

**Mutualism-Altruism cycles  
and Socially Mediated  
Speciation on Cellular Automata**

# *The 3 oby alleles yield 6 genotypes*

*oo*

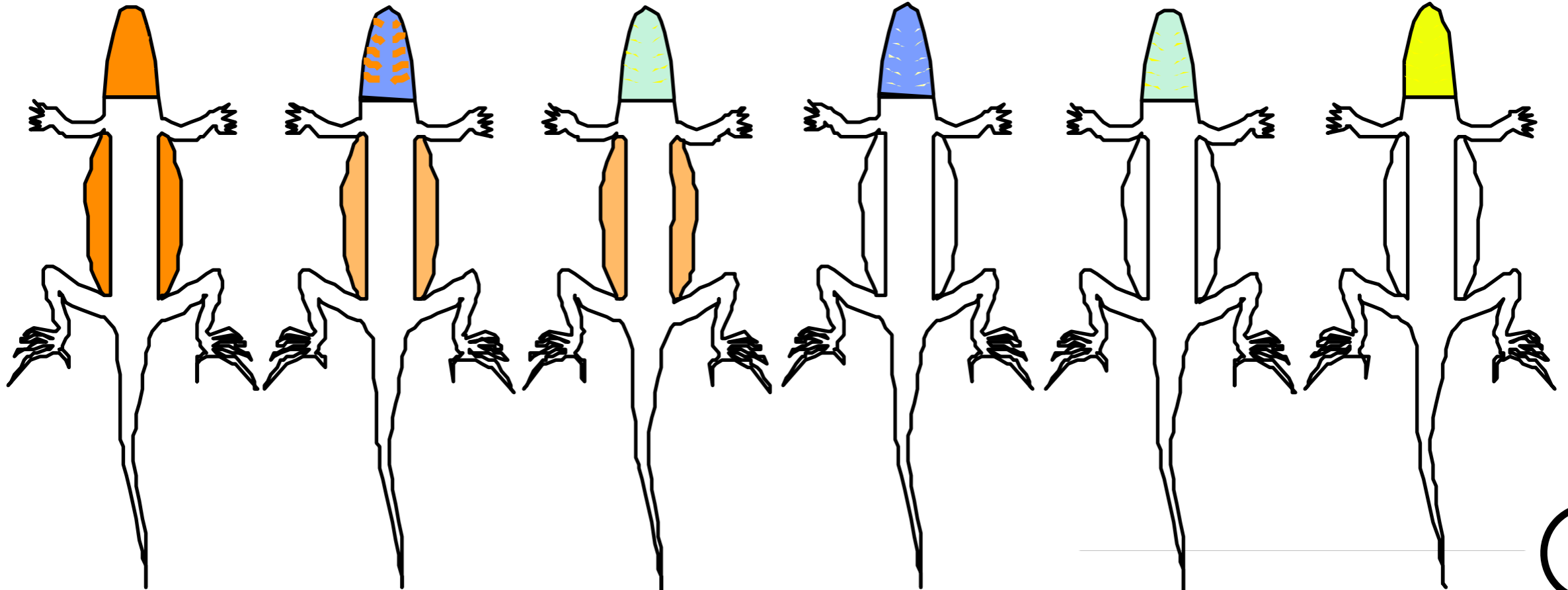
*bo*

*yo*

*bb*

*by*

*yy*



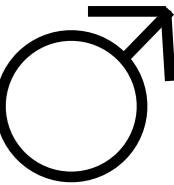
*O*



*B*



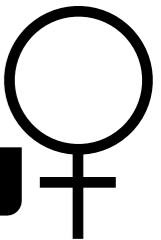
*Y*



*O*



*BY*



# Male color morph cycle



## RPS cycle

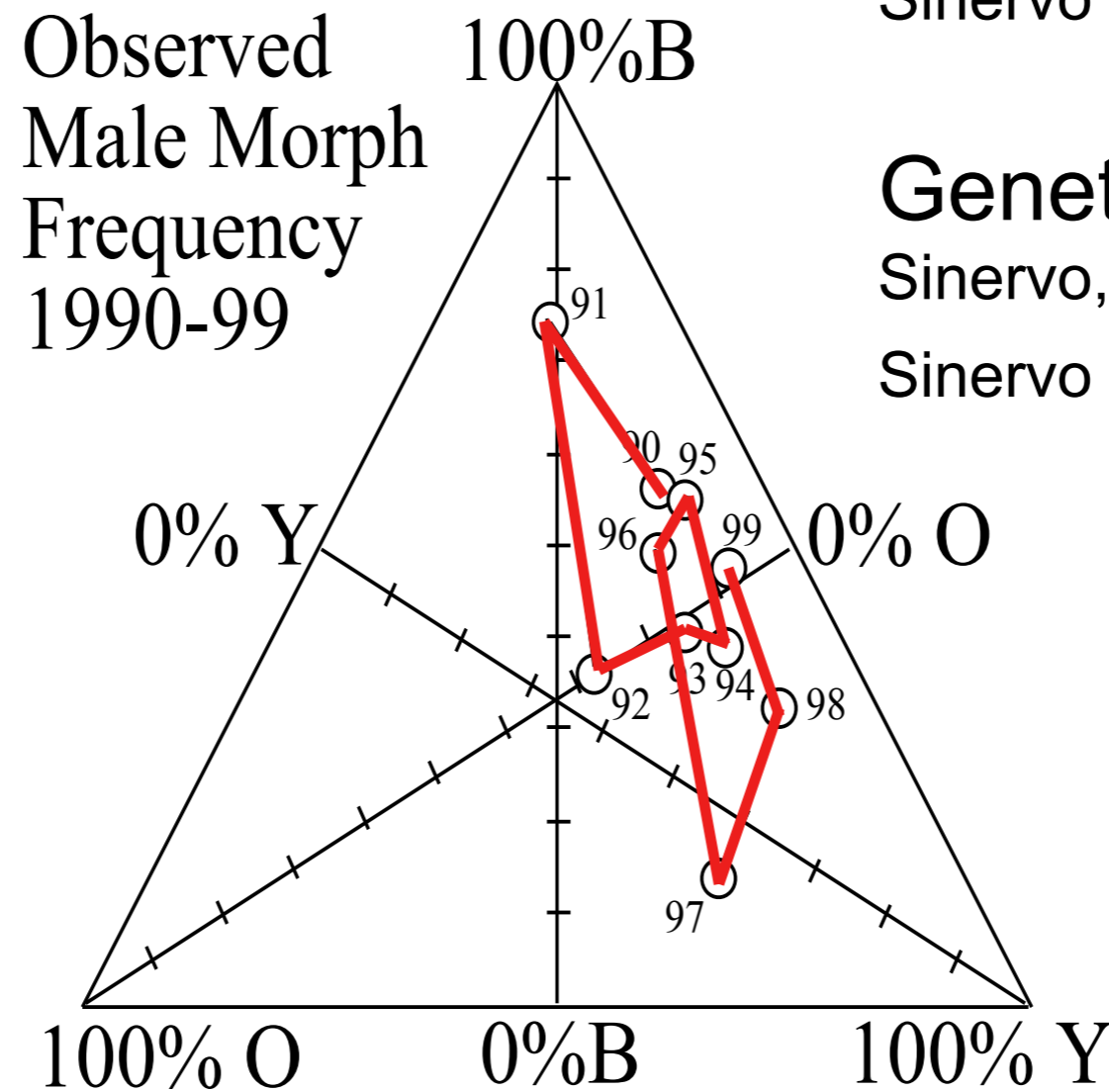
Sinervo & Lively, *Nature*, 1996

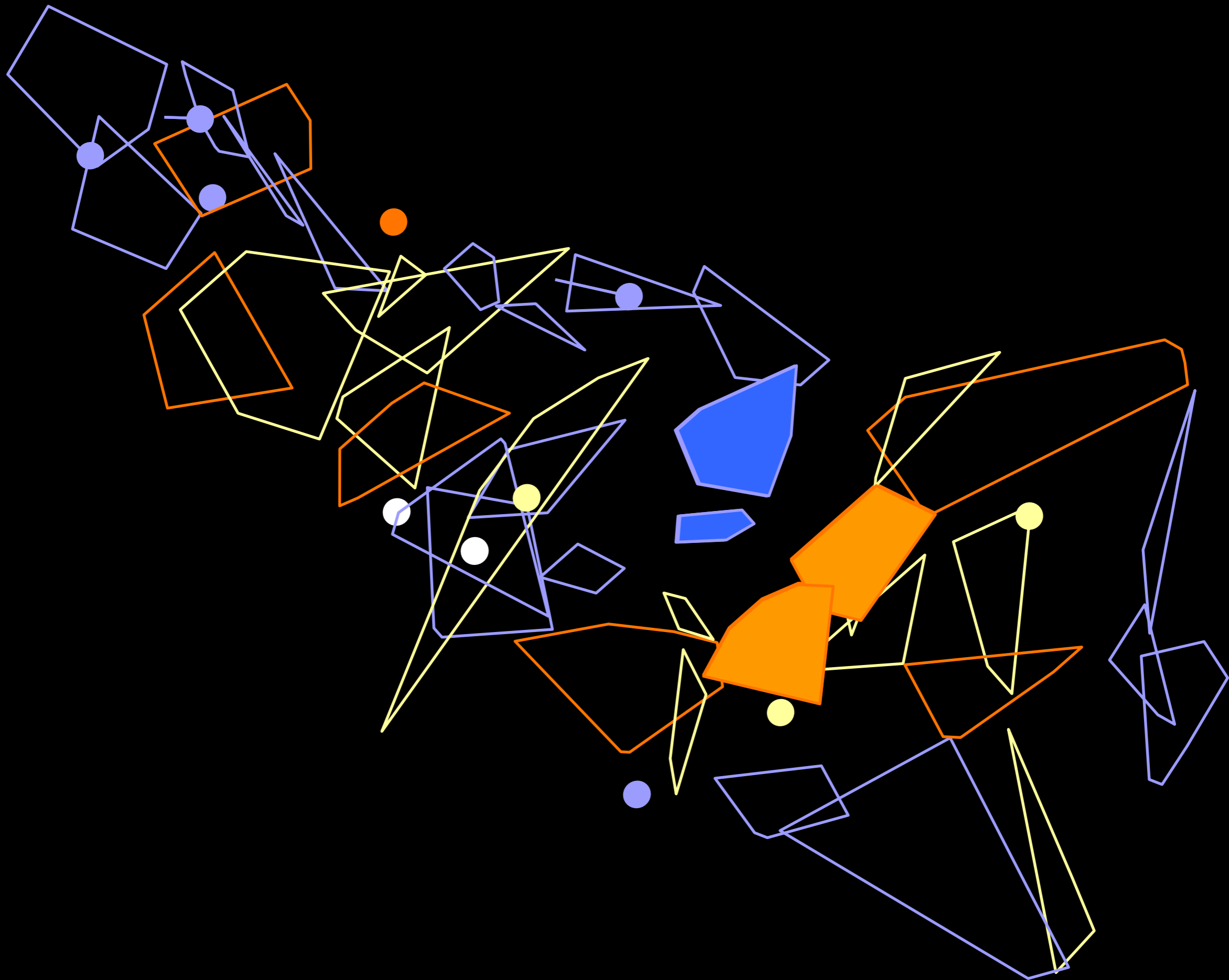
## Paternity results:

