When do opposites attract? Impact of genetic architecture on the evolution of disassortative mating

Ludovic Maisonneuve PhD student supervised by Violaine Llaurens and Charline Smadi

Institut de Systématique, Evolution et Biodiversité (UMR 7205 CNRS/MNHN/SU/EPHE/UA)
Muséum National d'Histoire Naturelle - CP50 45 rue Buffon 75005 PARIS FRANCE

Ludovic Maisonneuve

@lmaisonneuve5

ludovic.maisonneuve@mnhn.fr

National Audubon Society

Mate choice is key to evolution

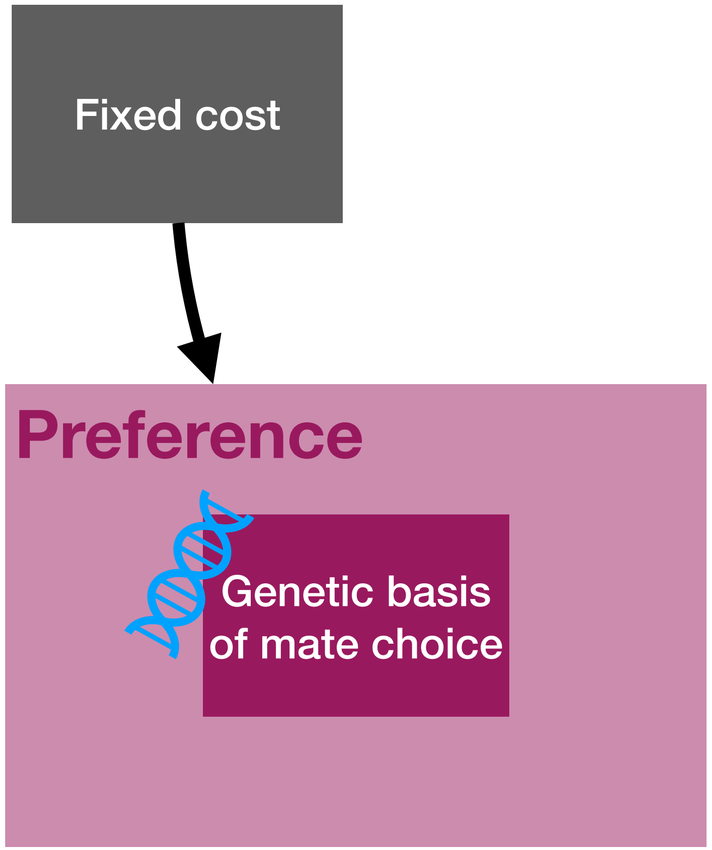
How do mate preferences evolve ?

Preference

Genetic basis
of mate choice

Otto et al. 2008

How do mate preferences evolve ?



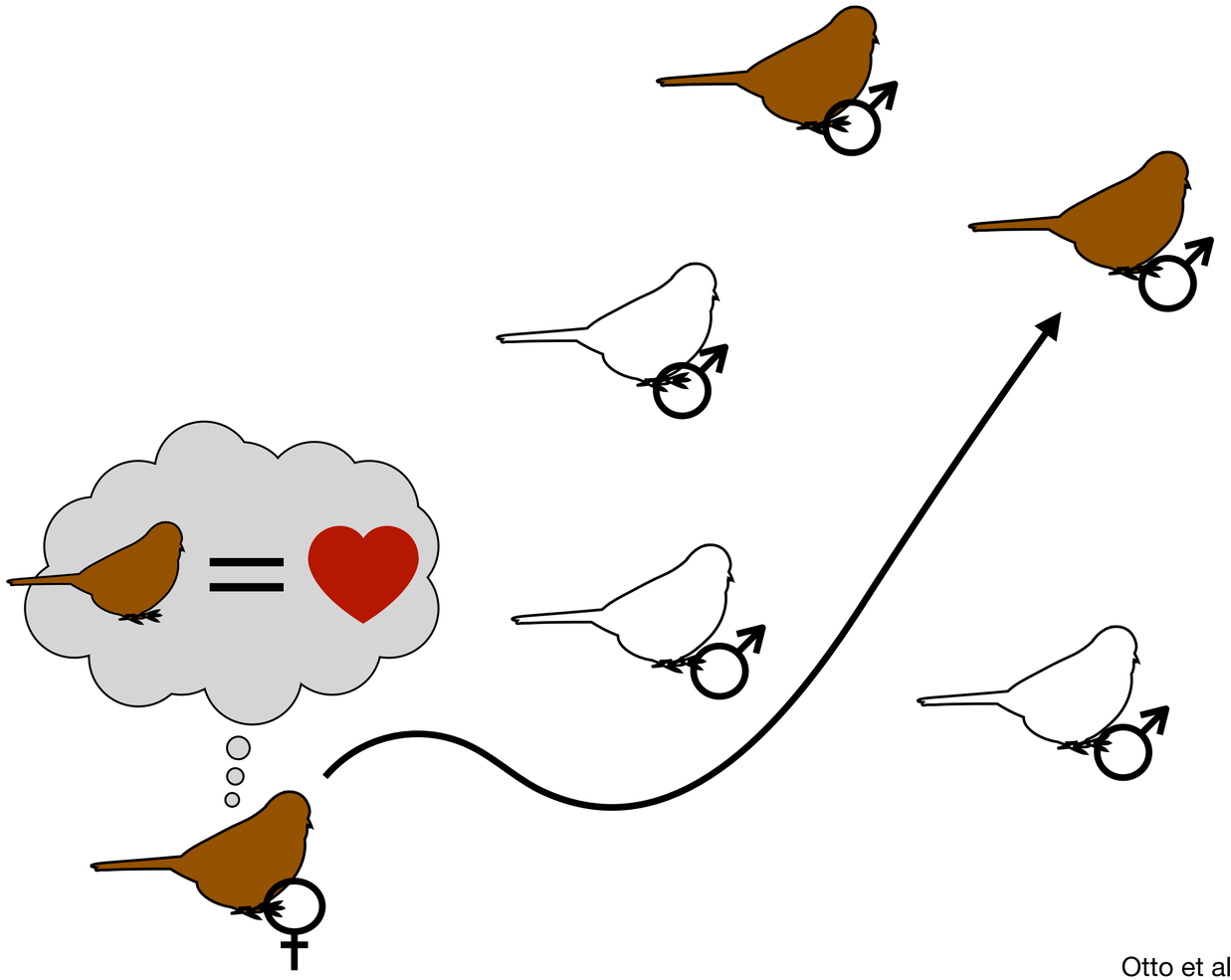
Otto et al. 2008

How do mate preferences evolve ?

Fixed cost

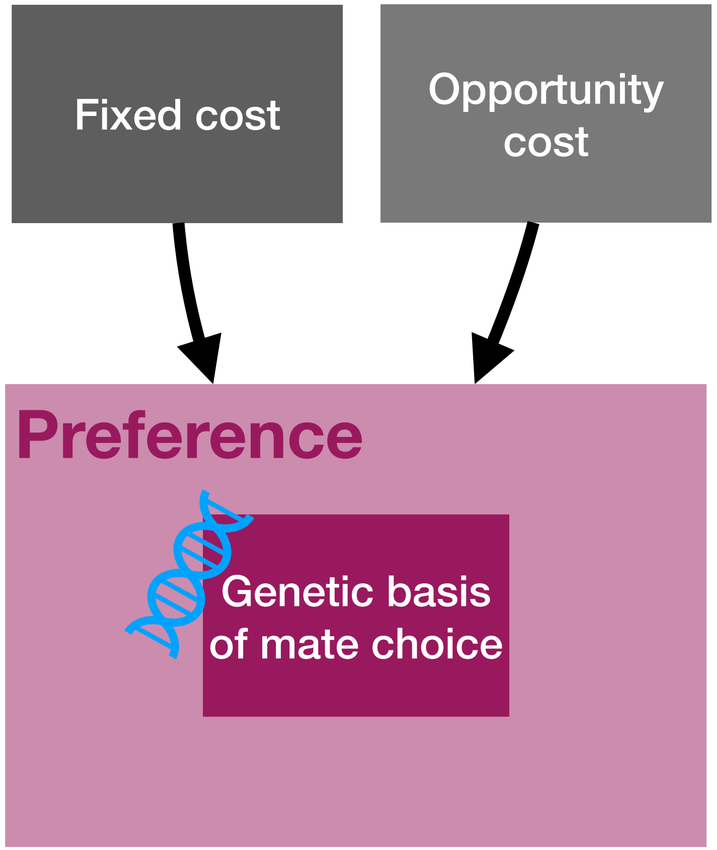
Preference

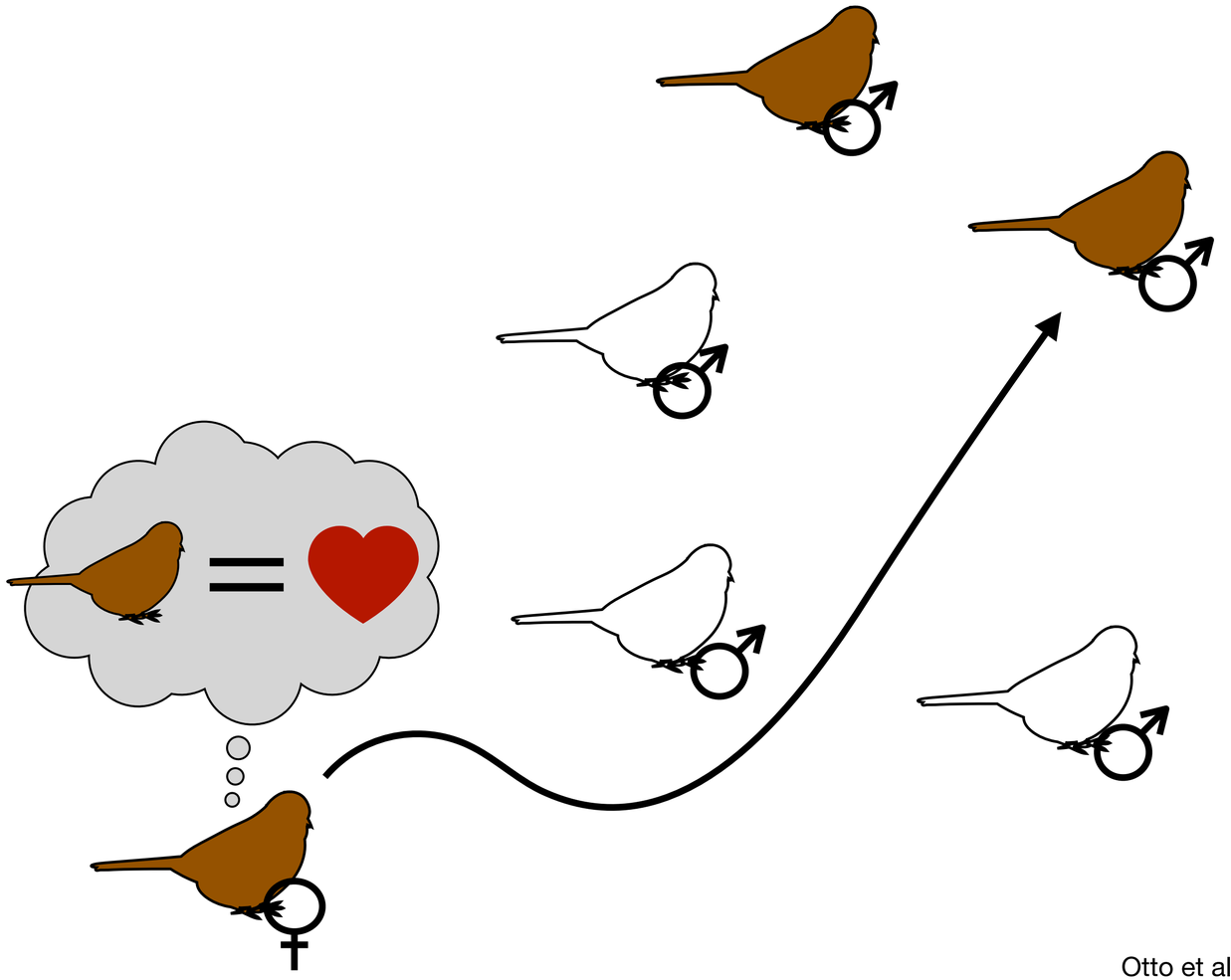
Genetic basis of mate choice



Otto et al. 2008

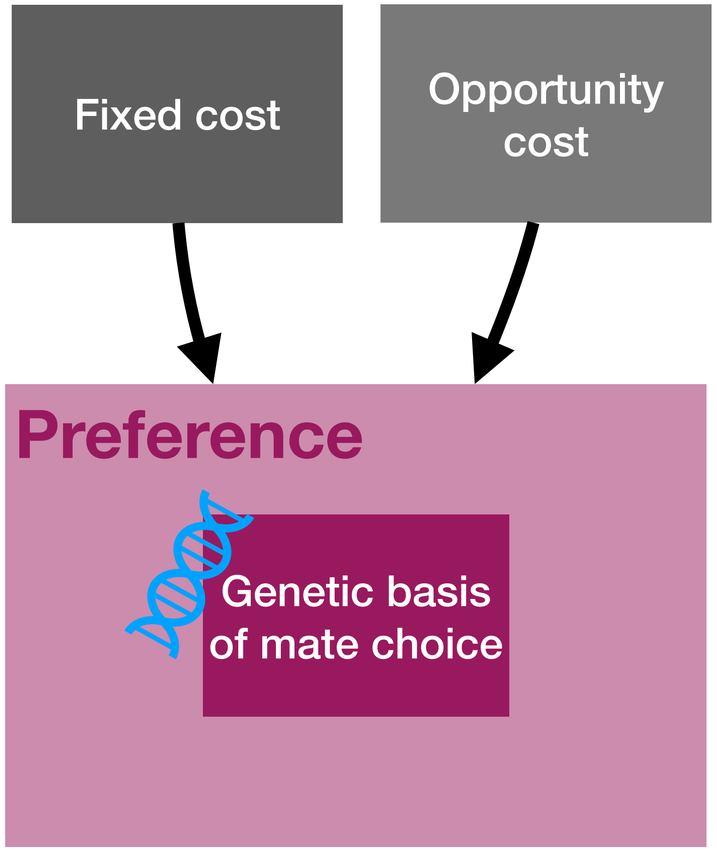
How do mate preferences evolve ?

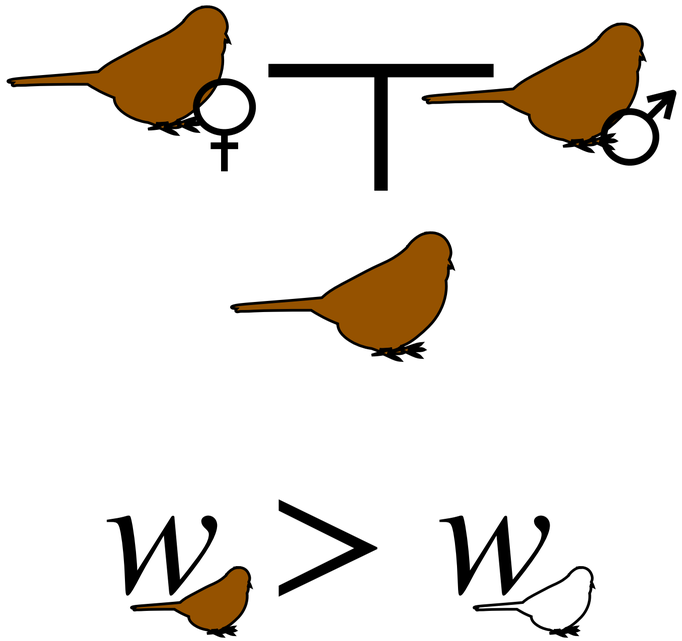




Otto et al. 2008

How do mate preferences evolve ?

