Simulation Model of Mating Behavior in Flies

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International Workshop on Hybrid Systems
Modeling, Simulation and Optimization
May 14-16, 2008
Koç University, Istanbul

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Outline

(1) The role of mating behavior in natural populations

(2) The model
- (2.1) the aim and applicability of the model
- (2.2) fundamental components of the model
- (2.3) quantification of parameters

(3) Simulation
- (3.1) simulation experiments and results

(4) What is next?

Mating Behavior

Species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups.

...behavior differences are among animals the most important factor in restricting random mating between closely related forms.

E. Mayr, 1942

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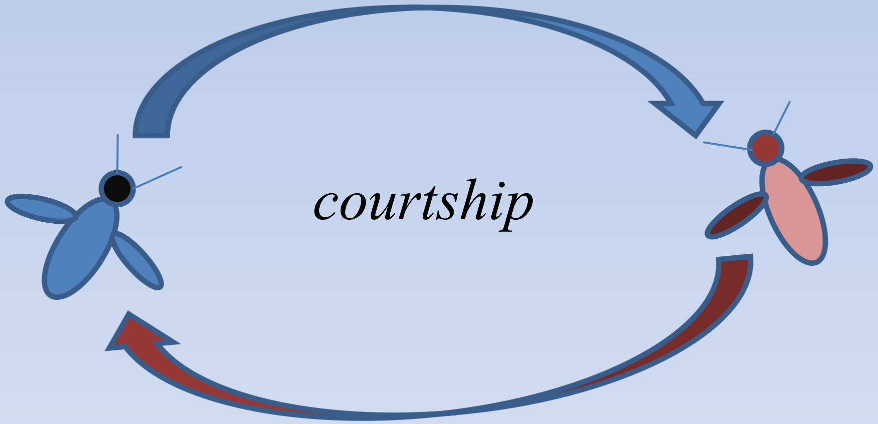
Mating Behavior

- Flies as model system
- Courtship before copulation (duration varies for both)
- Courtship is composed of signals (visual, olfactory, auditory, chemosensory, chemosensory)



- The signals should come from both male and femsle
- Female → threshold level → copulation

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The Model
the aim of the model

- Characterizing the effect of mating behavior in speciation
- Quantification of isolation
- How ethological isolation increases over time?
- Kence-Bryant Model
- Applicable to many species of flies

The Model

fundamental components of the model

Duration of Courtship

- vigor values

Assumption1: distribution of vigor within genotypes is Gaussian

Assumption2: both sexes are identically distributed (*coevolution*)

Duration of Copulation

- average copulation time (*e.g.* 15 min)
- $N(\mu, s)$

Positive Assortative Mating

- isolation angle [θ] (e.g. 0° → no isolation)

Vigor

- Male and female vigor represent the intensity of courtship signals of the courting male and female.
- *Assumption*: every single individual of a population has a unique vigor value (variation among individual flies → $N(\mu, s)$)
- MALES → increased activity results in increased mating success

↑ vigor → ↓ courtship time → ↑ mating success

- FEMALES → increased reluctance to mate
- Linear differential of the signals → “effective excitation”

H → initial threshold level

$$\text{courtship time} = \frac{H}{a_m - a_f}$$

Vigor

- *Assumption:* All females in a population exhibit a constant *Initial Threshold Level (H)*.