Zamudio & Sinervo, *PNAS*, 2000  
 Calsbeek & Sinervo, *PNAS*, 2003  
 Calsbeek & Sinervo, *JEB*, 2003  
 Sinervo & Clobert *Science*, 2003

## Genetics (theory & data):

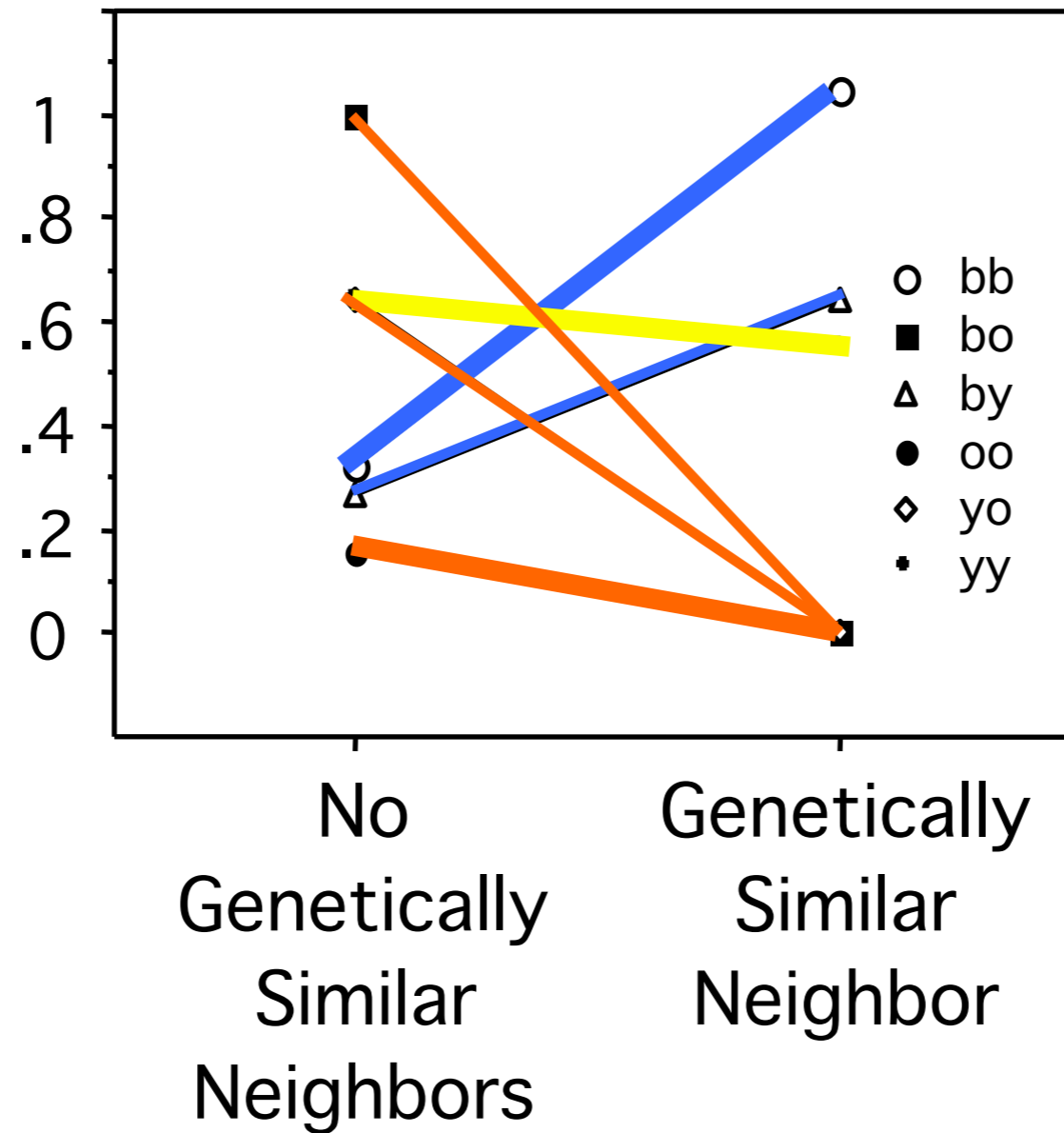
Sinervo, *Genetica*, 2001  
 Sinervo et al., *Evolution*, 2001





# *Genetic similarity and fitness*

Progeny Surviving  
to Maturity

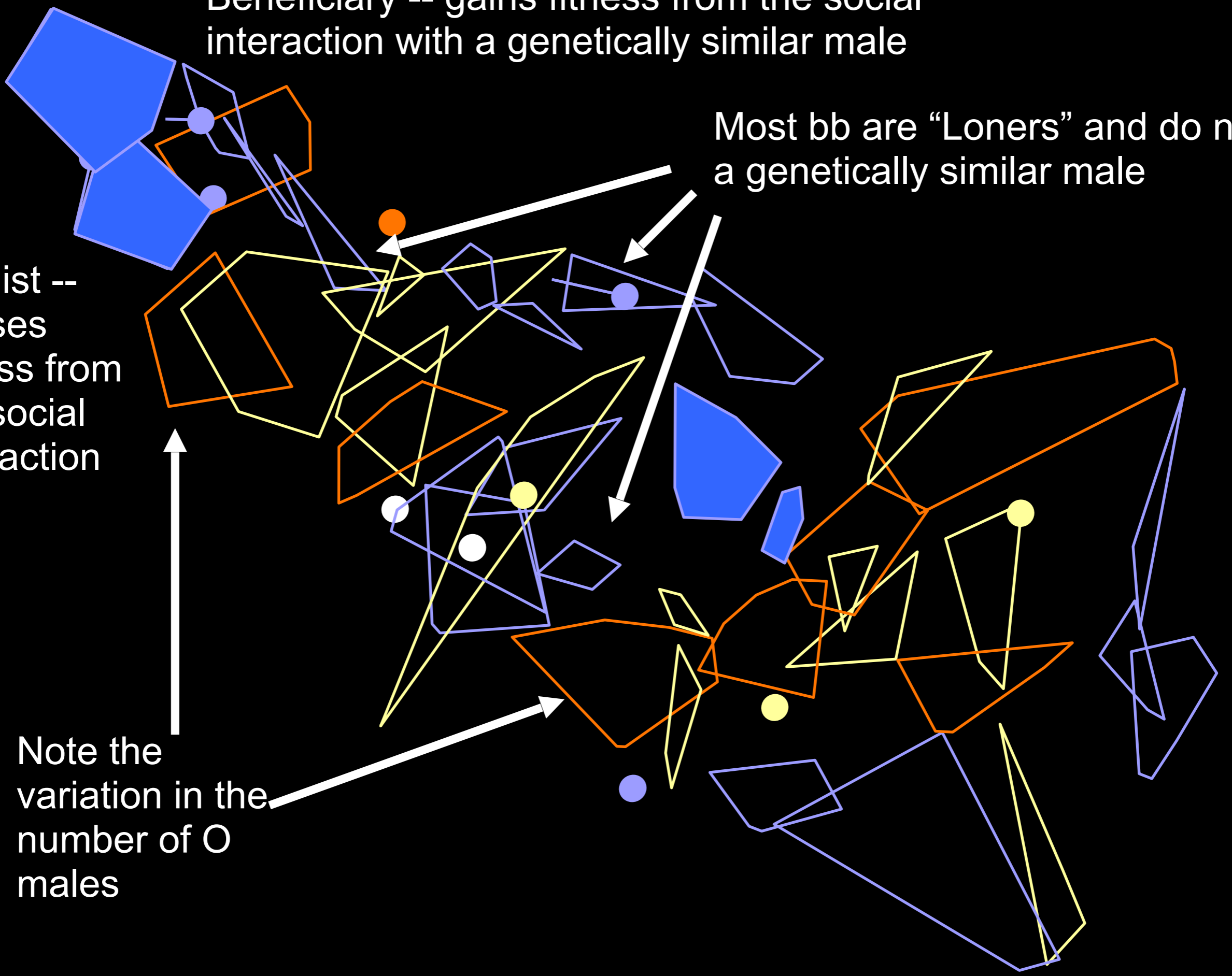


Beneficiary -- gains fitness from the social interaction with a genetically similar male

Most bb are "Loners" and do not find a genetically similar male

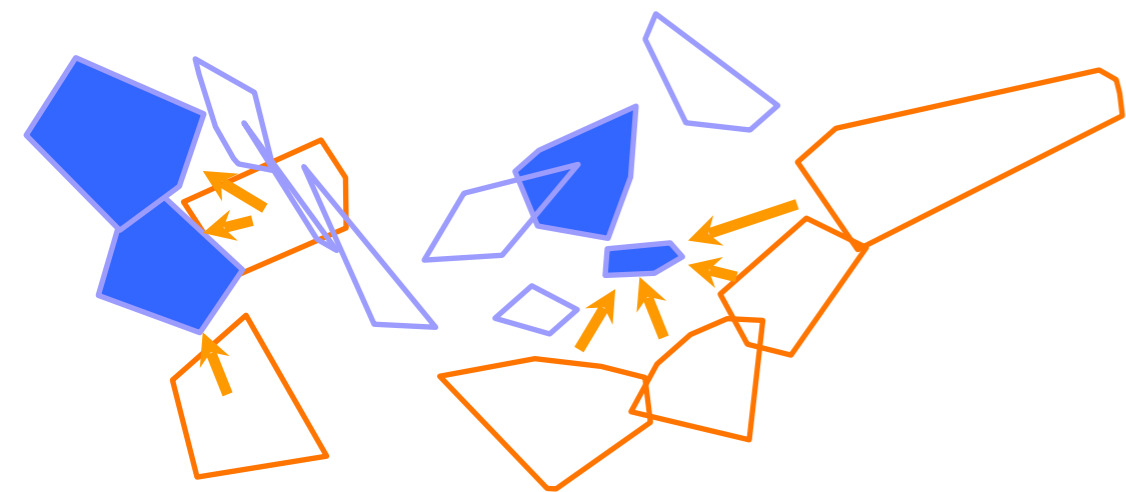
Altruist --  
Looses  
fitness from  
the social  
interaction