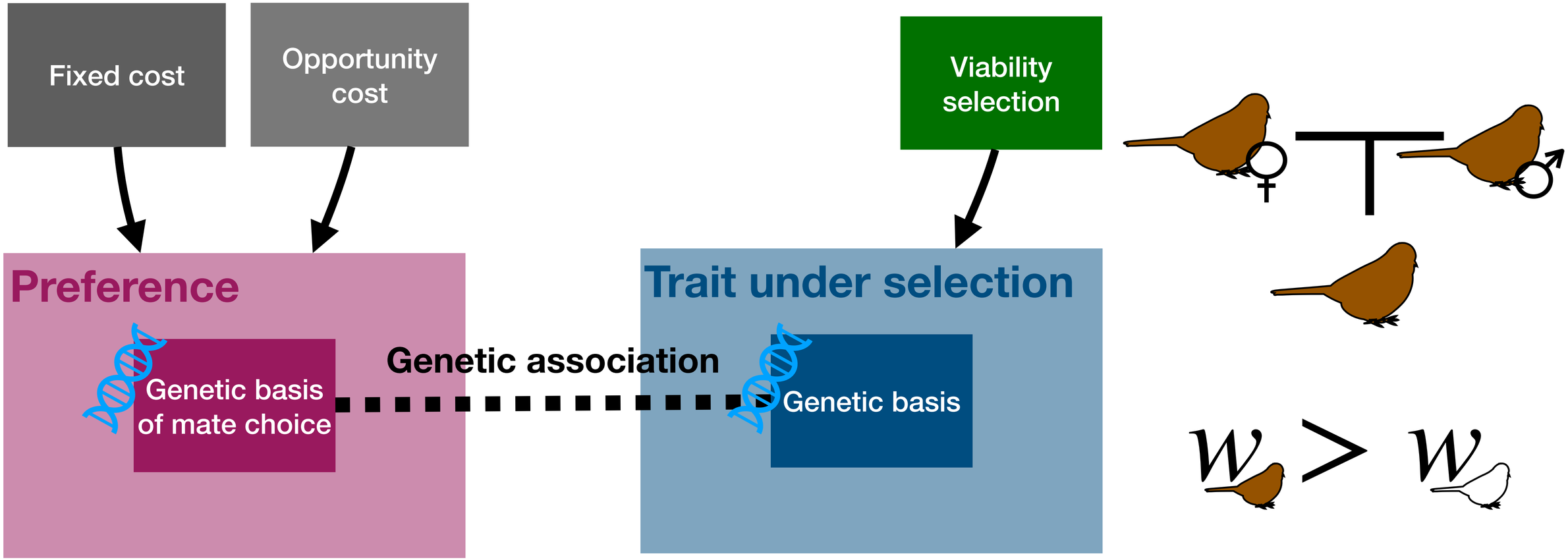




$$w_{\text{♂}} > w_{\text{♀}}$$

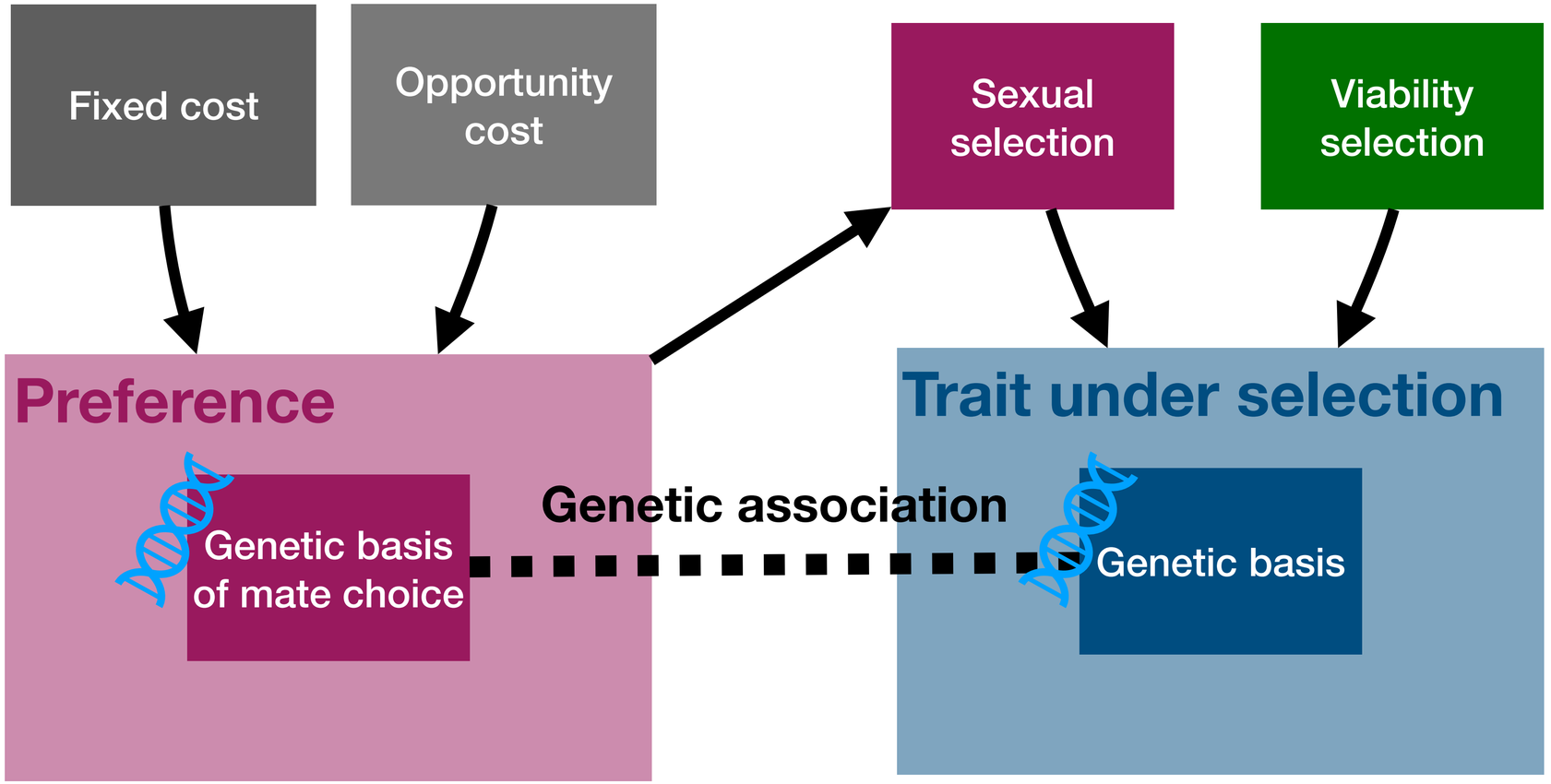
Otto et al. 2008

How do mate preferences evolve ?



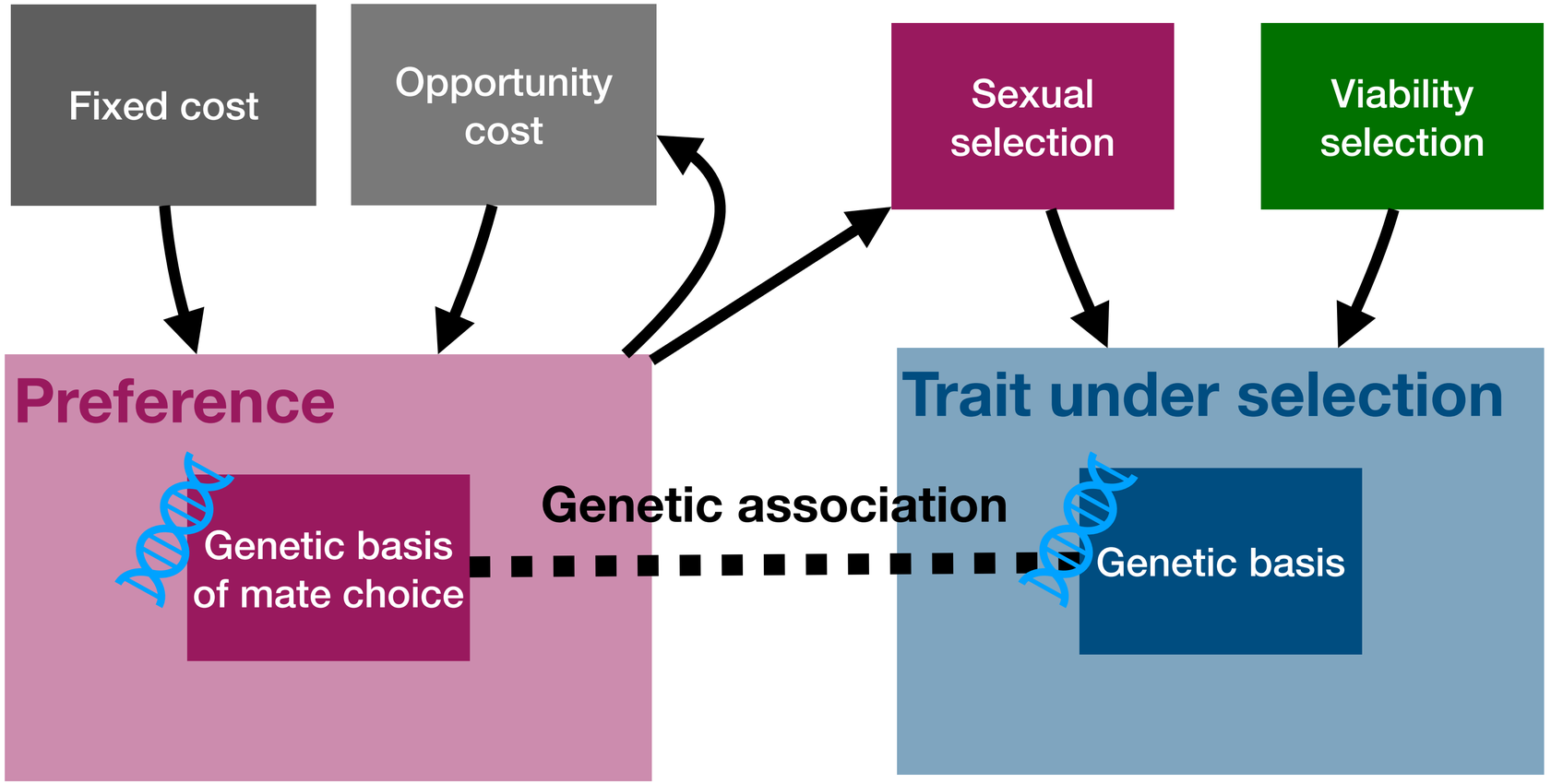
Otto et al. 2008

How do mate preferences evolve ?



Otto et al. 2008

How do mate preferences evolve ?



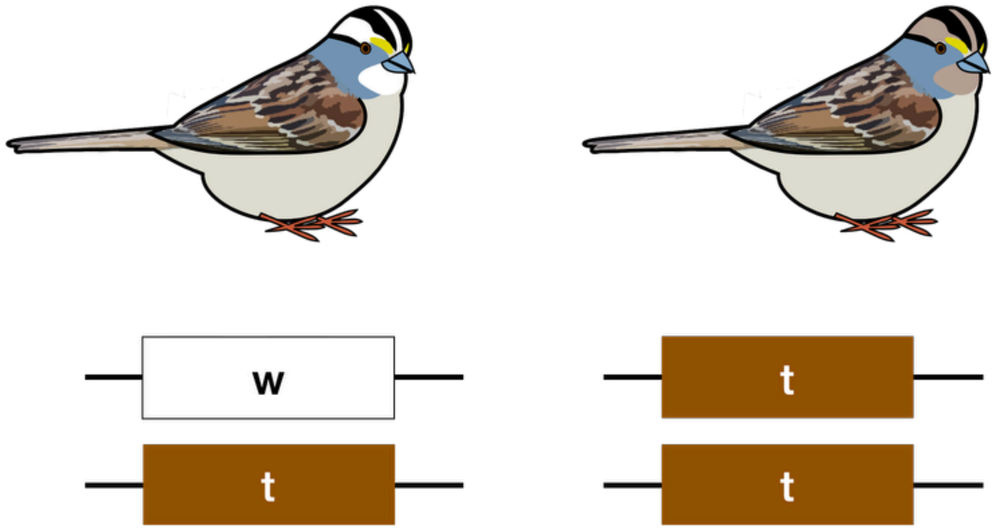
Otto et al. 2008

Disassortative mating

Lowter et al. 1961

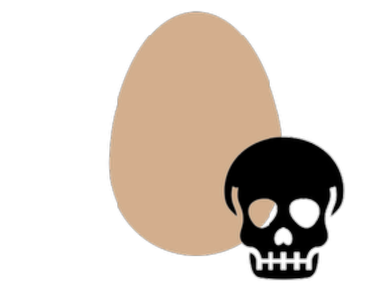
Disassortative mating

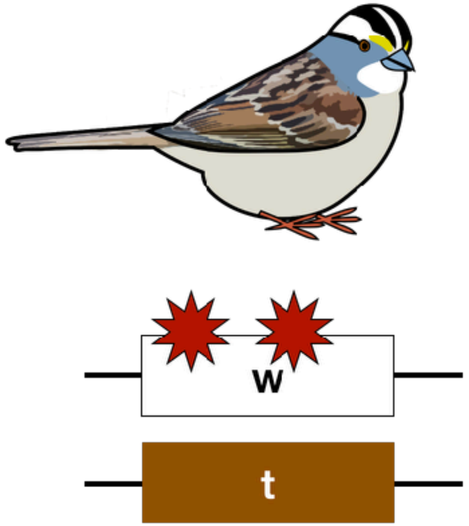
Lowter et al. 1961

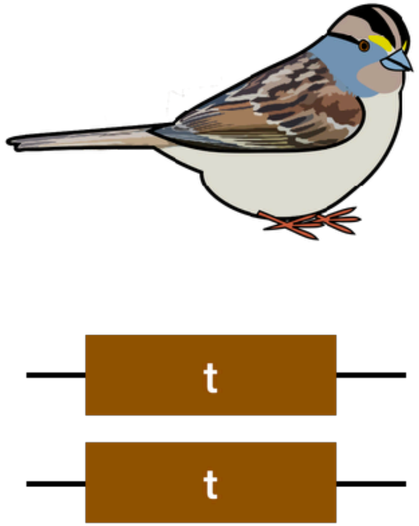


Disassortative mating

Lowter et al. 1961



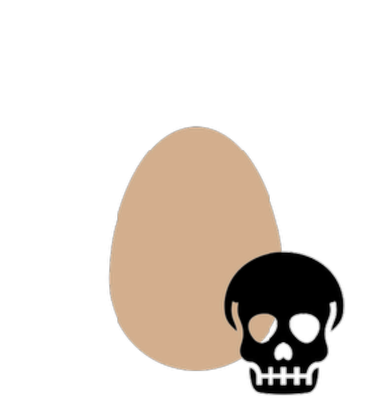


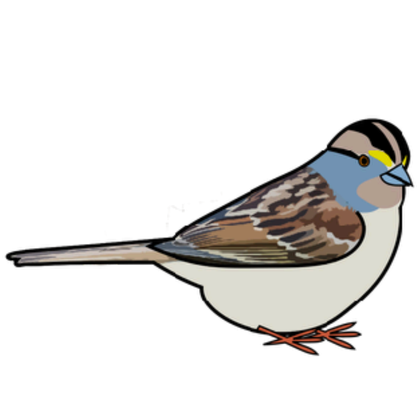


Genetic load

Disassortative mating

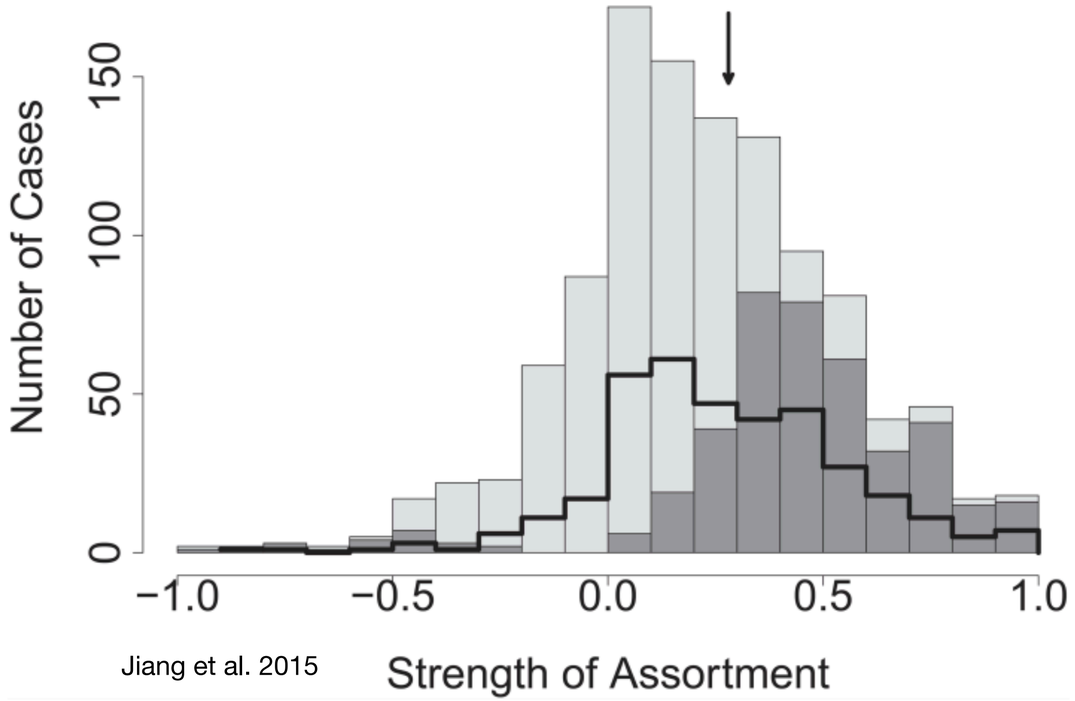
Lowter et al. 1961





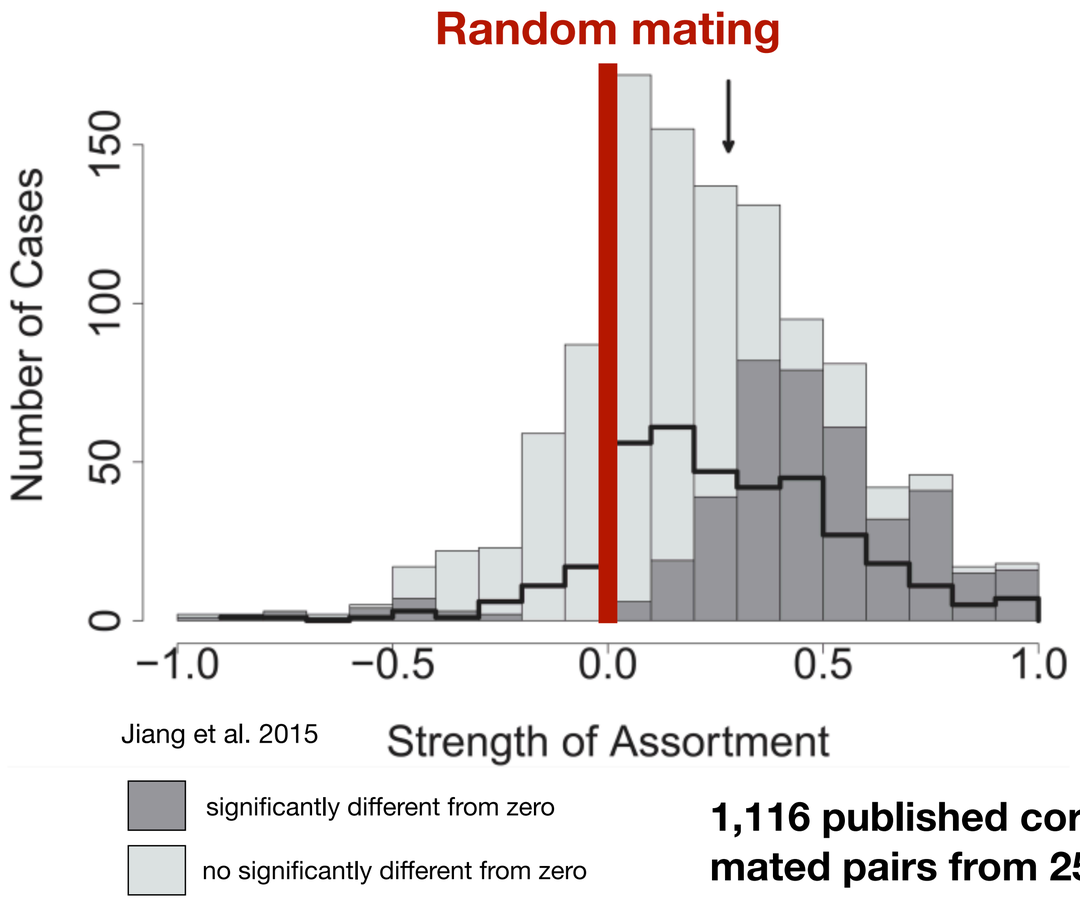
Genetic load

The disassortative mating seems rare



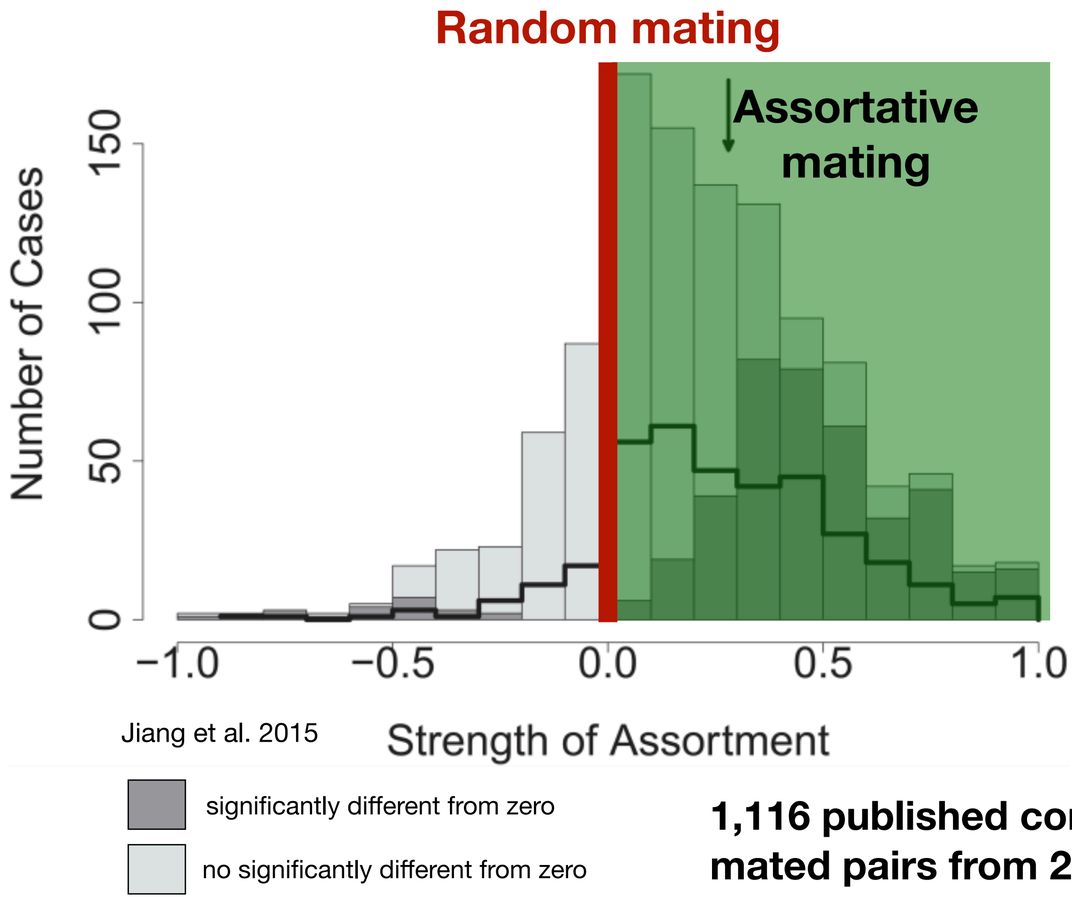
1,116 published correlations between mated pairs from 254 species in animals

