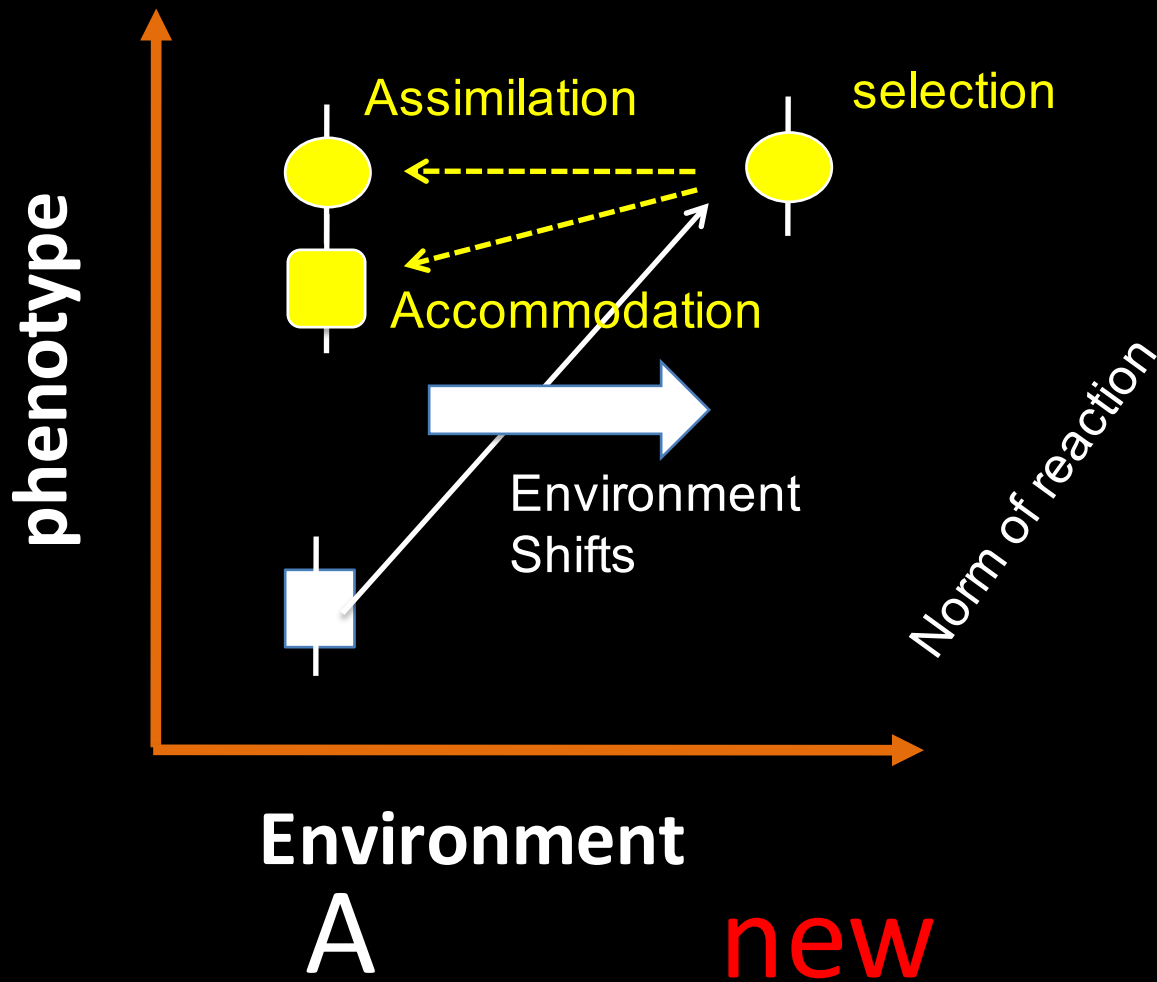


TRENDS in Genetics

$$V_p = V_g + V_e + V_g * V_e$$

# Genetic Assimilation



Spalding



Baldwin



Waddington



Schmalhausen



Pigglucci



West-Eberhard



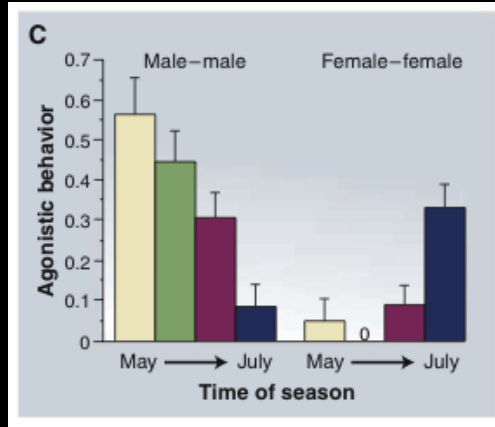
DEVELOPMENTAL  
PLASTICITY  
AND EVOLUTION



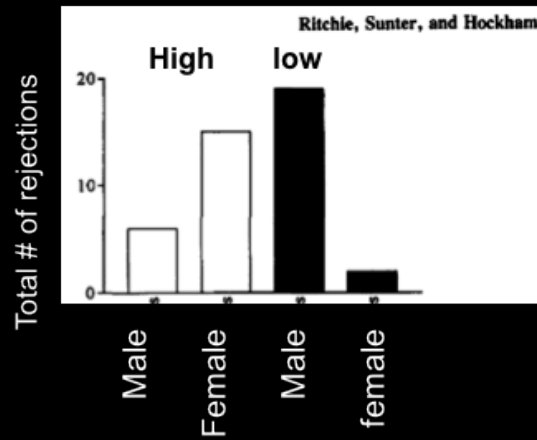
MARY JANE WEST-EBERHARD



*Ephippiger ephippiger*



Season



# Appropriate study systems

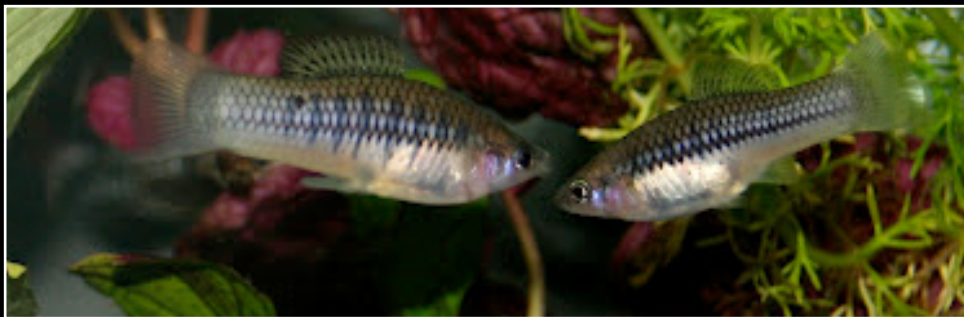
The Evolution of Alternate Reproductive Tactics among male swordtail fish.

Ancestral



Courting  
&  
Thrusting

Derived



Courting

Derived



Thrusting

## The role of phenotypic plasticity in evolution

Are there any potential biases toward certain trait types over others?

E.g.

- behavior exhibits extreme evolutionary lability
- behavioral plasticity is widespread and varies across populations

Do behavioral traits undergo genetic accommodation more often than other traits?

How fast can initial, plasticity-mediated changes be accommodated into genetically canalized divergences?

- field studies involve populations or species that have diverged by millions of years
- studies of the very early stages of population differentiation are needed

# Appropriate study systems

- 1) Quantifiable Plastic Phenotype
- 2) Ancestral Phenotype that exhibits plasticity &  
Derived Population(s) w/ fixed phenotype
- 3) Ability to induce plasticity in a controlled setting

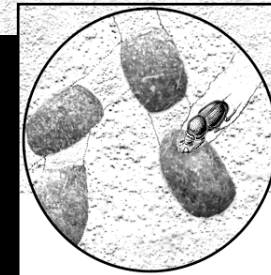
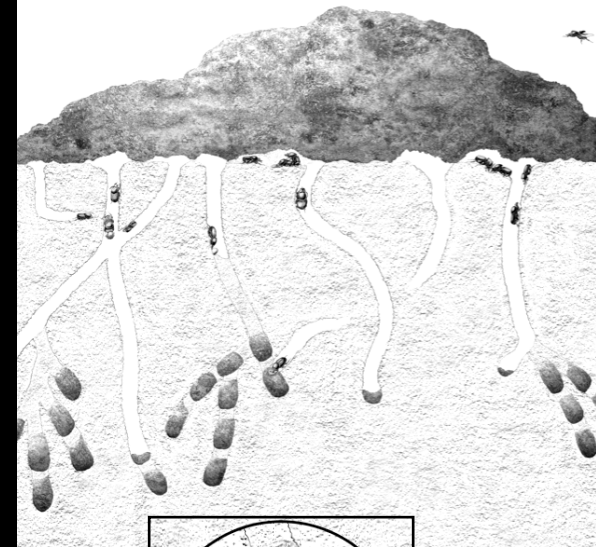
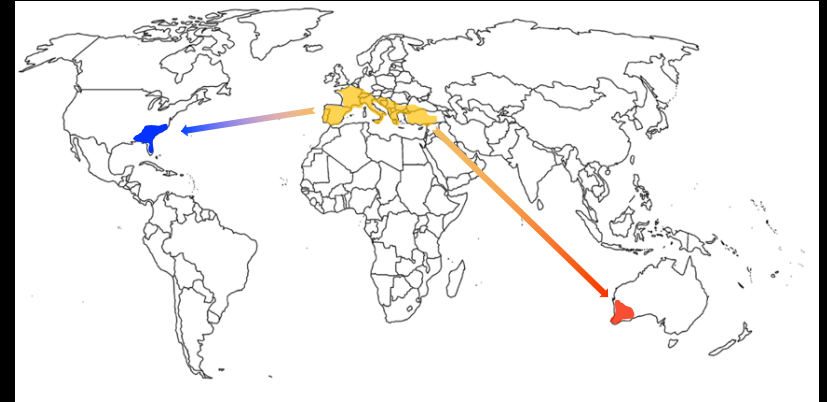
## *Onthophagus taurus*



What is the scope and speed of genetic accommodation?

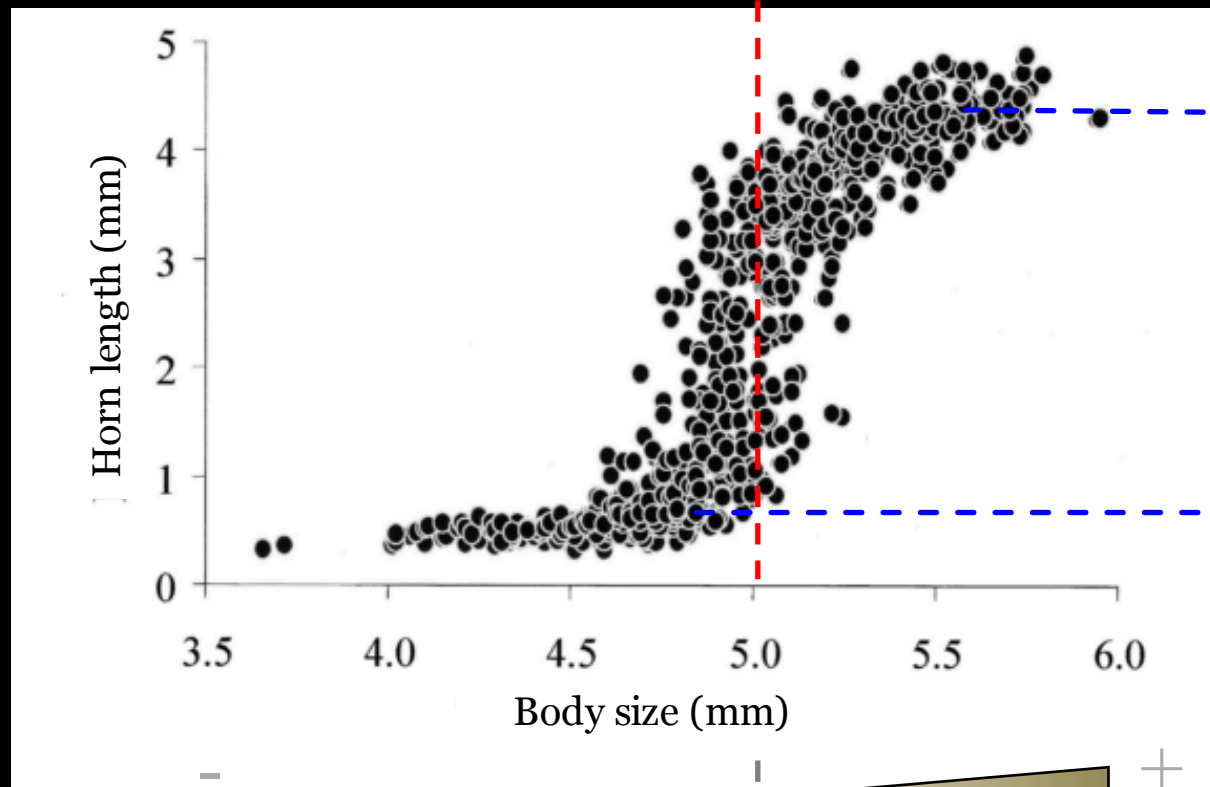
The role of ancestral plasticity in mediating

- the early stages of rapid population differentiation
  - in recently established exotic populations
- across diverse trait types that exhibit canalized divergences

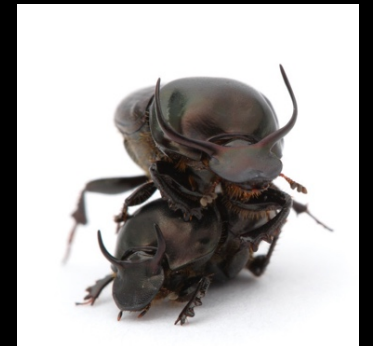


by Barrett Klen

# *Onthophagus taurus* is polyphenic



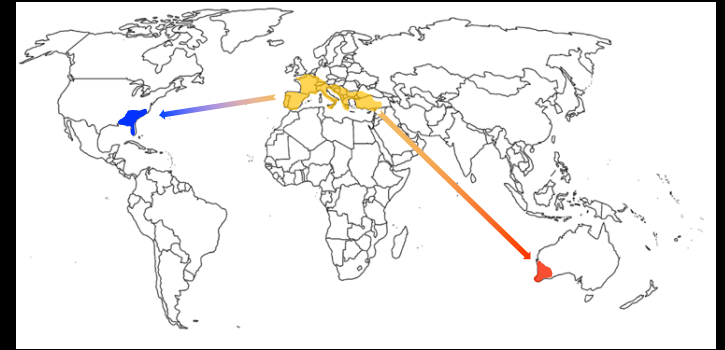
Nutrition (quantity & quality)





