FRONTIERS NIDA Mini-Convention November 11, 2011

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

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University of Illinois at Urbana-Champaign

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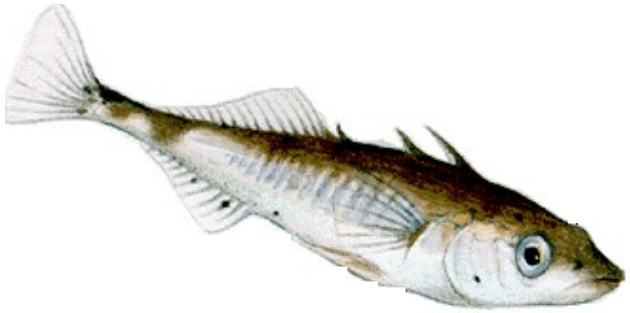
Integrative Biology

University of Illinois, Urbana

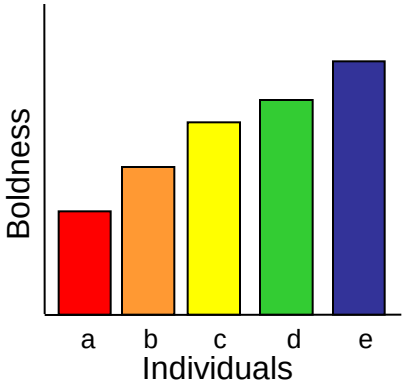


Individual differences

Behavioral syndromes:

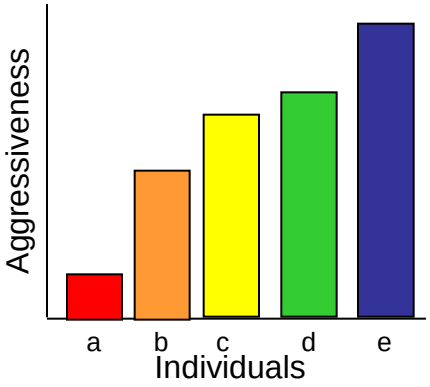
correlations between behaviors in different functional contexts (Sih et al 2004)

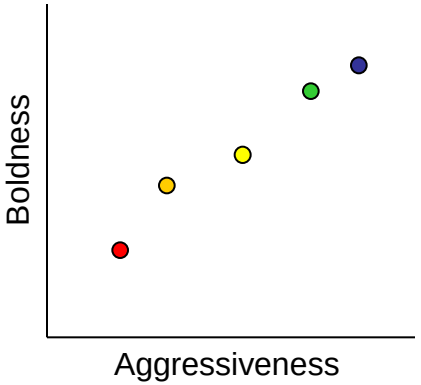
Boldness toward predators



Behavioral syndrome

Aggressiveness toward conspecifics



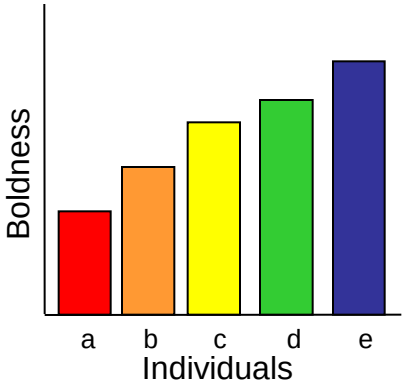


Huntingford 1976 *An Behav*

Behavioral syndromes:

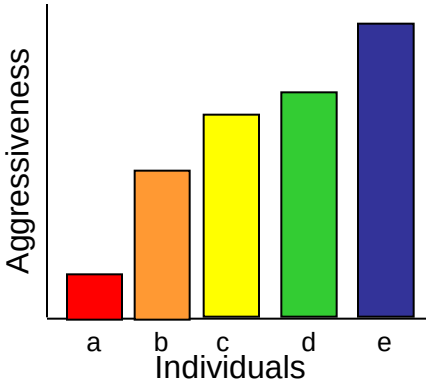
correlations between behaviors in different functional contexts (Sih et al 2004)

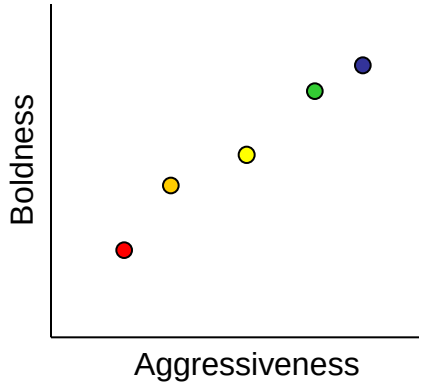
Boldness toward predators



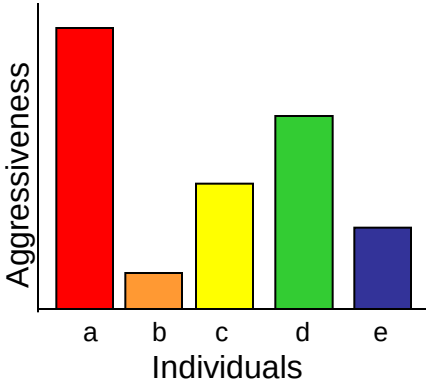
Behavioural syndrome

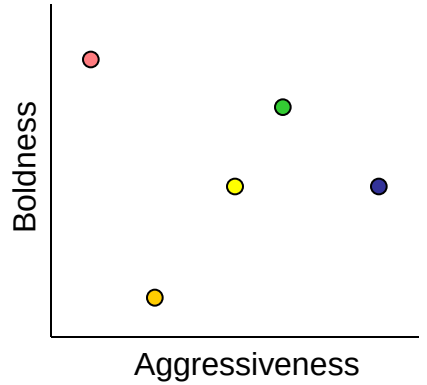
Aggressiveness toward conspecifics





No behavioral syndrome

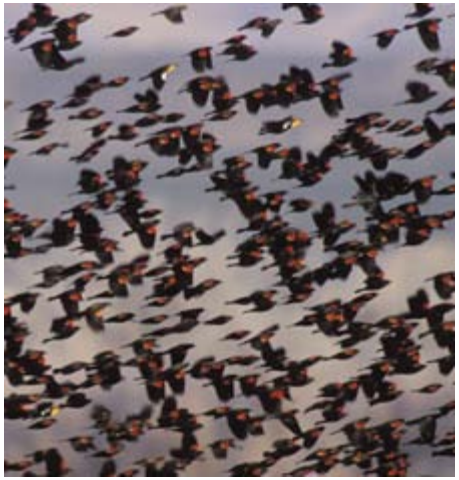




Huntingford 1976 *An Behav*

Carryovers across contexts?