The disassortative mating seems rare



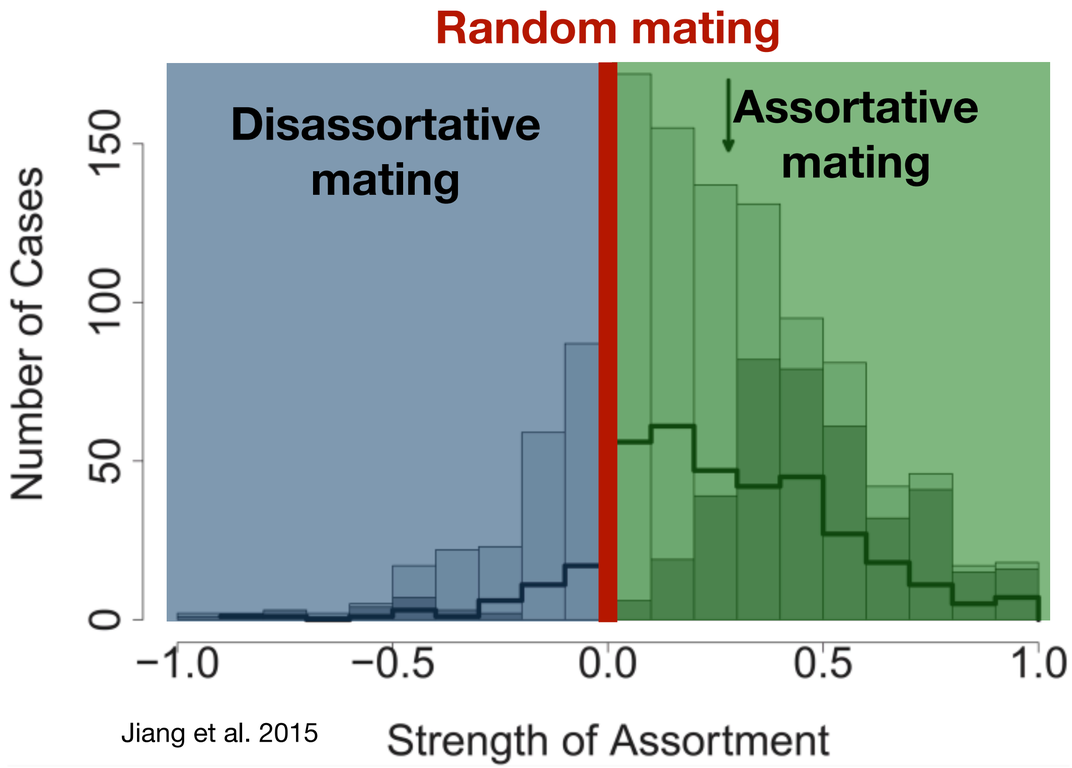
1,116 published correlations between mated pairs from 254 species in animals

The disassortative mating seems rare



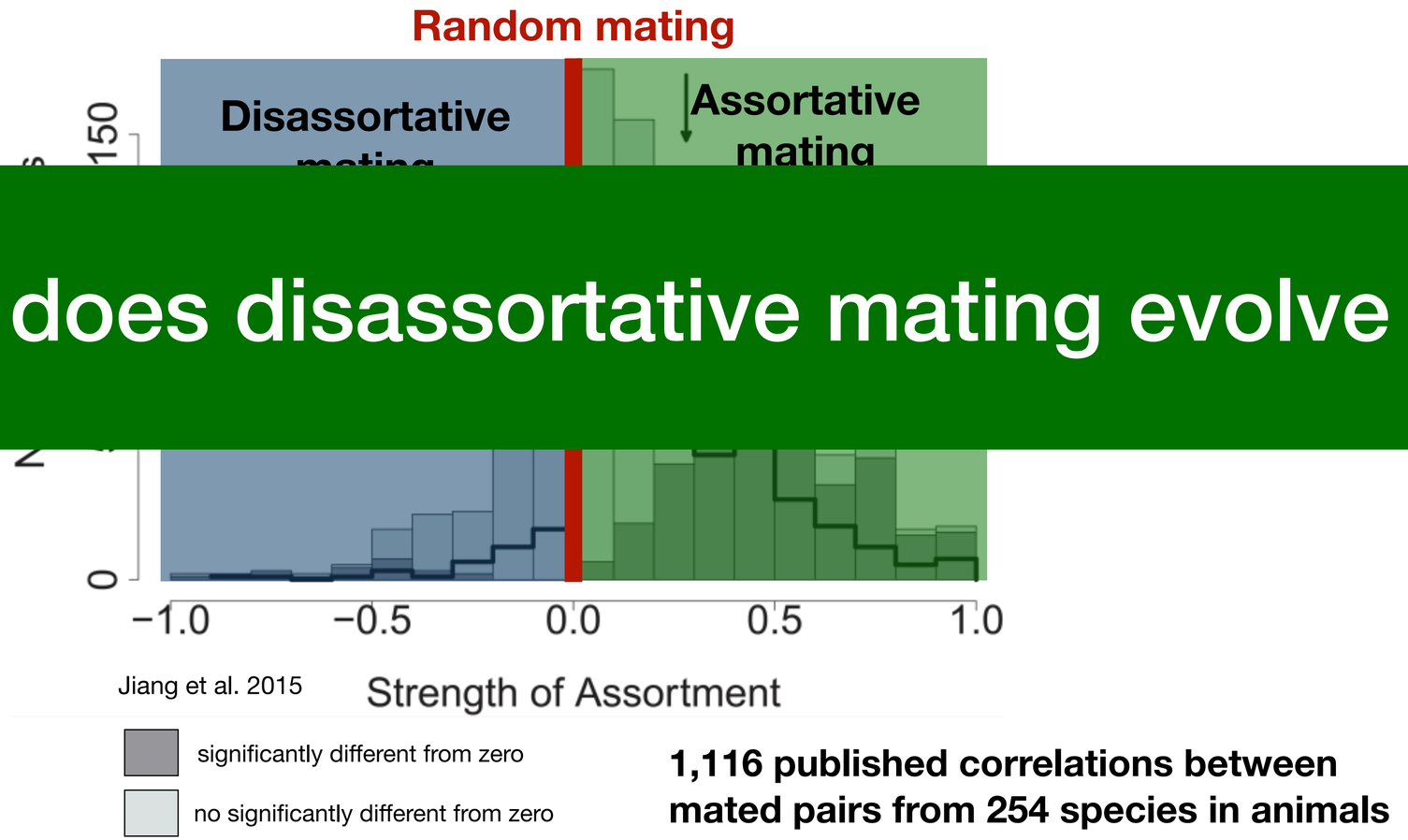
1,116 published correlations between mated pairs from 254 species in animals

The disassortative mating seems rare



1,116 published correlations between mated pairs from 254 species in animals

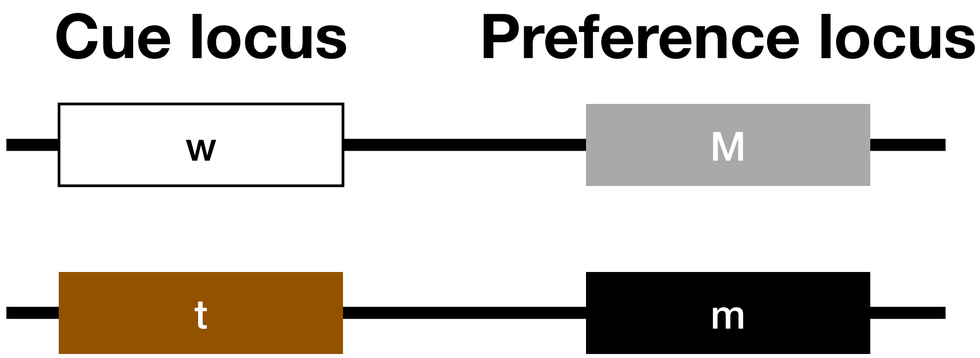
The disassortative mating seems rare



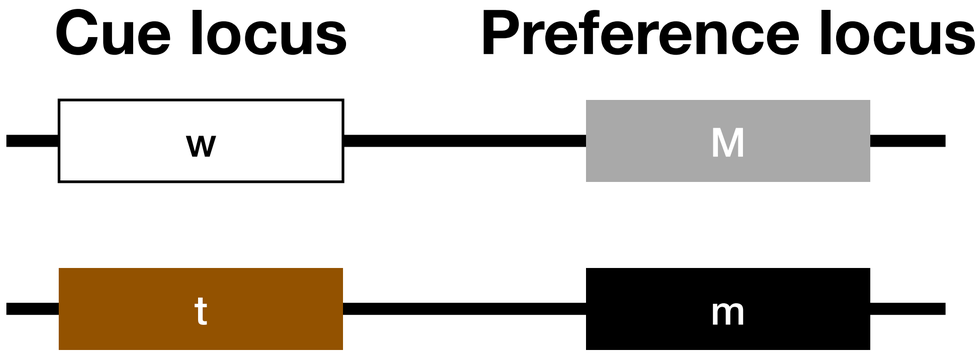
How does disassortative mating evolve ?

1,116 published correlations between mated pairs from 254 species in animals

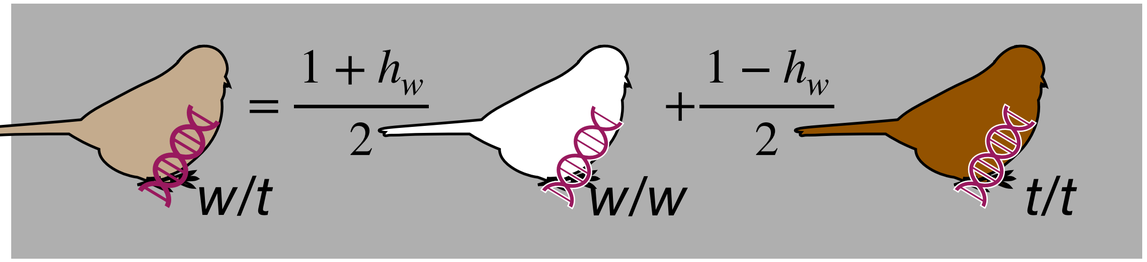
Otto et al. 2008



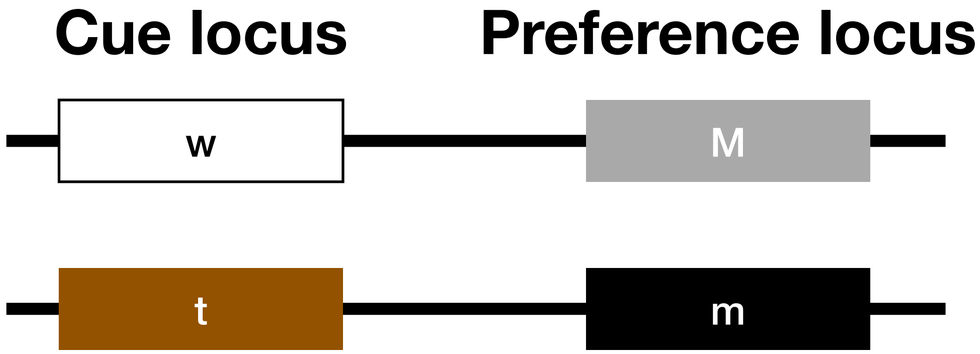
Otto et al. 2008



determine the cue

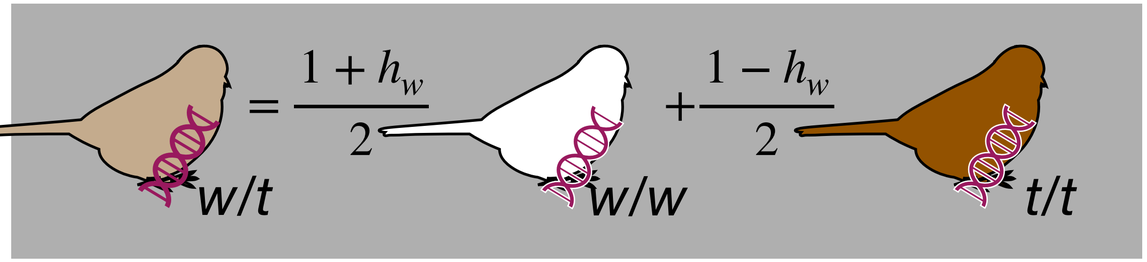


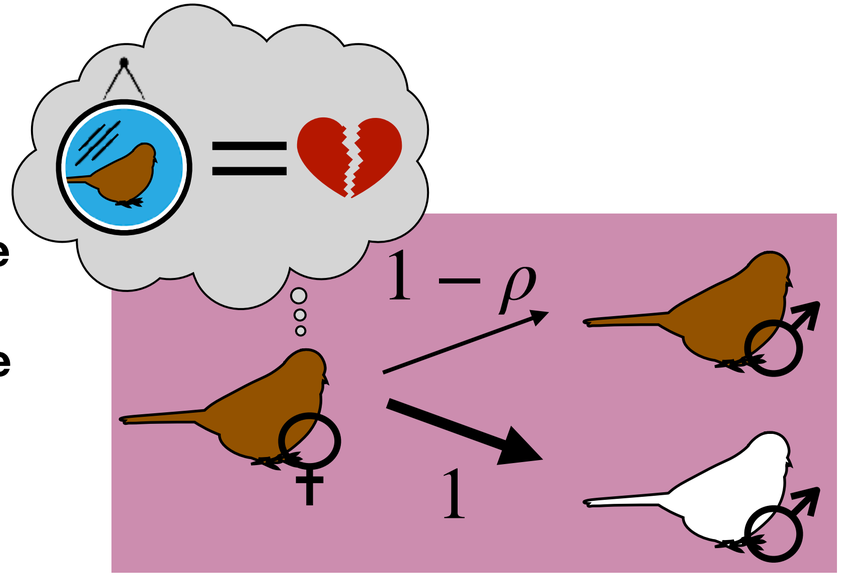
Otto et al. 2008



determine the cue

determine the strength of disassortative mating ρ





Otto et al. 2008

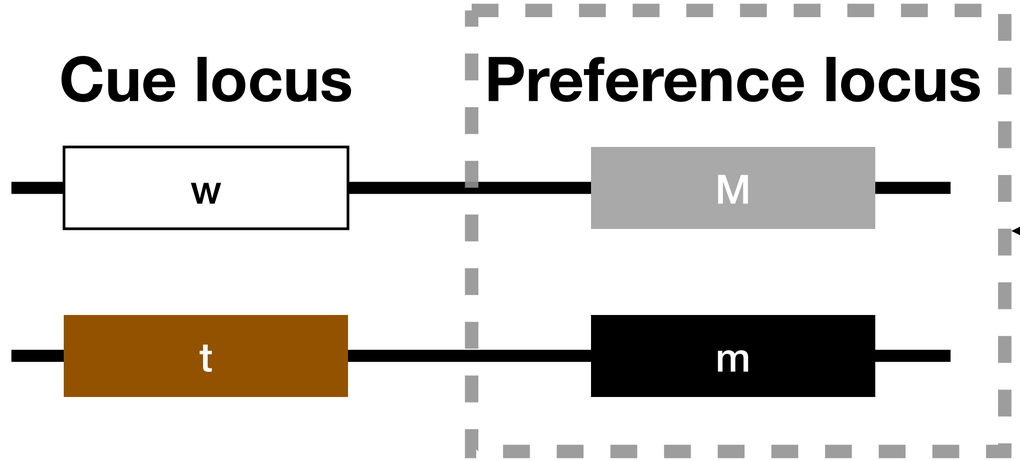
Cost of choosiness

Probability that a female of genotype i accepts a male during a mating encounter

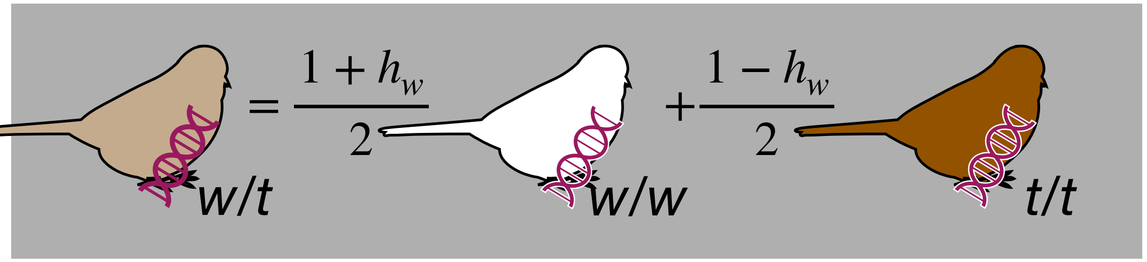
$$T_i = \sum_j \text{Pref}_{ij}(\rho_k)\text{freq of male j},$$