Note the  
variation in the  
number of O  
males

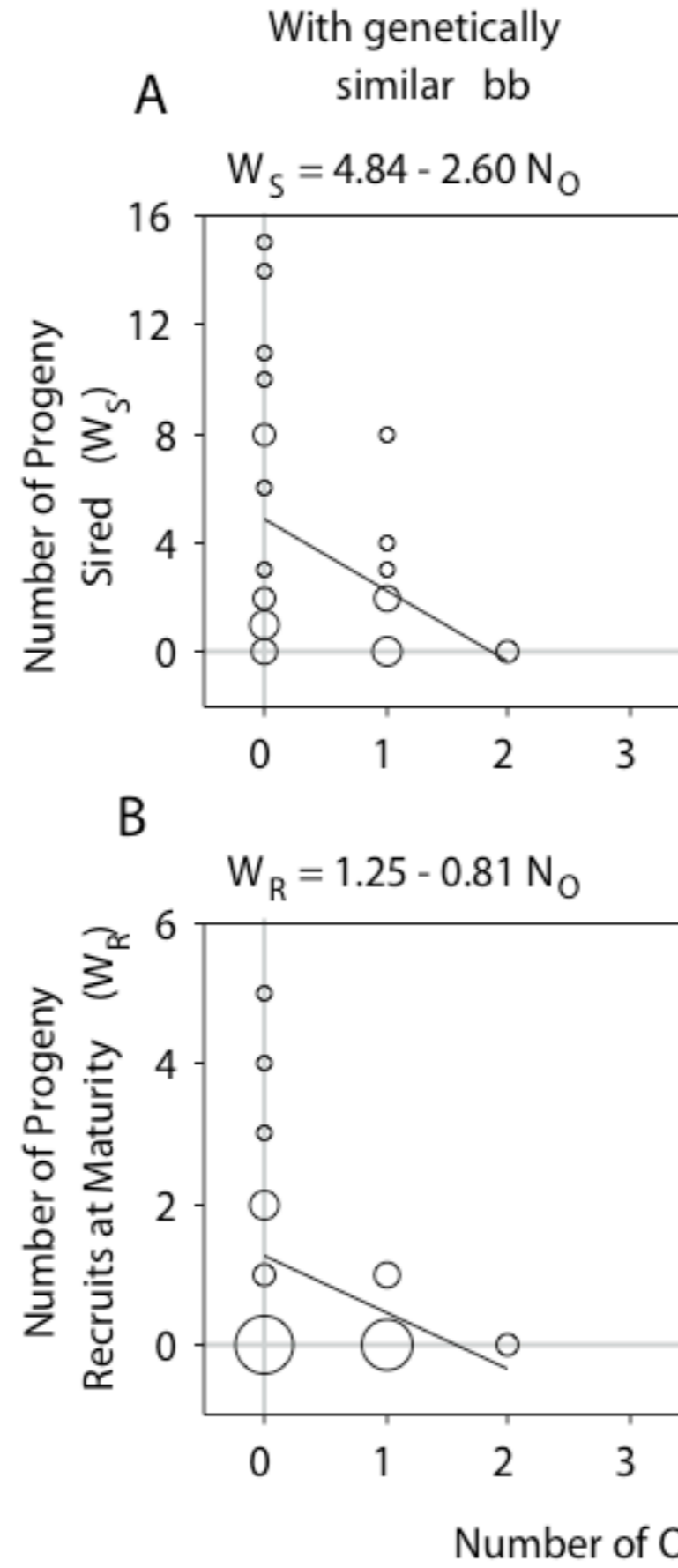


Average Fitness of two *bb* Cooperators (settle next to genetically similar males) compared to the average fitness of Loners *bb* males (e.g., males that do not form groups with genetically similar males).

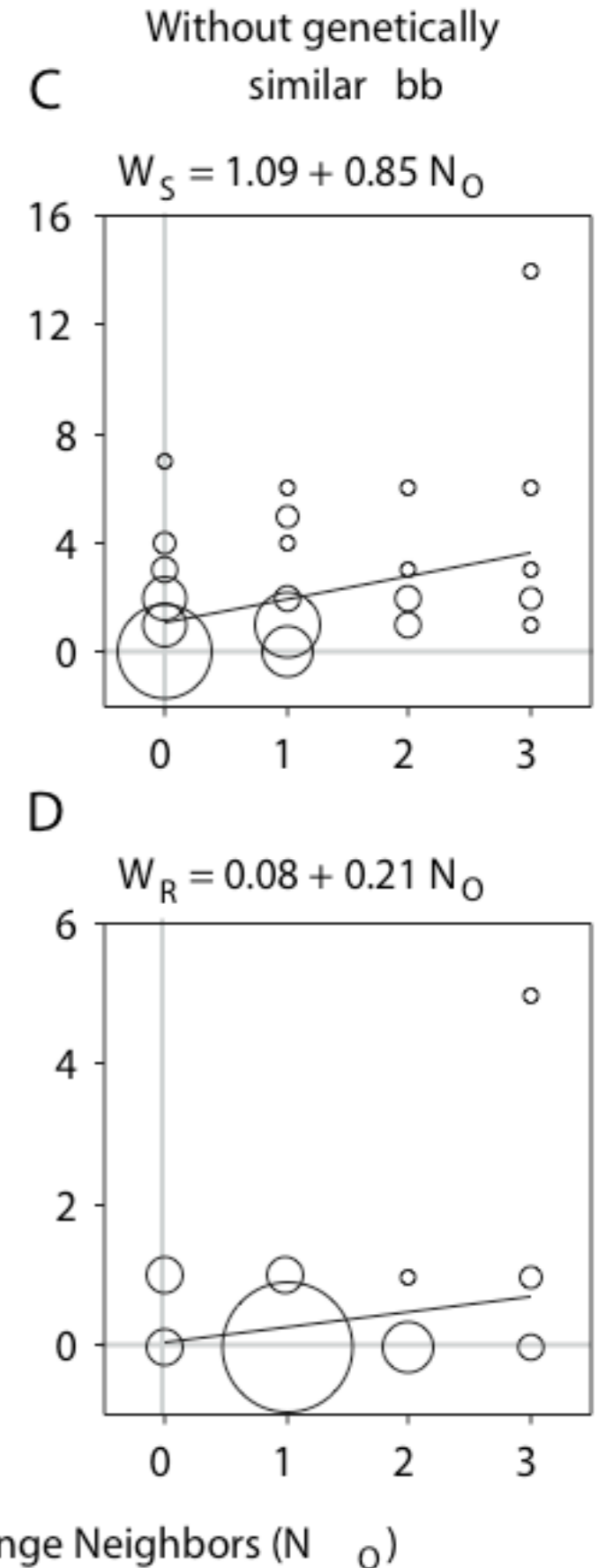
Plotted as a function of variation in the number of orange neighbors