Singing behavior



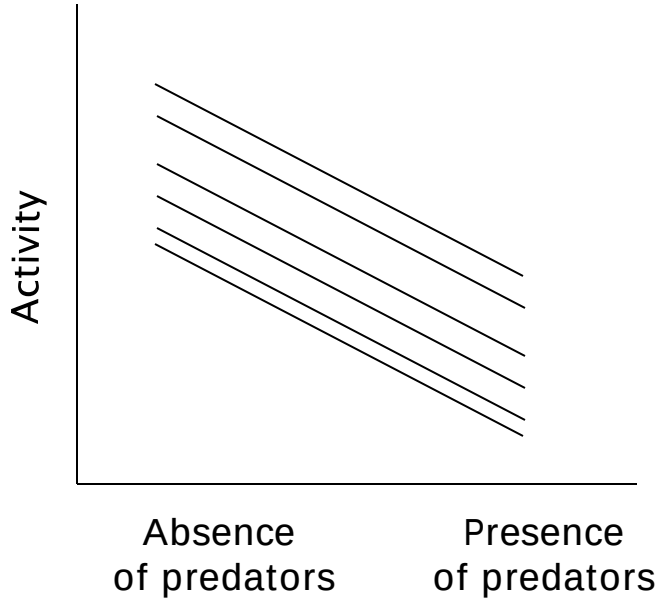
Social behavior

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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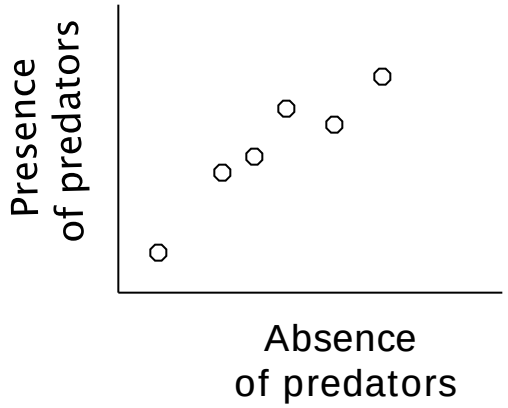

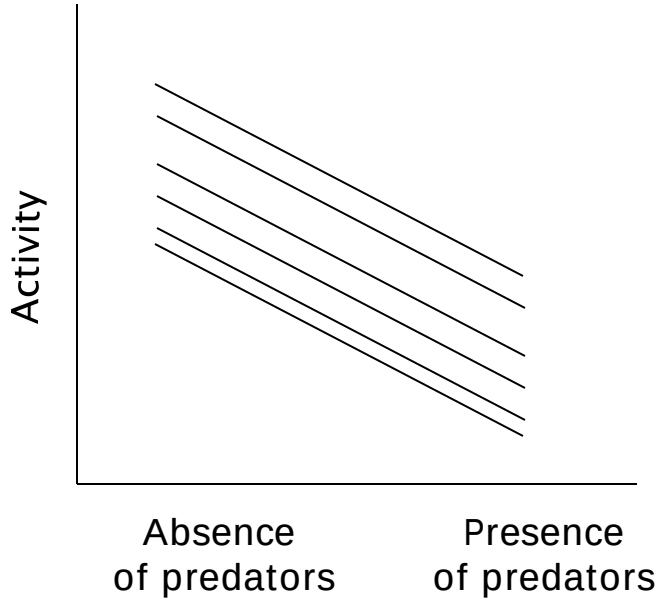

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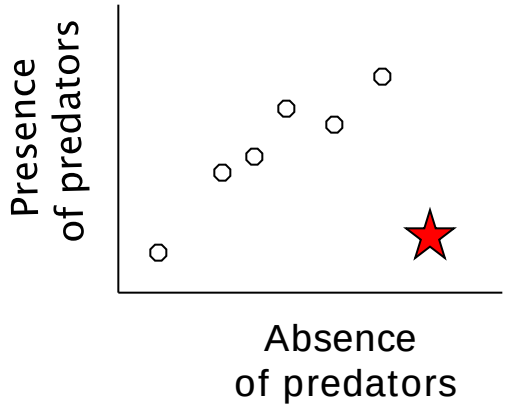
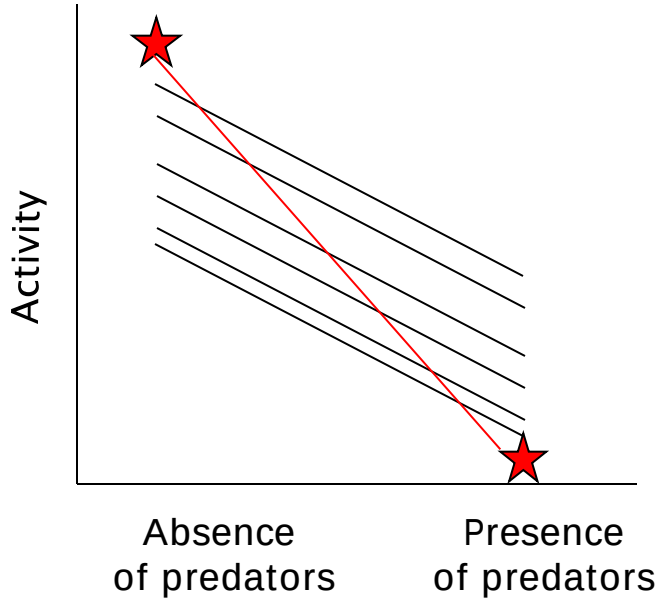