Fertility

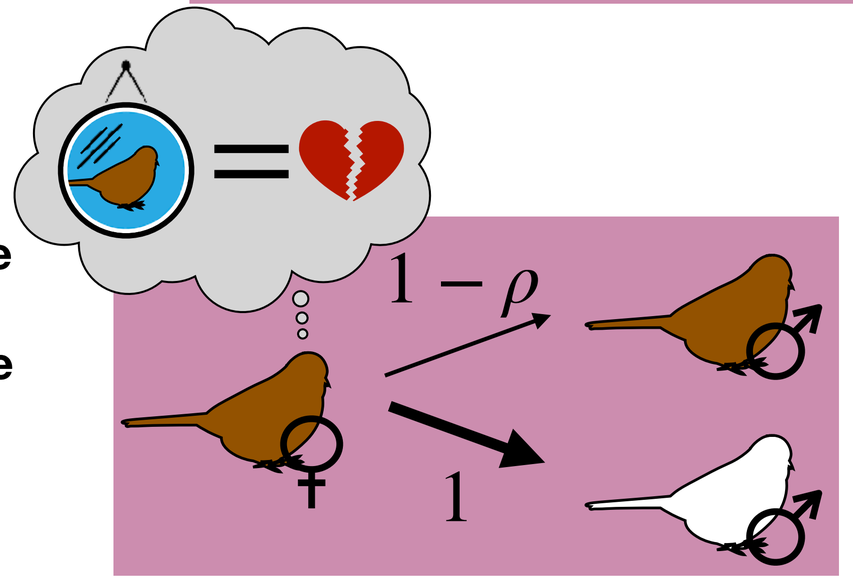
$$F_i = \underbrace{(1 - c_r + c_r T_i)}_{\text{relative cost}}\underbrace{(1 - c_f \rho)}_{\text{fixed cost}}$$



determine the cue



determine the strength of disassortative mating ρ



Otto et al. 2008

Cost of choosiness

Probability that a female of genotype i accepts a male during a mating encounter

$$T_i = \sum_j \text{Pref}_{ij}(\rho_k)\text{freq of male j},$$

Fertility

$$F_i = \underbrace{(1 - c_r + c_r T_i)}_{\text{relative cost}}\underbrace{(1 - c_f \rho)}_{\text{fixed cost}}$$

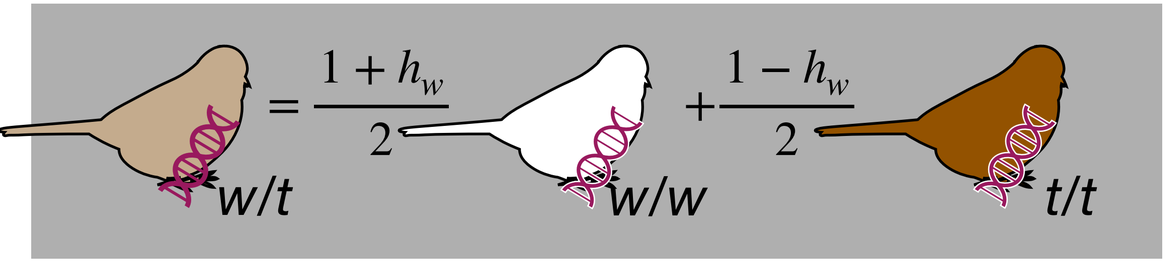
Viability selection

$W_{w/w}, W_{w/t}, W_{t/t}$

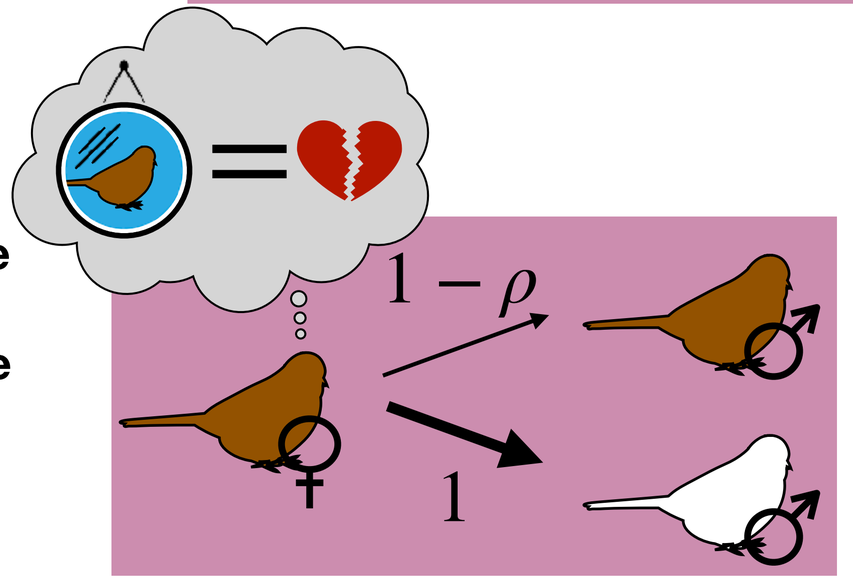
Cue locus: w, t

Preference locus: M, m

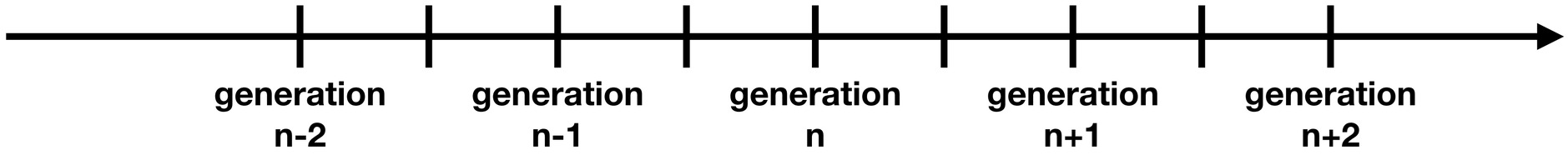
determine the cue



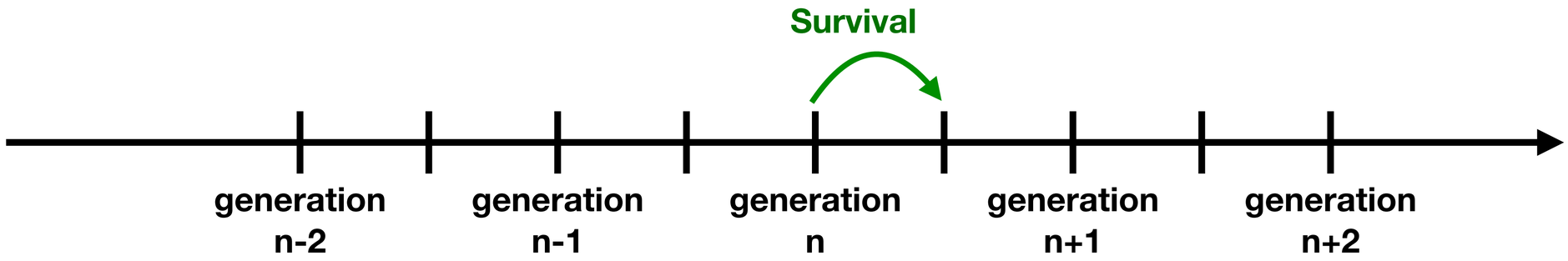
determine the strength of disassortative mating ρ



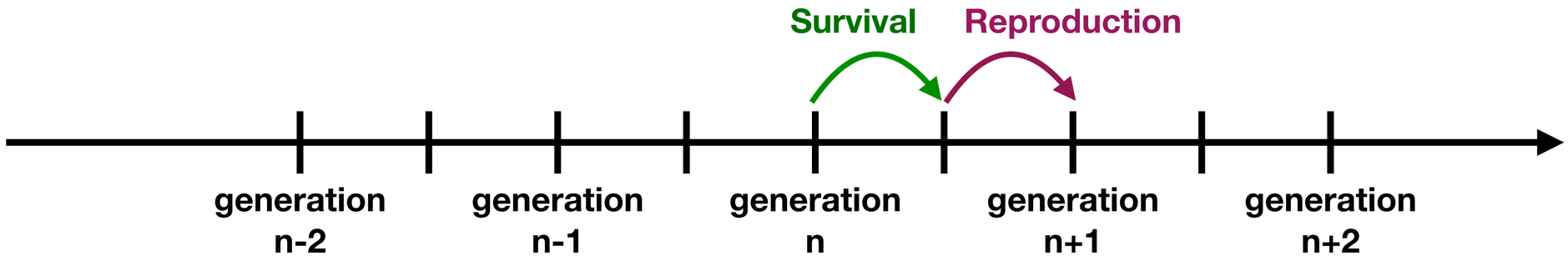
Quasi Linkage Equilibrium analysis



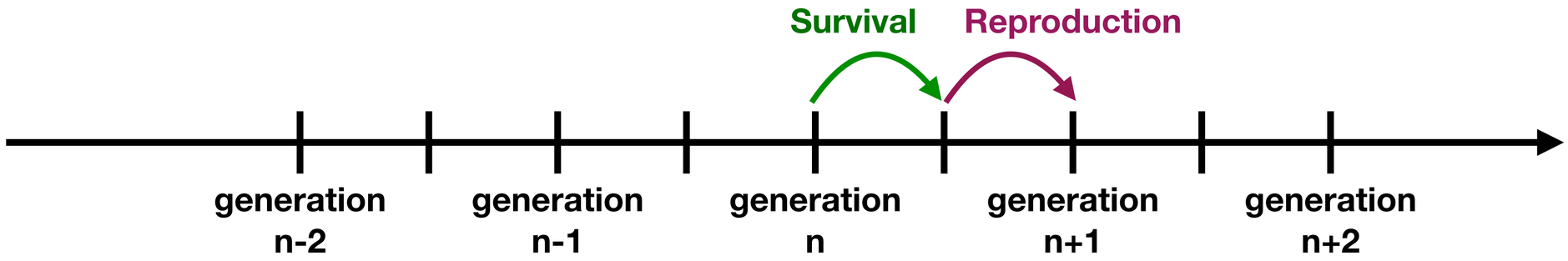
Quasi Linkage Equilibrium analysis

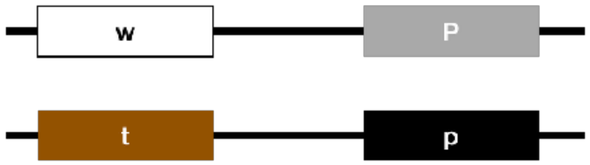


Quasi Linkage Equilibrium analysis



Quasi Linkage Equilibrium analysis

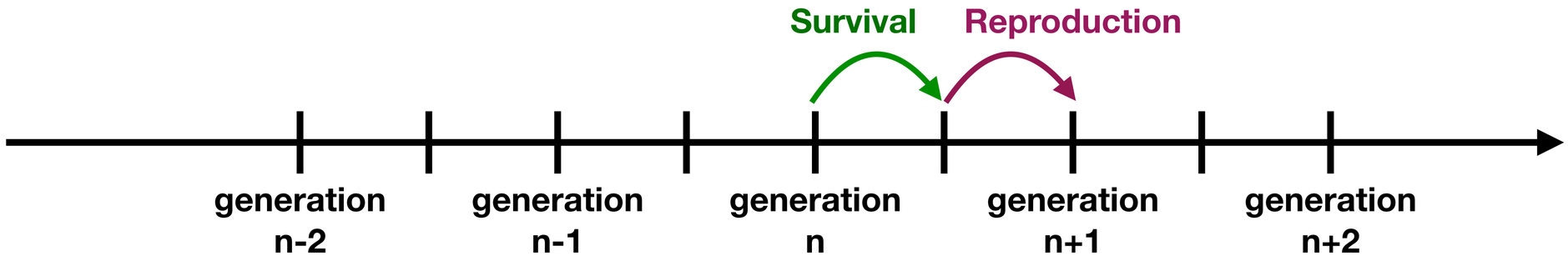


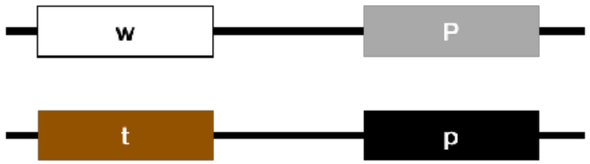


12 genotypic frequencies

↳ 11 genotypic frequencies to follow

Quasi Linkage Equilibrium analysis





12 genotypic frequencies

11 genotypic frequencies to follow

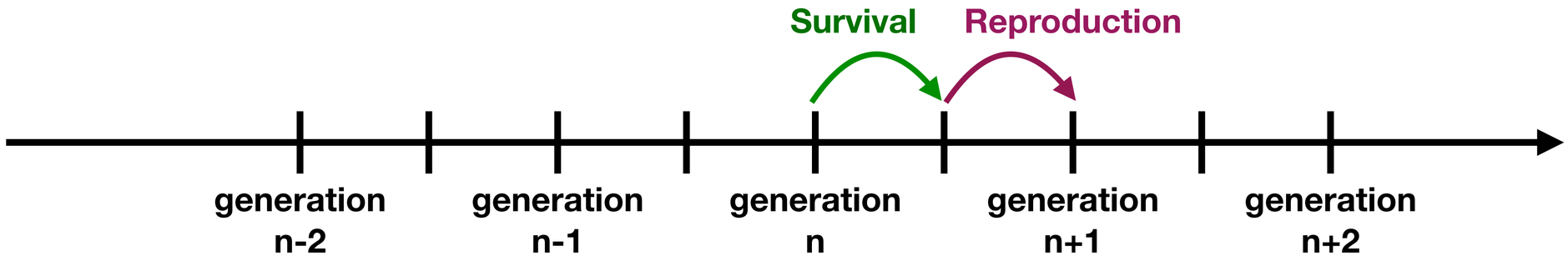
variable change

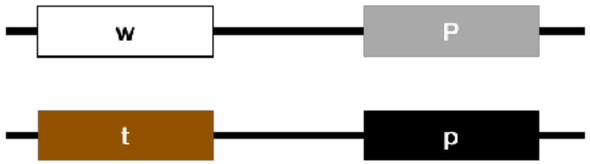
2 allelic frequencies p_w (white allele)

et p_m (disassortative mating allele)

9 genetic association terms

Quasi Linkage Equilibrium analysis





12 genotypic frequencies

11 genotypic frequencies to follow

variable change

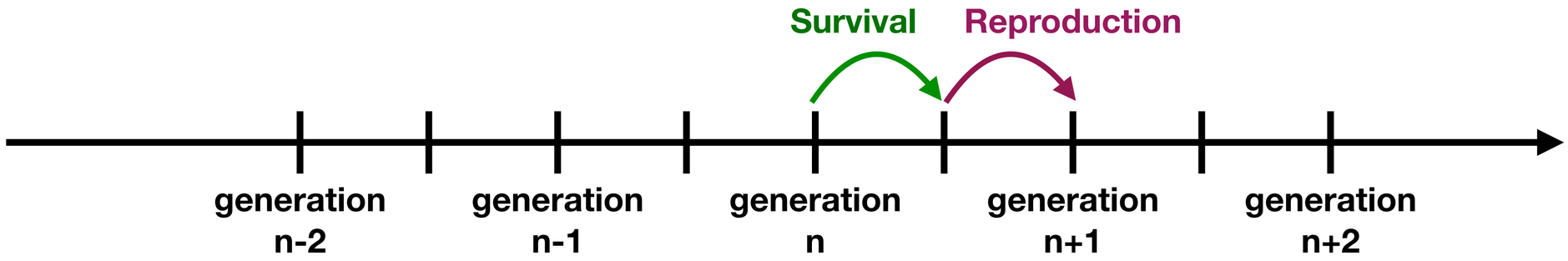
2 allelic frequencies p_w (white allele)

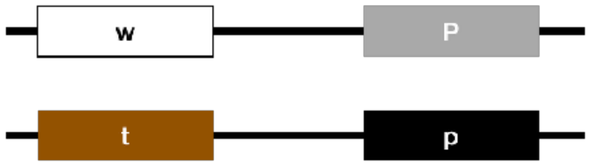
et p_m (disassortative mating allele)

9 genetic association terms

Assuming weak viable and sexual selection compared to recombination

Quasi Linkage Equilibrium analysis





12 genotypic frequencies

↳ 11 genotypic frequencies to follow

variable change

2 allelic frequencies p_w (white allele)

et p_m (disassortative mating allele)

9 genetic association terms

Assuming weak viable and sexual selection compared to recombination

↳ Association term reached equilibrium faster than allelic frequency

Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Under QLE hypothesis

$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Under QLE hypothesis

$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

$$G_{he,m} \approx \frac{1}{2} p_m(1-p_m)(p_w(1-p_w))^2 \Delta\rho(p_w^2 + (1-p_w)^2 + h_w(1-2p_w)) > 0$$

Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Under QLE hypothesis

$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

$$G_{he,m} \approx \frac{1}{2} p_m(1 - p_m)(p_w(1 - p_w))^2 \Delta\rho(p_w^2 + (1 - p_w)^2 + h_w(1 - 2p_w)) > 0$$