## Cooperators

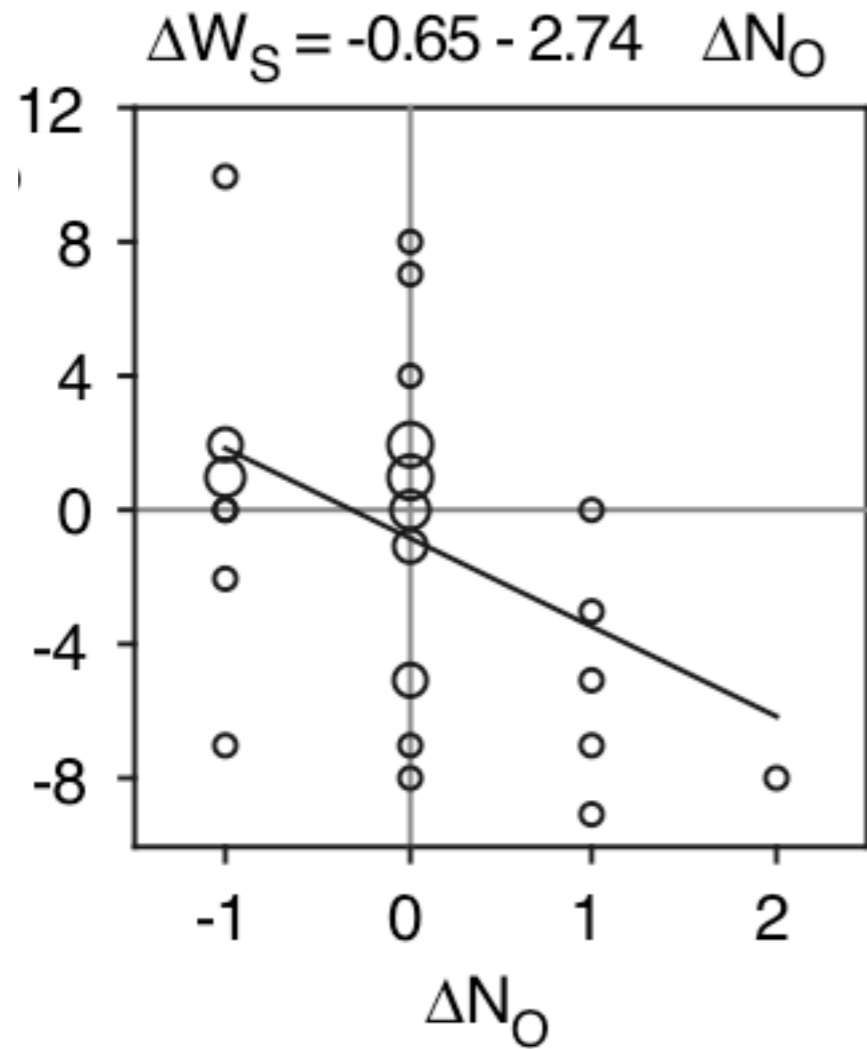


## Loners

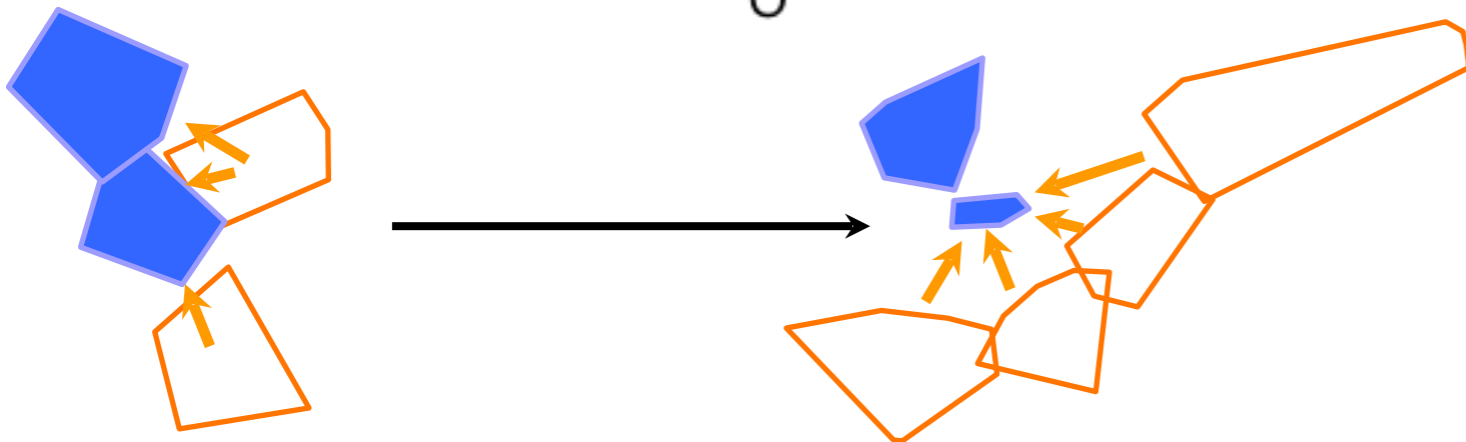
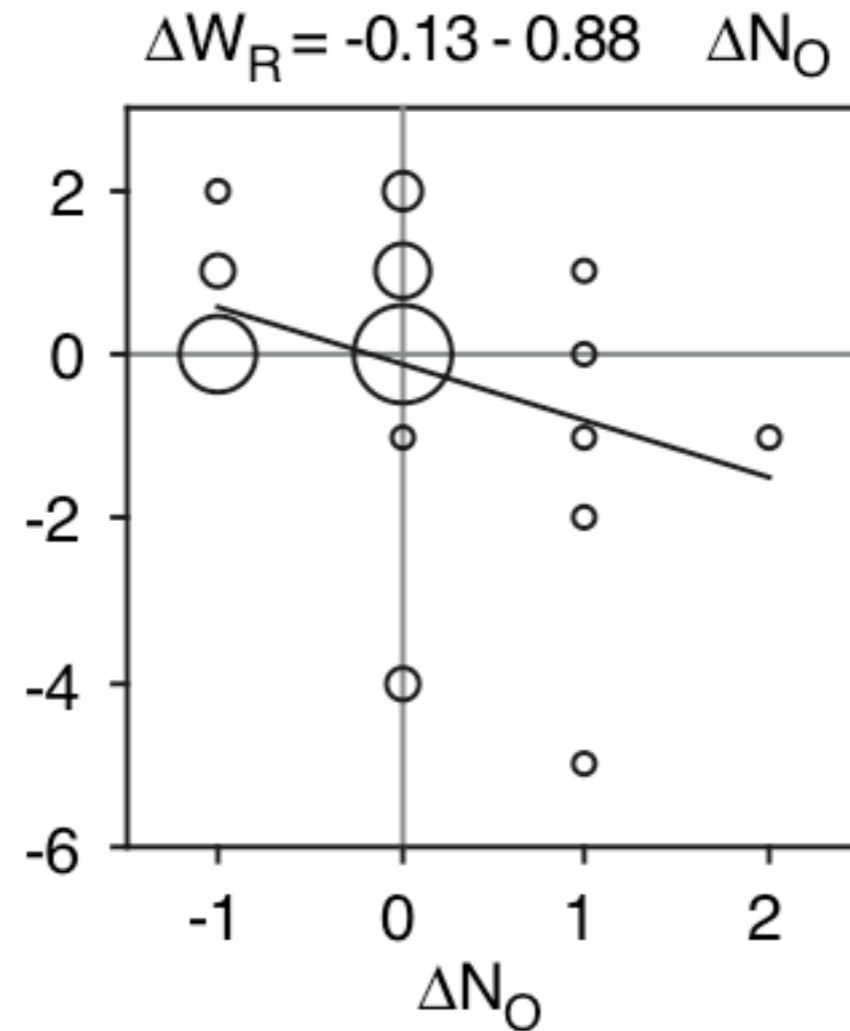


# The Effect of asymmetry in $N_O$ neighbors on fitness ( $W$ ) of beneficiary vs. altruist

## $\Delta$ Siring Success



## $\Delta$ Recruitment





The equations defining the frequency dependence of altruism/mutualism  
(all parameters,  $\beta_i$ , empirically estimated in previous graphs)

$$W_{\text{recipient } bb} [t] = \beta_1 + \beta_2 \times N_O[t] + W_{\Delta N_O}[t] / 2 \quad (1),$$

$$W_{\text{donor } bb} [t] = \beta_1 + \beta_2 \times N_O[t] - W_{\Delta N_O}[t] / 2 \quad (2),$$

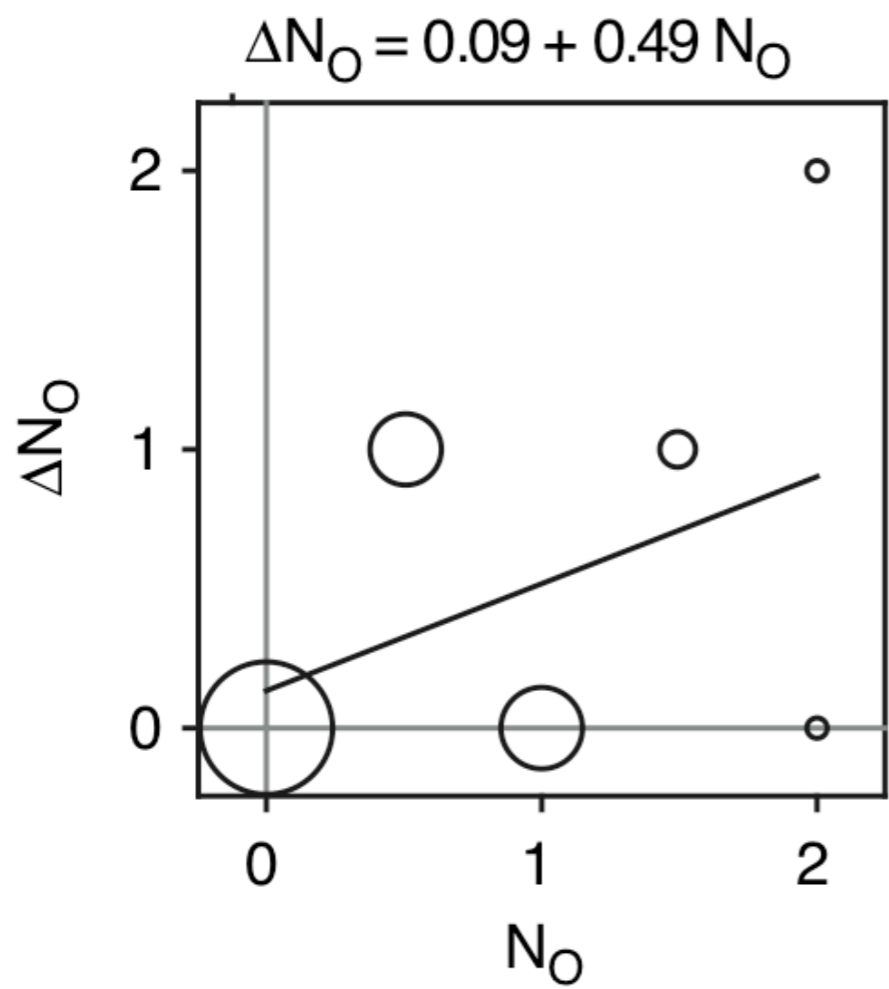
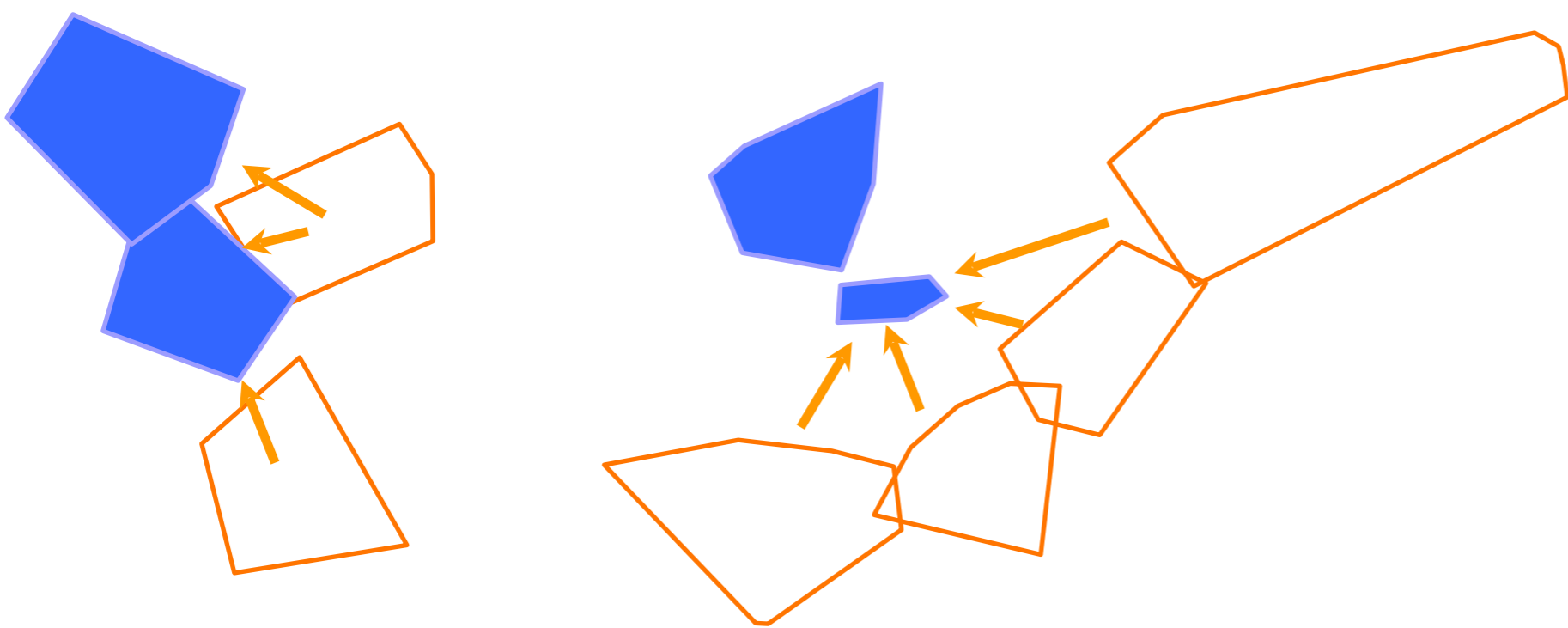
$$W_{\text{loner } bb} [t] = \beta_3 + \beta_4 \times N_O[t] \quad (3),$$