Sih et al 2004

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?**

2. **Why should individuals *differ* in how they behave?**

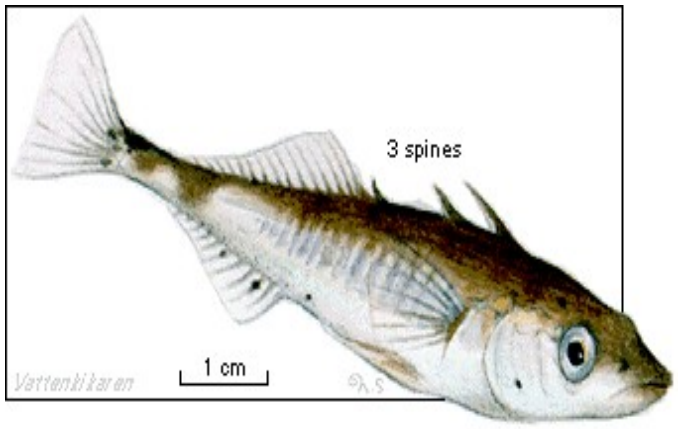
Natural selection erodes heritable variation that is related to fitness

Two points of this talk

1. Behavioral syndromes can be adaptive

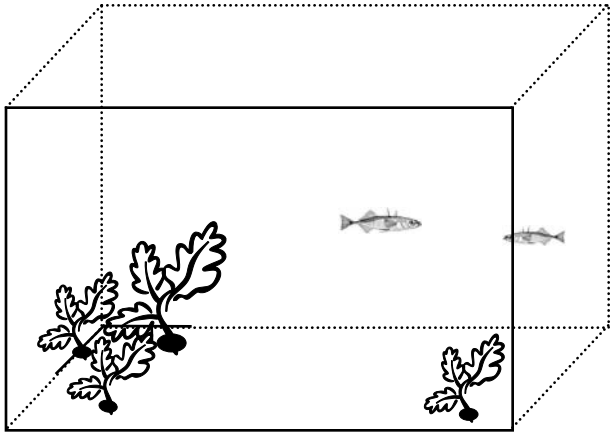
2. We can use whole genome expression data to ask about the causes of behavioral syndromes (comorbidity)

The star of the show: Threespined sticklebacks *Gasterosteus aculeatus*



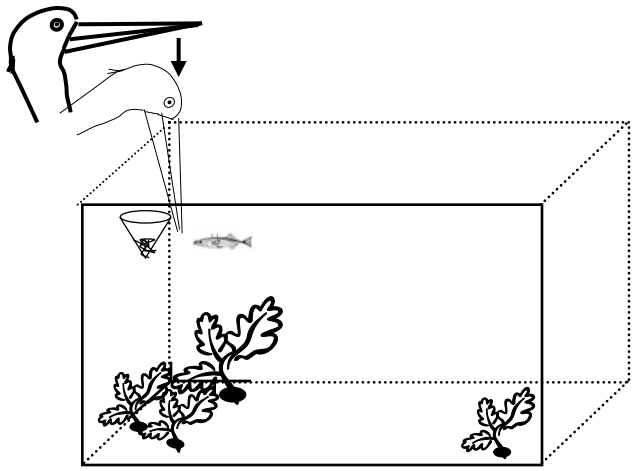
- Ethological tradition
- Variation among populations
- Genome sequenced

Measuring aggressiveness toward conspecifics



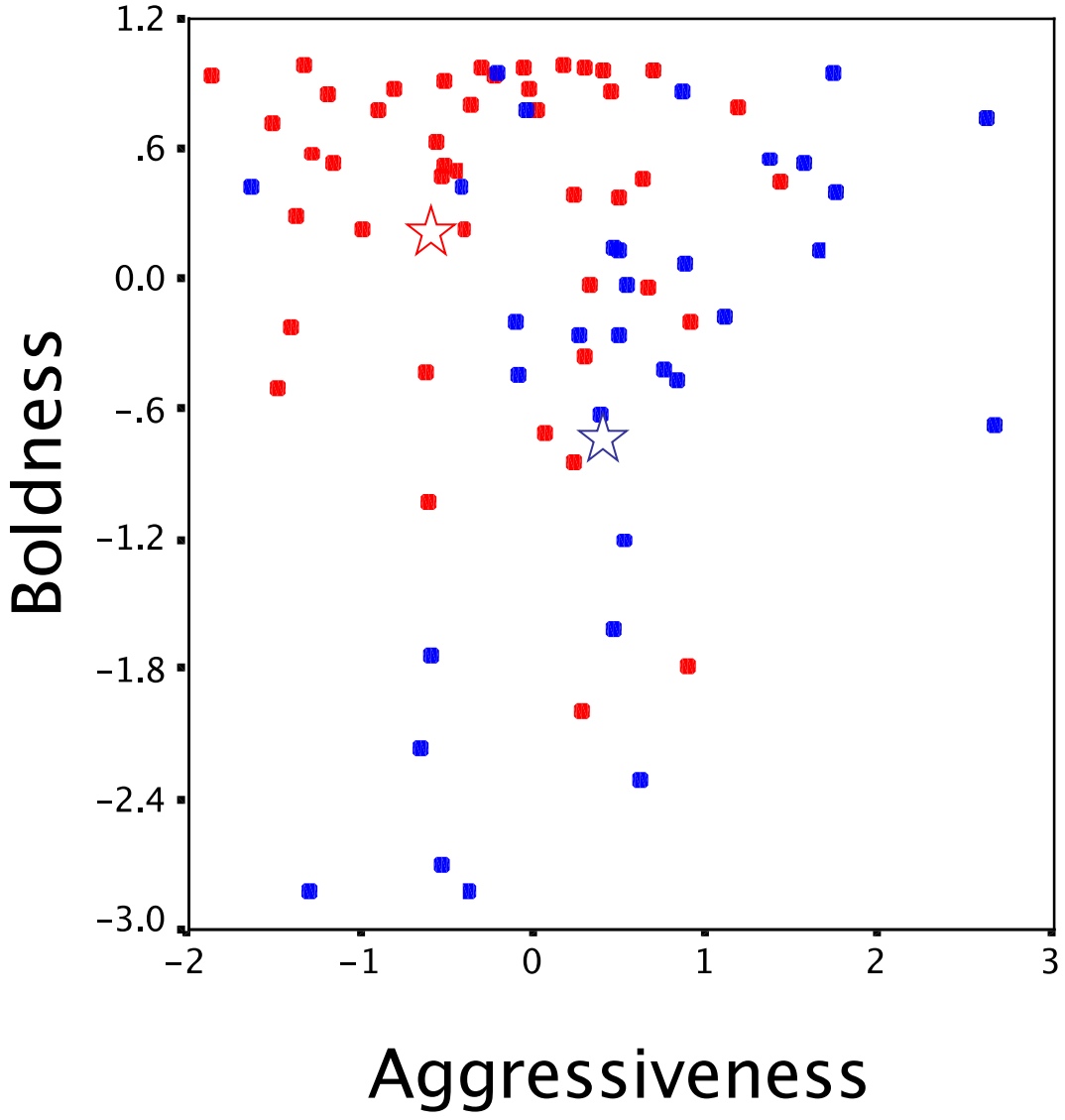
Orienting to and attacking a conspecific