*O. taurus* introduced ~ 50 years ago from the Mediterranean to US and Australia

- Population densities are much higher in WA than US



US: 5-10 beetles per dung pad

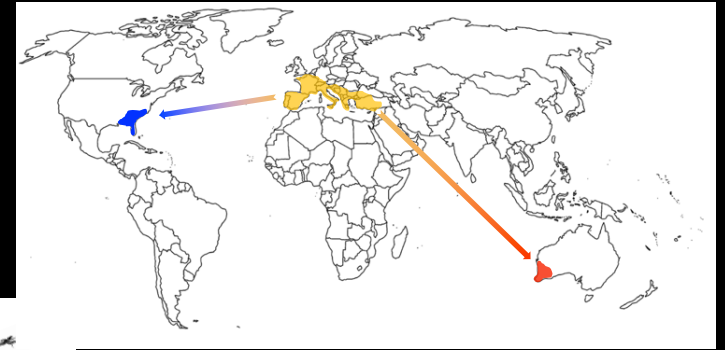
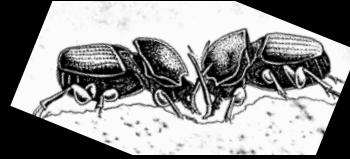


Australia: 800- 1,000 beetles per dung pad



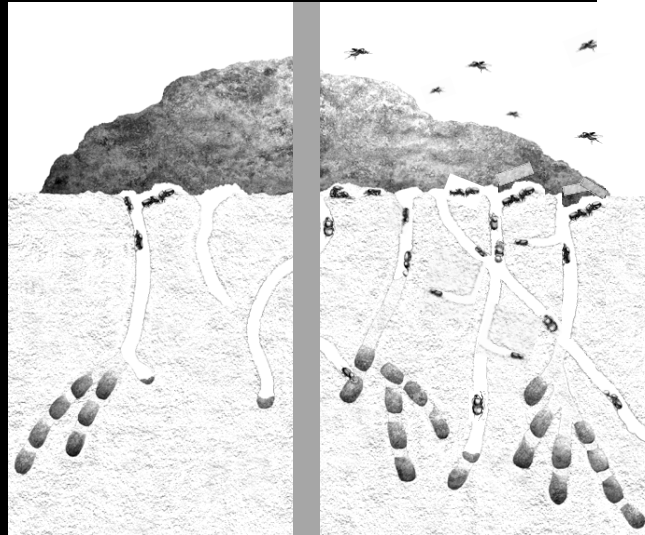
Moczek 2003

# Population densities are much higher in WA than US



## Low densities/US

- Few individuals per dung pad
- Most females manage to breed, low competition for dung
- Low levels of male-male competition over females



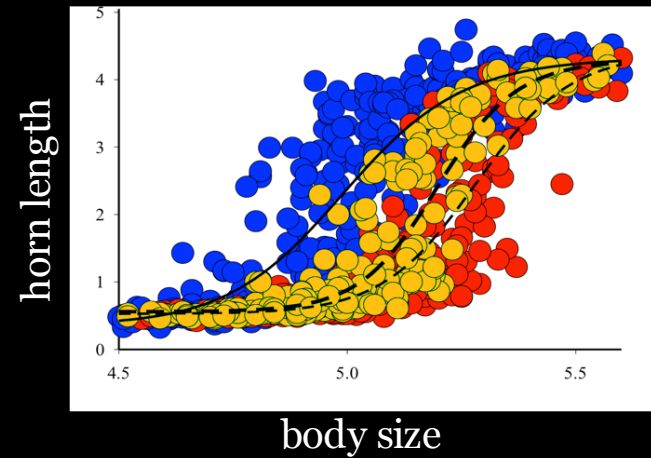
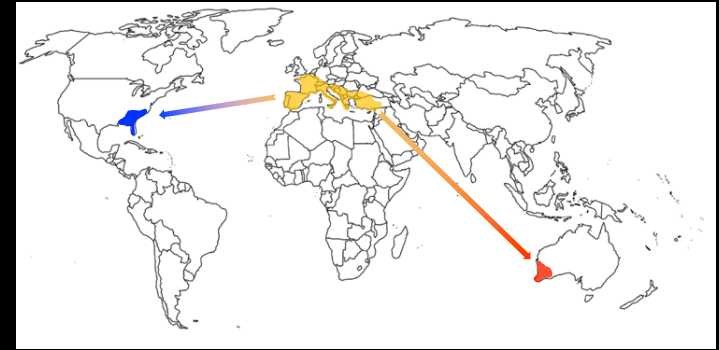
## High densities/WA

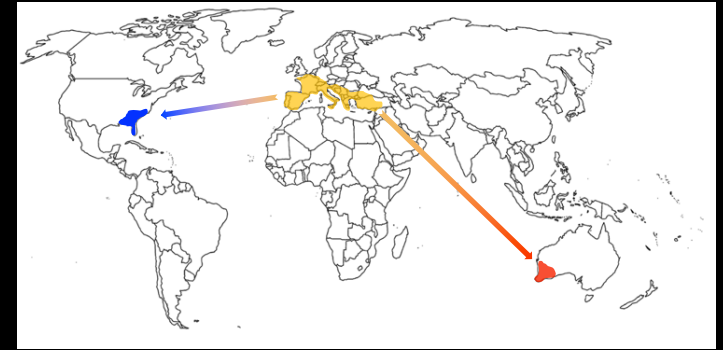
- Hundreds of individuals per dung pad
- Not all females manage to breed (resource limitation)
- Intense male-male competition over females

canalized divergences  
maintained in common  
garden

Type of trait	Trait	US	WA
Maternal behavioral trait	Brood ball weight	lighter	heavier
	Brood ball burial depth	deeper	shallower
Life history trait	Number of brood balls	less	more
	Ecllosion success	lower	higher
Morphological trait	Mean body size	larger	smaller
	Horn threshold	at smaller size	at larger size

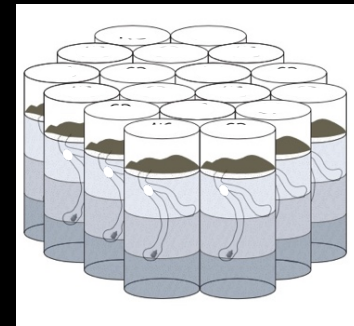
WA = high densities  
US = low densities



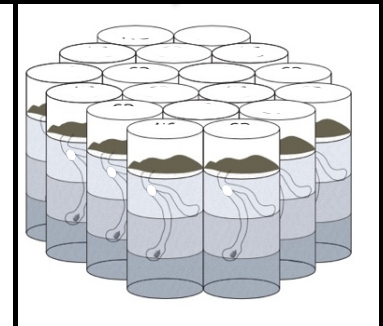


Type of trait	Trait	US	WA
Maternal behavioral trait	Brood ball weight	lighter	heavier
	Brood ball burial depth	deeper	shallower
Life history trait	Number of brood balls	less	more
	Ecllosion success	lower	higher
Morphological trait	Mean body size	larger	smaller
	Horn threshold	at smaller size	at larger size

WA = high densities  
 US = low densities



N = 20



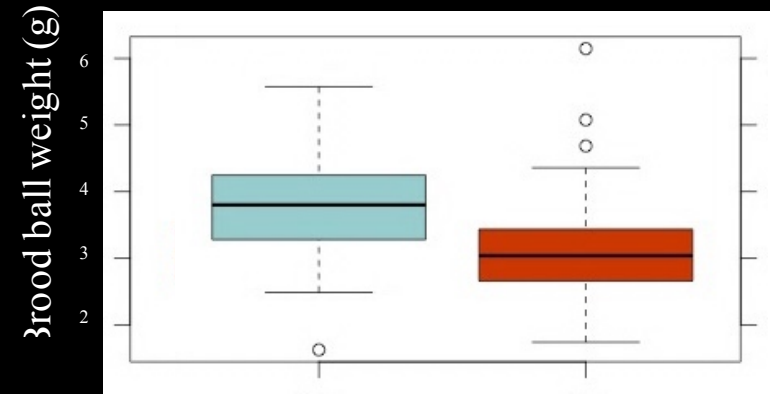
N = 20

Diagram modified from Macagno et al. *in review*

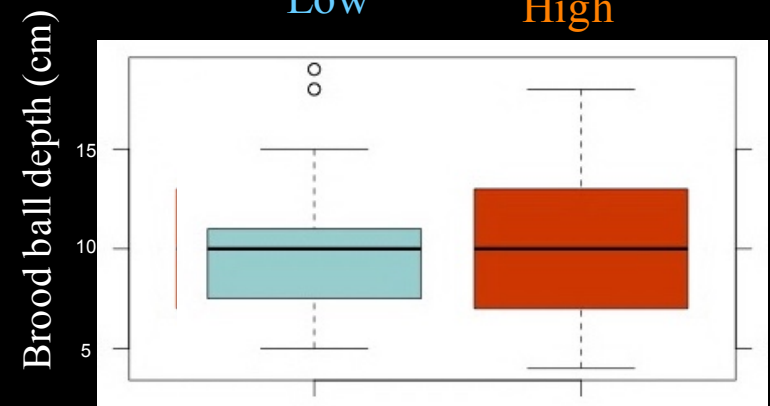
# RESULTS

Type of trait	Trait	US	WA	Plasticity	Direction
Maternal behavioral	Brood ball weight	lighter	heavier	✓	opposite
	Brood ball burial depth	deeper	shallower	✗	
Life history trait	Number of brood ball	less	more	✓	same
	Ecdysis success	lower	higher	✓	opposite
Offspring morphological trait	Mean body size	larger	smaller	✓	same
	Horn threshold	At smaller body size	At larger body size	✗	

WA = high densities  
 US = low densities



Low High



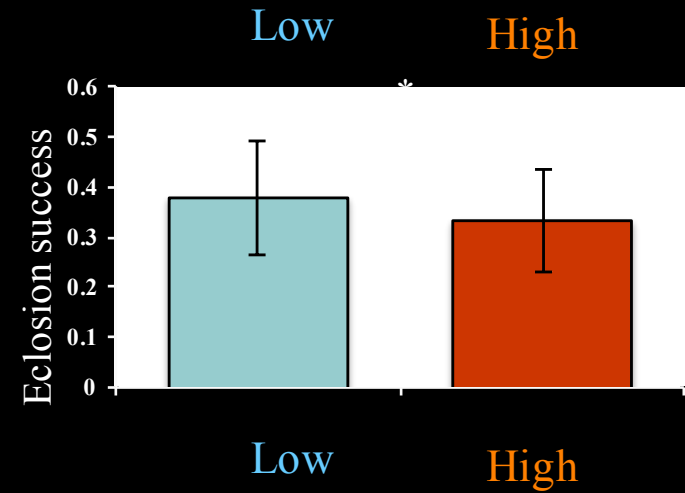
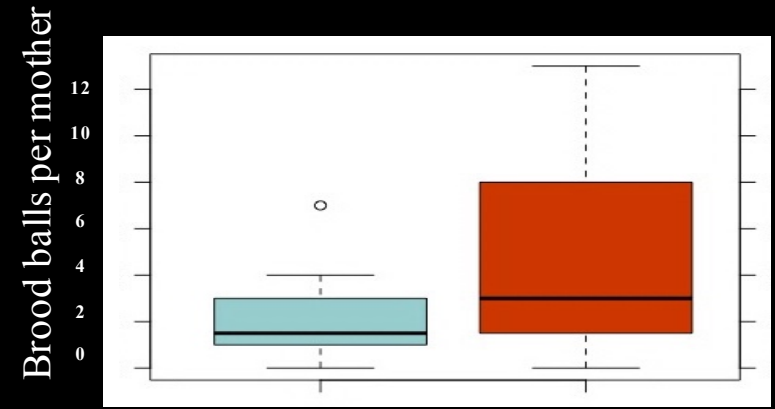
Low High



# RESULTS

Type of trait	Trait	US	WA	Plasticity	Direction
Maternal behavioral	Brood ball weight	lighter	heavier	✓	opposite
	Brood ball burial depth	deeper	shallower	✗	
Life history trait	Number of brood ball	less	more	✓	same
	Ecdysis success	lower	higher	✓	opposite
Offspring morphological trait	Mean body size	larger	smaller	✓	same
	Horn threshold	At smaller body size	At larger body size	✗	

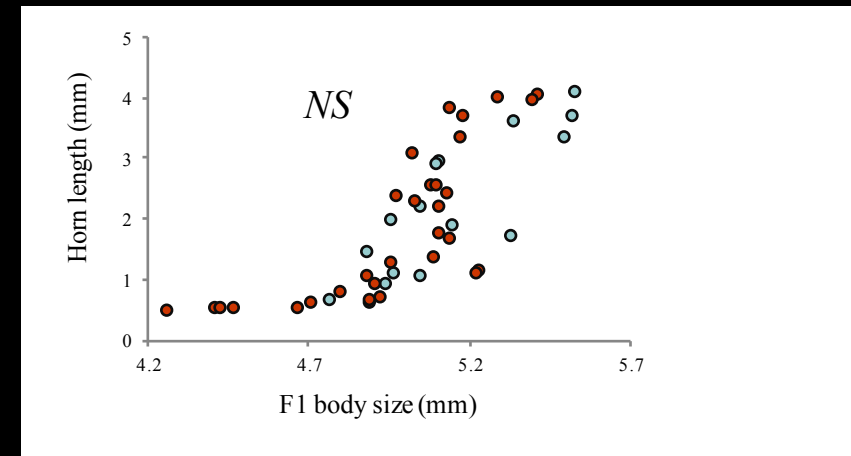
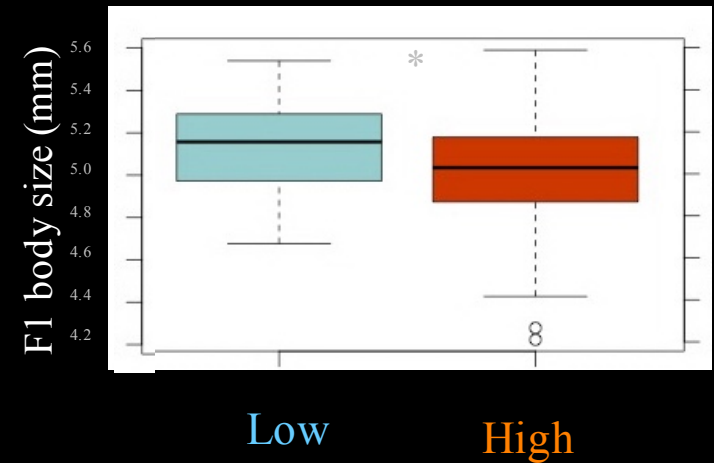
WA = high densities  
 US = low densities