$$W_{\Delta N_O}[t] = \beta_5 \times \Delta N_O[t] \quad (4),$$

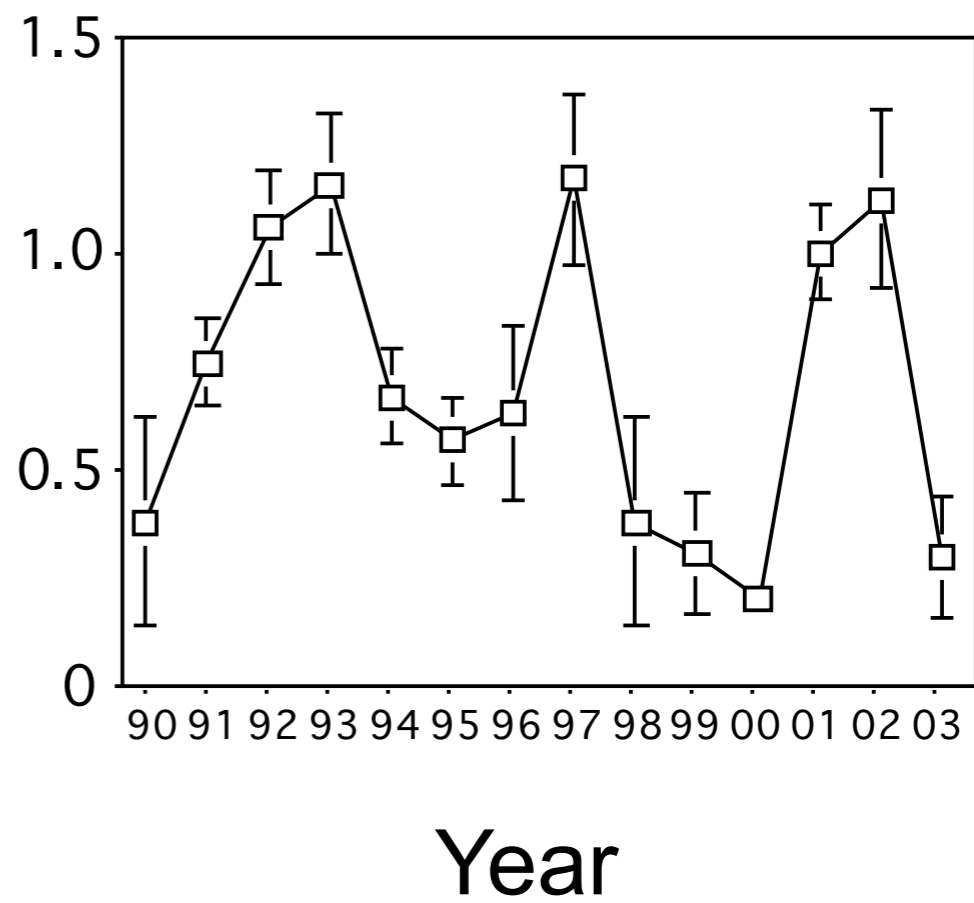
$$\Delta N_O[t] = \beta_6 + \beta_7 \times N_O(t) \quad (5),$$

$$W_{\Delta N_O}[t] = \beta_5 \times [ \beta_6 + \beta_7 \times N_O(t) ] \quad (6),$$

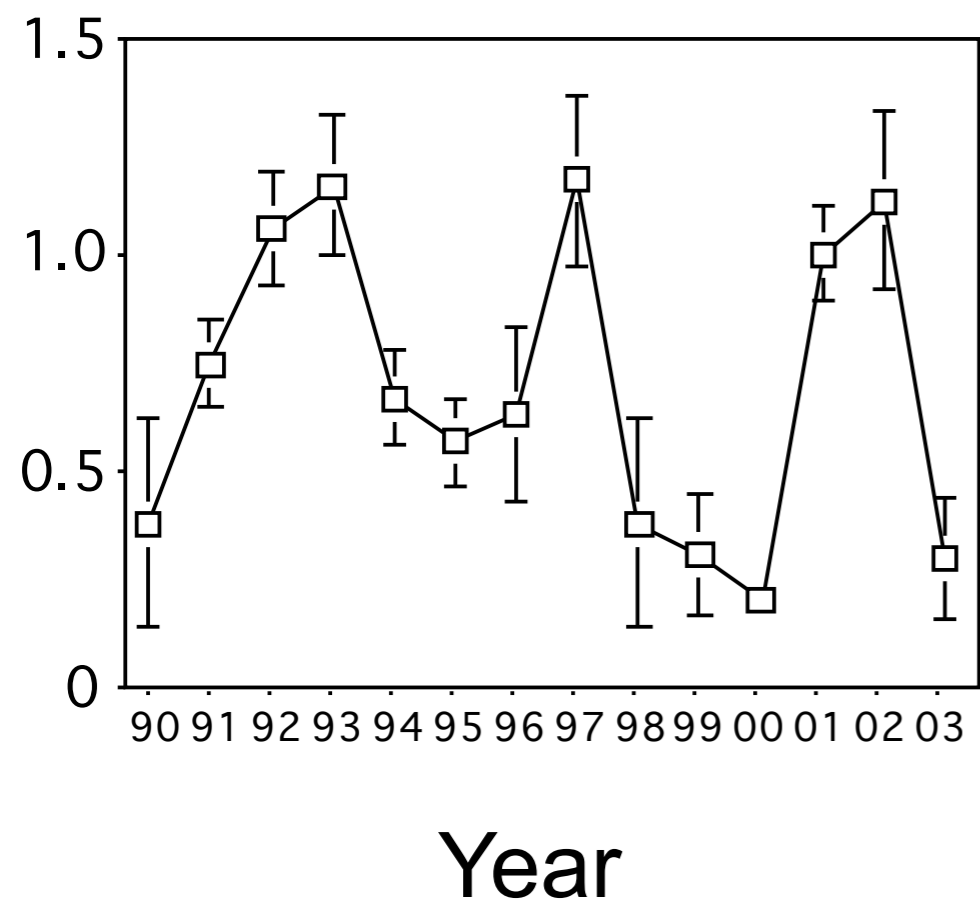
$$W_{\text{recipient } bb} [t] = \beta_1 + \beta_2 \times N_O[t] + \beta_5 \times [ \beta_6 + \beta_7 \times N_O(t) ] / 2 \quad (7).$$



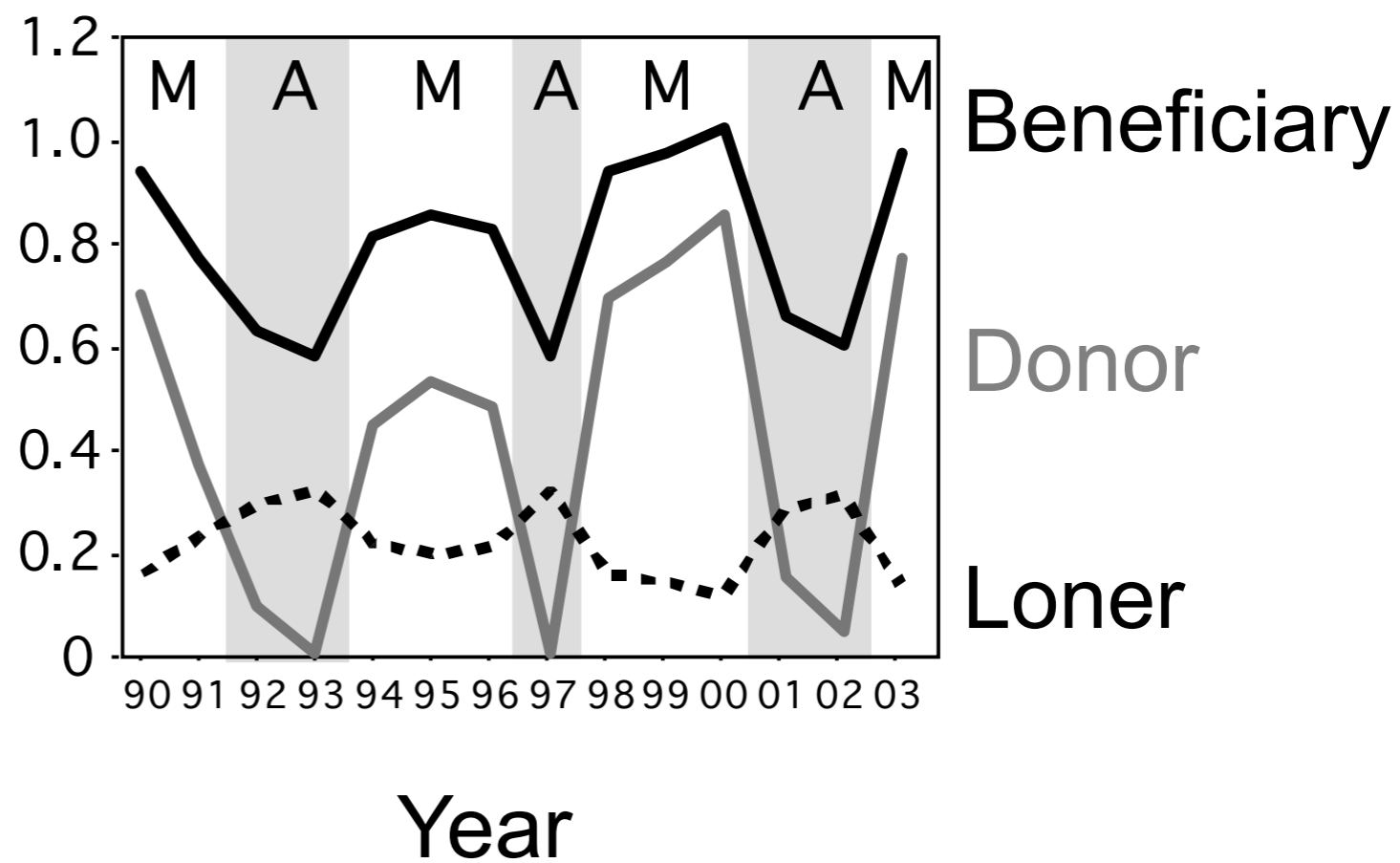
$N_O(t)$  for *bb* males



$N_o(t)$  for *bb* males



$W(t)$



# Gene 2 *Social Acts:*

Spite

Theivery

Cheat

Mutualism

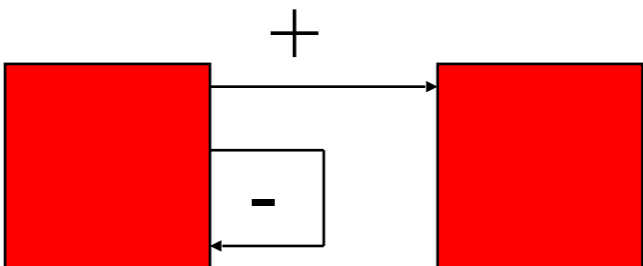
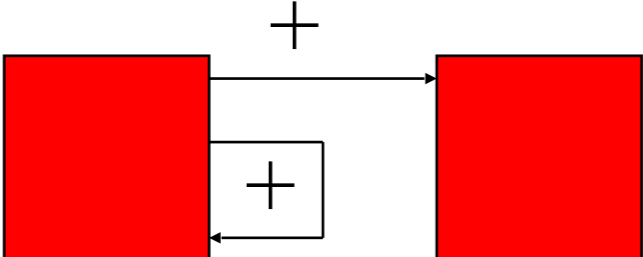
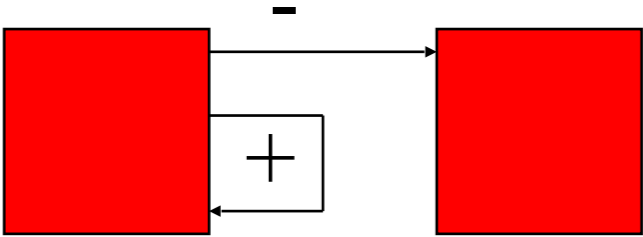
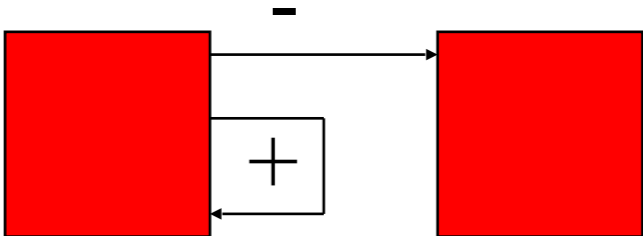
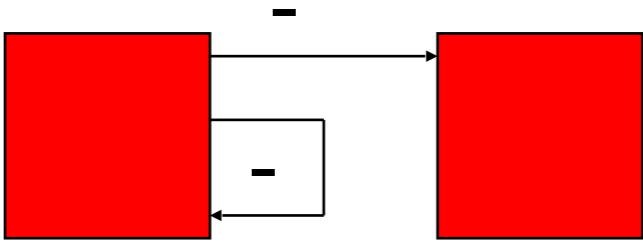
Altruism

