Eco-phenotypic physiologies: a new kind of modeling for unifying evolution, ecology and cultural transmission

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Motivation

We propose a mathematical **framework of formal relations** general enough to be applicable in

- biology (ecology and evolutionary biology)
- cultural transmission (economics)

We are interested in modeling some biological concepts we will call "eco-phenotypic concepts"

Development, plasticity, reaction norm, phenotypic heritability, epigenetics, and niche construction.

Physiology

Consider a population composed at each time of N_t agents and a set of resources R_t

A Physiology is an algorithm that defines the resource management behavior of the agent.

- the resources needed by the agent for the basic survival $\tilde{M}^i$
- the efficiency is the resource extraction α^i
- the efficiency of their use β^i
- the agent's *resource intake target* G_t^i

$$\bar{P}_t^i = (\tilde{M}_t^i, \alpha^i, \beta^i, G_t^i) \tag{1}$$

Environment

All the elements of the world and of the population that are not part of the agent.

- the resources R_t that are available to the population.
- The number of agents N_t
- the vector of all the other agents' physiologies $\bar{P}_t^{-i}$

$$\bar{E}_t^i = (R_t, N_t, \bar{P}_t^{-i}) \tag{2}$$

Resource extraction

$$\sum_i R_t^i \leq R_t$$

- own resource intake target G_t^i,
- others' resource intake targets G_t^{-i}
- the vector of all extraction efficiencies $\bar{\alpha}$

$$\bar{R}_t^i = (R_t, G_t^i, G_t^{-i}, \bar{\alpha}) \tag{3}$$

Notice that if $R_t^i < \tilde{M}_t^i$ then the agent dies.

Matching Function and Reproduction

each male with physiology i, that extracted R_t^i is matched with a female of physiology j that extracted R_t^j

γ_t^{ij} the share of R_t^i that an agent of physiology i in a ij matching devotes to own subsistence and $(1-\gamma_t^{ij})$ the share devoted for offspring production.

$$N_{t+1}^{ij}(R_t^i, R_t^j, \gamma_t^{ij}, \gamma_t^{ji}) \tag{4}$$

Niche construction and Resource Regeneration

$$R_{t+1} = (R_t - \sum_i R_t^i)(1 + \lambda)$$

if individuals resource extraction and physiologies are *niche constructing* then $\lambda_t(\bar{R}_t)$ so that

$$R_{t+1} = (R_t - \sum_i R_t^i)(1 + \lambda_t(\bar{R}_t)) \qquad (5)$$

Reaction Norms and the New Generation's Physiology (I)

Reaction norm: dictates how to use or not use information from the environment and from parental physiologies as cues to form a new physiology.

The reaction norm X^i_{t+1} accepts as inputs

- the resources the new generation faces R_{t+1}
- the parental physiologies P^i_t and P^j_t
- the physiologies agents in new generation meet during their formation process $\bar{P}_t$

$$P^i_{t+1} = X^i_{t+1}(R_t, P^i_t, P^j_t, \bar{P}_t) \tag{6}$$

Reaction Norms and the New Generation's Physiology (II)

$$P^i_{t+1} = X^i_{t+1}(R_t, P^i_t, P^j_t, \bar{P}_t)$$

- with probability p^{ij}_t the new individual born from matching ij takes i's reaction norm $X^i_{t+1} = X^i_t$
- with probability $1 - p^{ij}_t$ the new individual born from matching ij takes j's reaction norm $X^i_{t+1} = X^j_t$.

Summing up the framework

- Physiology: $\bar{P}_t^i = (\tilde{M}_t^i, \alpha^i, \beta^i, G_t^i)$
- Environment: $\bar{E}_t^i = (R_t, N_t, \bar{P}_t^{-i})$
- Resource Extraction: $\bar{R}_t^i = (R_t, G_t^i, G_t^{-i}, \bar{\alpha})$
- Matching and Reproduction: $N_{t+1}^{ij}(R_t^i, R_t^j, \gamma_t^{ij}, \gamma_t^{ji})$
- Niche construction and resource generation: $R_{t+1} = (R_t - \sum_i R_t^i)(1 + \lambda_t(\bar{R}_t))$
- Reaction Norms and new physiology: $P_{t+1}^i = X_{t+1}^i(R_t, P_t^i, P_t^j, \bar{P}_t)$

Next Steps

- Fixing one reaction norm, studying how the shape of the different elements impact the dynamics of the population
- Compare the patterns of different reaction norms (adaptive and forward looking reaction norms)
- Make reaction norms compete (plasticity in most successful population, necessary feature for a reaction norm to survive, . . .)