↳ the disassortative mating allele is associated with heterozygote

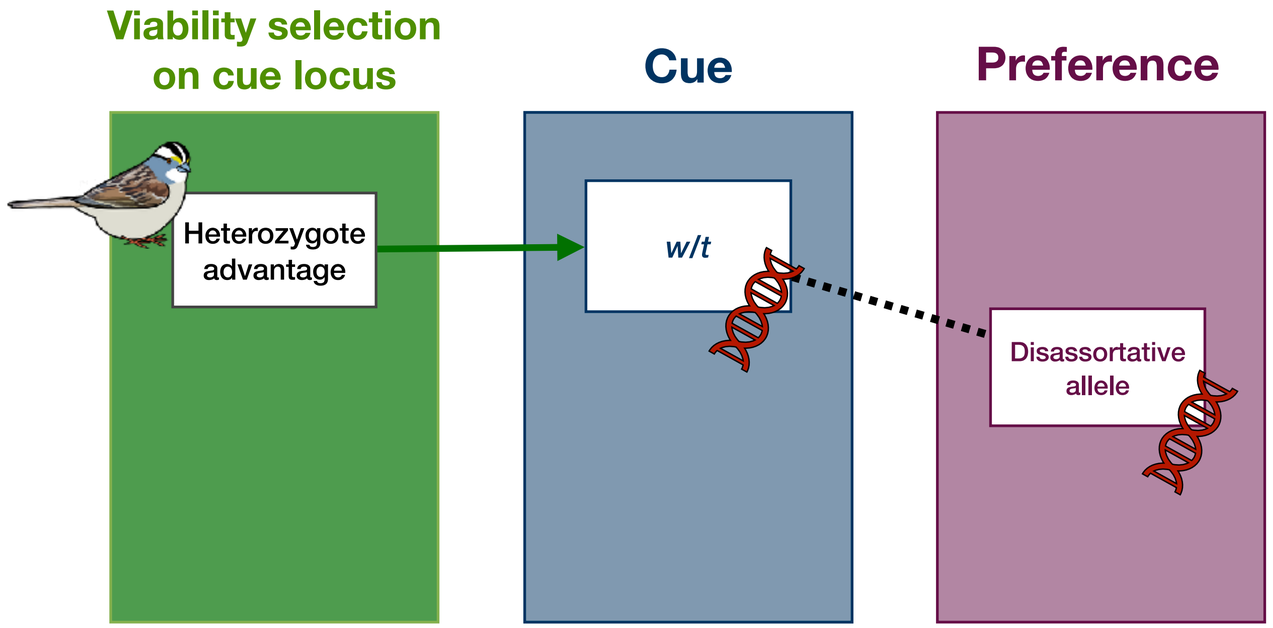
Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Under QLE hypothesis

$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

$$G_{he,m} \approx \frac{1}{2} p_m(1-p_m)(p_w(1-p_w))^2 \Delta\rho(p_w^2 + (1-p_w)^2 + h_w(1-2p_w)) > 0$$

the disassortative mating allele
is associated with heterozygote



genetic association

Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

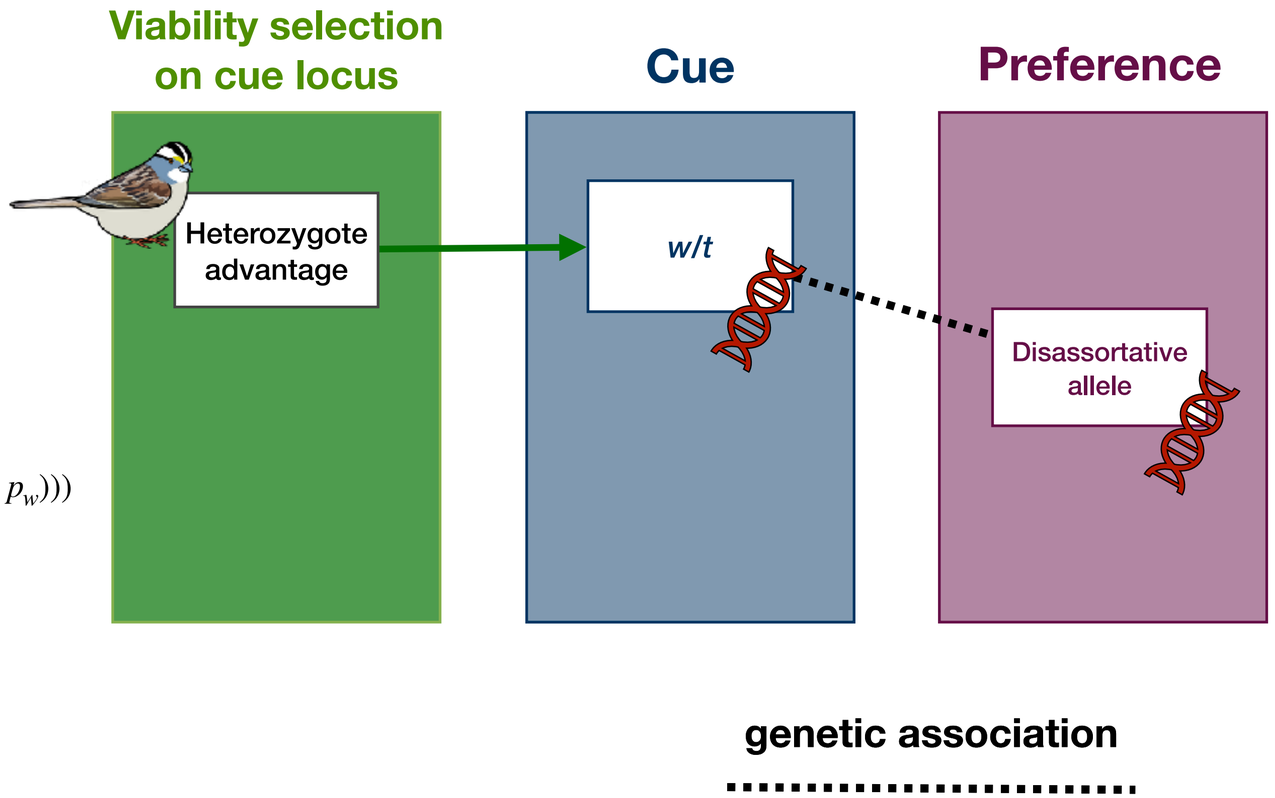
Under QLE hypothesis

$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

$$G_{he,m} \approx \frac{1}{2} p_m(1-p_m)(p_w(1-p_w))^2 \Delta\rho(p_w^2 + (1-p_w)^2 + h_w(1-2p_w)) > 0$$

→ the disassortative mating allele is associated with heterozygote

$$G_{wm} \approx G_{w,m} \approx \frac{p_m(1-p_m)p_w(1-p_w)}{2}\Delta\rho(((1-p_w)^4 - p_w^4) + \frac{h_w}{2}(p_w^2 + (1-p_w)^2 - 2p_w(1-p_w)))$$



Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Under QLE hypothesis

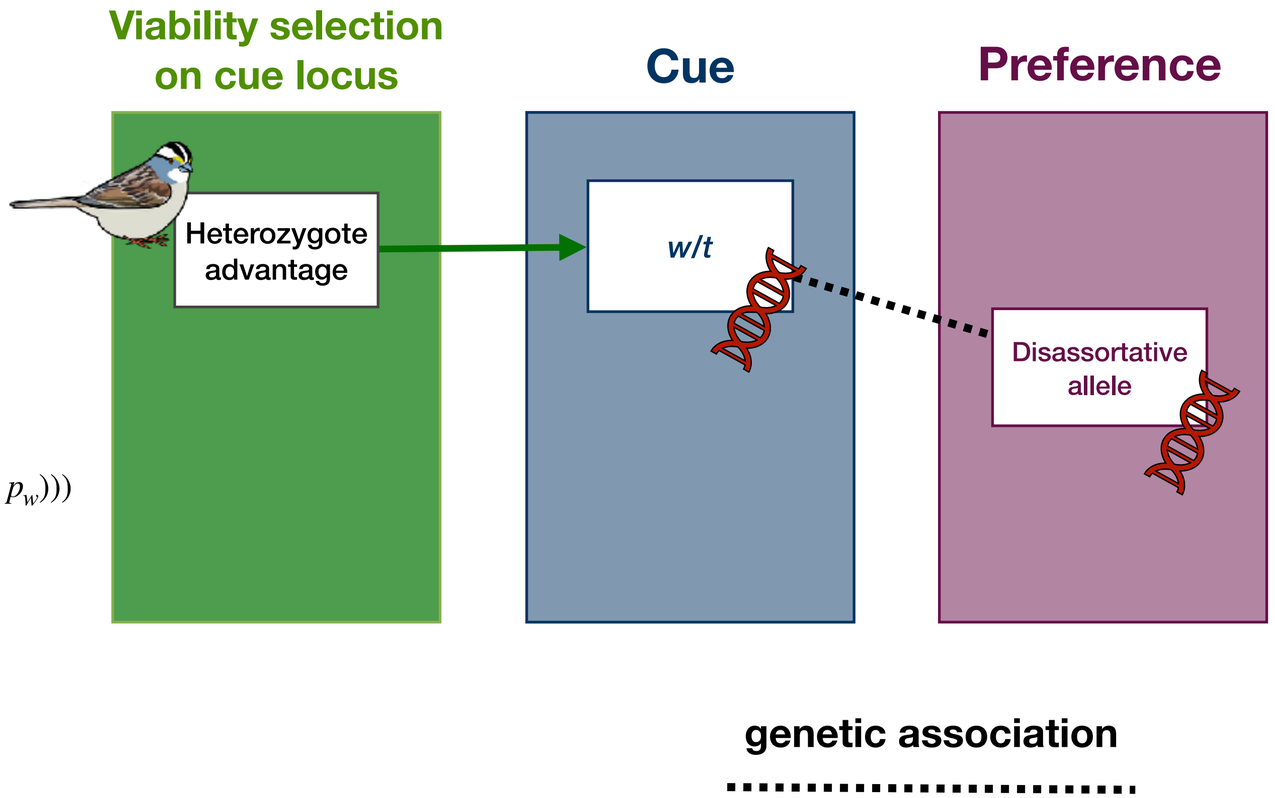
$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

$$G_{he,m} \approx \frac{1}{2} p_m(1-p_m)(p_w(1-p_w))^2 \Delta\rho(p_w^2 + (1-p_w)^2 + h_w(1-2p_w)) > 0$$

→ the disassortative mating allele is associated with heterozygote

$$G_{wm} \approx G_{w,m} \approx \frac{p_m(1-p_m)p_w(1-p_w)}{2}\Delta\rho(((1-p_w)^4 - p_w^4) + \frac{h_w}{2}(p_w^2 + (1-p_w)^2 - 2p_w(1-p_w)))$$

G_{wm} and $G_{w,m}$ as the same sign as $1 - 2p_w$



Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Under QLE hypothesis

$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

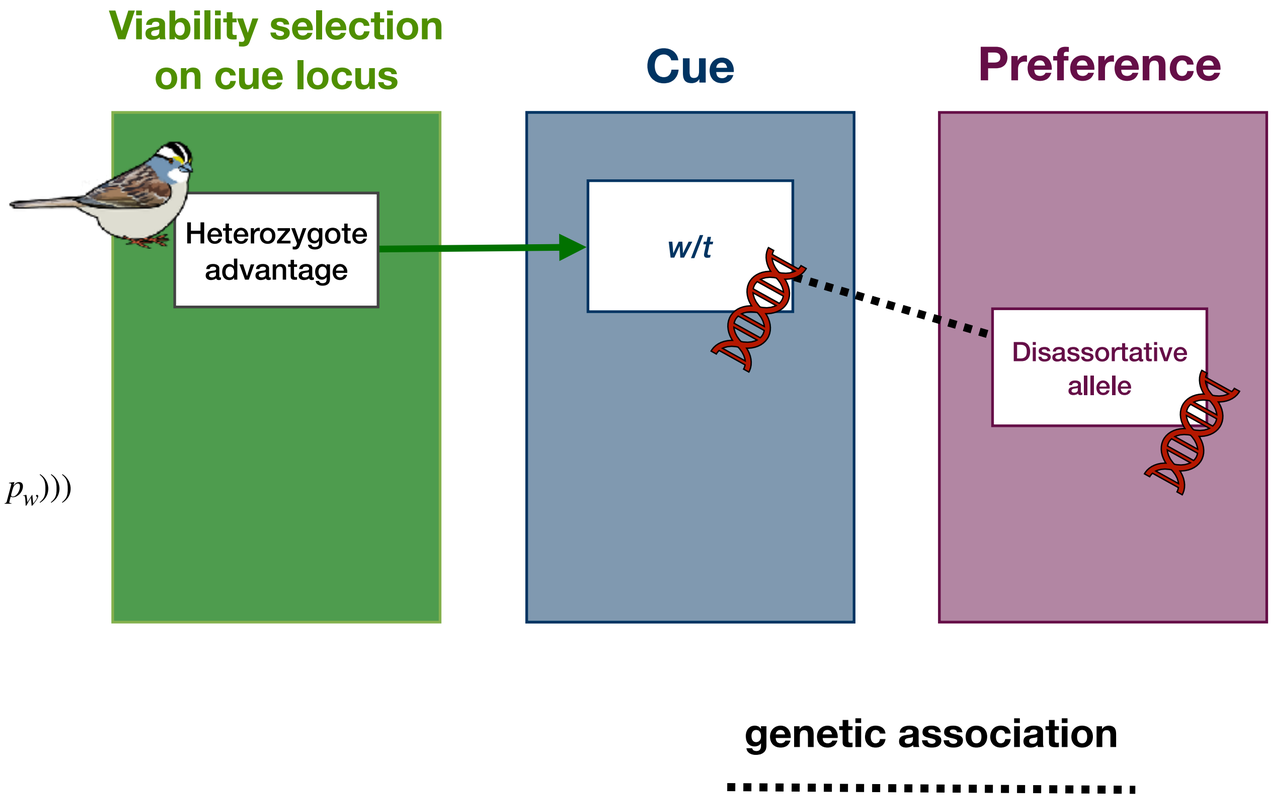
$$G_{he,m} \approx \frac{1}{2} p_m(1-p_m)(p_w(1-p_w))^2 \Delta\rho(p_w^2 + (1-p_w)^2 + h_w(1-2p_w)) > 0$$

↳ **the disassortative mating allele is associated with heterozygote**

$$G_{wm} \approx G_{w,m} \approx \frac{p_m(1-p_m)p_w(1-p_w)}{2}\Delta\rho(((1-p_w)^4 - p_w^4) + \frac{h_w}{2}(p_w^2 + (1-p_w)^2 - 2p_w(1-p_w)))$$

G_{wm} and $G_{w,m}$ as the same sign as $1 - 2p_w$

↳ **the disassortative mating allele is associated with the rarest allele**



Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Under QLE hypothesis

$$\Delta p_m \approx G_{he,m}(H_{ns} + H_{ss}) + (G_{wm} + G_{w,m})\frac{\Delta p_w}{D_C} + \textbf{cost}$$

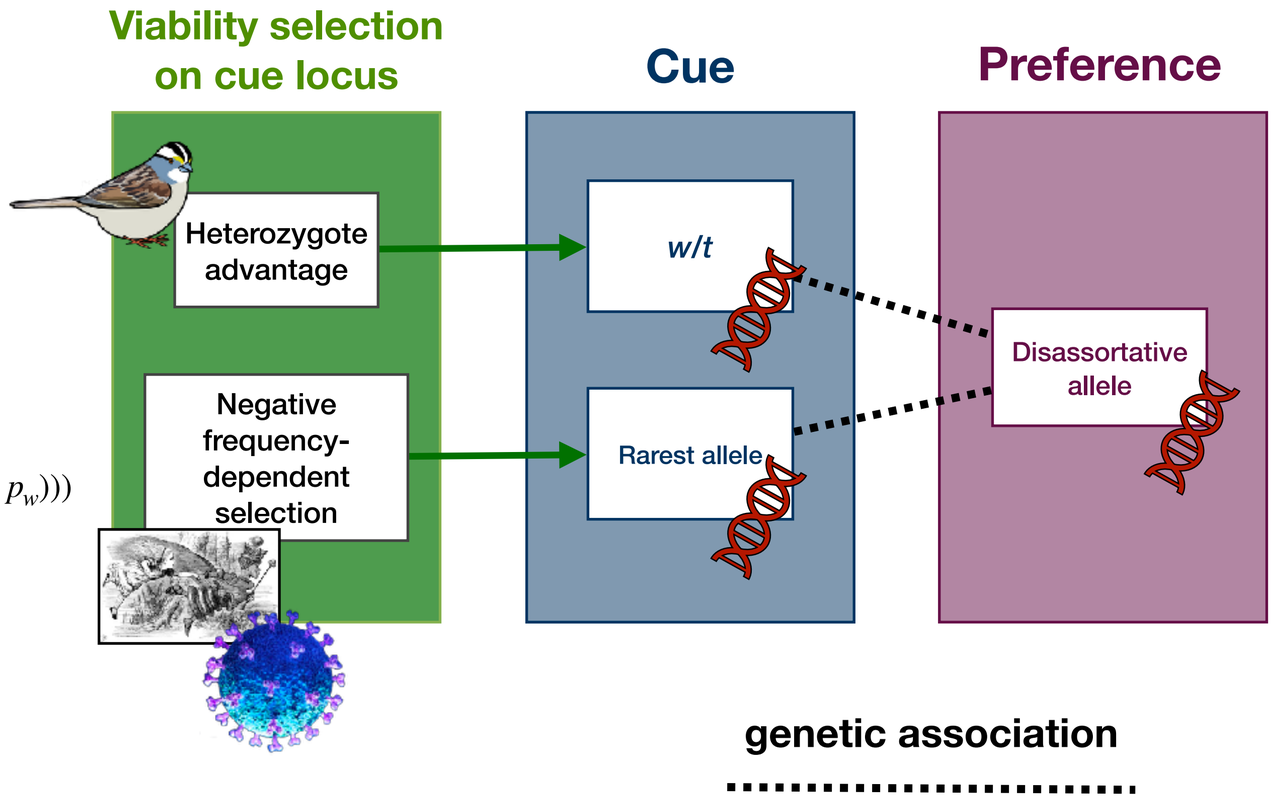
$$G_{he,m} \approx \frac{1}{2} p_m(1-p_m)(p_w(1-p_w))^2 \Delta\rho(p_w^2 + (1-p_w)^2 + h_w(1-2p_w)) > 0$$

↳ the disassortative mating allele is associated with heterozygote

$$G_{wm} \approx G_{w,m} \approx \frac{p_m(1-p_m)p_w(1-p_w)}{2}\Delta\rho(((1-p_w)^4 - p_w^4) + \frac{h_w}{2}(p_w^2 + (1-p_w)^2 - 2p_w(1-p_w)))$$