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*)



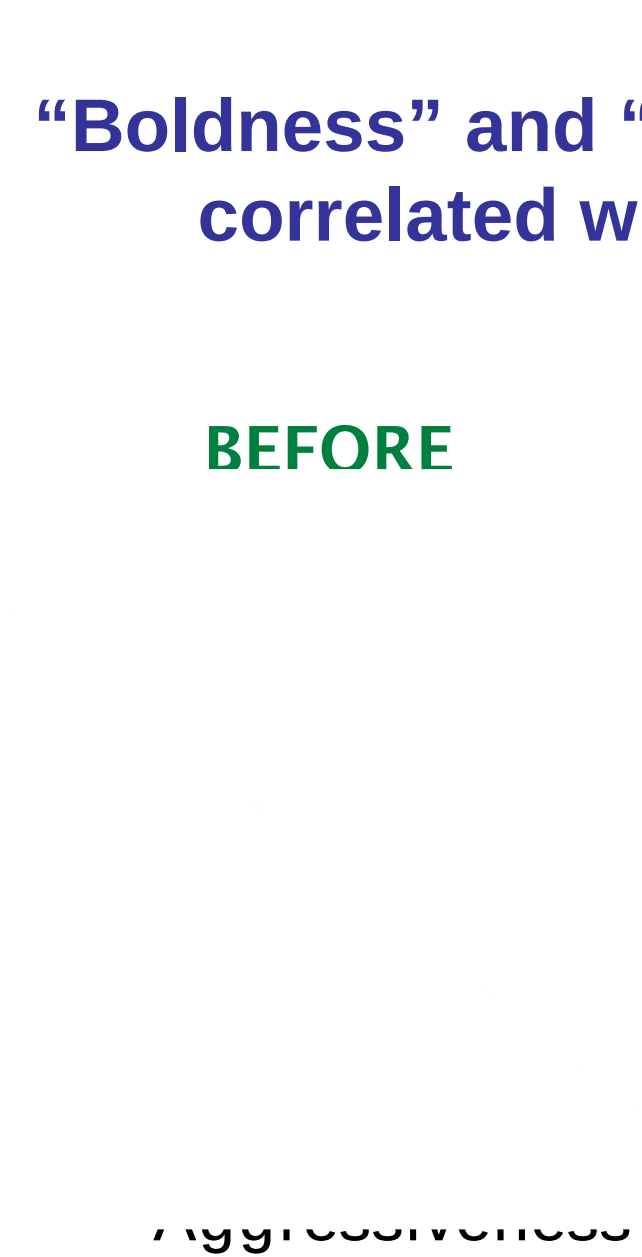
PREDATION PRESSURE DIFFERS BETWEEN THE POPULATIONS

(see also Dingemanse et al 2007)

- Navarro: r=0.52, n=29, P<0.01
- Putah: r=0.13, n=42, *NS*

“Boldness” and “aggressiveness” were not correlated with each other ‘before’

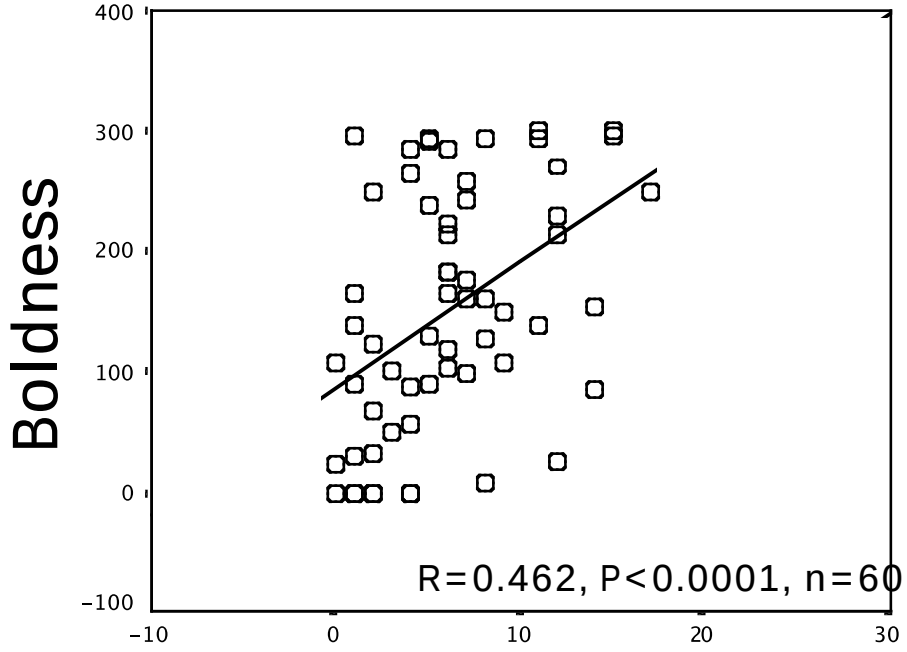
BEFORE



Predation generated the syndrome!