# RESULTS

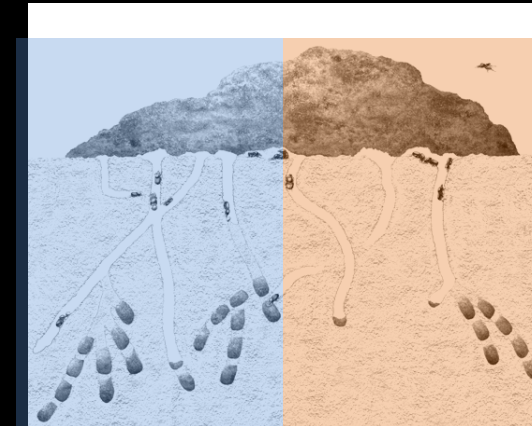
Type of trait	Trait	US	WA	Plasticity	Direction
Maternal behavioral	Brood ball weight	lighter	heavier	✓	opposite
	Brood ball burial depth	deeper	shallower	✗	
Life history trait	Number of brood ball	less	more	✓	same
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Offspring morphological trait	Mean body size	larger	smaller	✓	same
	Horn threshold	At smaller body size	At larger body size	✗	

WA = high densities  
 US = low densities



# RESULTS

Type of trait	Trait	US	WA	Plasticity	Direction
Maternal behavioral	Brood ball weight	lighter	heavier	✓	opposite
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Offspring morphological trait	Mean body size	larger	smaller	✓	same
	Horn threshold	At smaller body size	At larger body size	✗	



WA = high densities  
US = low densities

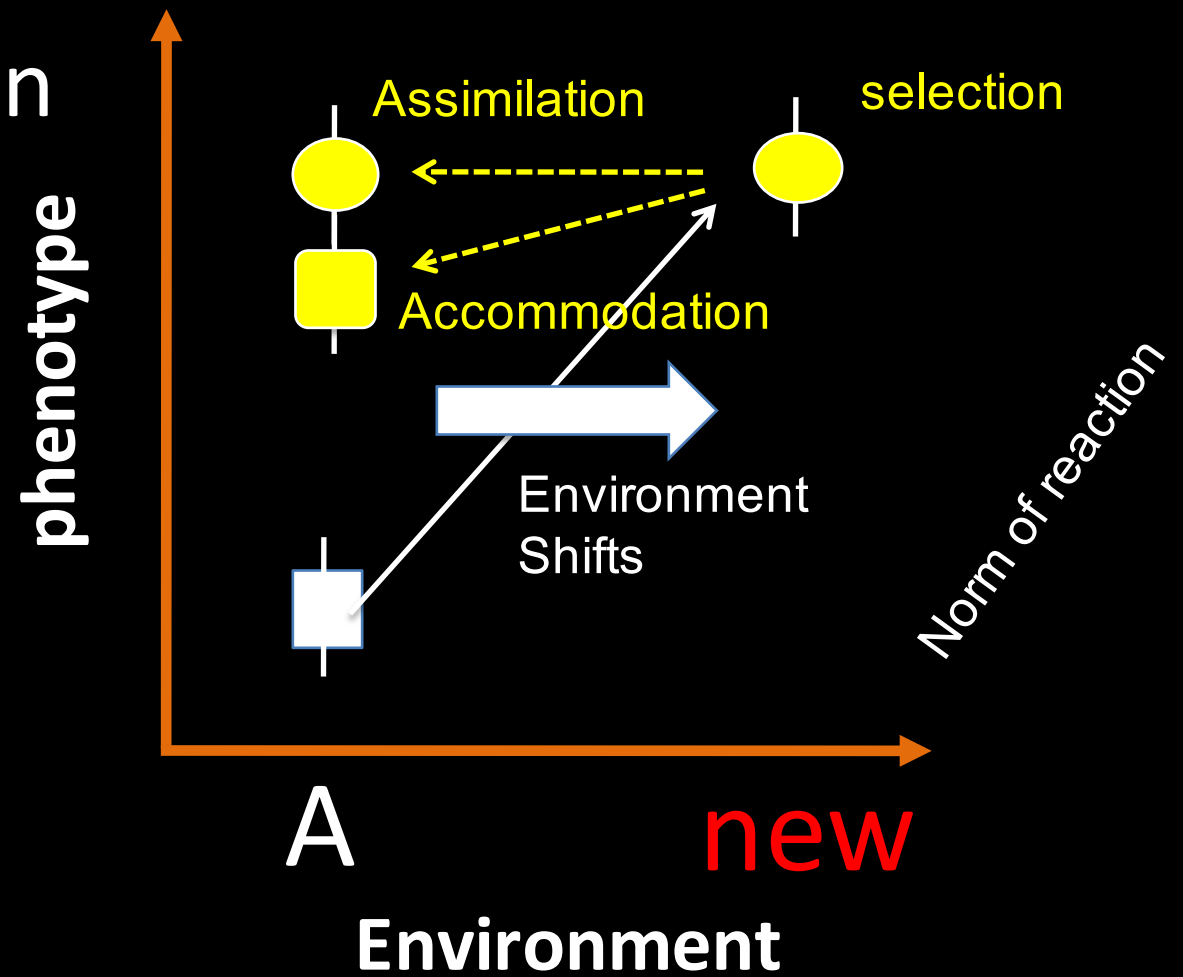


Sofia Casasa

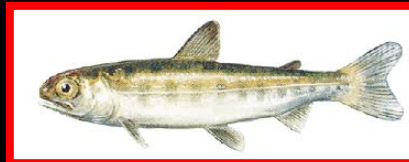
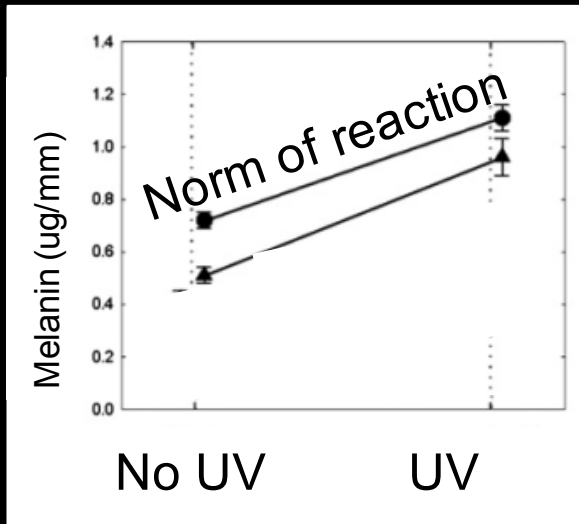




# Genetic Assimilation

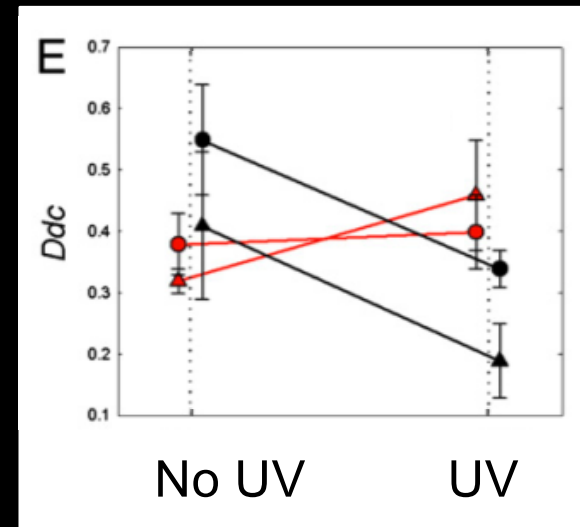


# Assimilation of Daphnia Pigmentation Response



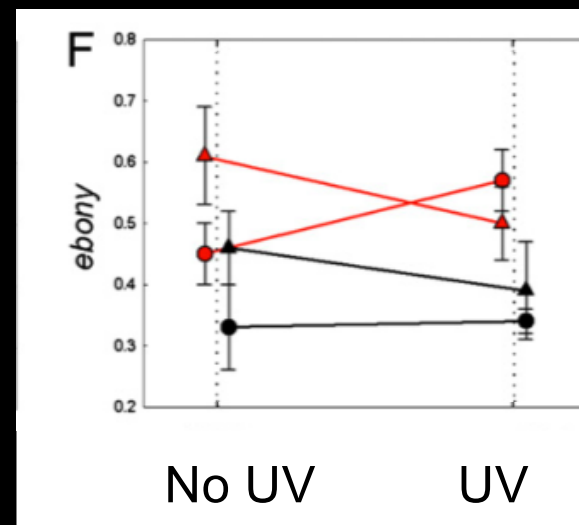
Fishless Lake 1 ▲  
 Lake 2 ●  
 w/ Fish Lake 3 ▲  
 Lake 4 ●

## *Dopa-decarboxylase*



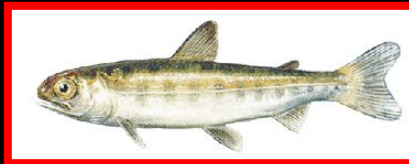
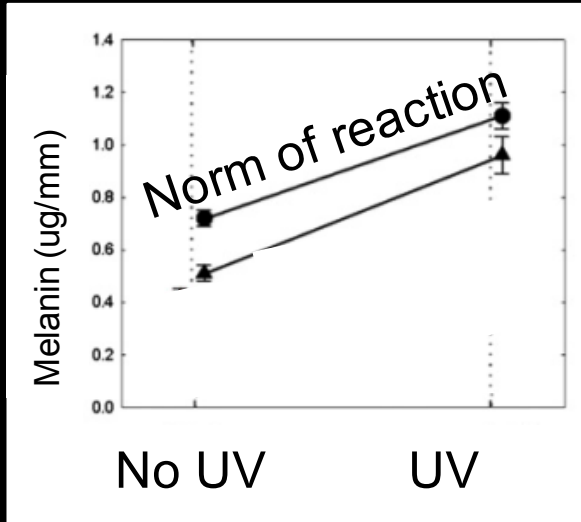
Genetic  
 Assimilation  
 of gene  
 expression  
 plasticity

## *ebony* (melanin pathway)

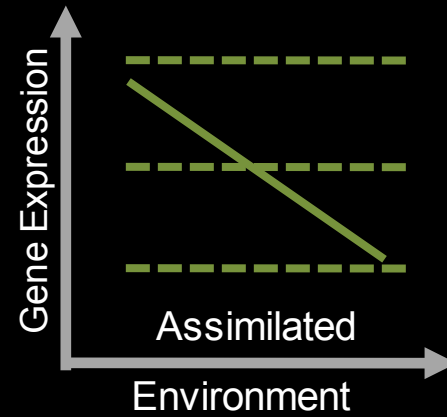


Novel  
 Constitutive  
 gene  
 expression

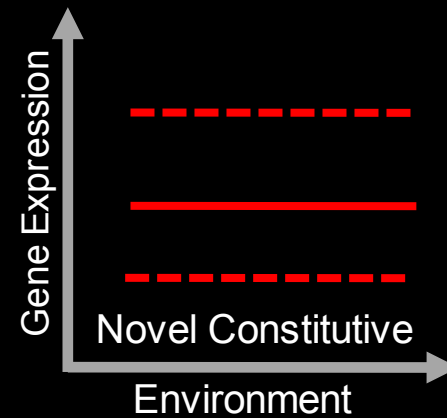
# Assimilation of Daphnia Pigmentation Response



- Fishless Lake 1 ▲
- Lake 2 ●
- w/ Fish Lake 3 ▲
- Lake 4 ●



Genetic Assimilation of gene expression plasticity



Novel Constitutive gene expression

# Appropriate study systems

- 1) Quantifiable Plastic Phenotype
- 2) Ancestral Phenotype that exhibits plasticity &  
Derived Population(s) w/ fixed phenotype
- 3) Ability to induce plasticity in a controlled setting
- 4) Genomic Resources

