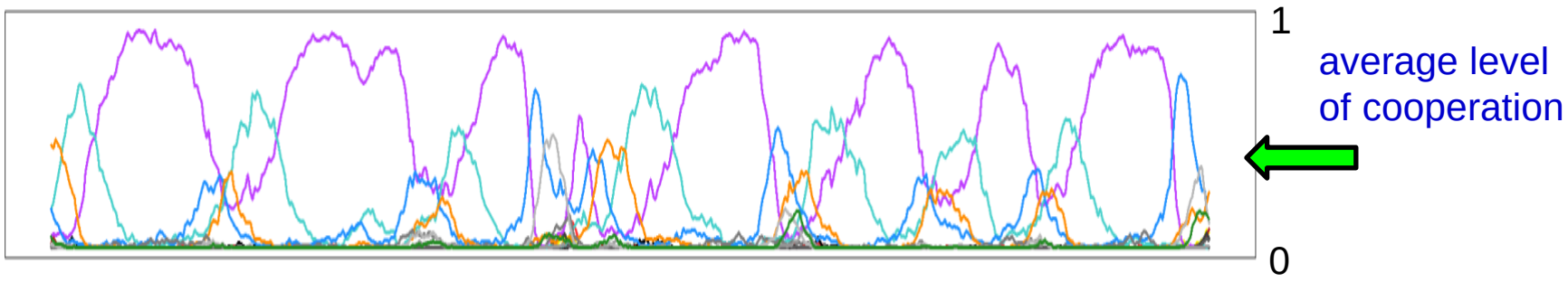
- mechanistic models of intermediate complexity
- keep ecological realism; consider very simple mechanisms (regulation networks)
- individual-based evolutionary simulations

Do mechanisms matter for the course and outcome of eco-evolutionary processes

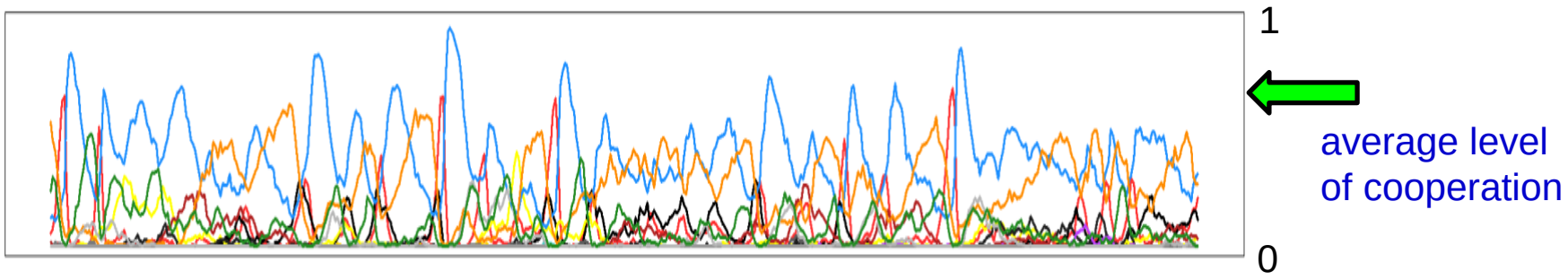
Why do mechanisms matter?

(1) Genotype-phenotype mapping & mutational bias

Traditional model: cycles involving mostly **GRIM** and **Pavlov**



Mechanistic model: cycles involving mostly **TFT** and **MNG**

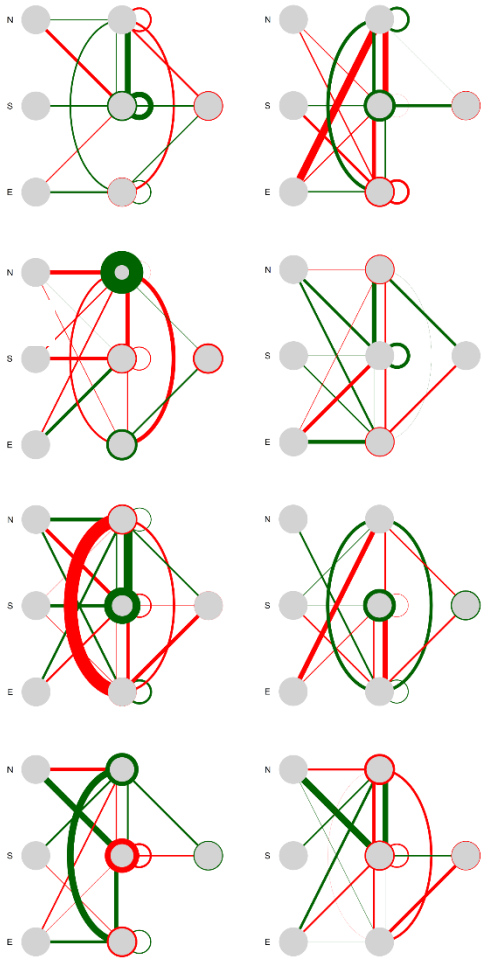


Van den Berg & Weissing, ProcB 2015

Why do mechanisms matter?