BEFORE

AFTER

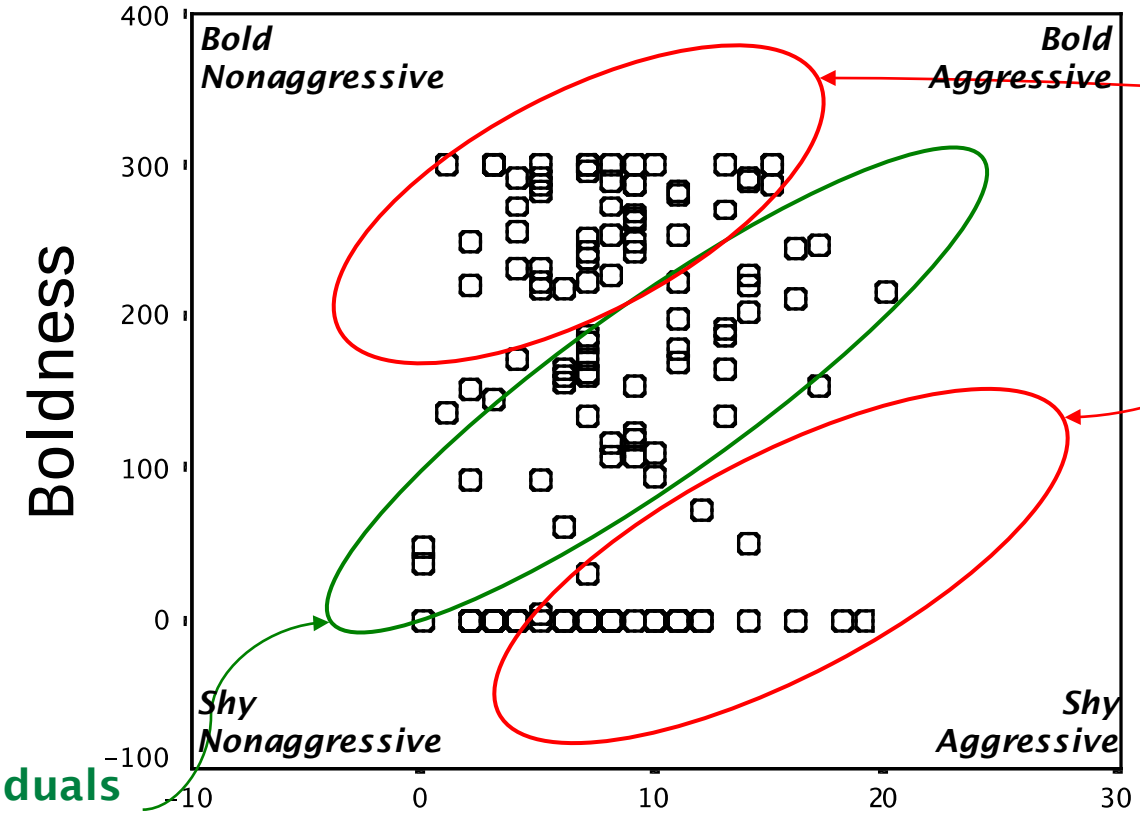


Aggressiveness

Aggressiveness

Control: Before NS, After NS
Tank: NS

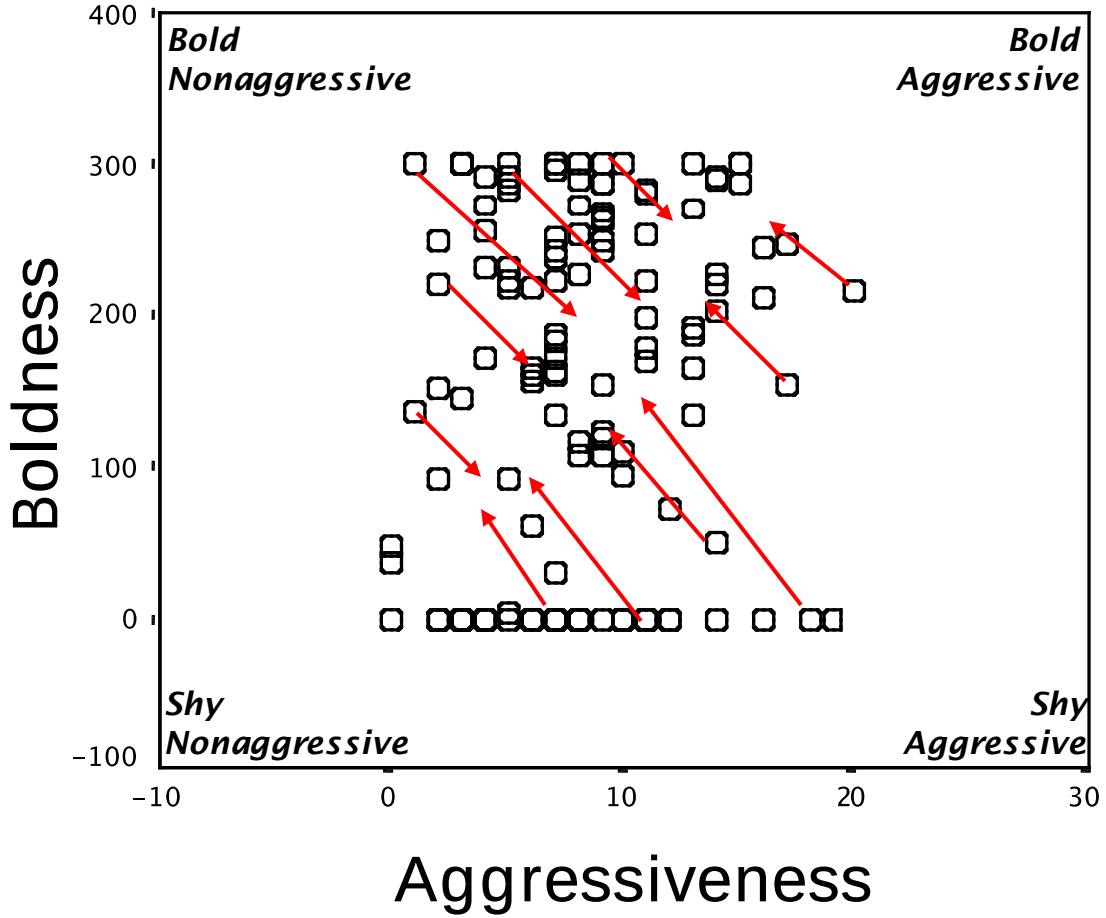
Two ways this could have happened
1. Selection via disproportionate survivorship