Orange

Yellow

Blue

Actor      Recipient



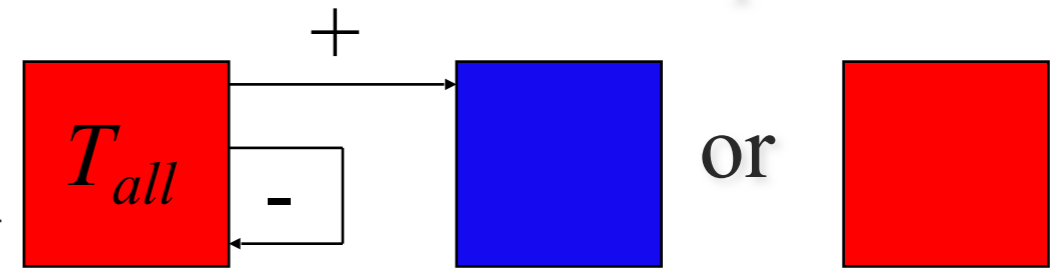
# Gene 3: Tolerance to other tags.

## ALTRUISM

Actor

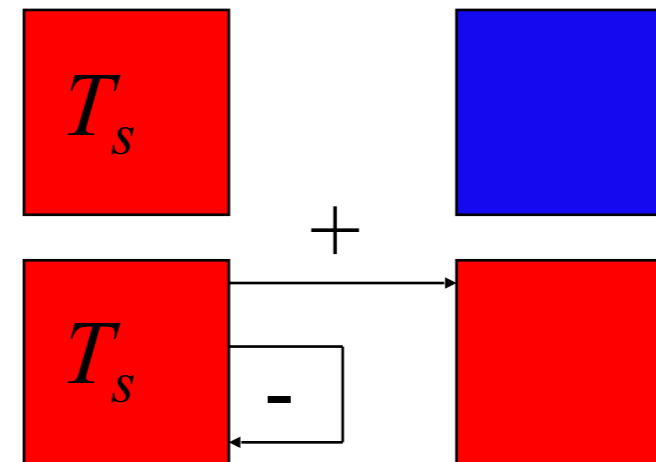
Recipient

$T_{all}$  = completely tolerant

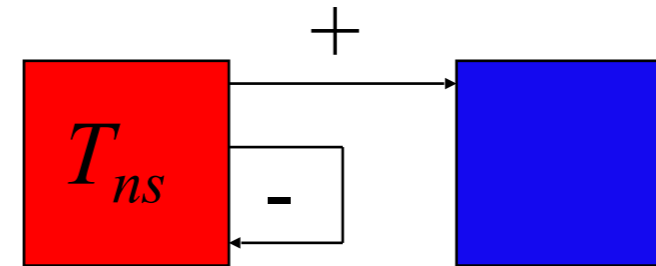


$T_s$  = act with self only

Blue



$T_{ns}$  = act with non-self only



$T_0$  = completely intolerant

Yellow



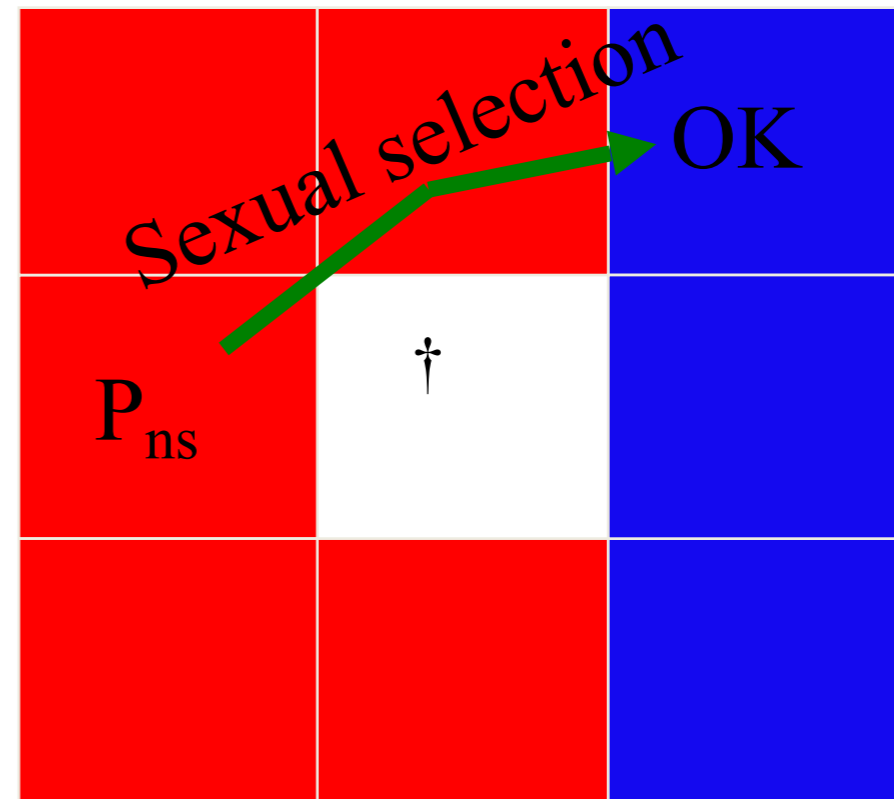
# *Locus 3: Mating preference*

3 alleles:

$P_0$  = mate with random player

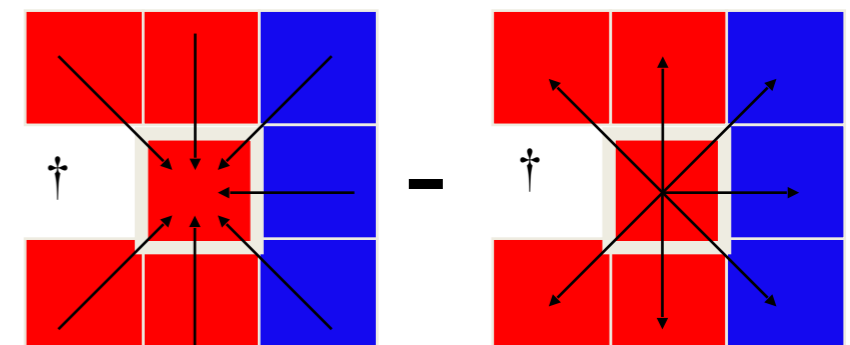
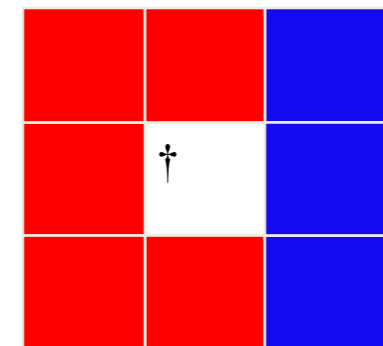
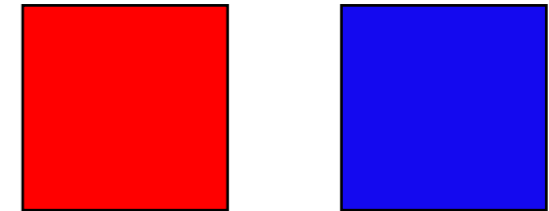
$P_{ns}$  = mate with random player if not same tag

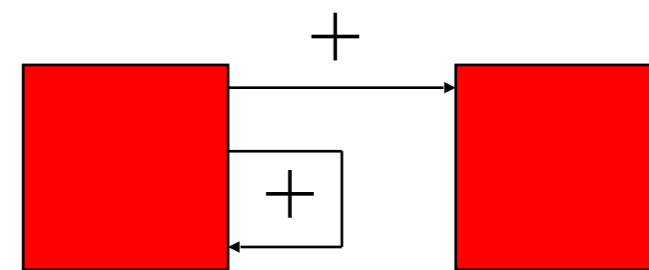
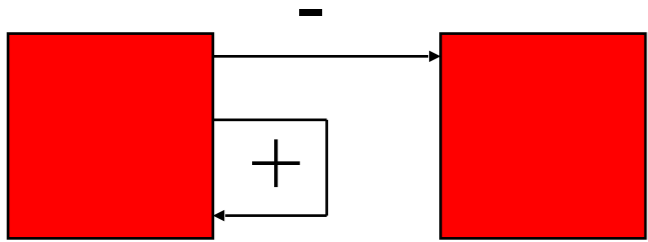
$P_s$  = mate with random player if same tag