# Behavioral Plasticity Bees

Age Polyethism

Aggression

Nurse

Guard

Forager



African Bees

Aggression

Nurse

Guard

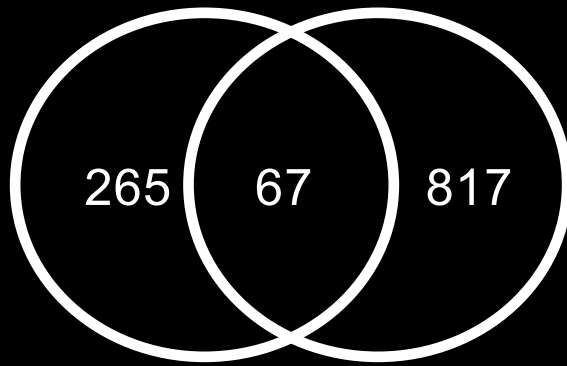
Forager

# Genetic Assimilation of Aggression

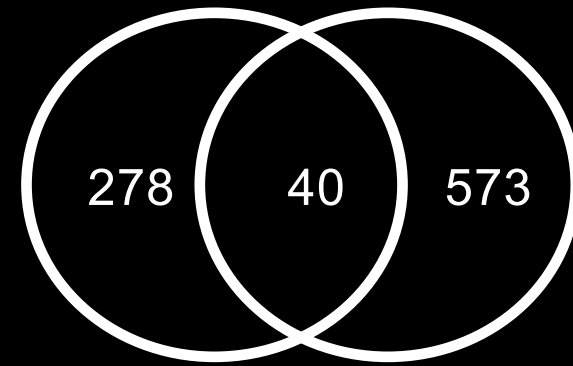
Decreased expression with aggression

Increased expression with aggression

## Age Polyethism



AHB<EHB old<young

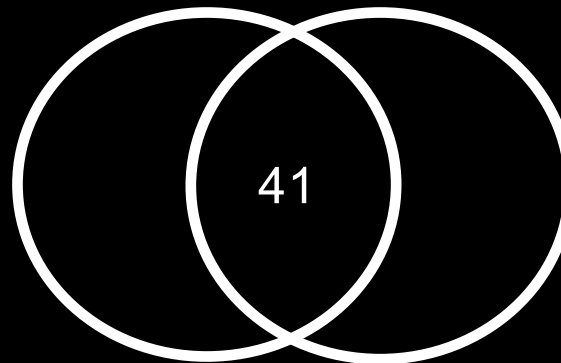


AHB>EHB old>young

## Hormone Treatment

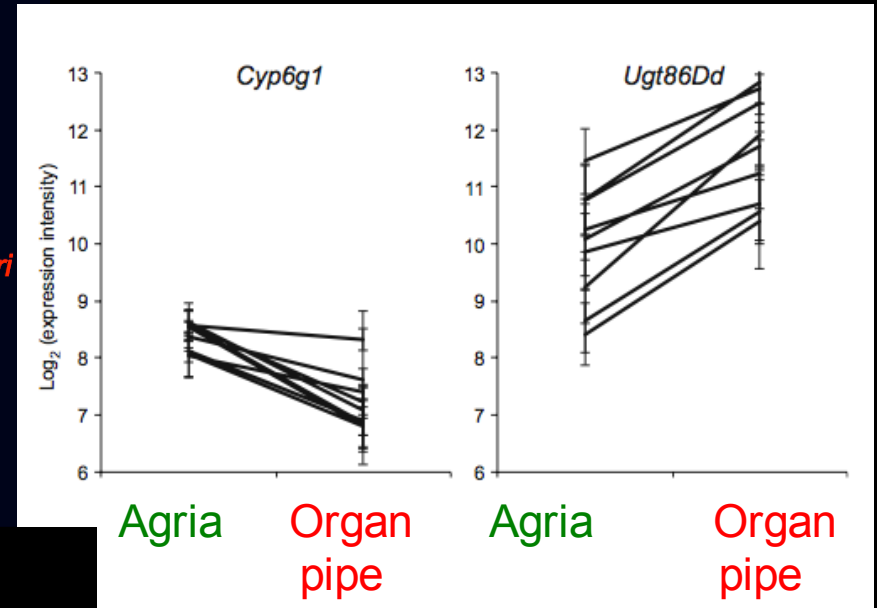
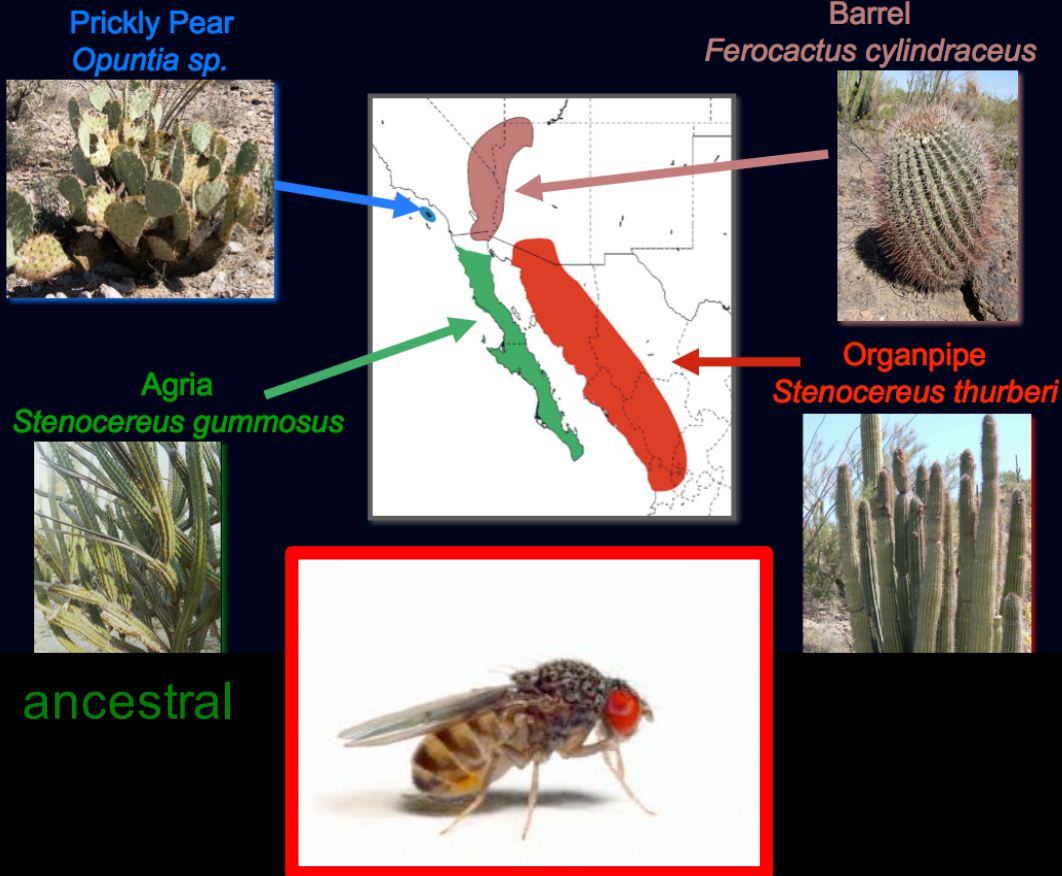
Species

Phermone



# Appropriate study systems (QTL)

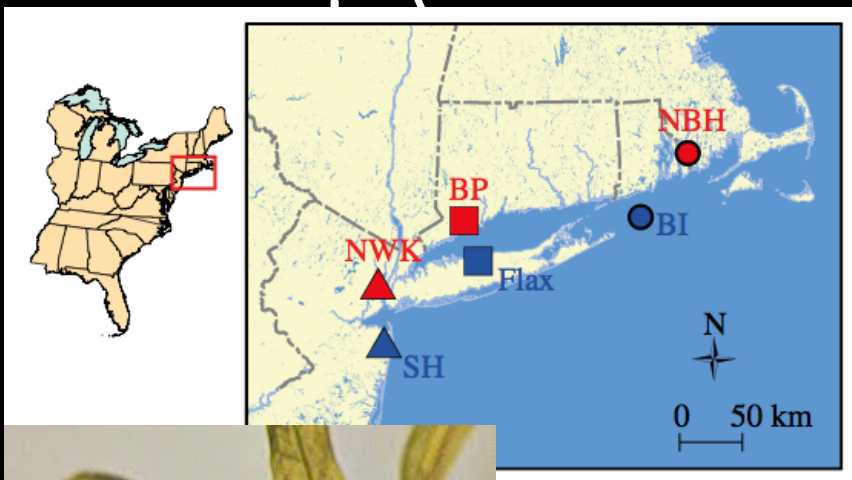
## Distribution of host use in *D. mojavensis*



9 isogenic lines reveal  
intra-specific variation

Effect	p<0.01
Cactus	2066
Line	1070
LineXCactus	667

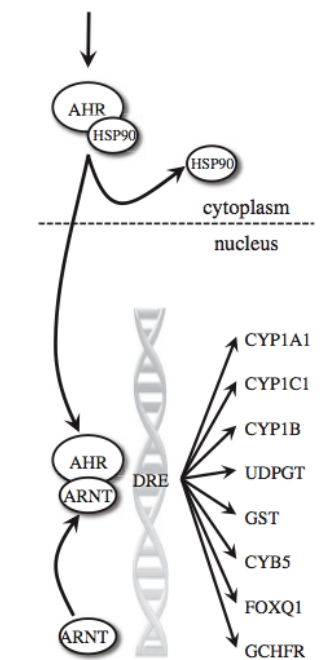
# Appropriate study systems (candidate genes)