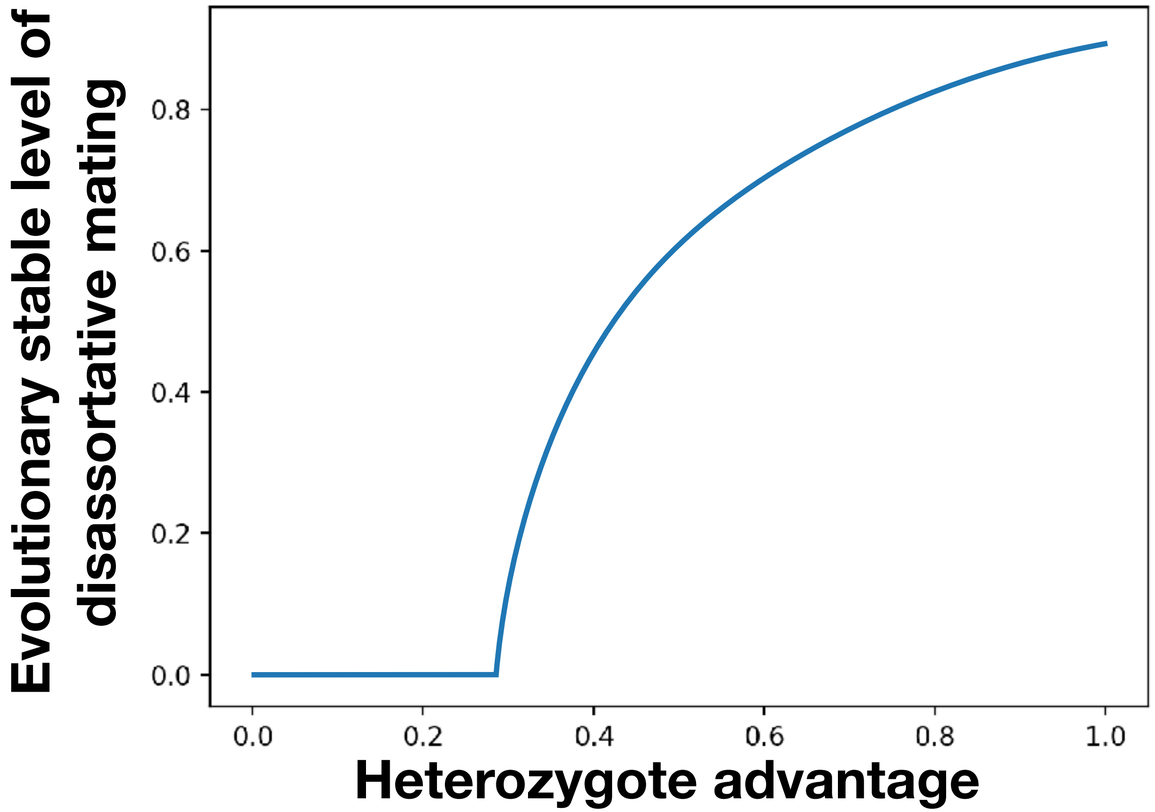
G_{wm} and $G_{w,m}$ as the same sign as $1 - 2p_w$

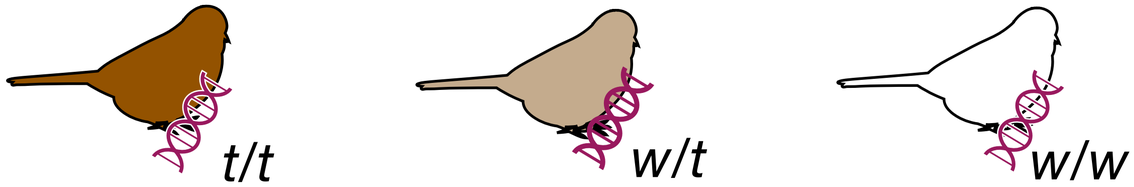
↳ the disassortative mating allele is associated with the rarest allele



Heterozygote advantage and negative frequency-dependent selection promote the evolution of disassortative mating

Relaxing QLE hypothesis

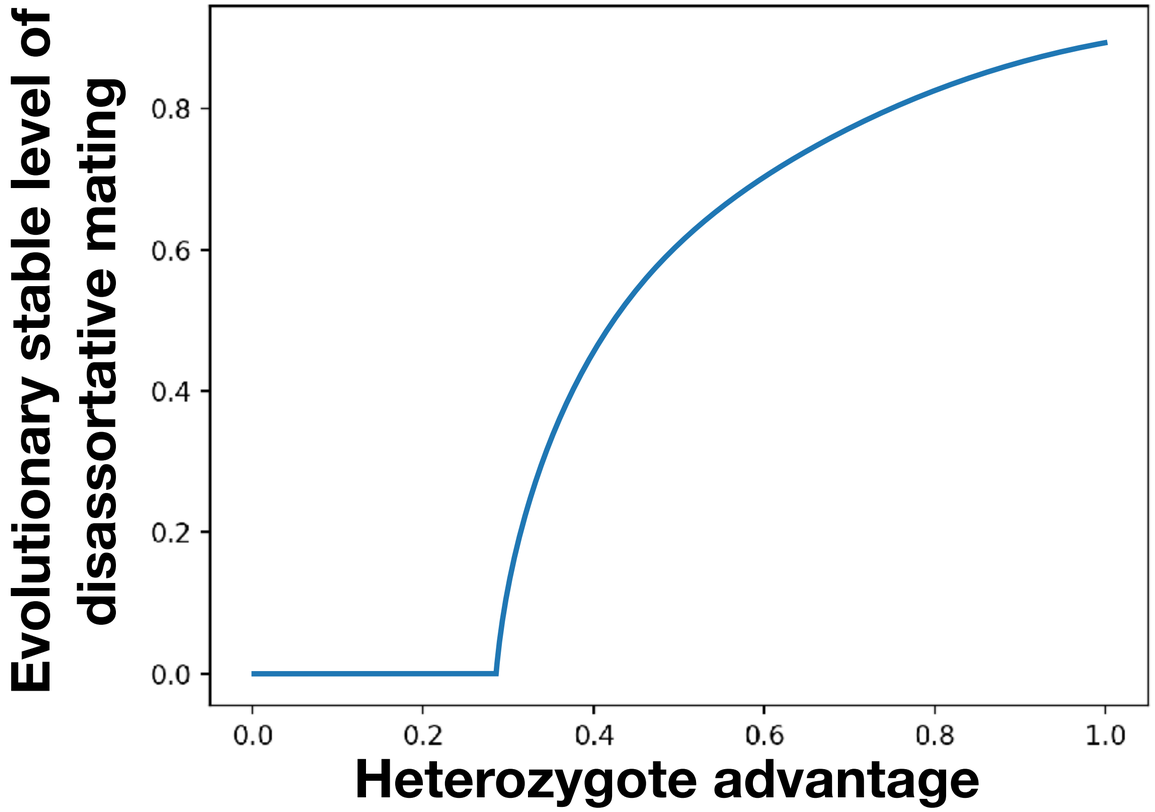




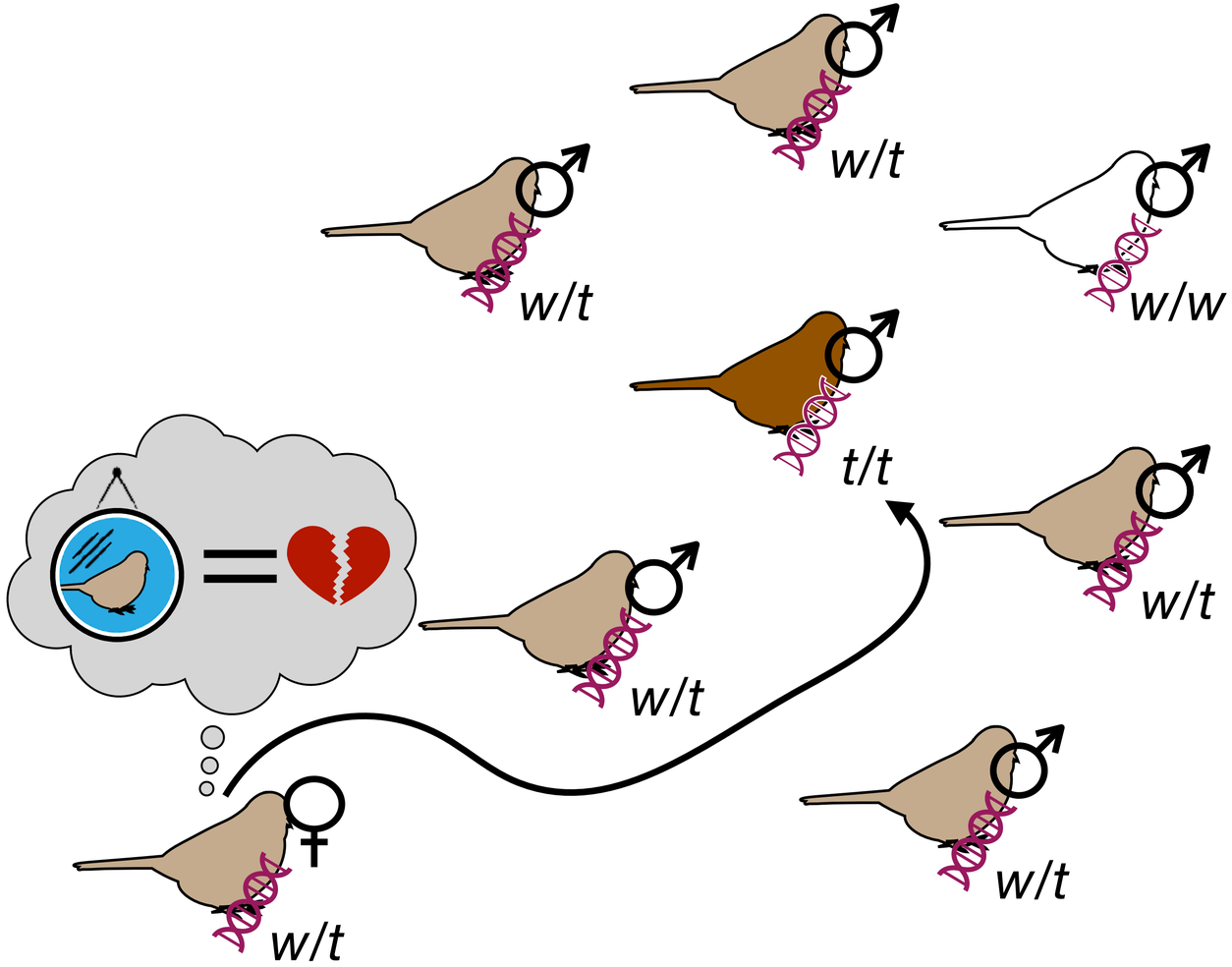
Fitness: $W_{w/w} = W_{t/t} = 1 - \delta/2, W_{w/t} = 1$

Cost of choosiness and sexual selection limit the evolution of disassortative mating