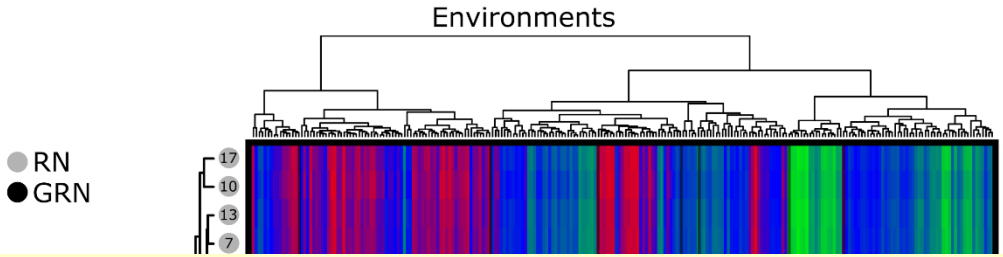
(2) Cryptic variation and enhanced evolvability

- Very different networks can induce the same behavioural response
- Therefore many different networks can coexist for long periods of time (cryptic variation)
- When conditions change, this variation gets exposed to selection, allowing rapid adaptation to novel conditions

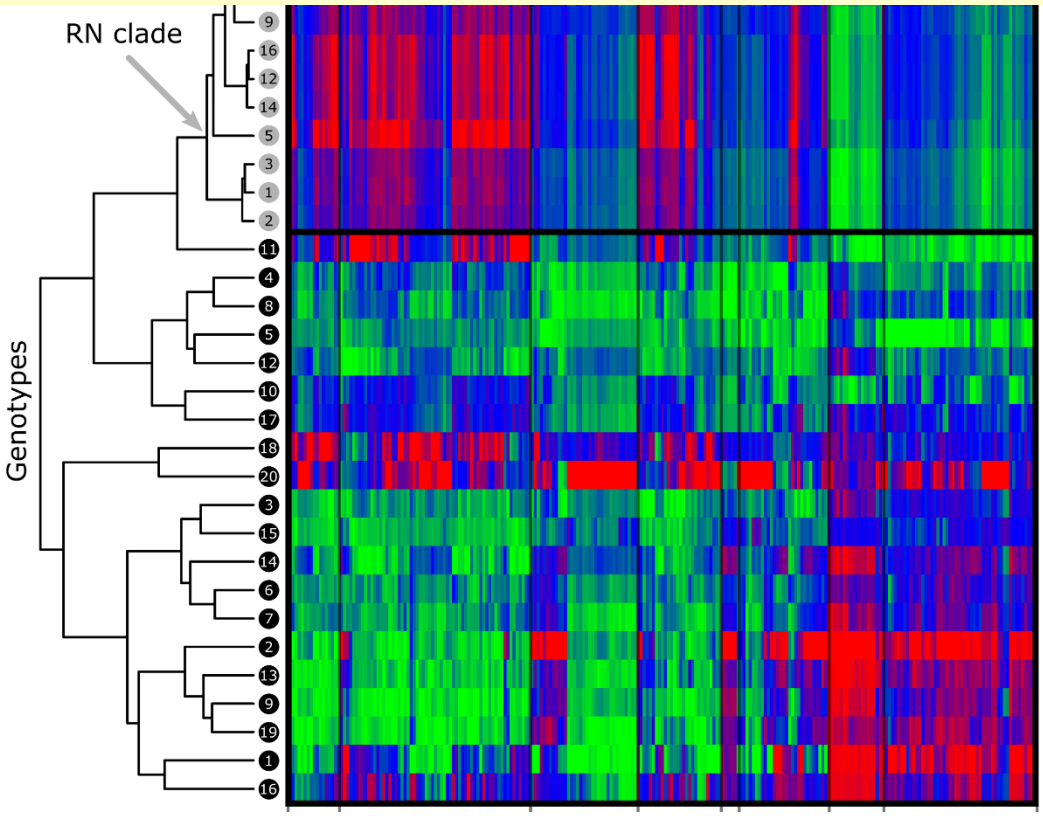


Van Gestel & Weissing, Sci Adv 2016; Nature 2018

When the environment changes…



GRNs have MUCH higher adaptive potential…



Van Gestel & Weissing,
Sci Adv 2016

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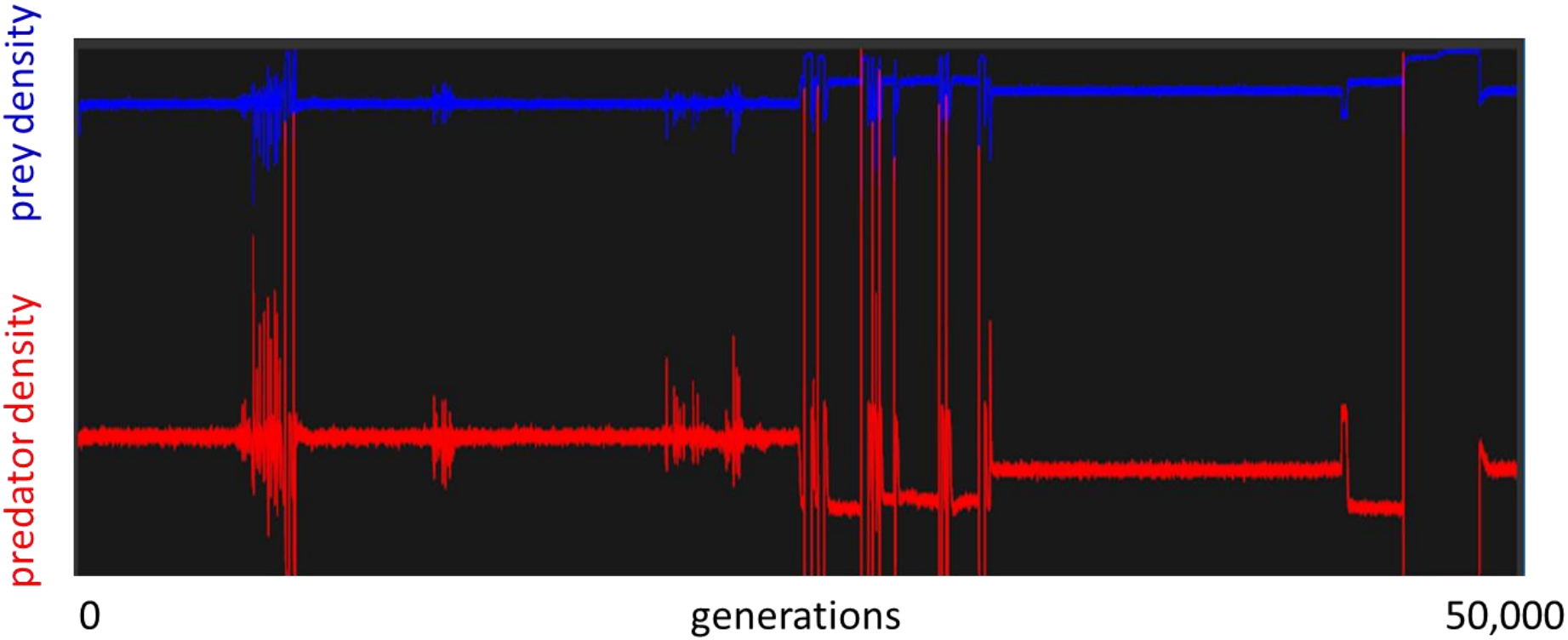