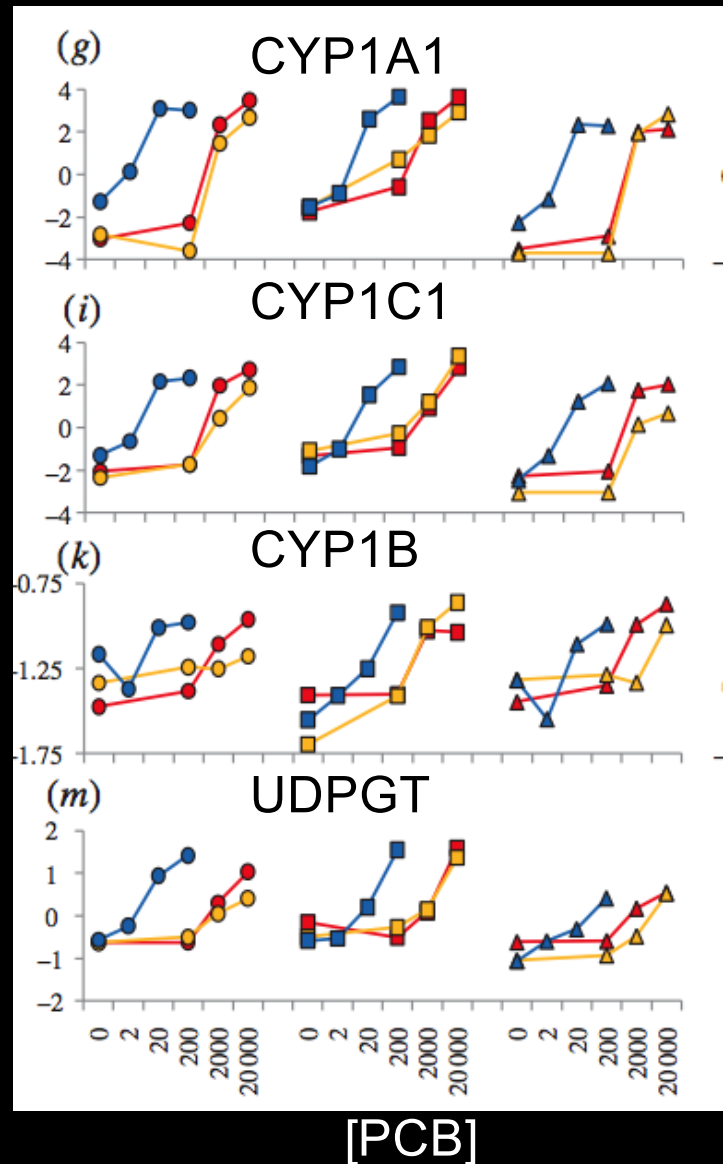
*Fundulus*

toxin resistant populations  
toxin sensitive populations

Dioxins/PCBs



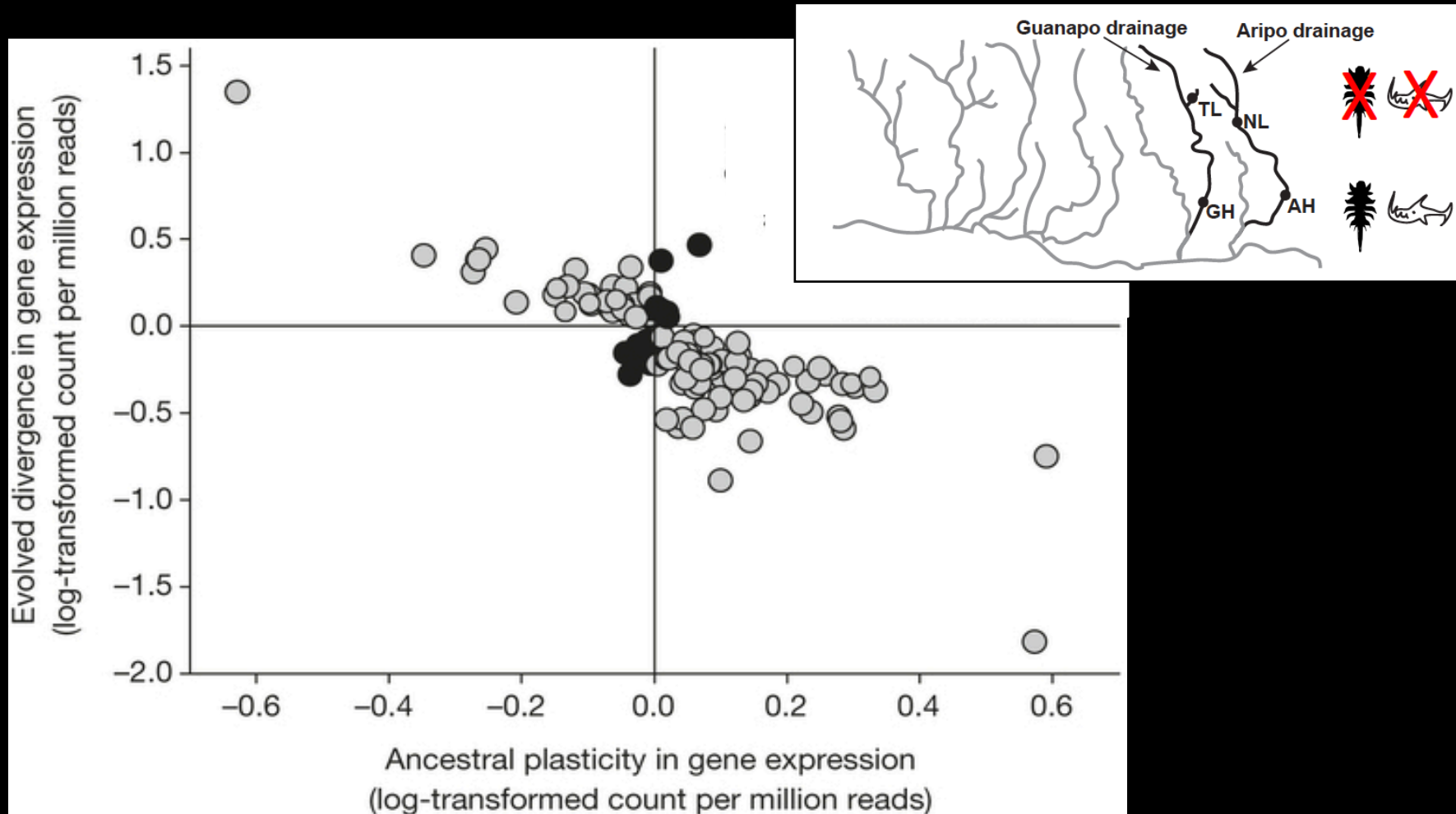
NWK/SH BP/Flax NBH/BI



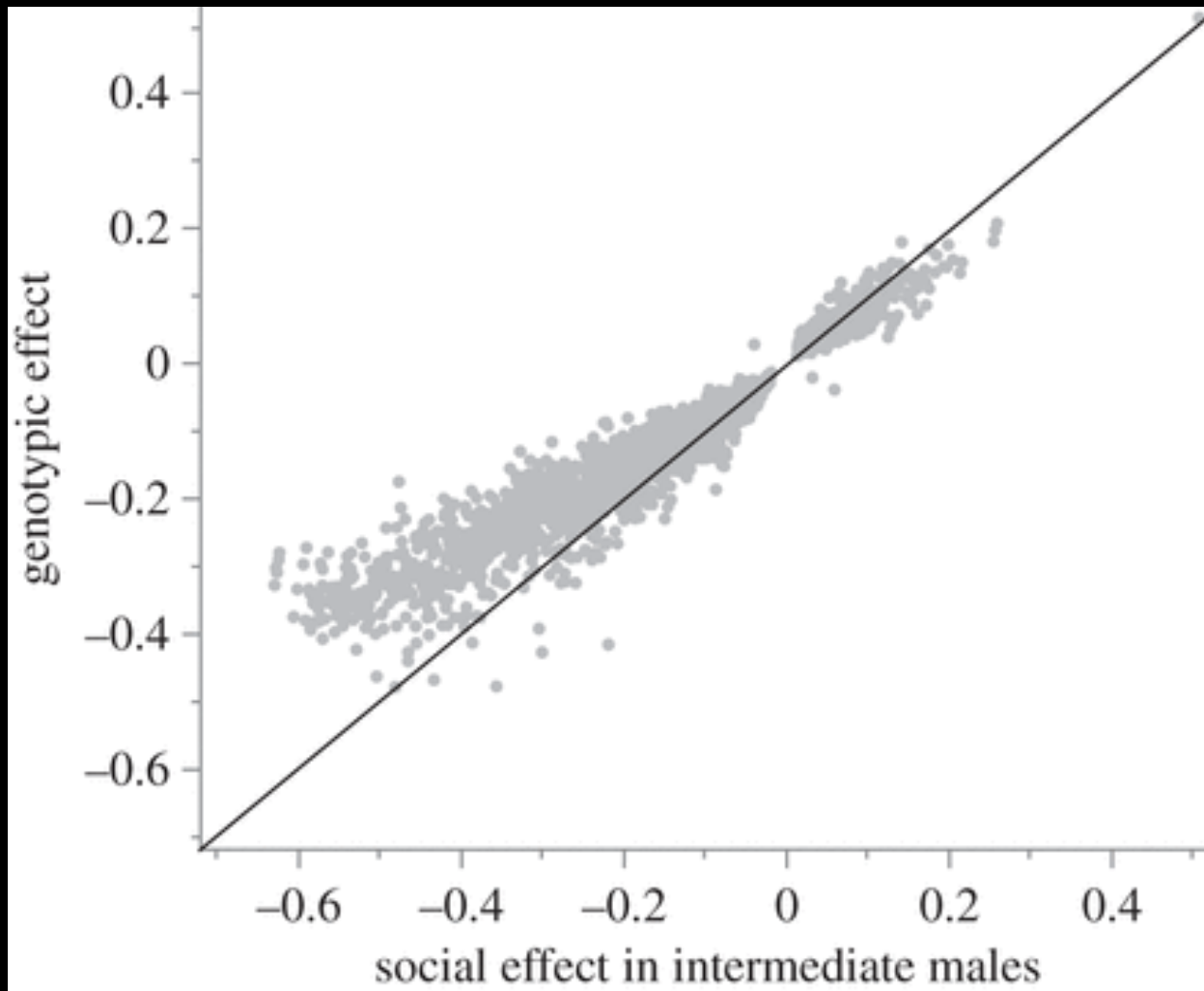
Whitehead et al (2012) PRS



# Opposite direction of plasticity in gene expression and the evolution of adaptive gene expression



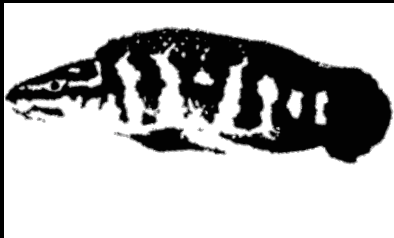
# Parallel plastic and genomic influence on gene expression associated with Alternate Reproductive tactics in sailfin Mollies.



Fraser etl al 2014 PRS

# Sex-biased Behaviors

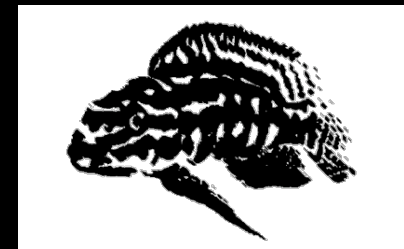
Conventional



*J. transcriptus*



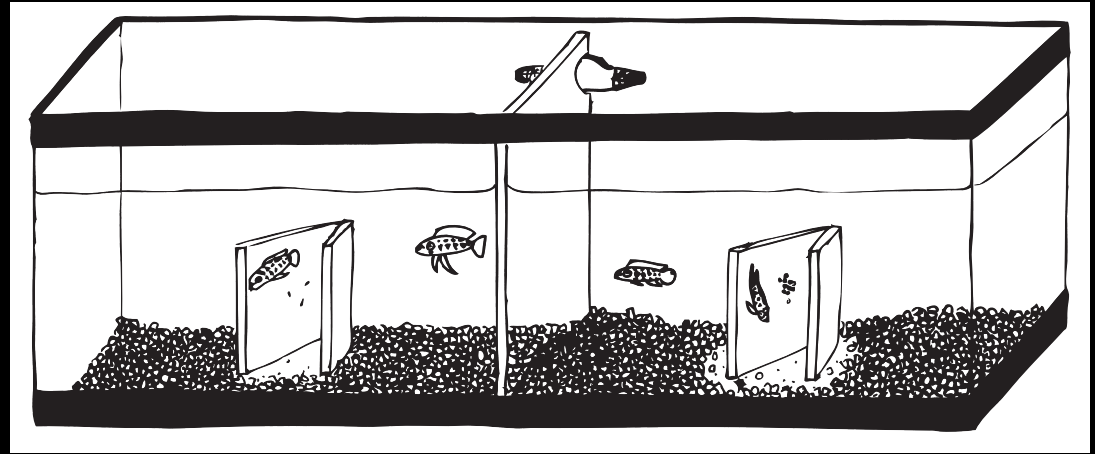
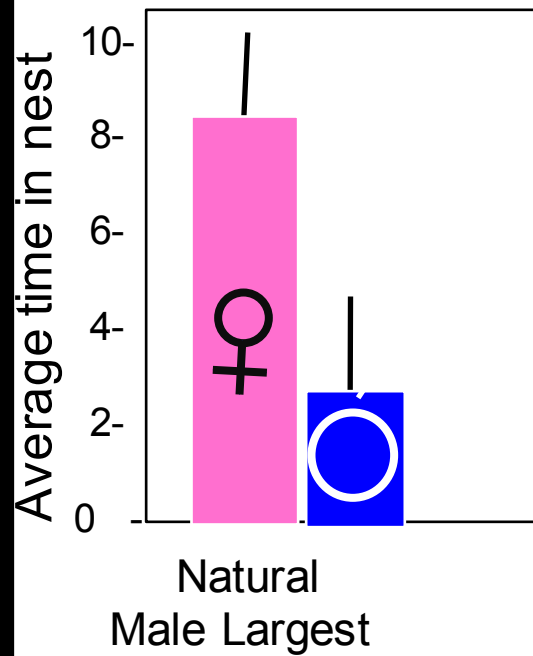
Reversed



*J. marlieri*

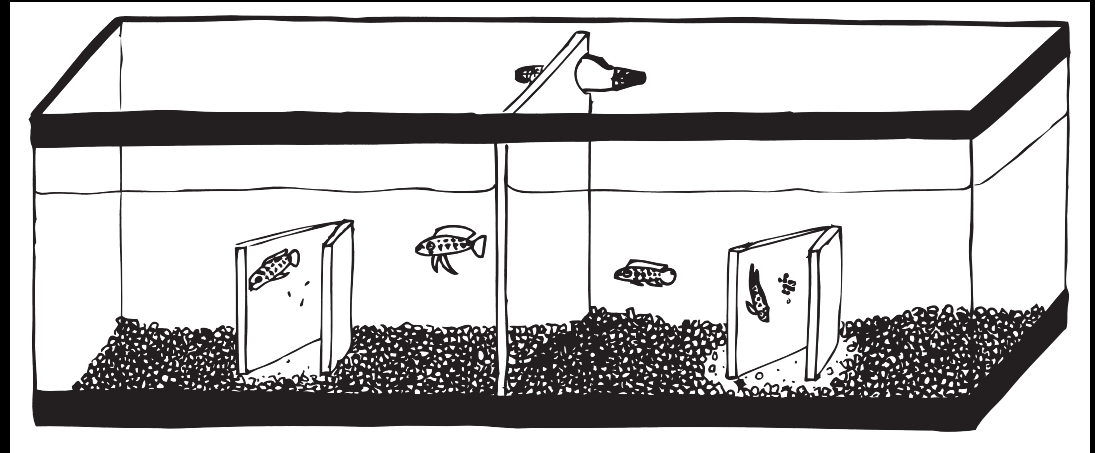
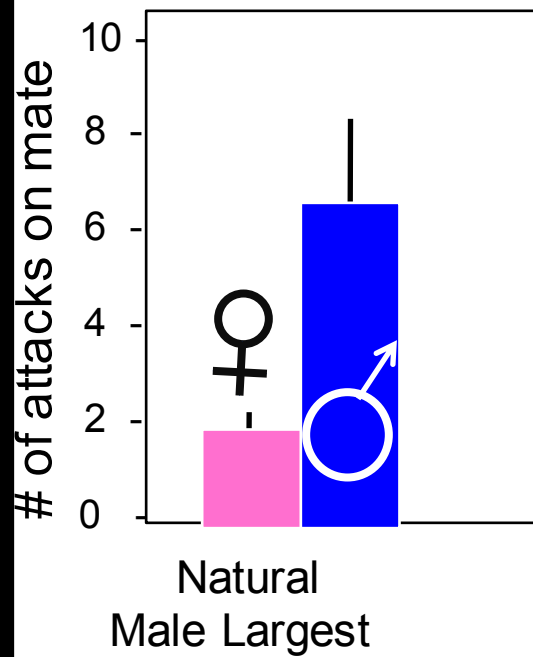
# Sex-biased Behaviors

*J. transcriptus*



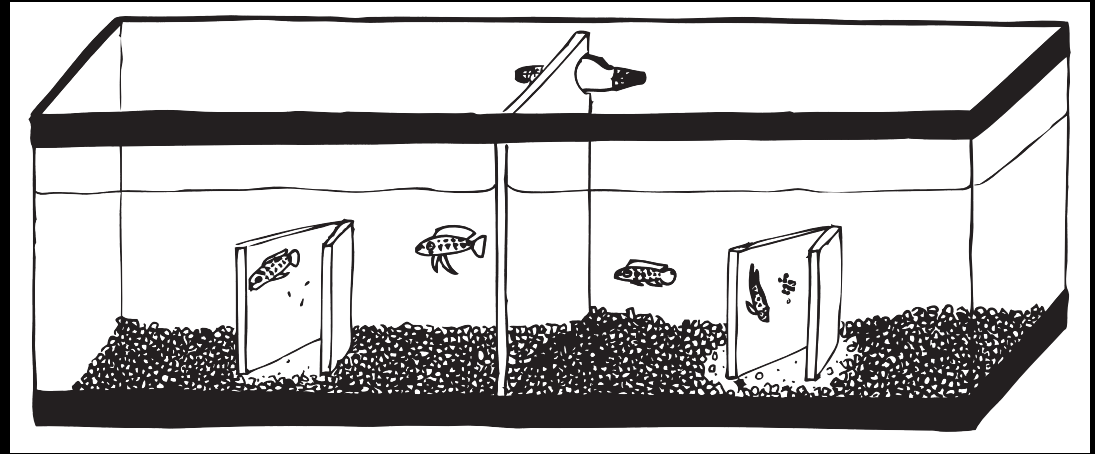
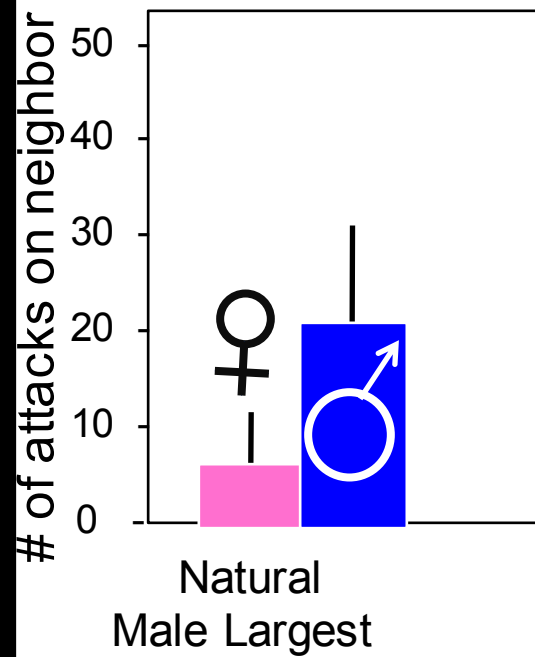
# Sex-biased Behaviors

*J. transcriptus*



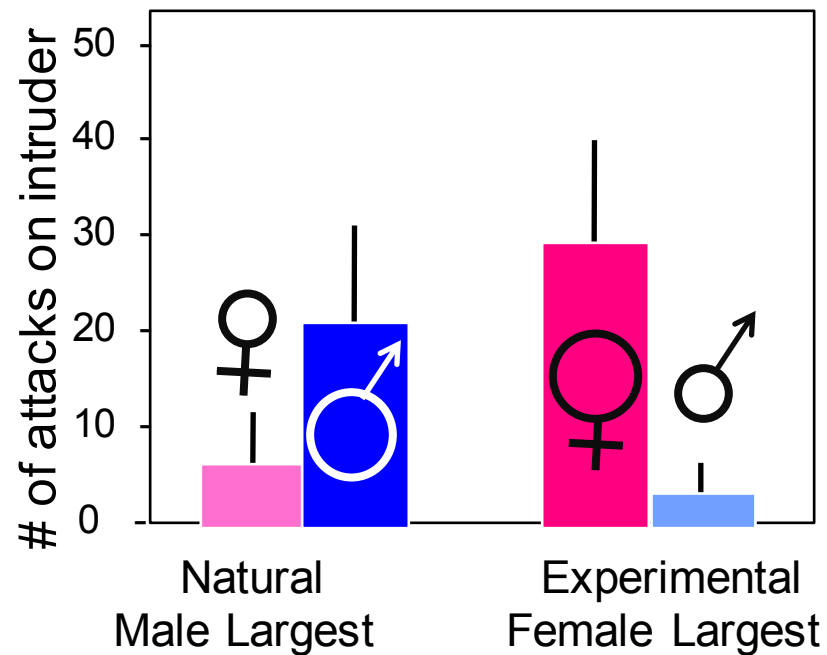
# Sex-biased Behaviors

*J. transcriptus*



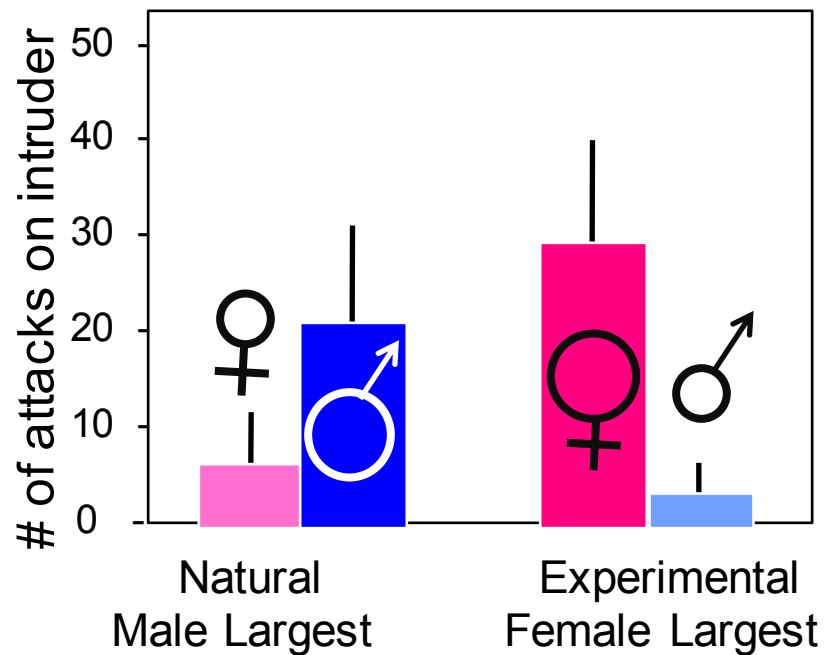
# Plasticity for Sex-biased Behaviors

*J. transcriptus*

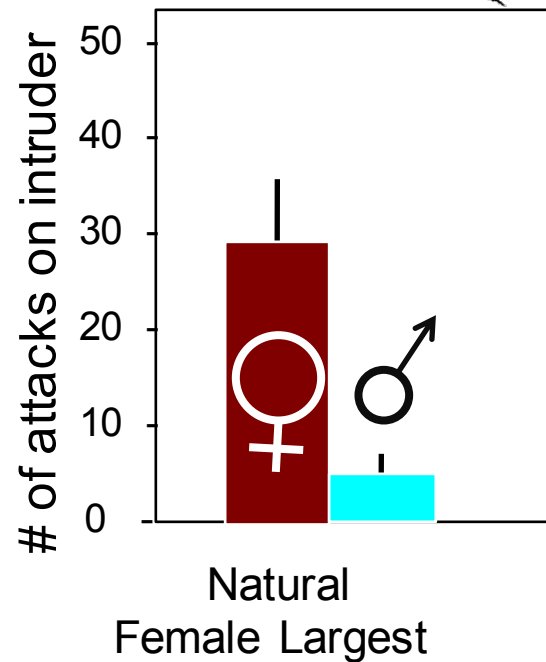
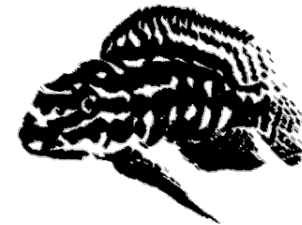