# *Sexual Model with Actors*

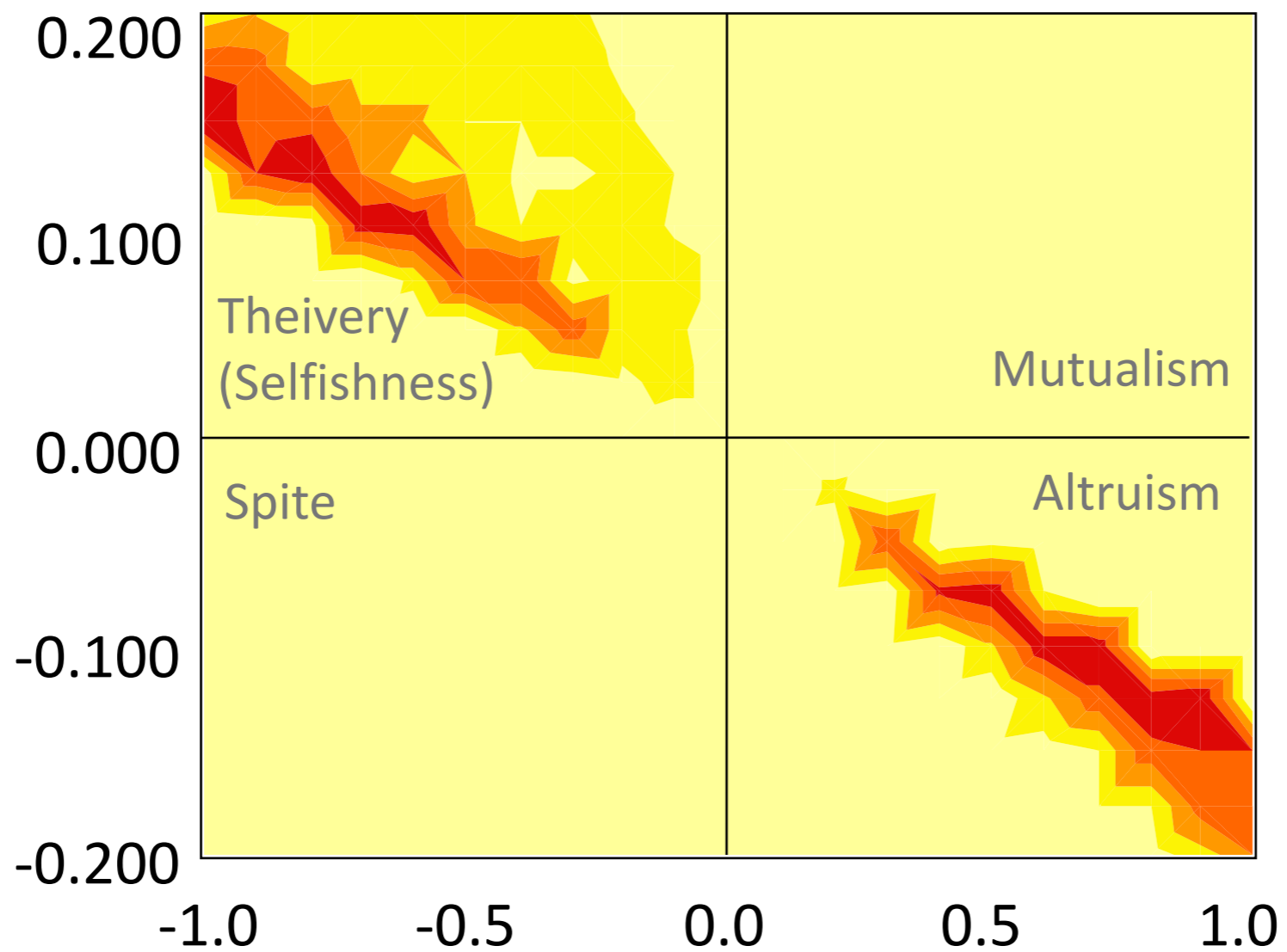
1. Grid of cells wrapped over a torus
2. There are two “tags” in the system
3. Random mortality occurs and vacant cells are colonised by the progeny of the neighbour with the highest social fitness
4. Social fitness is the net effect of neighbours less the costs of interacting with neighbours. Two independent “acts” occur between any pair of players. Individuals act as recipients and donors.





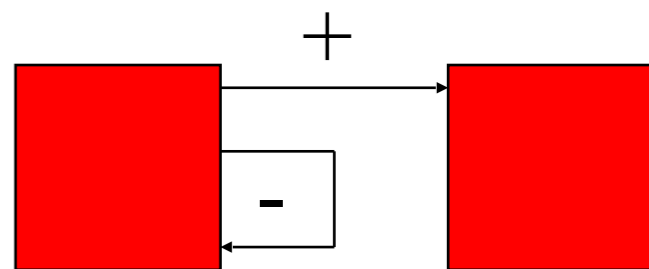
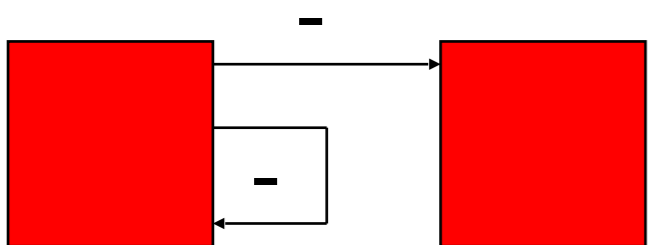
**ACTOR**

