The evolution of developmental sensitivity

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William Blake, “Ancient of Days”
Daphnia, planktonic crustaceans

Food production and consumption among the Ache

Agrawal et al., 1999
One of the most significant facts about us may finally be that we all begin with the natural equipment to live a thousand kinds of life but end in the end having lived only one.

Clifford Geertz (1973) “The Interpretations of Cultures”

In the beginner’s mind there are many possibilities, but in the expert’s there are few.

Nature / Nurture

Genes or Environment
Natural selection shapes the way developmental processes respond to environmental variation.

Environment plays a proximate role in shaping development.

Natural selection plays an ultimate role in shaping the developmental system.

The goal is to create a framework that allows for natural selection to shape development that is...

**contingent**: experience dependent

**dynamic**: current options depend upon past outcomes

**incremental**: more time developing a trait leads to increased expertise
Dynamic Programming, or
how to see London in one day
Dynamic Programming, or how to see London in one day

Start

End
Dynamic Programming, or how to see London in one day
Dynamic Programming, or how to see London in one day
Dynamic Programming, or how to see London in one day

Start

End
Dynamic Programming, or
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Start

End

21 \rightarrow 13 \rightarrow 5

20/16 \rightarrow 17 \rightarrow 17

23/20 \rightarrow 17 \rightarrow 17

0

8

3

6

9

21

8

8

8
Dynamic Programming, or how to see London in one day

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Model 1: Tradeoff between sampling and specialization

The ecology is in one of two states (e.g., safe, dangerous). There is a corresponding phenotype for each state (e.g., sleek, armored).

Individuals have a prior belief about the ecological state.

In each time period, individuals can sample a cue providing information about the ecological state or specialize development toward either of the phenotypes.

There are no costs to developing incorrectly.

But, there is a tradeoff. The earlier one specializes, the higher the probability of specializing incorrectly. The later one specializes, the less expert one can become.
The benefit of specialization

- Diminishing
- Linear
- Increasing

Fitness vs. Developmental Time
Mature phenotypes

- Diminishing returns
- Linear Returns
- Increasing Returns

Cue validity

Prior = 0.75
Optimal policy

Increasing tradeoff can lead to differential plasticity

Prior = 0.75
Sampling is most likely to evolve when priors are weak, cue validities are moderate, and fitness returns are diminishing. Here, the benefits of improving one’s estimate outweigh opportunity costs of information search.
Model 2: No tradeoff between sampling and specialization

The ecology is in one of two states and there is a corresponding phenotype for each state.

Individuals have a prior belief about the ecological state.

Individuals passively receive a cue providing information about the ecological state in each time period.

In each time period, individuals choose to either specialize development toward either of the phenotypes or delay specialization.

There may costs to developing incorrectly.

There still is a tradeoff. The earlier one specializes, the higher the probability of specializing incorrectly which is costly. The later one specializes, the less expert one can become.

W Frankenhuis & K Panchanathan, Unpublished
Mature phenotypes

Bimodal distribution

Prior Probability

Cue Validity

Diminishing Linear Penalty

Increasing Linear Diminishing Reward

Increasing Penalty

Specialists

Generalists
Measuring sensitivity

Follow a **focal individual** through development. In each time period, make a duplicate and **adopt out**; at the same time, **adopt in** another individual who has received the opposite cues so far.

Simulate 10,000 such sets of individuals. For each, compute the Euclidean distance between the focal individual and the twin adopted out, and the focal and the individual adopted in.

Dotted line measures the expected phenotypic distance between a focal individual and a twin adopted out. The top black line of the shaded region measures the distance between the focal and the individual adopted in.
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