# Plasticity for Sex-biased Behaviors

*J. transcriptus*

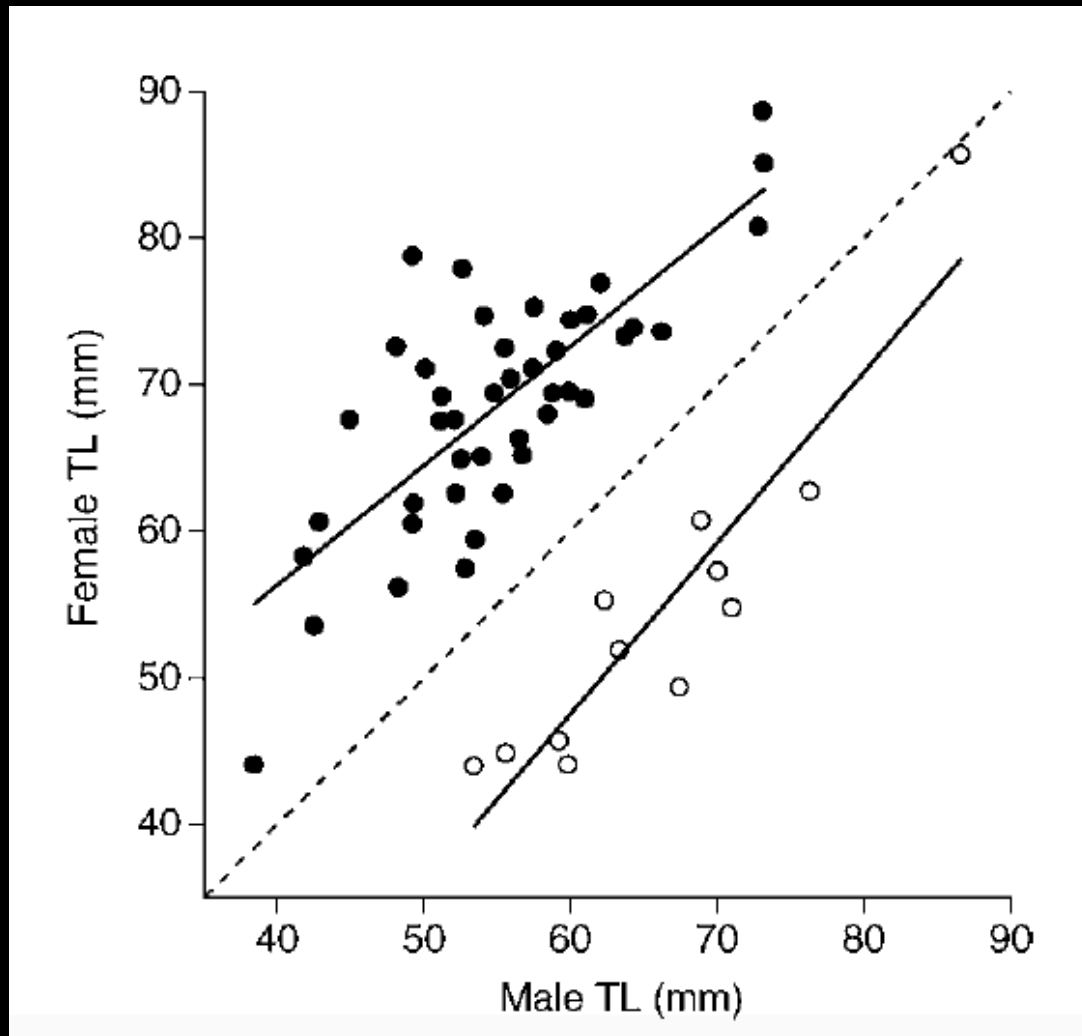


*J. marlieri*



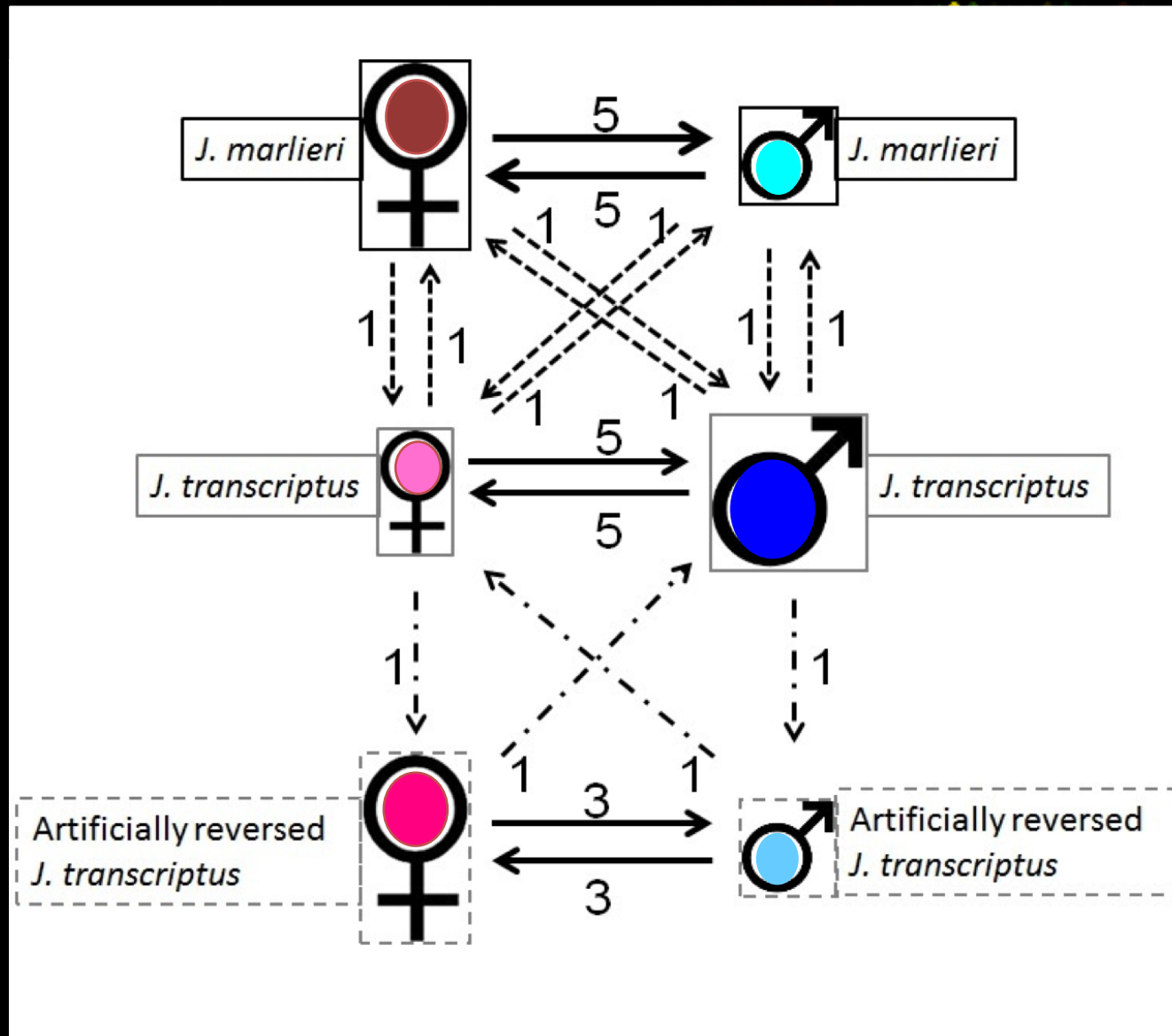


*J. ornatus* exhibits both conventional and reversed pairings in the field.



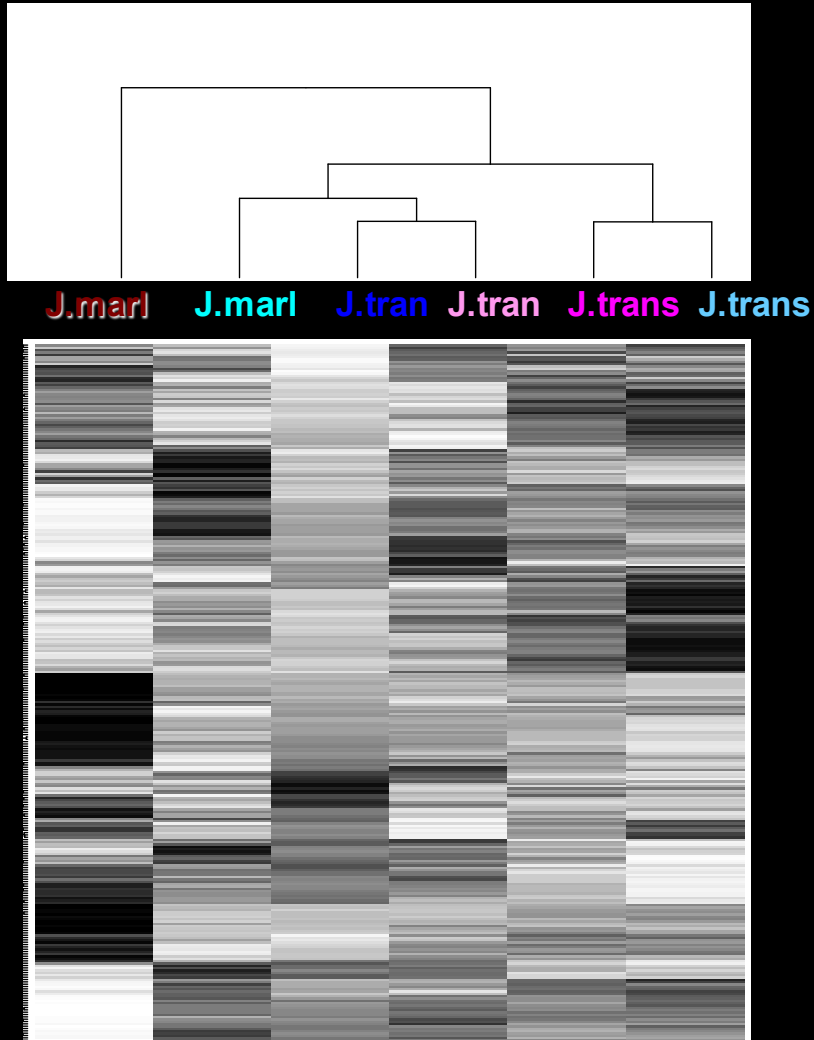
Awata & Khoda 2004  
Behaviour 141:1135-1149

