An Evolutionary Perspective on Behavioral Syndromes: Insights from Whole Genome Expression Data

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Individual differences
Behavioral syndromes: correlations between behaviors in different functional contexts (Sih et al 2004)

- **Boldness toward predators**
  - Individuals a, b, c, d, e

- **Aggressiveness toward conspecifics**
  - Individuals a, b, c, d, e

Huntingford 1976 *An Behav*
Behavioral syndromes: correlations between behaviors in different functional contexts (Sih et al. 2004)

Boldness toward predators

Aggressiveness toward conspecifics

- Boldness syndrome
- No behavioral syndrome

Huntingford 1976 *An Behav*
Carryovers across contexts?

- Singing behavior
- Social behavior
- Aggressive behavior
- Parental behavior
Behavioral syndromes are mysterious from an evolutionary point of view, for two reasons

1. Why should individuals behave consistently, either through time or across functional contexts?

Sih et al. 2004
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1. Why should individuals behave consistently, either through time or across functional contexts?

2. Why should individuals differ in how they behave?

*Natural selection erodes heritable variation that is related to fitness*
Two points of this talk

1. Behavioral syndromes can be adaptive

2. We can use whole genome expression data to ask about the causes of behavioral syndromes (comorbidity)
The star of the show:
Threespined sticklebacks
*Gasterosteus aculeatus*

- Ethological tradition
- Variation among populations
- Genome sequenced
Measuring aggressiveness toward conspecifics

Orienting to and attacking a conspecific
Measuring boldness towards predators

Time spent eating under predation risk
“Boldness” and “aggressiveness” were genetically correlated in one population but not another (Bell 2005 JEB).

Navarro: $r=0.52$, $n=29$, $P<0.01$

Putah: $r=0.13$, $n=42$, $NS$

PREDATION PRESSURE DIFFERS BETWEEN THE POPULATIONS

(see also Dingemanse et al 2007)
“Boldness” and “aggressiveness” were not correlated with each other ‘before’
Predation generated the syndrome!

Control: Before NS, After NS  
Tank: NS
Two ways this could have happened

1. Selection via disproportionate survivorship

These individuals survived

These individuals died
Two ways this could have happened

2. Behavioral plasticity
Directional selection favored increased “aggressiveness”, decreased “boldness”

<table>
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<tr>
<th></th>
<th>$\beta \pm SE$</th>
<th>$p$</th>
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<td># Orients</td>
<td>$0.432 \pm 0.212$</td>
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<tr>
<td>Time eating</td>
<td>$-0.330 \pm 0.202$</td>
<td>0.05</td>
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<td># Orients * Time eating</td>
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<td>0.62</td>
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<td># Orients$^2$</td>
<td>$-0.111 \pm 0.156$</td>
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<td>Time eating$^2$</td>
<td>$0.258 \pm 0.294$</td>
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<tr>
<td>Constant</td>
<td>$-0.285 \pm 0.368$</td>
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Bell & Sih 2007 Ecology Letters
Plasticity:
Sticklebacks became less aggressive
Experimental evidence that the boldness-aggressiveness behavioral syndrome is adaptive when predation pressure is high

- “Boldness” and “aggressiveness” were not packaged together as a syndrome before exposure to real predation risk.

- The boldness-aggressiveness behavioral syndrome appeared among the survivors.

- Both selection and plasticity generated the syndrome.
Two points of this talk

1. Behavioral syndromes can be adaptive

2. We can use whole genome expression data to ask about the causes of behavioral syndromes (comorbidity)
Pleiotropy is the textbook cause of a behavioral syndrome.

Gene/Hormone

+ → Behavior A

+ → Behavior B

+ → Behavior C

Aggressive behavior

Parental behavior
Our first experiments compared brain gene expression following exposure to a (nonlethal) predator and following an aggressive interaction with a conspecific (relative to controls).
Differentially expressed genes in response to a predator

Differentially expressed genes in response to a conspecific

Preliminary results:
Are there any genes on both lists?

A few
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