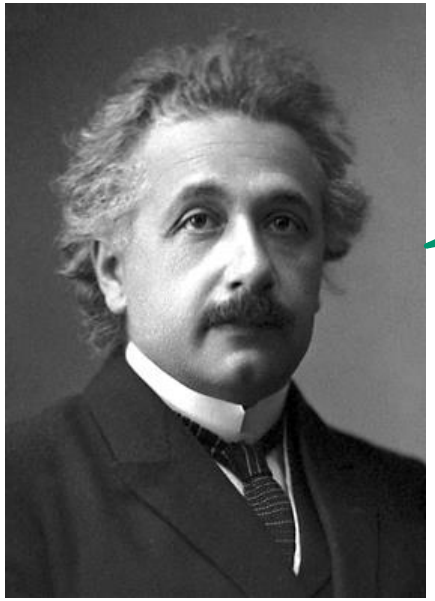


- Rapid evolution (eco-evolutionary dynamics)
- Quasi-equilibrium, but never-ending change
- Surprising 'innovative' solutions

Netz & Weissing 2018 (ms)

General conclusion

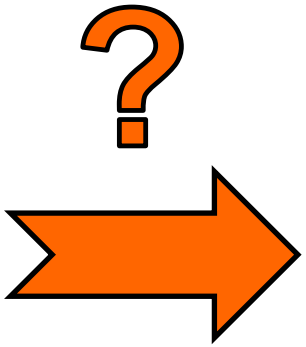
- Mechanisms matter! Evolutionary predictions based on mechanistic models can be quite different from those of phenomenological models.
- Do not trust oversimplified models! Models with more degrees of freedom can lead to very different predictions.



Models should be as simple as possible. But not simpler!

more info:

www.rug.nl/research/gelifes/tres



- Several **postdoc and PhD positions** available…

European Research Council