# Experimental Design



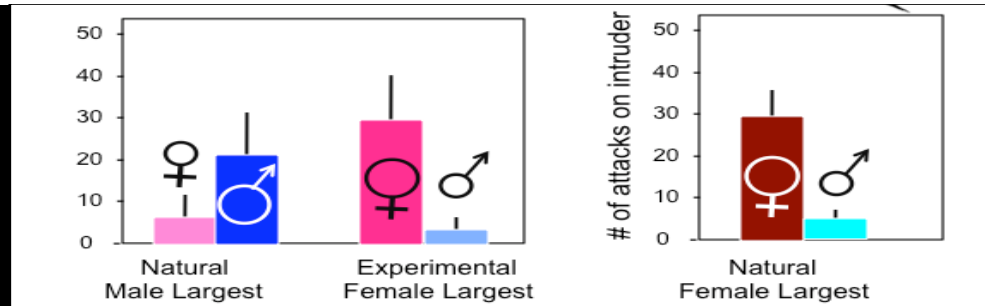
# Gene Expression Profile

---

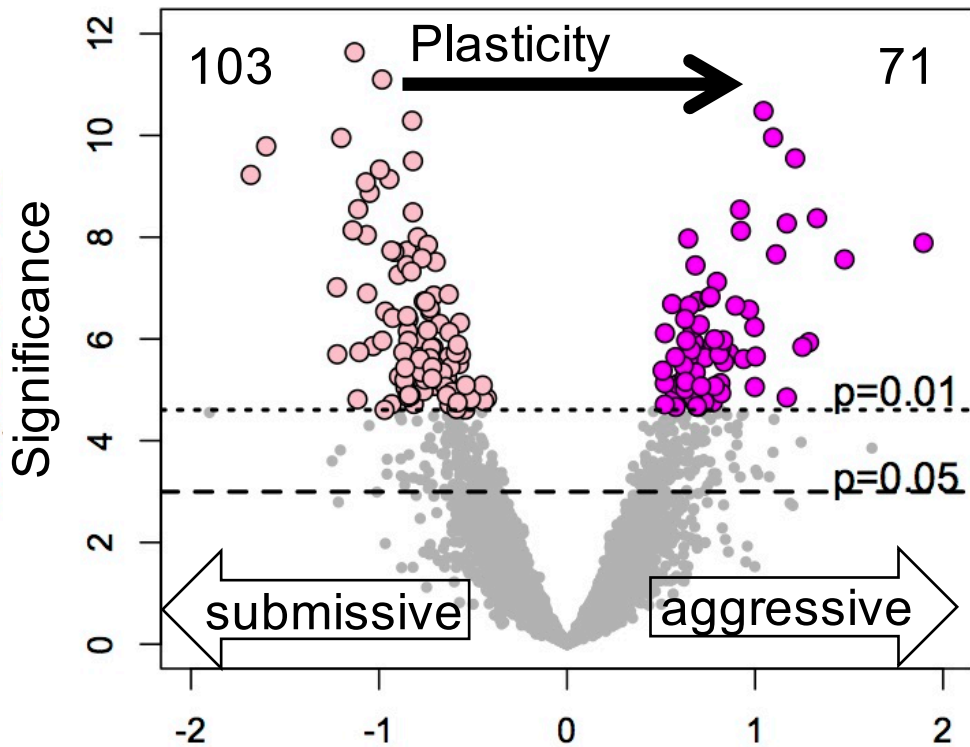


regulated genes  $p < 0.01$

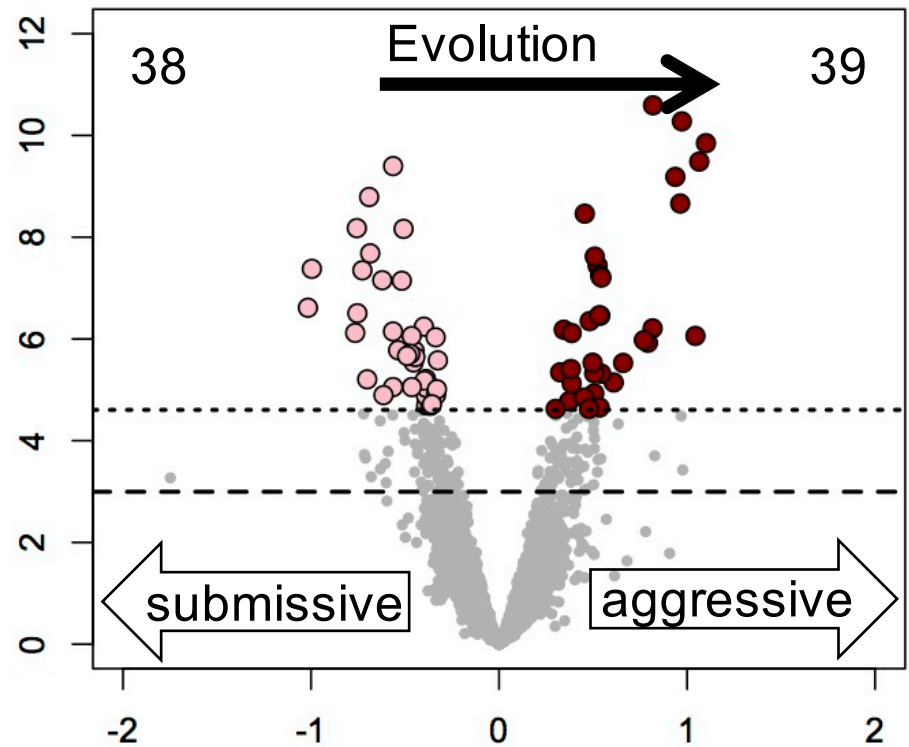
# Cost of Plasticity



## Aggressive Female Phenotype

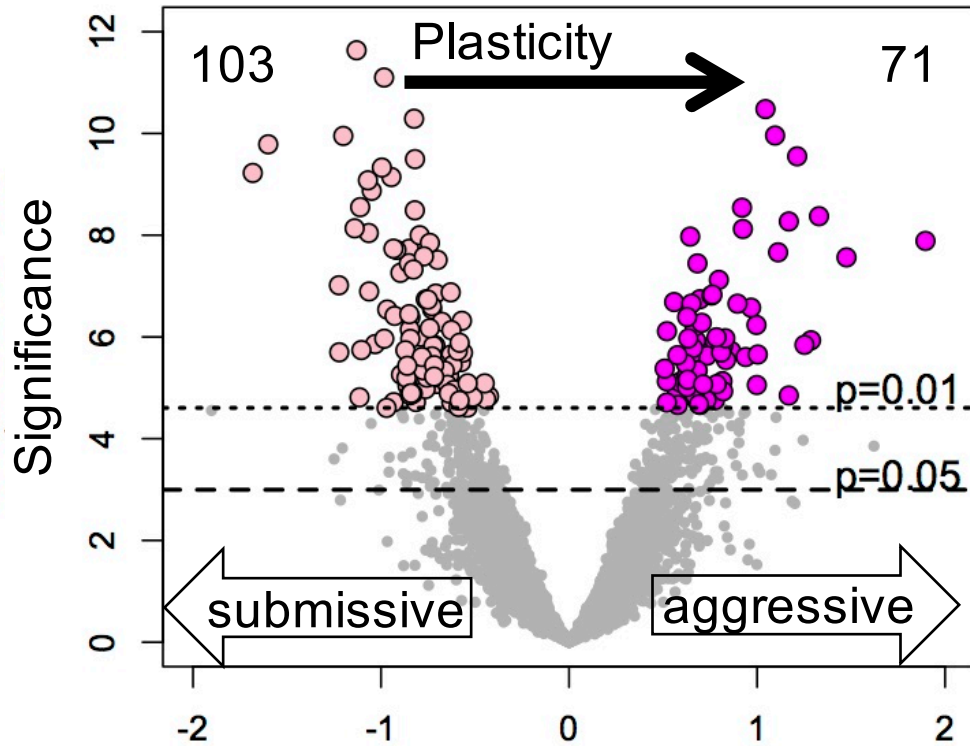
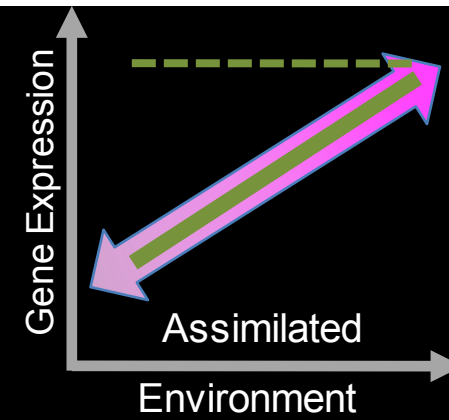


Relative Expression Level

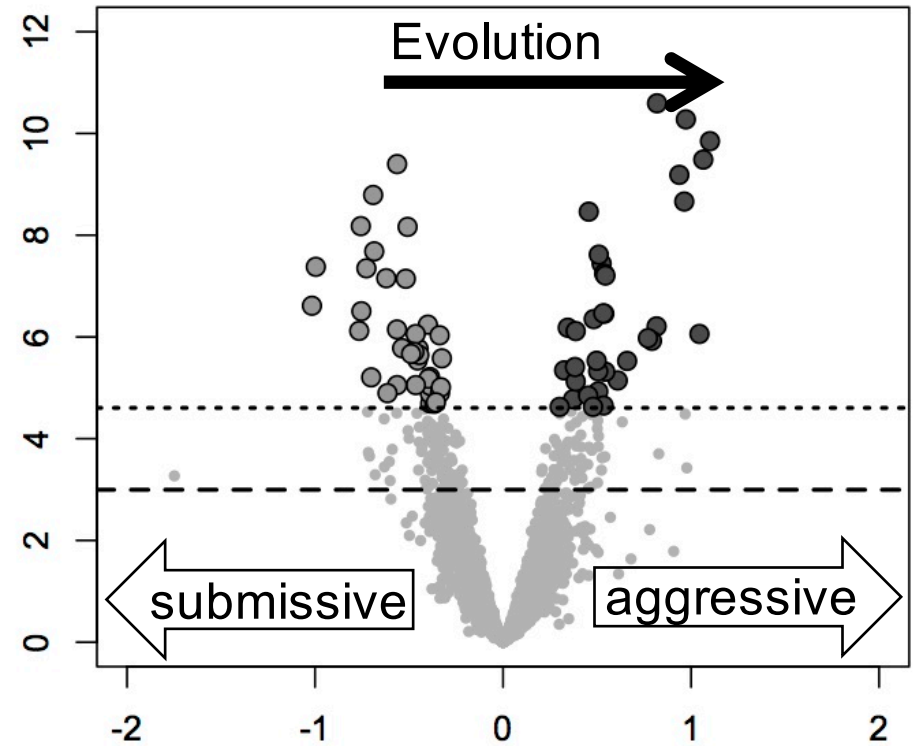


Relative Expression Level

# Aggressive Female Phenotype

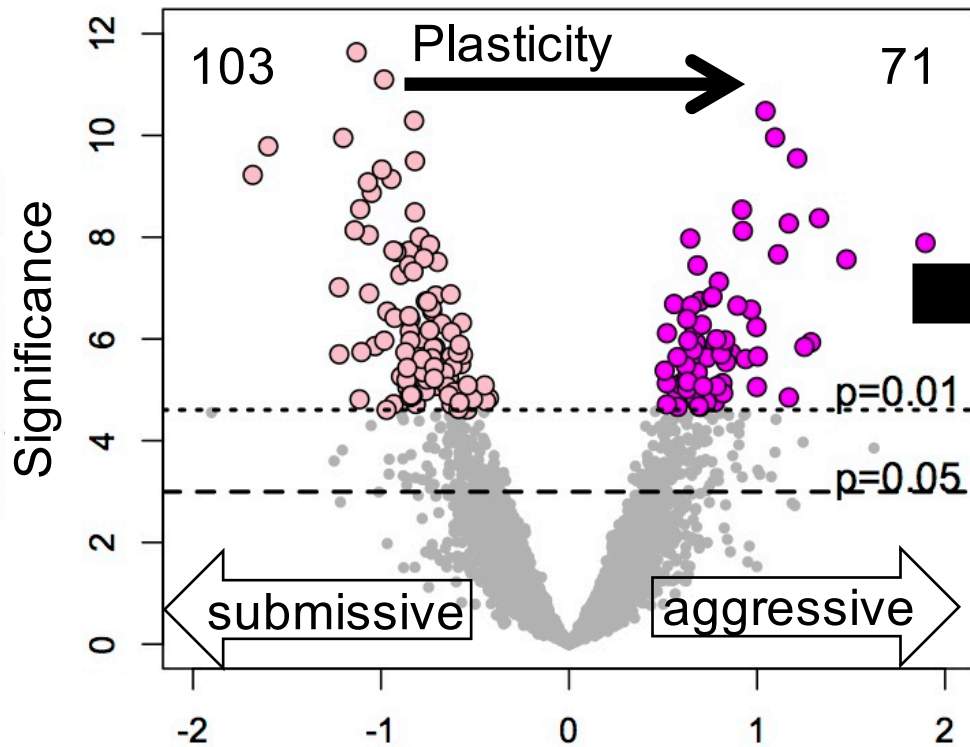
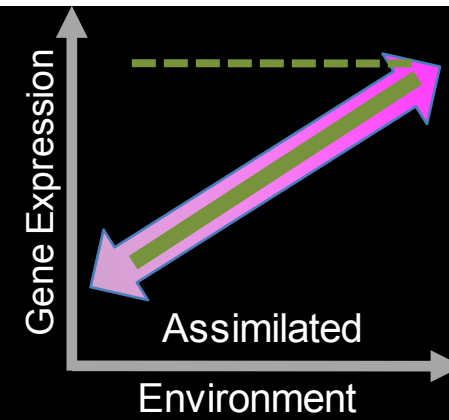


Relative Expression Level

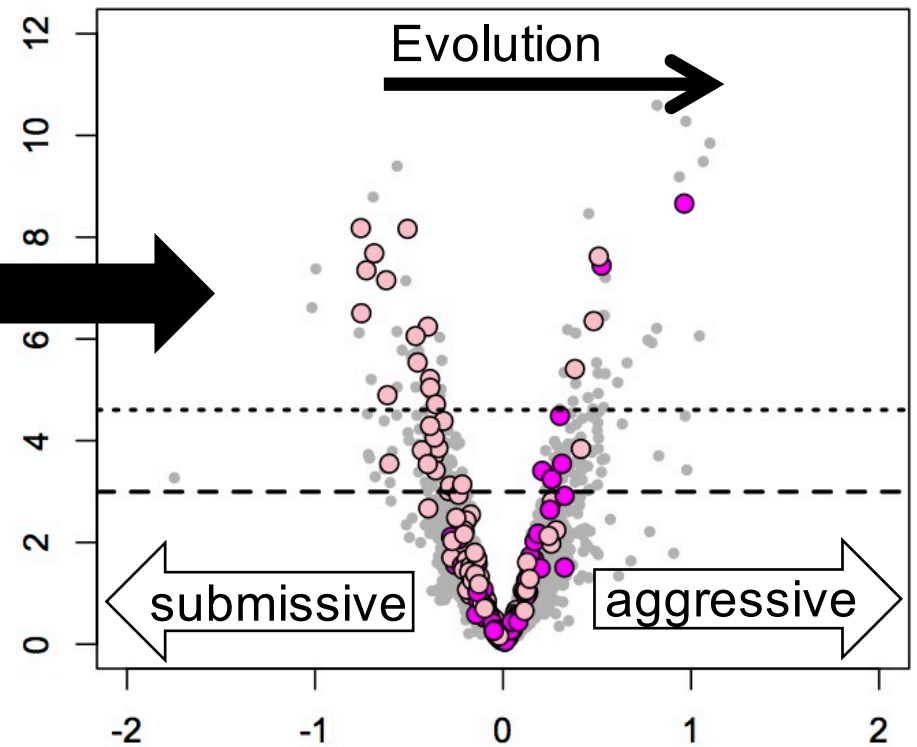


Relative Expression Level

# Aggressive Female Phenotype



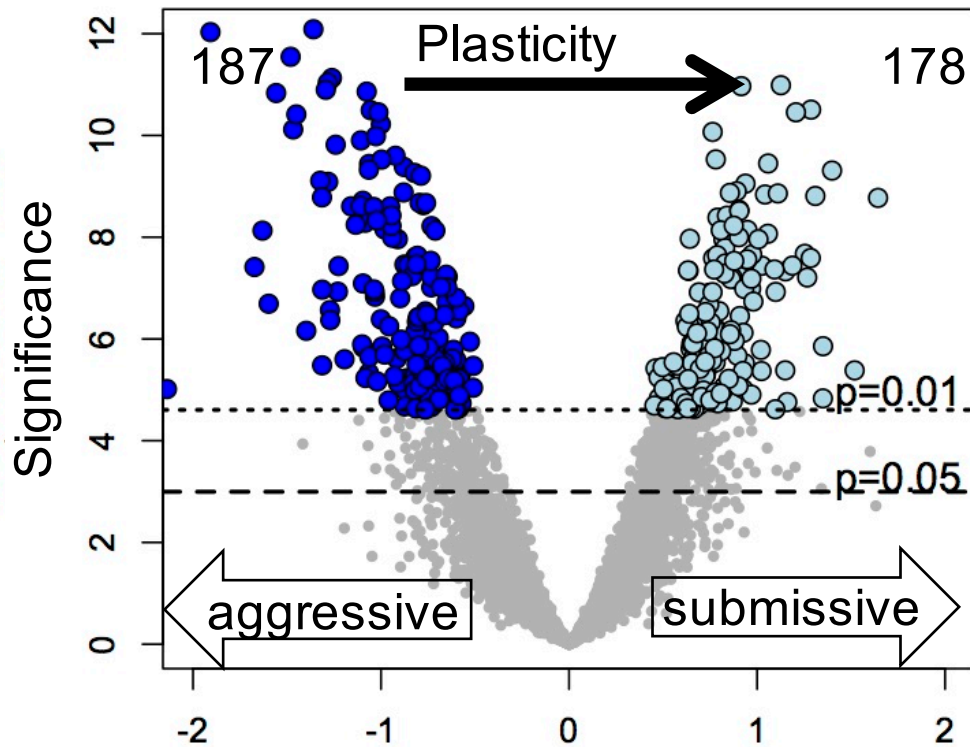
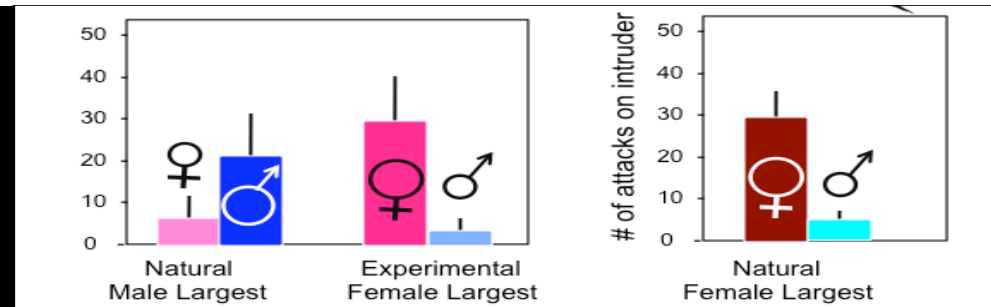
Relative Expression Level