These individuals died

These individuals survived

Two ways this could have happened
2. Behavioral plasticity



Directional selection favored increased "aggressiveness", decreased "boldness"

"Aggressiveness"

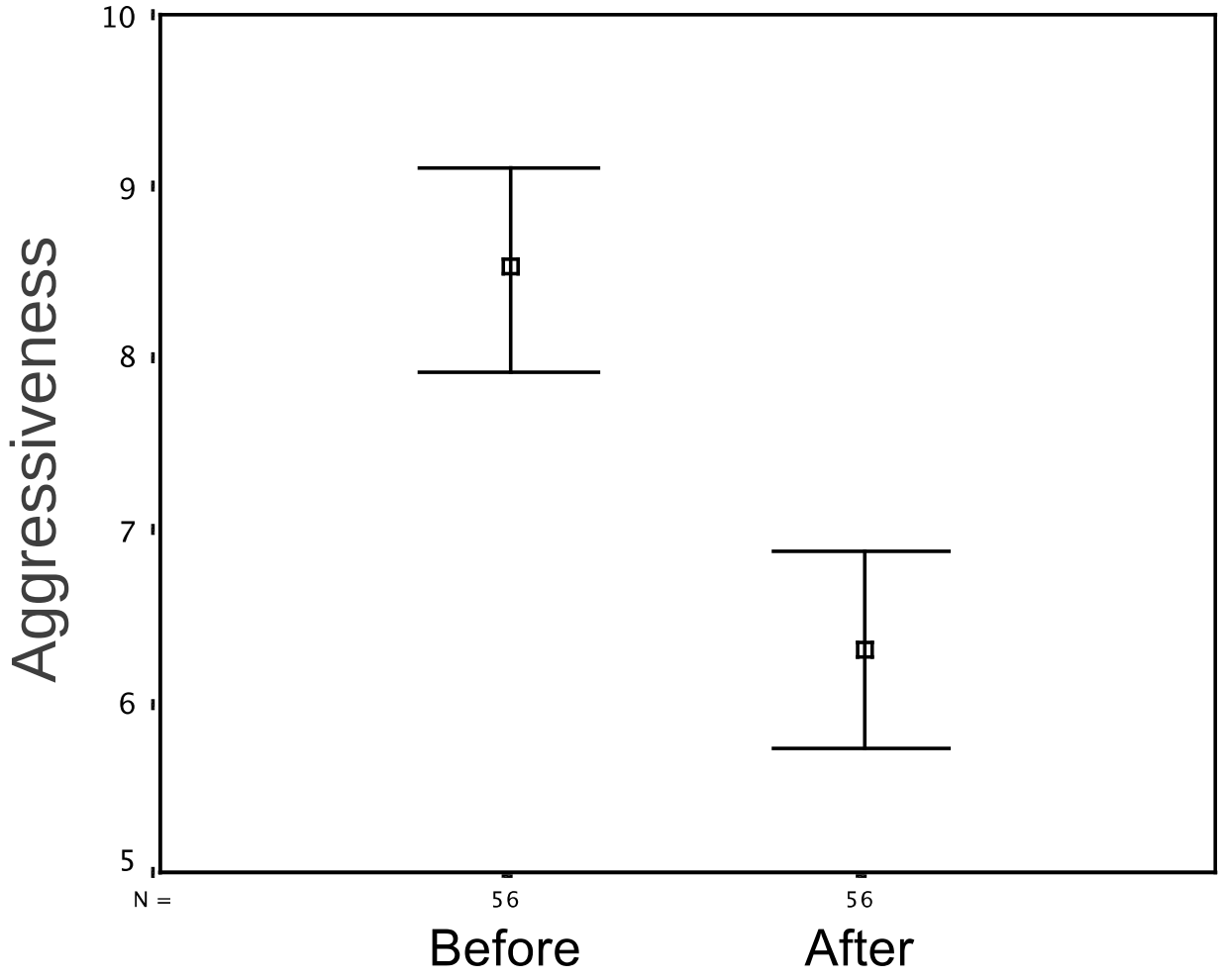
"Boldness"

	$\beta \pm SE$	p
# Orients	0.432 ± 0.212	0.04
Time eating	-0.330 ± 0.202	0.05
# Orients * Time eating	0.095 ± 0.193	0.62
# Orients^2	-0.111 ± 0.156	0.47
Time eating^2	0.258 ± 0.294	0.38
Constant	-0.285 ± 0.368	0.43

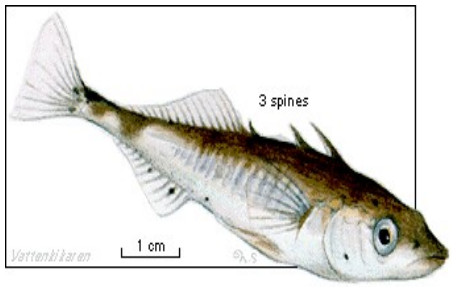
Bell & Sih 2007 *Ecology Letters*

Plasticity:

Sticklebacks became less aggressive



Experimental evidence that the boldness-aggressiveness behavioral syndrome is adaptive when predation pressure is high



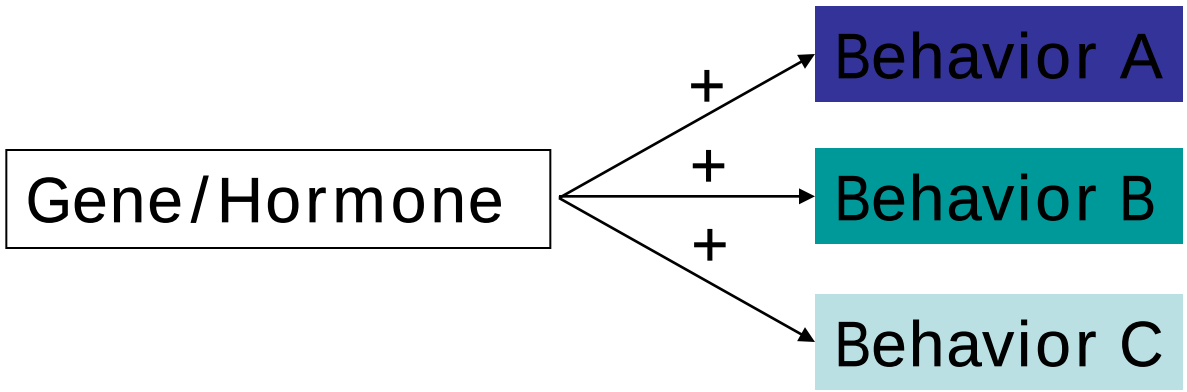
- “Boldness” and “aggressiveness” were not packaged together as a syndrome before exposure to real predation risk.
- The boldness-aggressiveness behavioral syndrome appeared among the survivors.
- Both selection and plasticity generated the syndrome.

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



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).

vs. control

vs. control

Differentially expressed genes in response to a predator

ID	logFC	AveExpr	t	P.Value
ENSGACT000C	3.96400072	6.80965806	7.71100353	2.00E-06
ENSGACT000C	-1.71111924	8.93053751	-6.2691697	1.99E-05
ENSGACT000C	1.27767463	5.8[illegible]	[illegible]	[illegible]
ENSGACT000C	1.47331778	5.6[illegible]	[illegible]	[illegible]
ENSGACT000C	-1.82268859	7.5873738	-5.99099515	3.21E-05
ENSGACT000C	2.61609287	6.7582394	5.85897362	4.03E-05
ENSGACT000C	2.9095063	7.90325068	5.74846965	4.90E-05
ENSGACT000C	-1.28103675	10.[illegible]	-5.71616589	5.18E-05
ENSGACT000C	-1.45118577	[illegible]	[illegible]	[illegible]
ENSGACT000C	1.06389949	[illegible]	[illegible]	[illegible]
ENSGACT000C	-1.04482182	7.83176392	-5.40878252	8.98E-05
ENSGACT000C	-1.15796511	5.21660596	-5.40700538	9.01E-05
ENSGACT000C	-1.25706822	7.90217103	-5.36477497	9.73E-05
ENSGACT000C	-1.43729735	10.2231468	-5.29314[illegible]	[illegible]
ENSGACT000C	1.17374329	9.60978592	5.192[illegible]	[illegible]
ENSGACT000C	1.05453454	8.14411738	5.16103391	0.00014124
ENSGACT000C	1.05604658	10.4382316	4.9724209	0.00020039
ENSGACT000C	-1.07846171	7.59630601	-4.92435043	0.00021924
ENSGACT000C	0.96311602	11.4608616	4.86194777	0.00024647
ENSGACT000C	-1.77662012	6.99994263	-4.84837968	0.00025284
ENSGACT000C	-1.22630355	6.95061188	-4.82925672	0.00026211
ENSGACT000C	1.18014254	9.16346671	4.78670981	0.00028402
ENSGACT000C	-1.79854069	10.5330242	-4.7092631	0.0003289
ENSGACT000C	-1.47308447	7.25243051	-4.68123254	0.00034689
ENSGACT000C	1.38980207	9.08624235	4.66131544	0.00036029
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ENSGACT000C	-1.28621653	5.42774887	-4.64463586	0.00037193
ENSGACT000C	1.21975293	7.22679384	4.64122004	0.00037436
ENSGACT000C	1.7233546	11.7544607	4.62591384	0.00038549
ENSGACT000C	-0.96649046	5.55239457	-4.62394378	0.0003869
ENSGACT000C	1.18801288	5.35343288	4.62336862	0.00038732
ENSGACT000C	-1.14871759	5.45177113	-4.61340469	0.00039476
ENSGACT000C	1.42495573	8.22709944	4.59758087	0.00040688
ENSGACT000C	1.04471947	5.7608261	4.57947767	0.00042121
ENSGACT000C	1.06904589	6.47656381	4.56619109	0.00043206
ENSGACT000C	1.30521539	6.94758214	4.56581402	0.00043237
ENSGACT000C	0.93537996	6.55639315	4.55922372	0.00043787
ENSGACT000C	0.91413447	6.47630261	4.55846026	0.00043851
ENSGACT000C	-1.12913415	6.68136437	-4.54401583	0.00045082
ENSGACT000C	1.38258806	9.20343883	4.53824474	0.00045583
ENSGACT000C	1.21428229	6.36987912	4.53395674	0.0004596
ENSGACT000C	0.91870473	6.73292996	4.51312734	0.00047835
ENSGACT000C	1.14304683	7.7299686	4.5116584	0.0004797
ENSGACT000C	1.13953425	5.14171384	4.50236383	0.00048834
ENSGACT000C	1.33234962	7.66072363	4.49208818	0.00049809
ENSGACT000C	1.12315127	5.57353927	4.48110326	0.00050872