Effect on Self



Effect on social partner

**RECIPIENT**

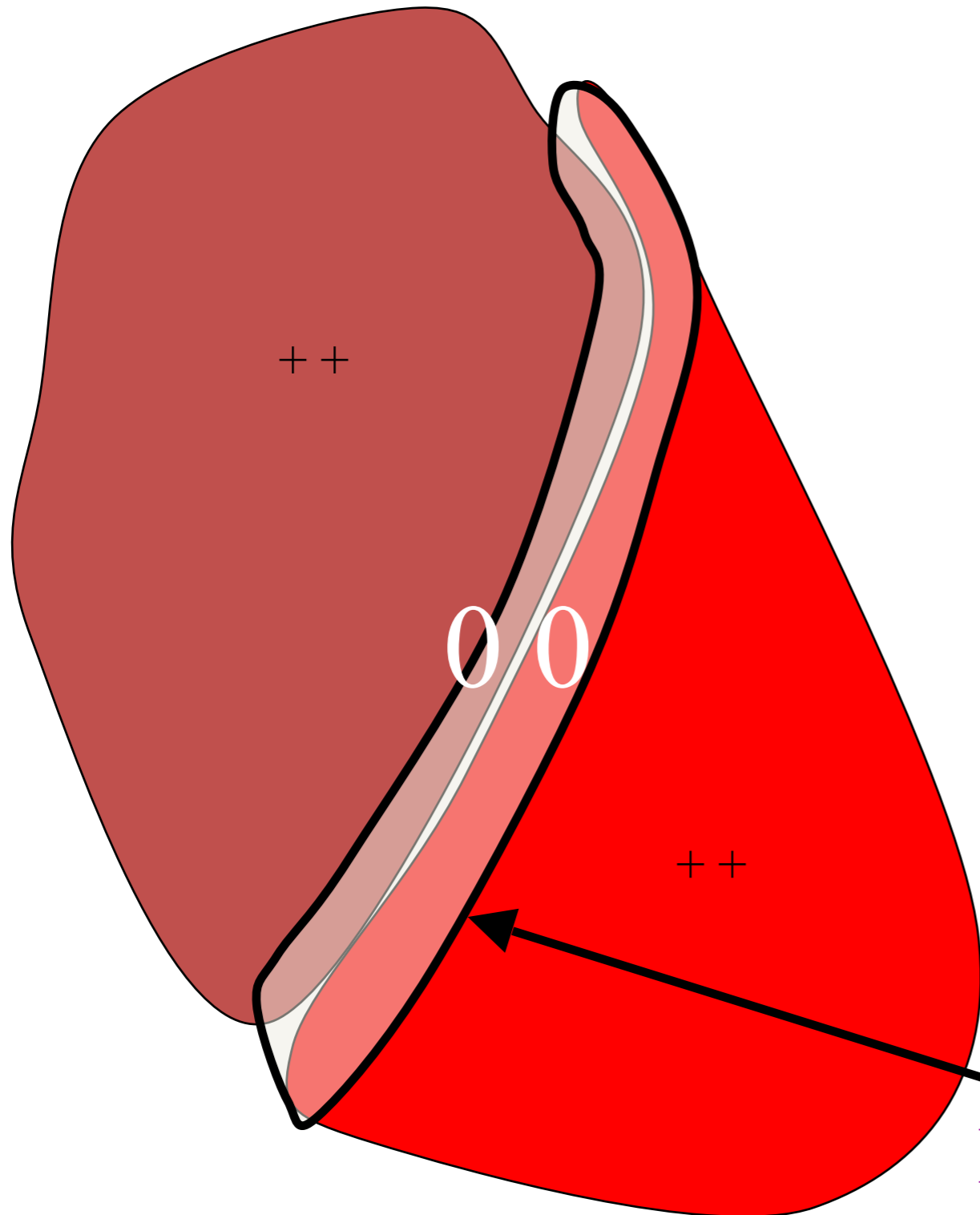




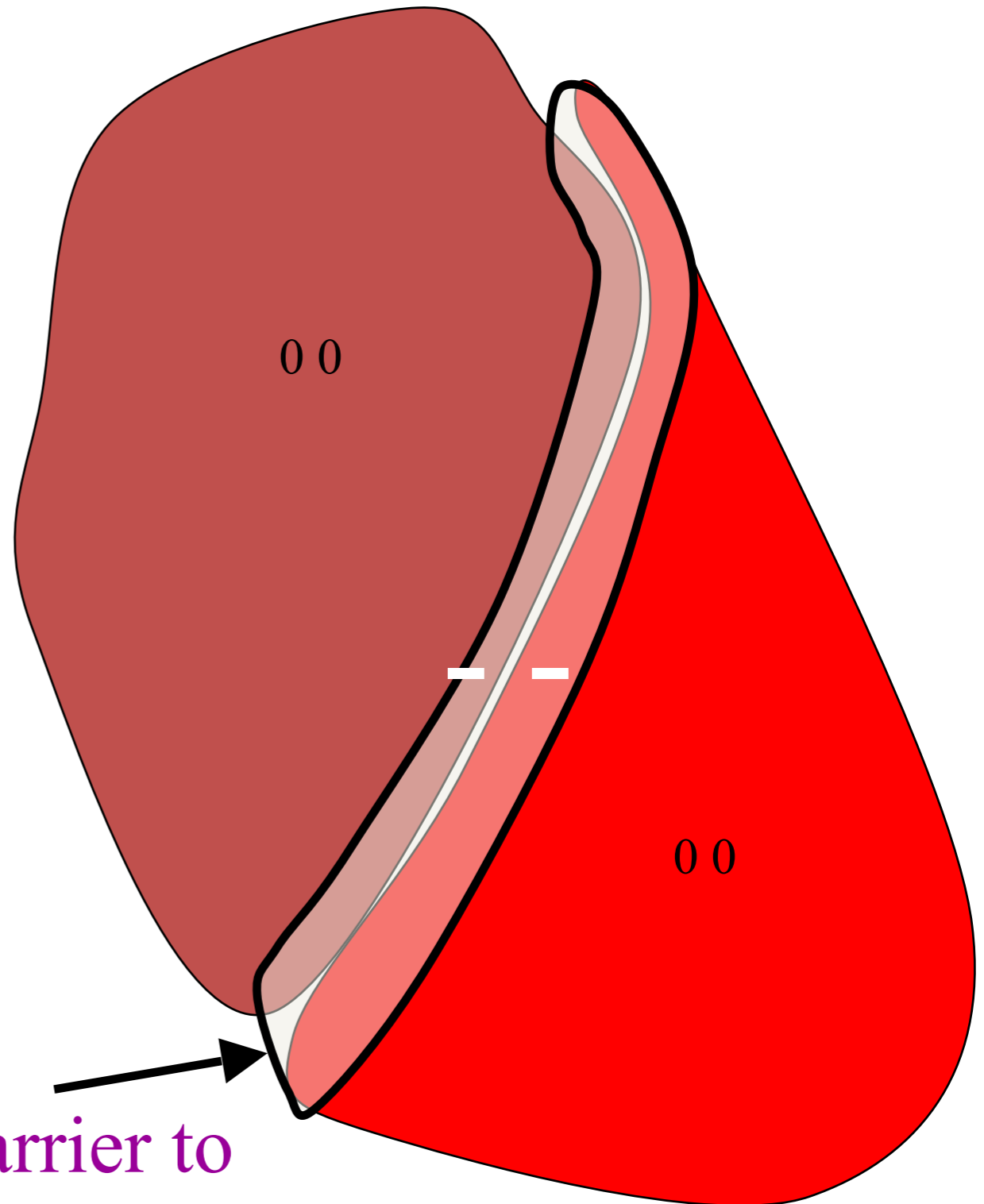
# *Altruism act rule*

# *Thievery act rule*

$T_s$



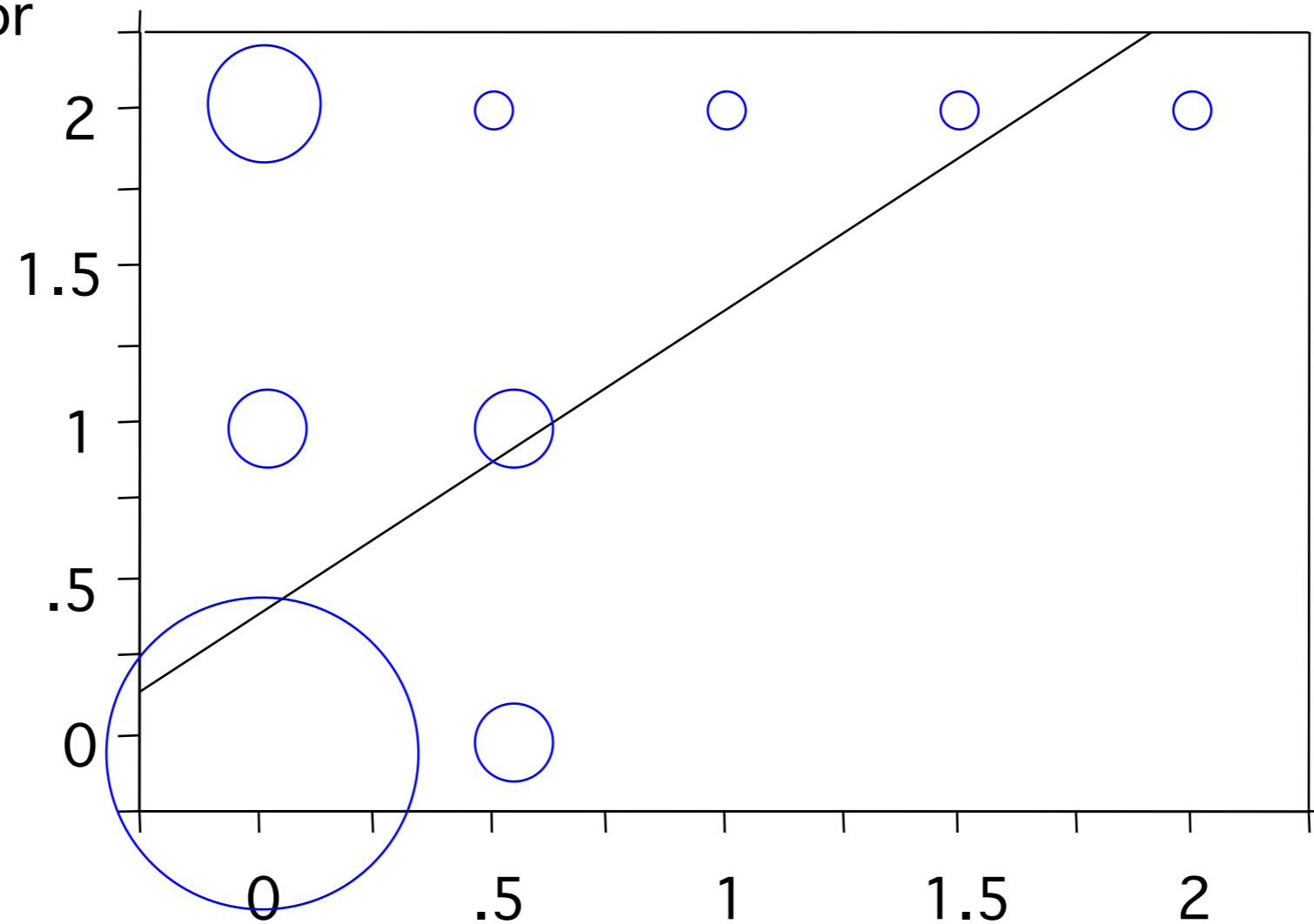
$T_{ns}$



Barrier to  
gene flow

Dyadic behavior (find genetically similar mate/partner with  $b$  alleles) is heritable in sons and daughters:  $h^2=0.98$   
Daughters:  $h^2=1.05$ , Sons:  $h^2=0.89$  in separate regressions.

Dyadic behavior  
of Progeny

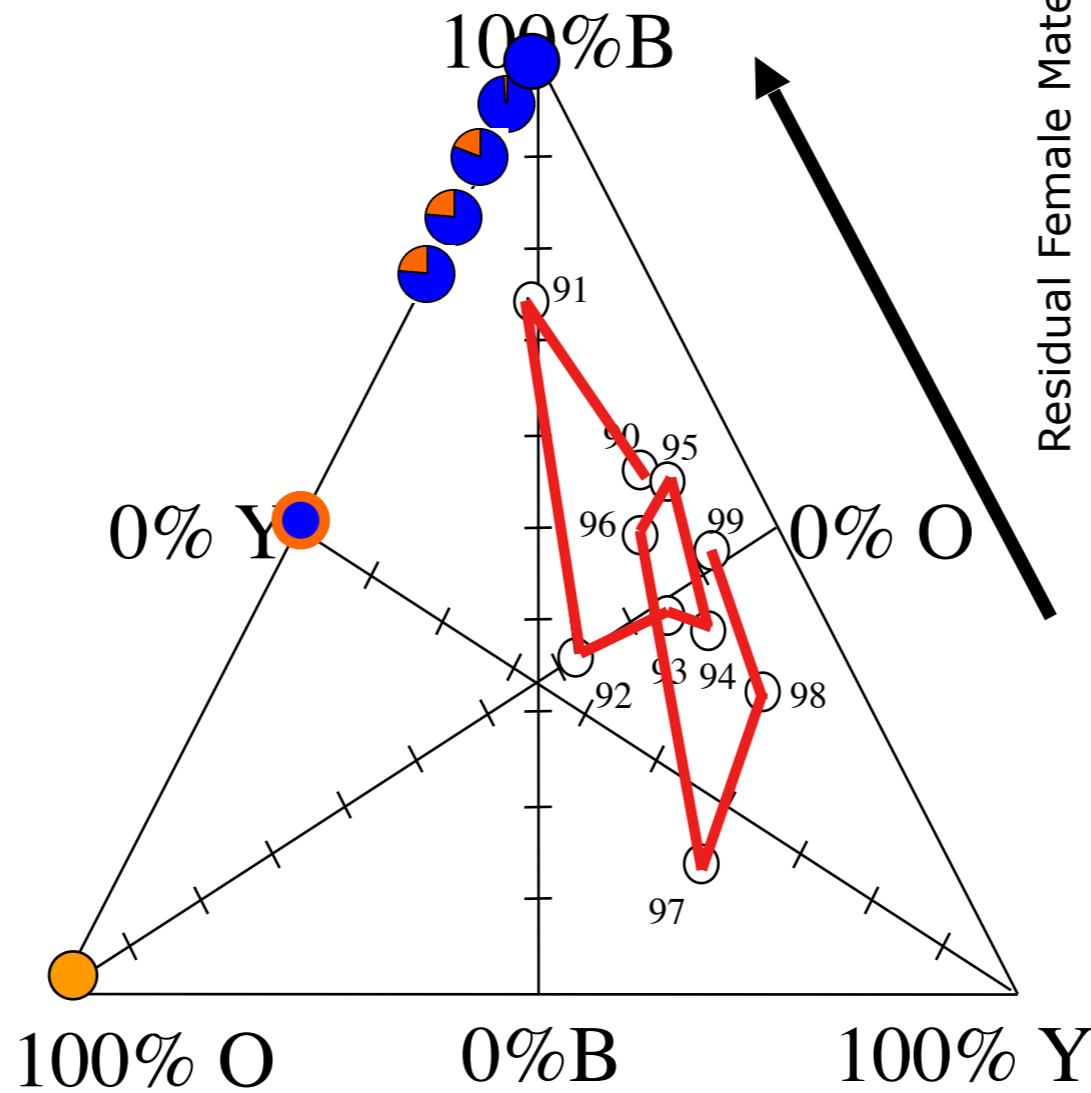


Average of Sire and Dam Dyadic behavior

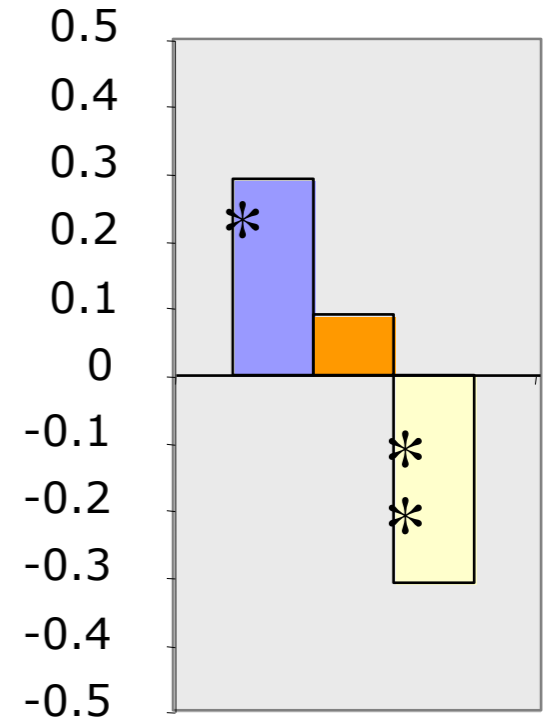
# Assortative mating of OBY alleles and the RPS cycle



Yellow (*y*) alleles can be lost because *bb* females mate assortatively with *bb* males



Residual Female Mate Choice



B beats Y:  
Mutualism





# Geographic surveys by Ammon Corl