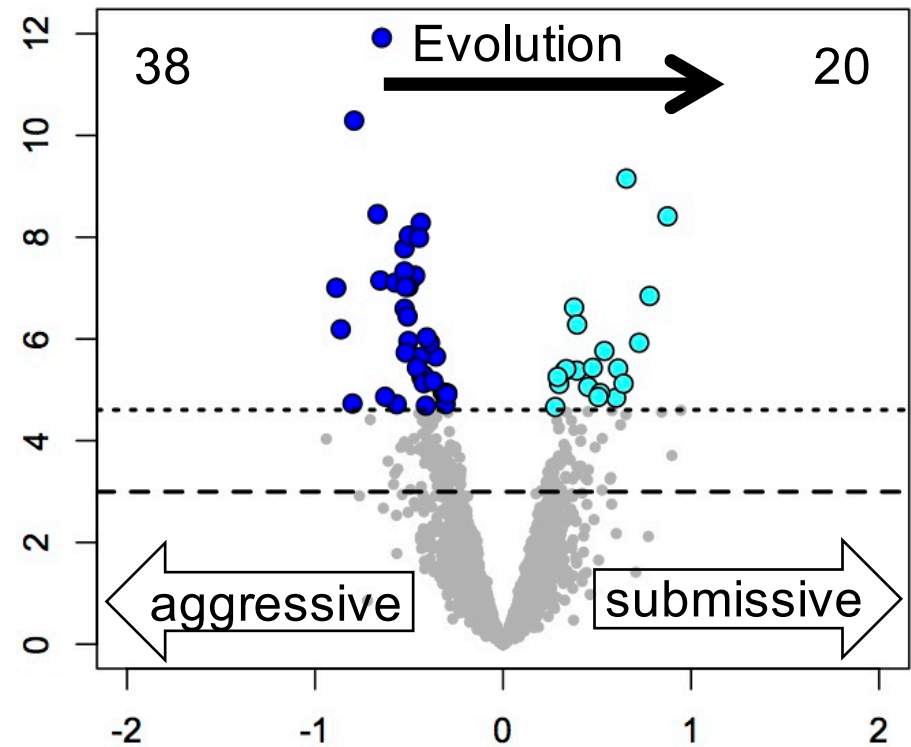
Relative Expression Level

# Cost of Plasticity

## Submissive Male Phenotype



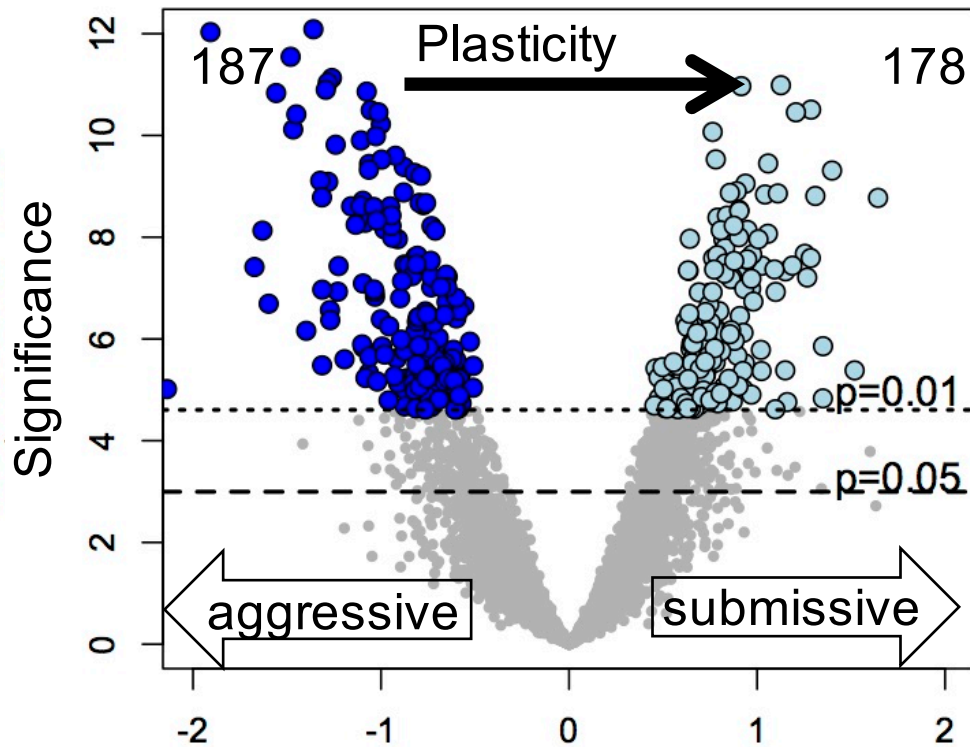
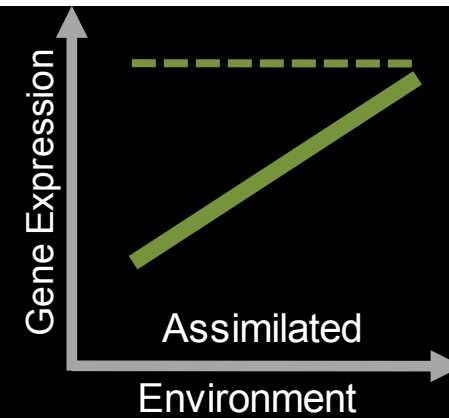
Relative Expression Level



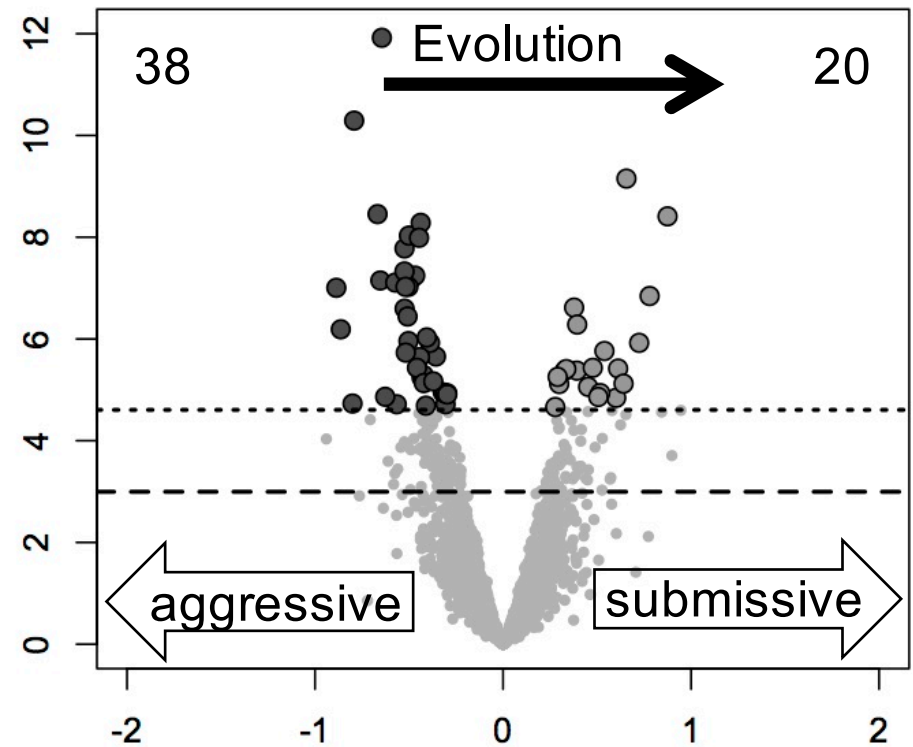
Relative Expression Level

# Cost of Plasticity

## Submissive Male Phenotype



Relative Expression Level

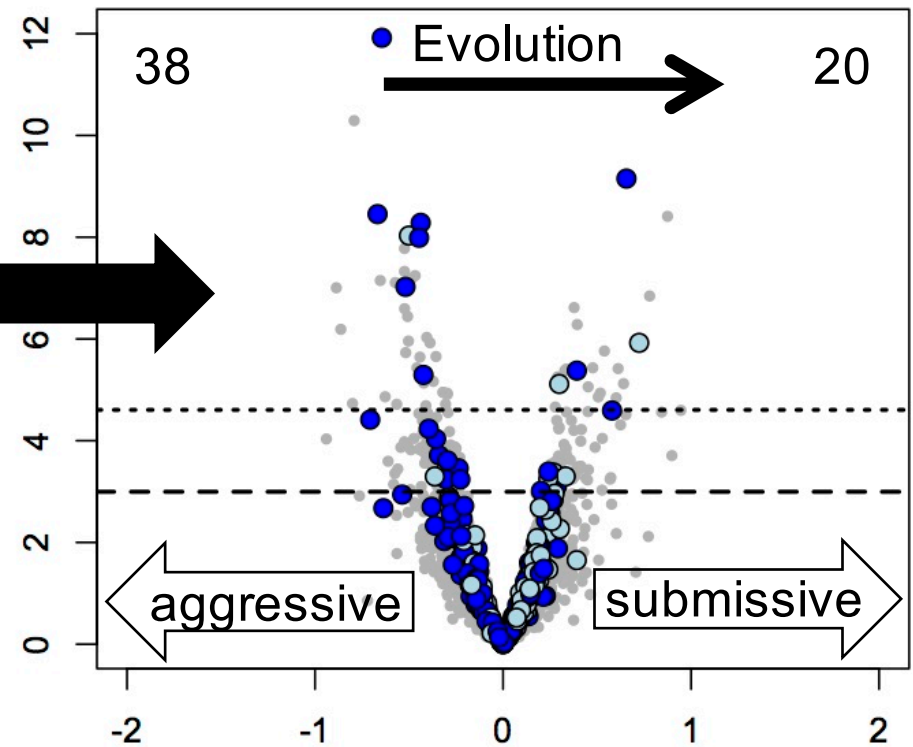
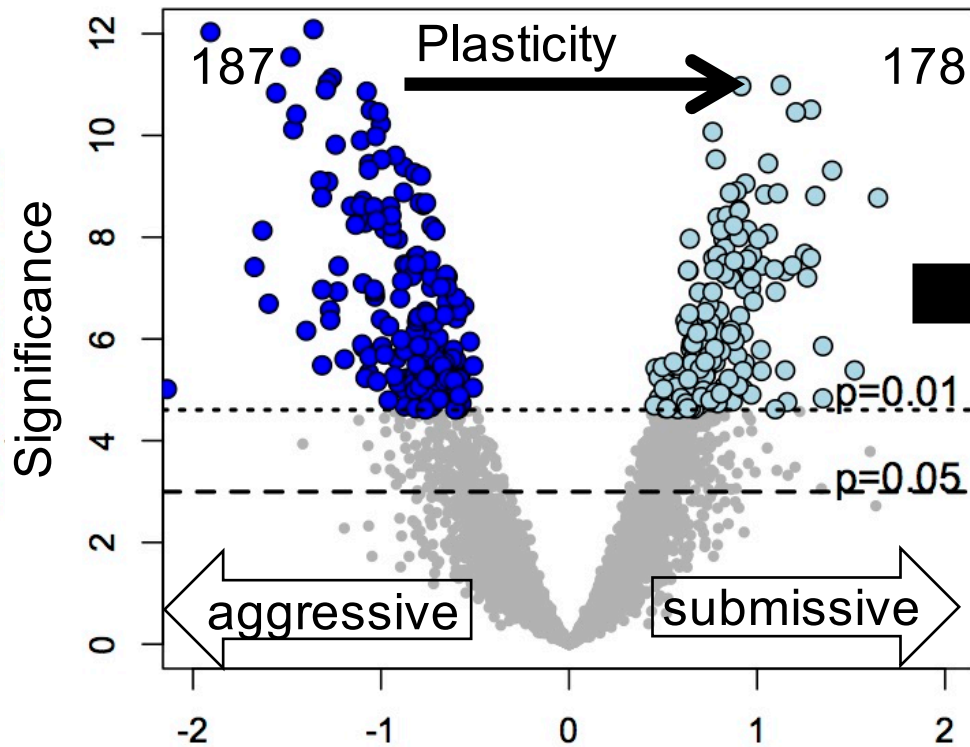
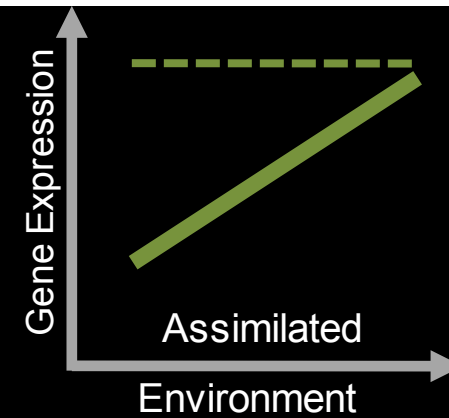


Relative Expression Level



# Cost of Plasticity

## Submissive Male Phenotype



Relative Expression Level

Relative Expression Level

# What can genomic studies tell us of Molecular Mechanism?

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What patterns of evolved gene expression plasticity underlie evolved phenotypic plasticity?

Do seemingly parallel cases of evolved plasticity rely on the same mechanisms?

Are different mechanisms used in specific types of evolved plasticity?

Are different types of genes predisposed different patterns of evolved plasticity?