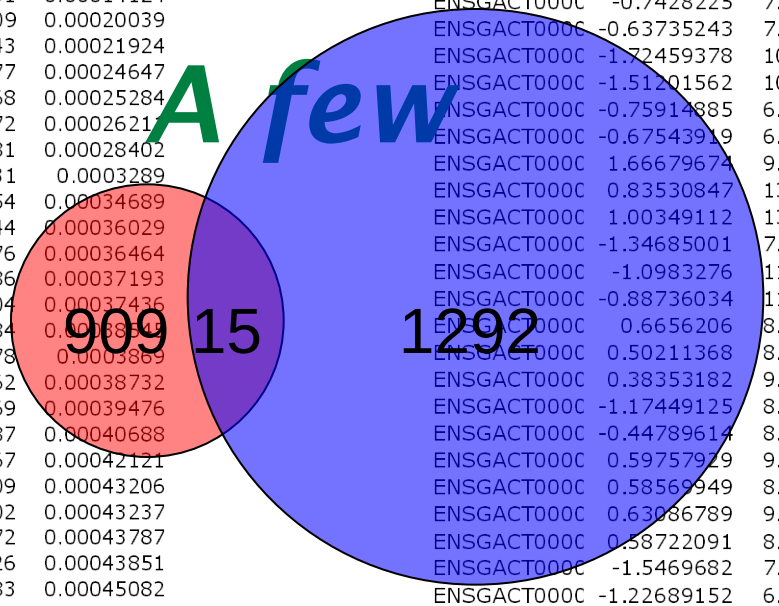
Differentially expressed genes in response to a conspecific

Name	logFC	AveExpr	t	P.Value
ENSGACT000C	1.53699956	8.55975345	4.62764701	5.26E-05
ENSGACT000C	1.46[illegible]	8.45454696	4.72708923	3.92E-05
ENSGACT000C	1.38[illegible]	8.30059369	4.68097654	4.49E-05
ENSGACT000C	1.73[illegible]	8.44857306	5.66347968	8.60E-06
ENSGACT000C	0.52885135	6.98584997	4.89515758	2.38E-05
ENSGACT000C	0.62399932	7.01595991	4.52349969	7.14E-05
ENSGACT000C	-0.71415381	11.2909507	-4.63982281	5.07E-05
ENSGACT000C	1.03[illegible]	8.[illegible]5716	5.80702091	1.57E-06
ENSGACT000C	0.51[illegible]	7.738[illegible]503	6.74560726	9.73E-08
ENSGACT000C	-0.68461468	8.77225459	-4.84728232	2.75E-05
ENSGACT000C	0.28205416	6.94793683	5.03528721	4.08E-05
ENSGACT000C	-0.755[illegible]092	7.70287065	-4.35904739	0.00011563
ENSGACT000C	-0.[illegible]07311357	7.73734707	-5.35410858	1.84E-05
ENSGACT000C	-0.[illegible]7885333	6.9476131	-5.91263028	4.68E-06
ENSGACT000C	-0.7428225	7.33317776	-4.71229381	9.17E-05
ENSGACT000C	-0.63735243	7.80541663	-4.29425443	0.00013965
ENSGACT000C	-1.72459378	10.4241775	-4.93919214	2.09E-05
ENSGACT000C	-1.51201562	10.7788351	-4.56648403	6.30E-05
ENSGACT000C	-0.75914885	6.92851184	-5.78316616	1.68E-06
ENSGACT000C	-0.67543919	6.92804603	-4.18144716	0.00019371
ENSGACT000C	1.66679674	9.37491742	5.14375697	3.11E-05
ENSGACT000C	0.83530847	13.4748094	4.72761741	3.91E-05
ENSGACT000C	1.00349112	13.2062186	4.25138774	0.00015818
ENSGACT000C	-1.34685001	7.86247332	-5.28038768	2.22E-05
ENSGACT000C	-1.0983276	11.8291236	-4.54210242	6.76E-05
ENSGACT000C	-0.88736034	11.4406665	-4.31096401	0.00013302
ENSGACT000C	0.6656206	8.29392013	4.17018873	0.00020012
ENSGACT000C	0.50211368	8.66918733	4.42506912	9.53E-05
ENSGACT000C	0.38353182	9.78453306	4.22244662	0.00017203
ENSGACT000C	-1.17449125	8.72349206	-4.52948619	0.0001451
ENSGACT000C	-0.44789614	8.34775216	-4.99854484	4.47E-05
ENSGACT000C	0.59757929	9.84414604	5.00200698	4.43E-05
ENSGACT000C	0.58569949	8.13500543	4.17236049	0.00019887
ENSGACT000C	0.63086789	9.27170965	4.2674784	0.00015095
ENSGACT000C	0.58722091	8.01995173	4.17459693	0.00019758
ENSGACT000C	-1.5469682	7.37196514	-5.38540332	1.71E-05
ENSGACT000C	-1.22689152	6.90958149	-5.73872075	7.15E-06
ENSGACT000C	-0.68166903	6.94858525	-5.63630045	2.61E-06
ENSGACT000C	-0.46580229	7.03483345	-4.31263304	0.00013238
ENSGACT000C	-0.76386438	7.19029991	-5.94174115	1.05E-06
ENSGACT000C	-0.92557084	7.43980589	-6.00562874	8.68E-07
ENSGACT000C	-0.83628694	7.72481566	-5.16231387	1.08E-05
ENSGACT000C	-0.99624592	7.63446231	-5.28766443	7.40E-06
ENSGACT000C	0.70138835	8.63219863	4.72706112	8.83E-05
ENSGACT000C	-0.56300685	7.67575255	-5.44748485	4.59E-06

Preliminary results:

Are there any genes on both lists?

A few



Acknowledgements

Adaptive syndromes:
Andy Sih
Lauren Valverde
Brett Hanshew

Gene expression:
Osee Sanogo
Mark Band
Jenny Drnevich
Molly Kent

Funding:
National Institutes of Health (NIGMS)
National Science Foundation
American Association of University Women
University of Illinois