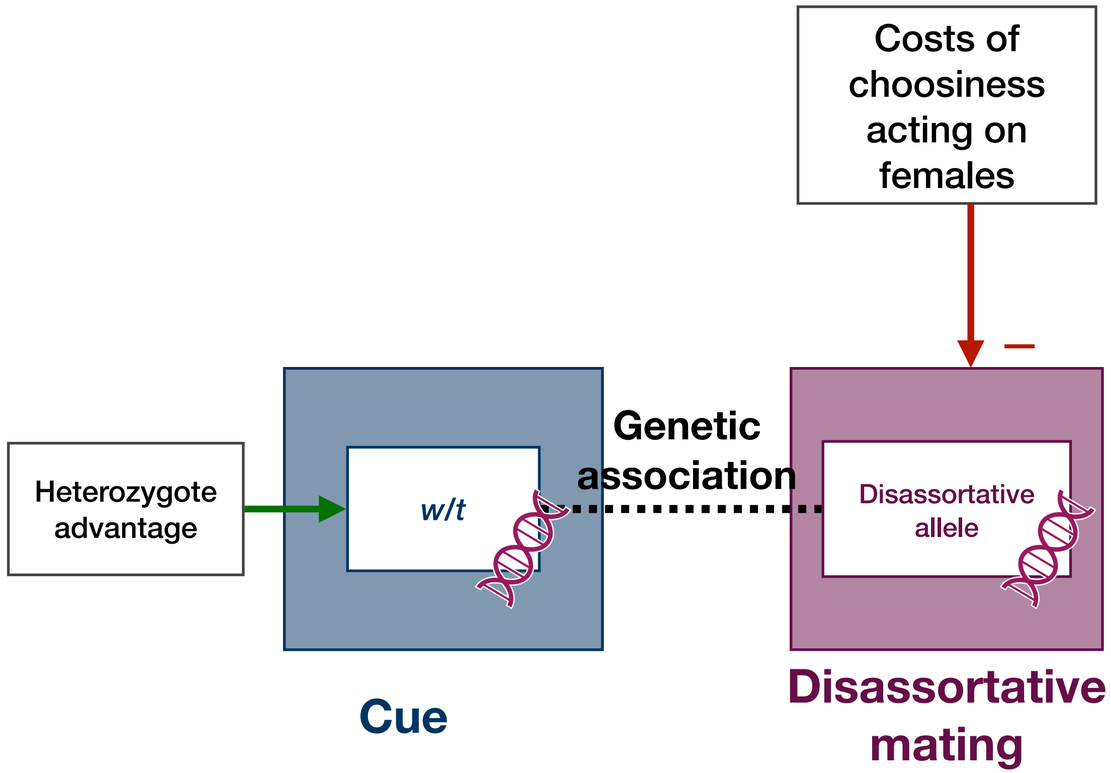
Relaxing QLE hypothesis

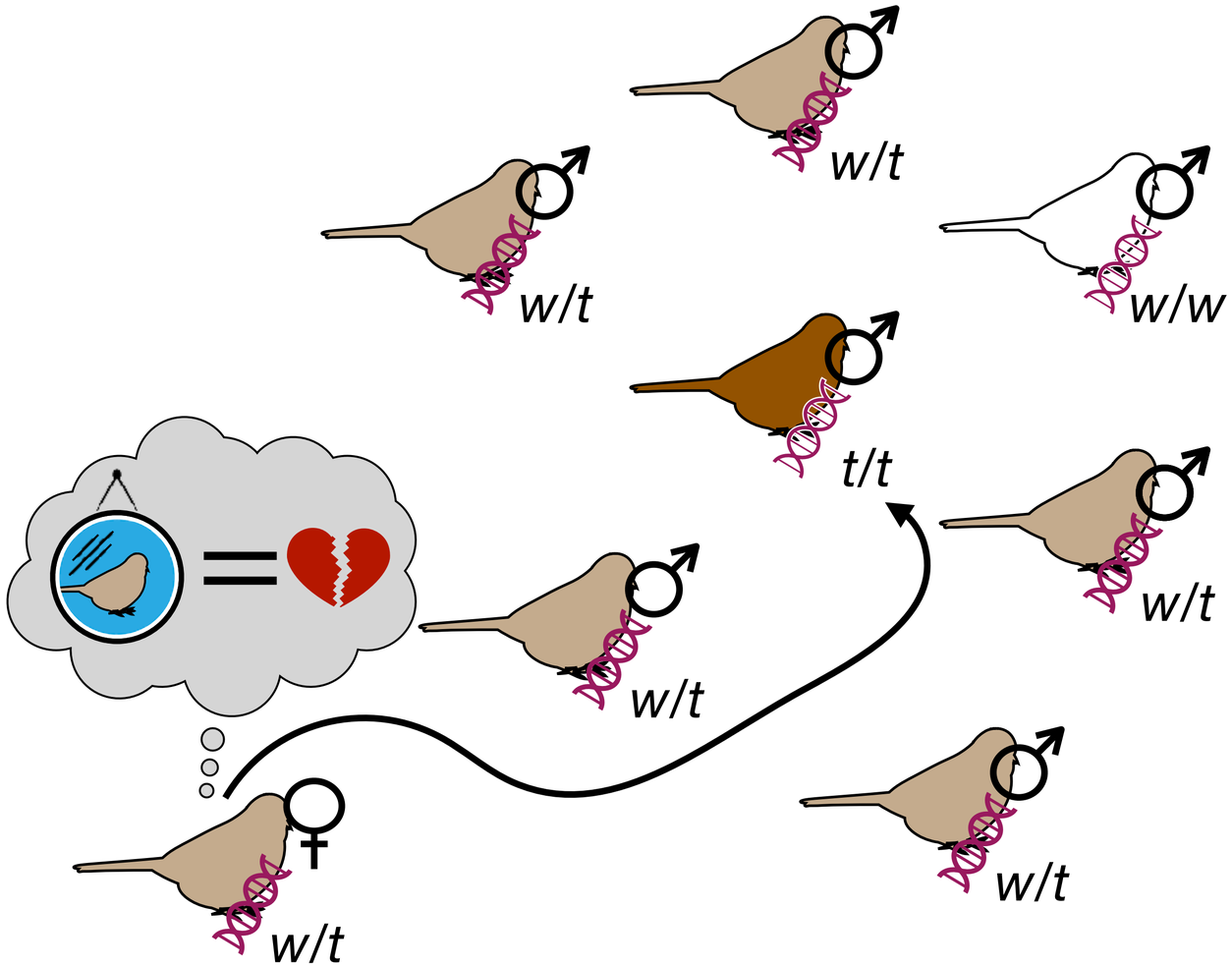


Fitness: $W_{w/w} = W_{t/t} = 1 - \delta/2, W_{w/t} = 1$

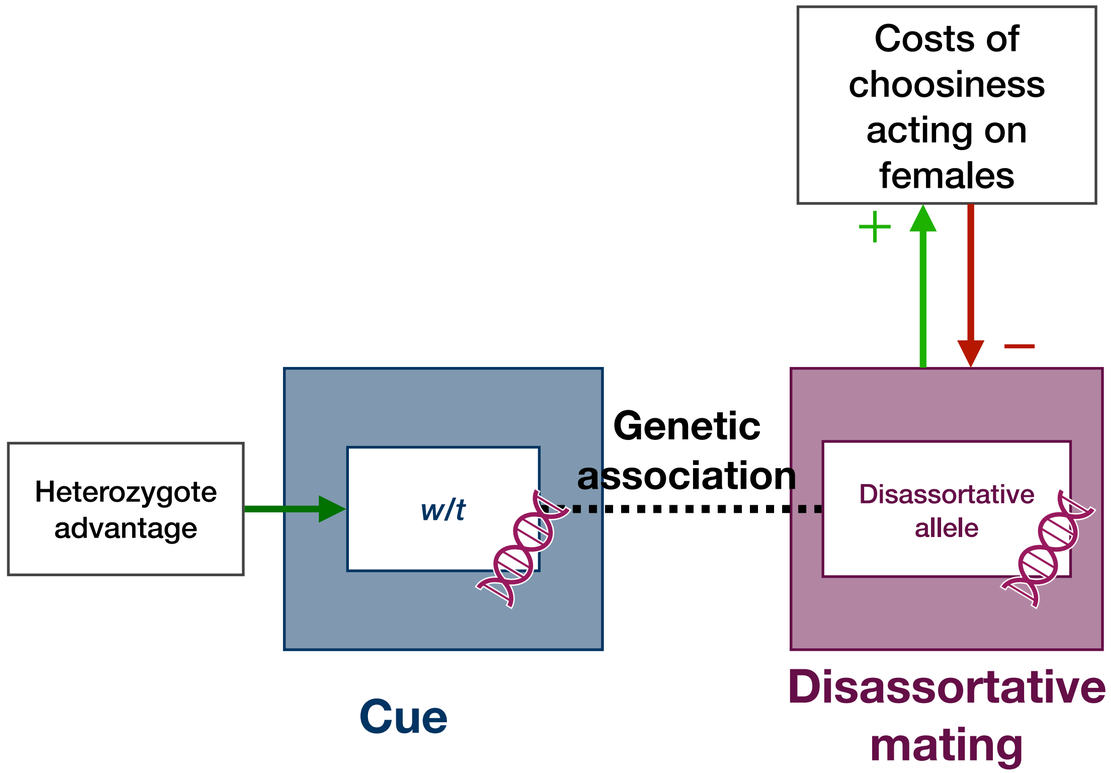


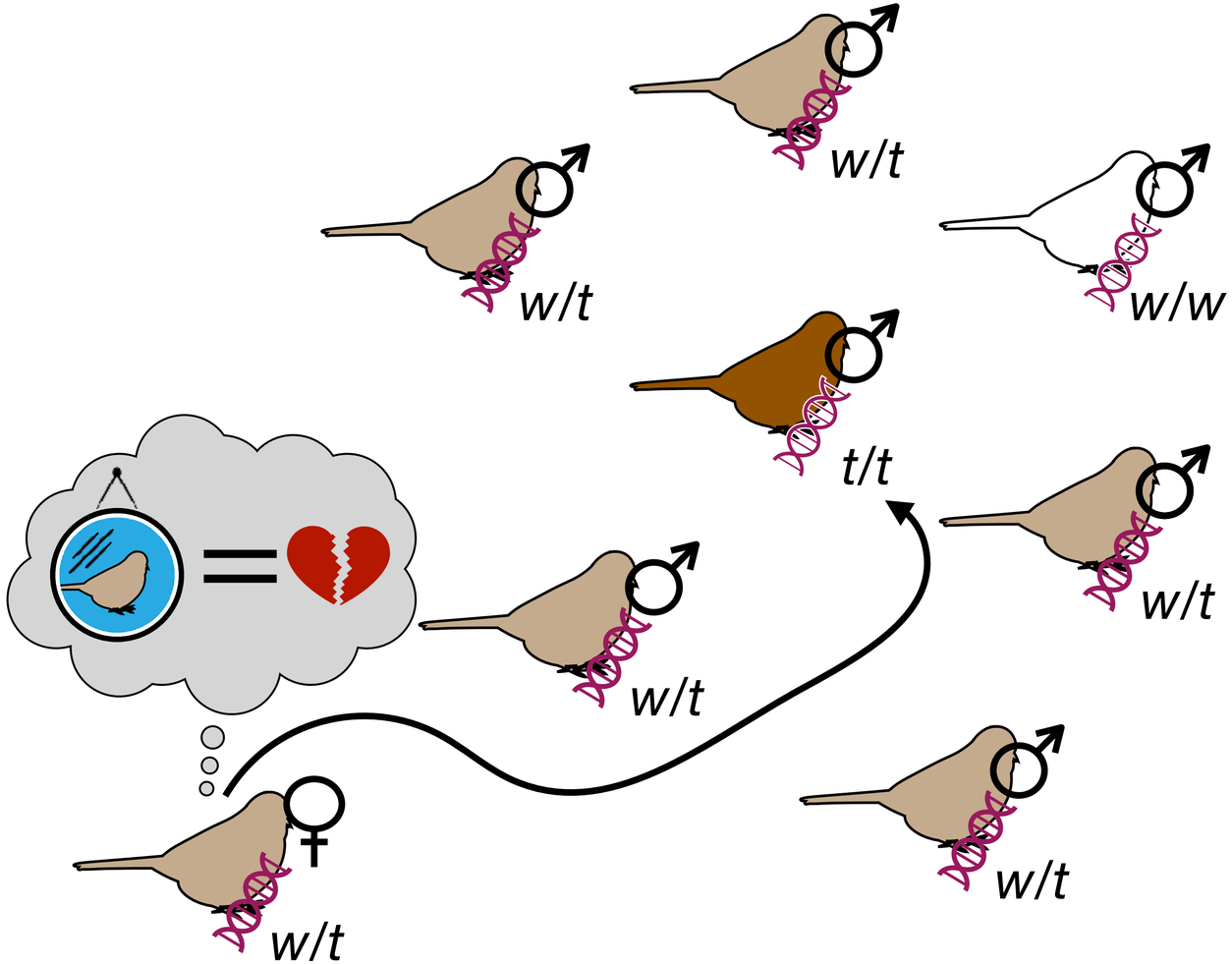
Cost of choosiness and sexual selection limit the evolution of disassortative mating



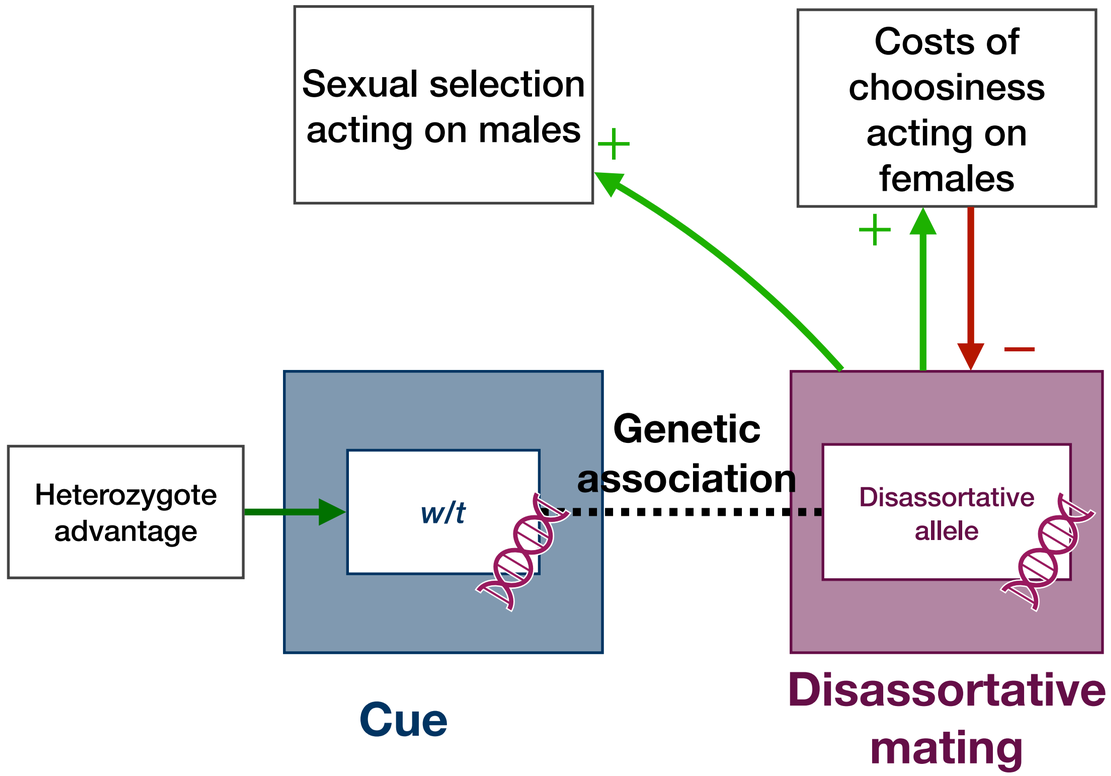


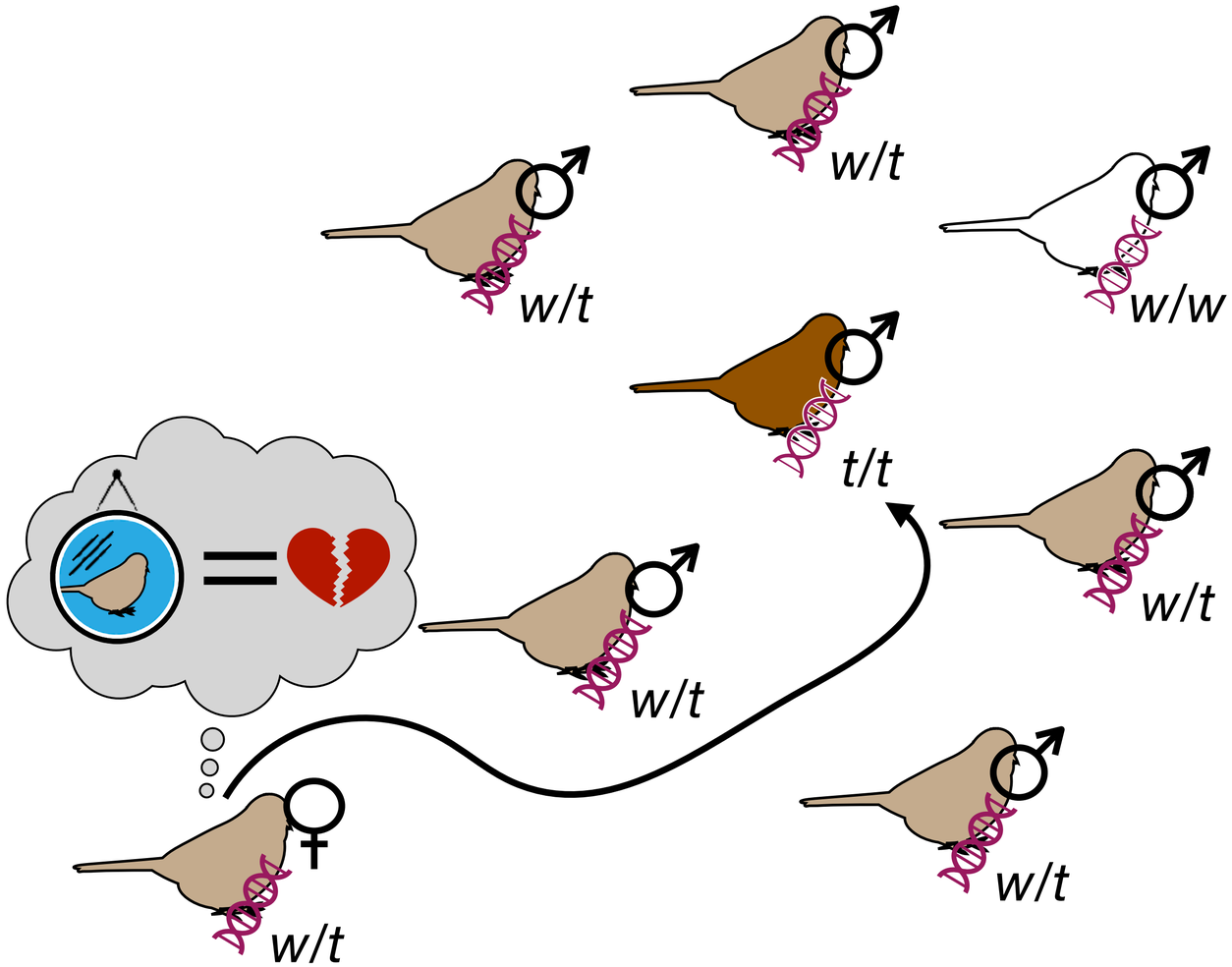
Cost of choosiness and sexual selection limit the evolution of disassortative mating



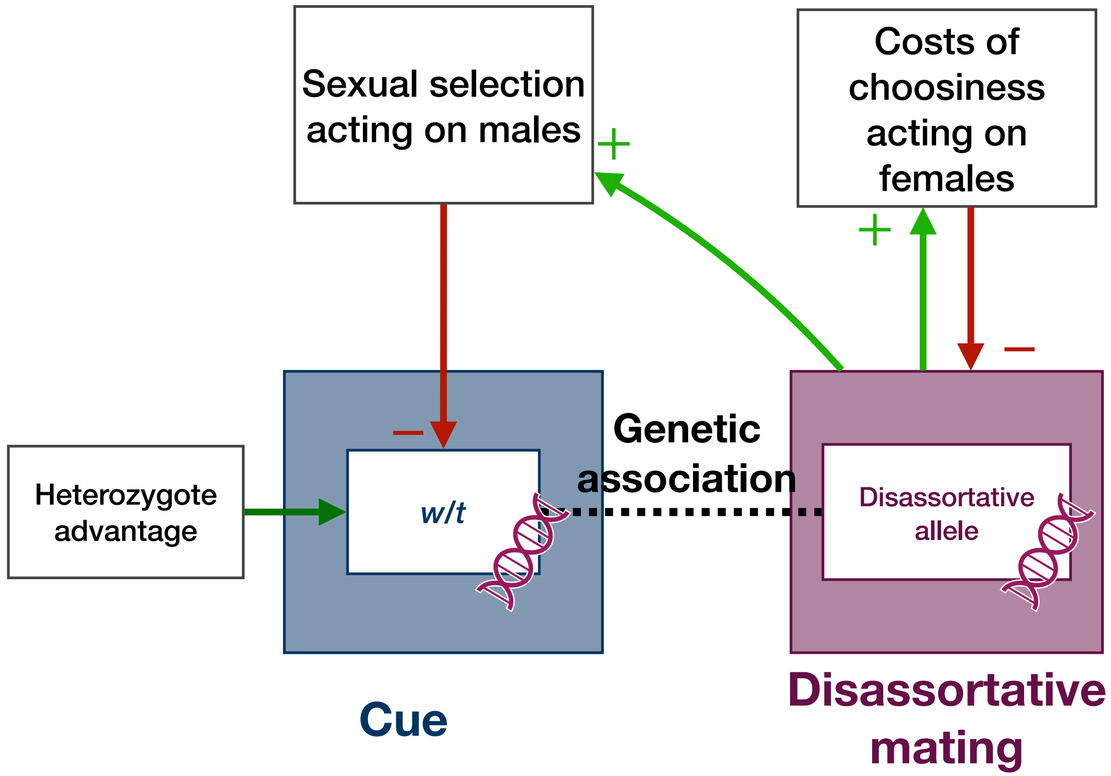


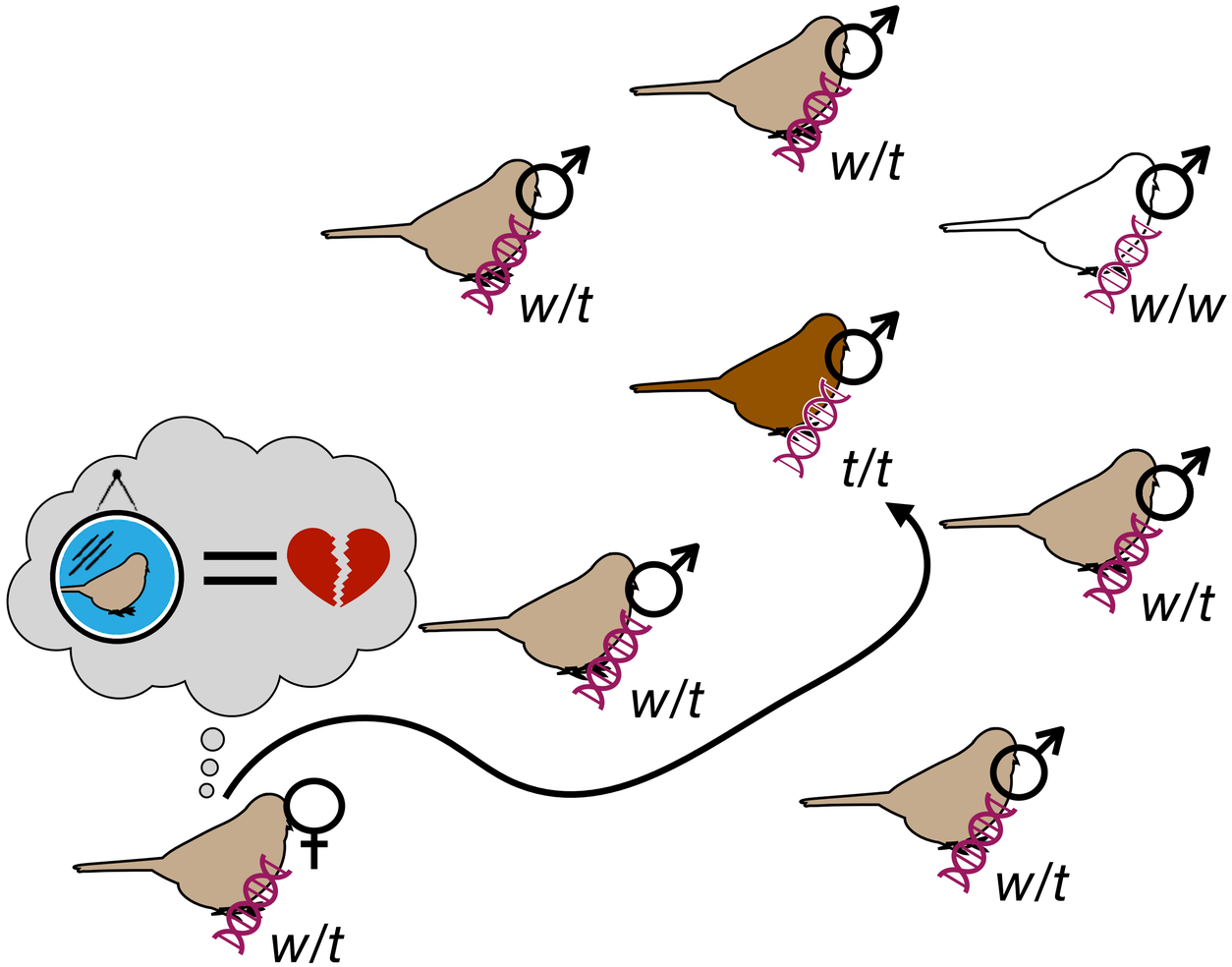
Cost of choosiness and sexual selection limit the evolution of disassortative mating



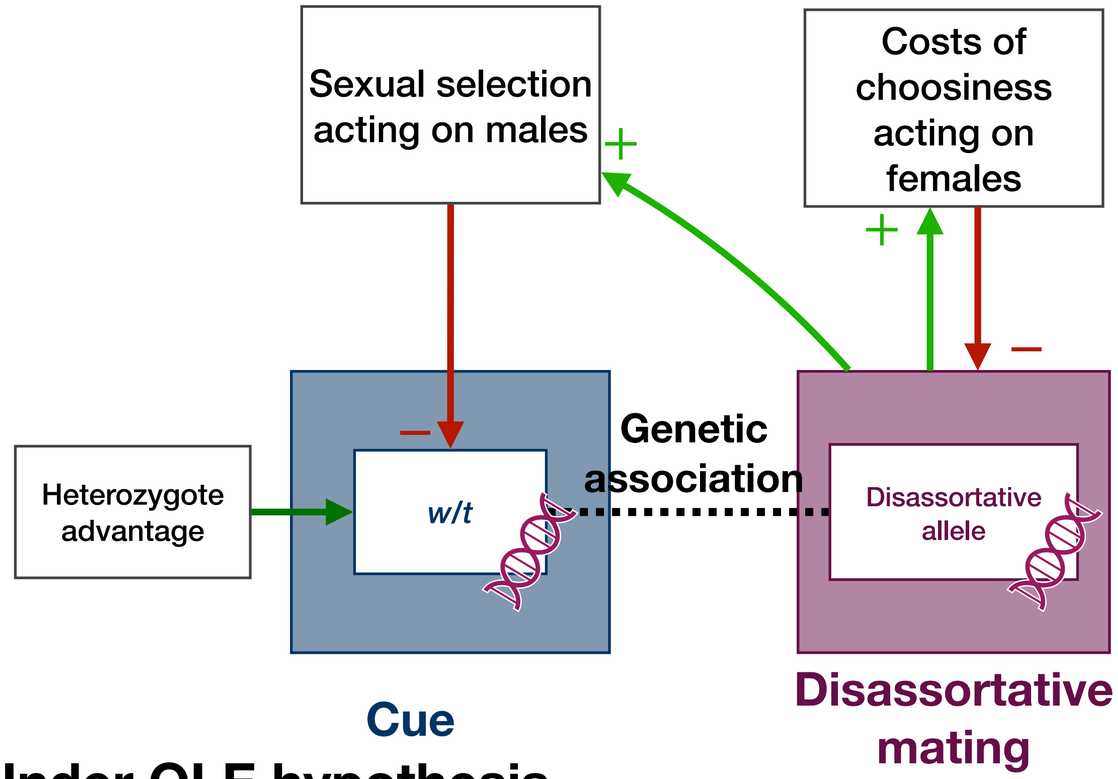


Cost of choosiness and sexual selection limit the evolution of disassortative mating



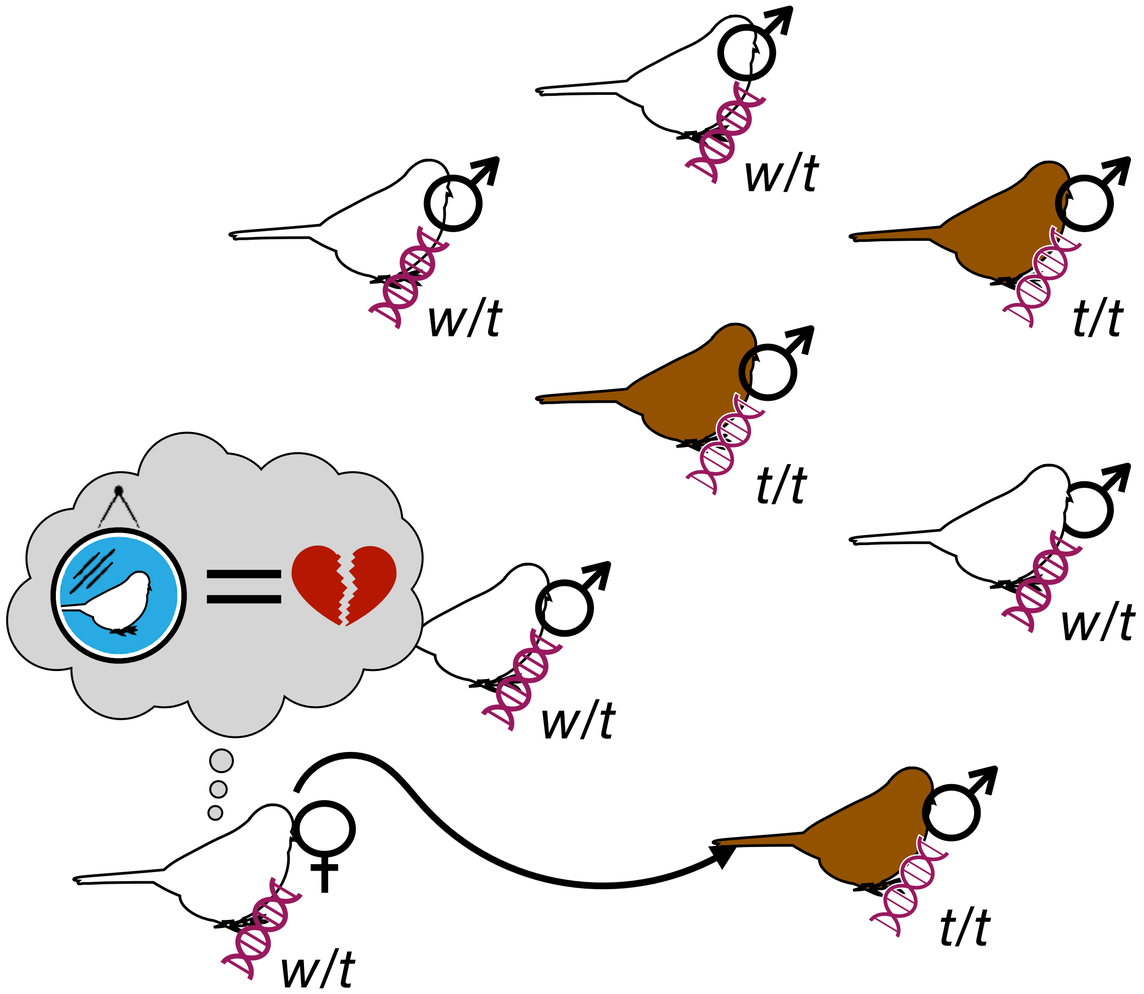


Cost of choosiness and sexual selection limit the evolution of disassortative mating



Under QLE hypothesis

The negative feedback limiting the evolution of disassortative mating is minimal when one cue allele is rare and dominant

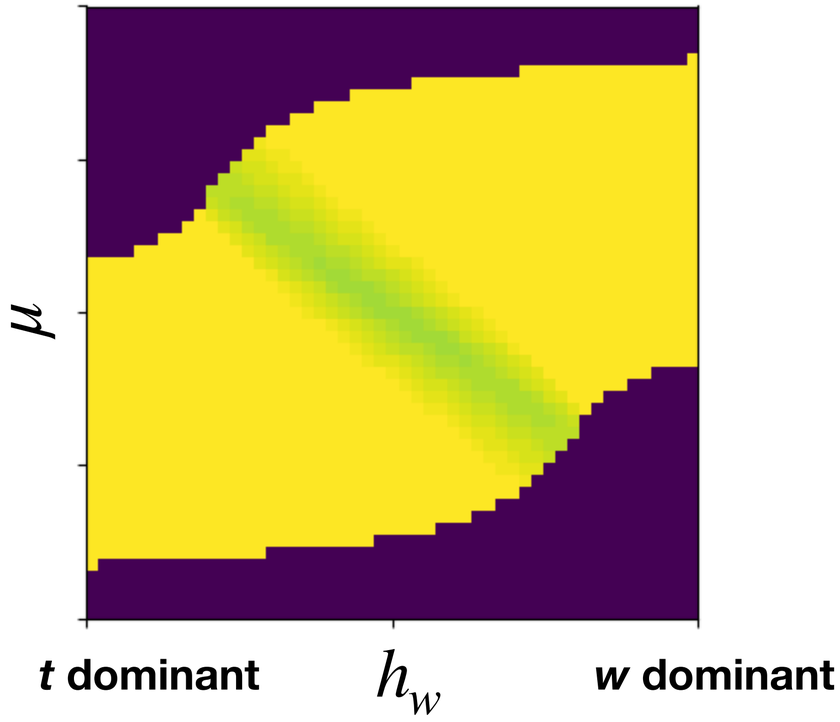


High level of disassortative mating is promoted when the dominant cue allele is associated with genetic load

$$w_{w/w} = 1 - \frac{1+\mu}{2}\delta$$

$$w_{w/t} = 1$$

$$w_{t/t} = 1 - \frac{1-\mu}{2}\delta$$



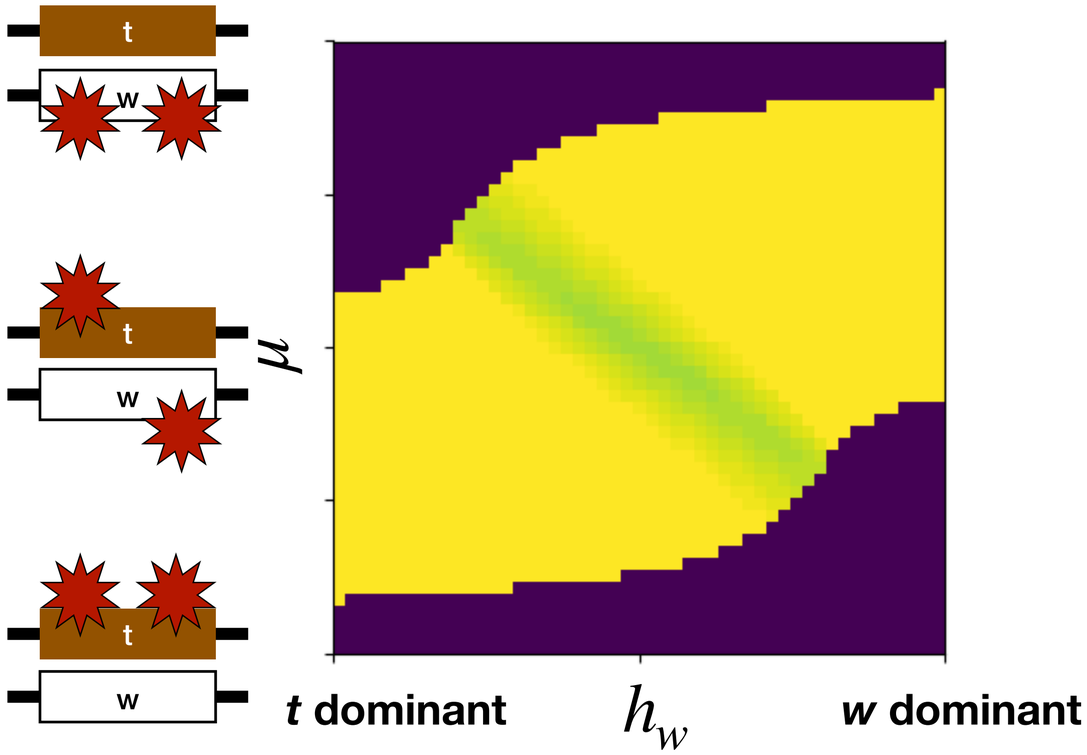
Random mating

Evolutionary stable level of disassortative mating

Strict disassortative mating

High level of disassortative mating is promoted when the dominant cue allele is associated with genetic load

Genetic load

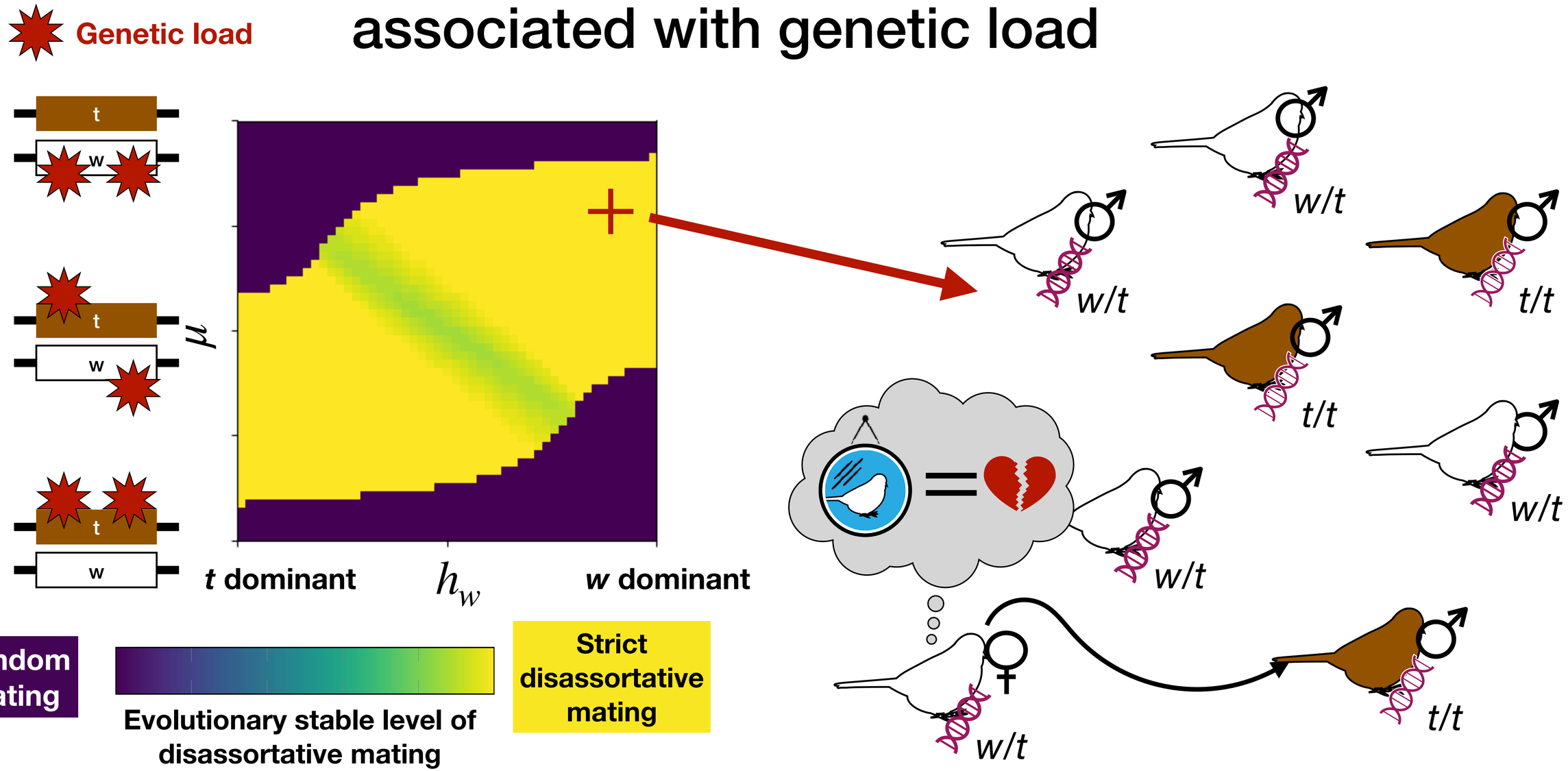


Random mating

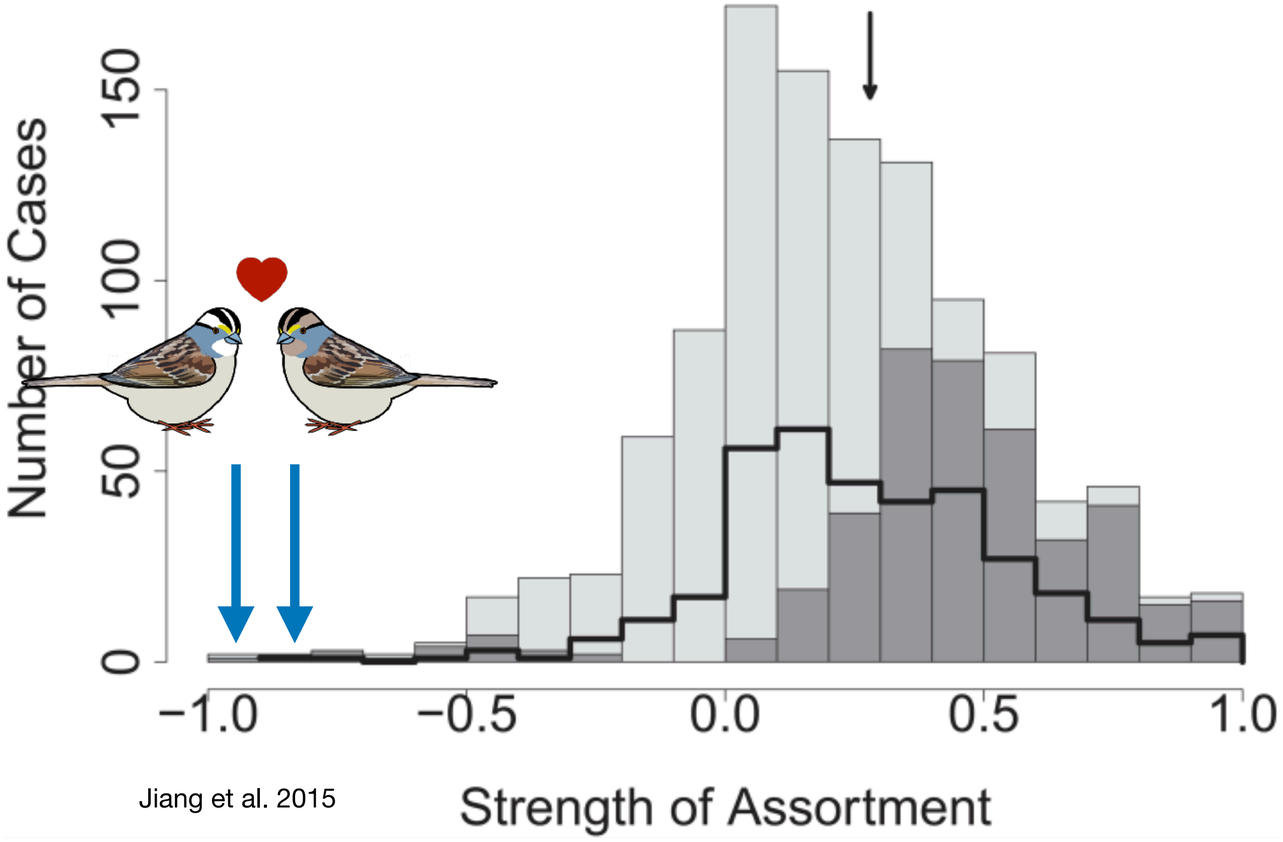
Evolutionary stable level of disassortative mating

Strict disassortative mating

High level of disassortative mating is promoted when the dominant cue allele is associated with genetic load



Prediction matches with disassortative mating observed in the *white throated sparrow*

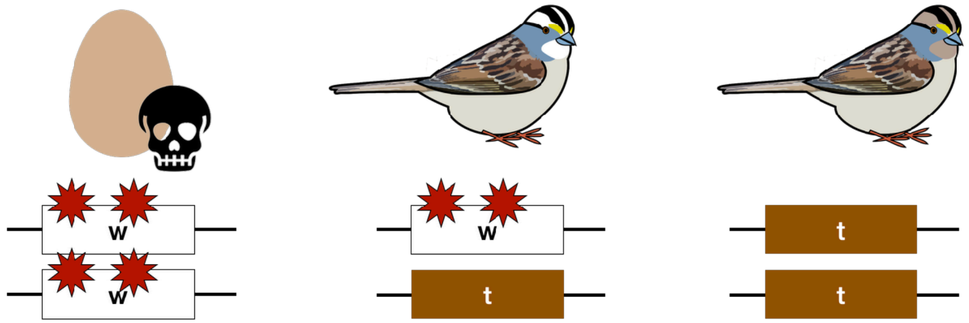


Jiang et al. 2015

significantly different from zero

no significantly different from zero

Genetic architecture of cue



Thank you for your attention !!

When do opposites attract? A model uncovering the evolution of disassortative mating,
The American Naturalist, In press

Thomas Beneteau

Mathieu Joron

Charline Smadi

Violaine Llaurens

National Audubon Society