$$\text{courtship time} = \frac{H}{a_m - a_f}$$

$$= \frac{\mathbf{1}}{\boldsymbol{A_m - A_f}}$$

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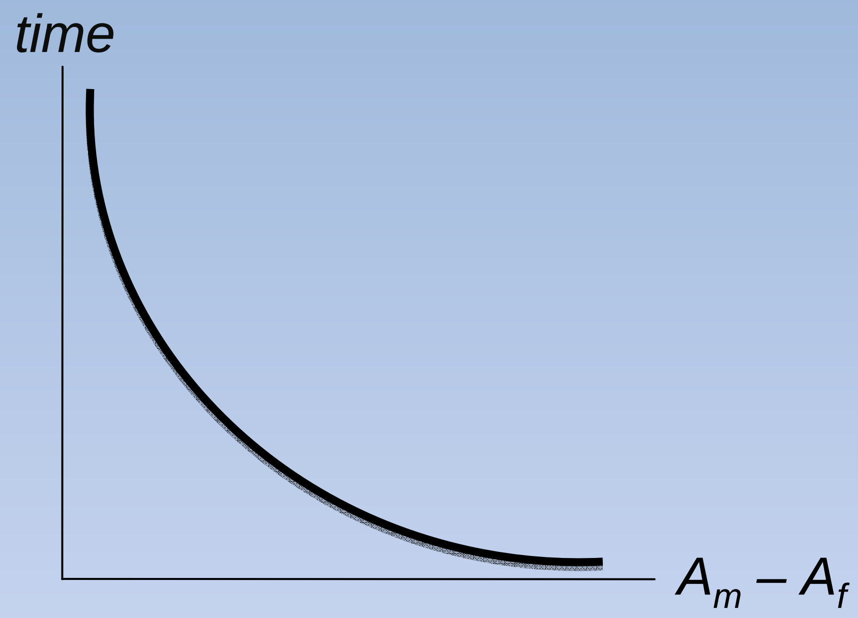
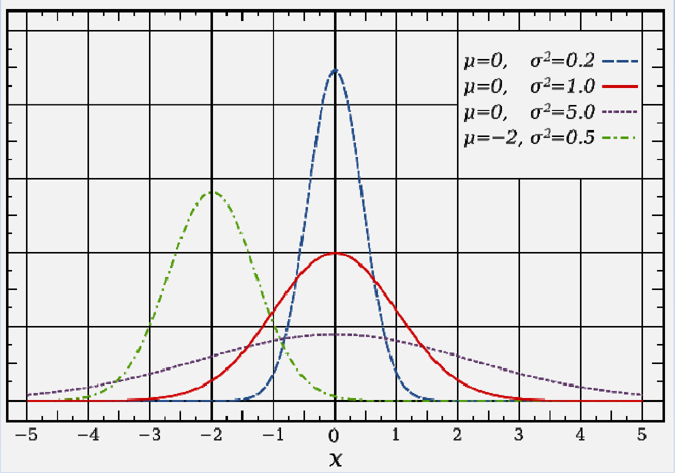


- Basic model of the simple hyperbolic relationship between *average effective excitation*, $A_m - A_f$, *and mating speed.*

Duration of Copulation

- A_m and A_f are not correlated with copulation time
- Copulation time is independent from mating time
- Not all copulations of a given genotype exhibit identical durations (laboratory observations)

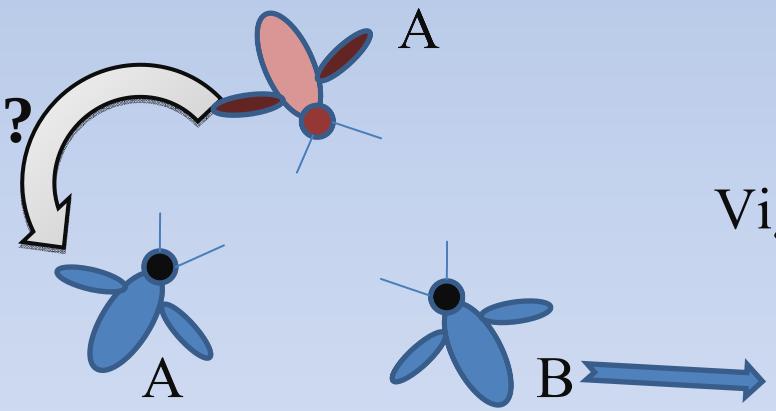
- μ
- σ



Randomly assigned

Positive assortative mating

- *Assortative mating* (or *assortative pairing*); sexually reproducing organisms tend to mate with individuals that are
  - like themselves in some respect (*positive assortative mating*) or
  - dissimilar (*negative assortative mating*)



Vigor of A_m and B_m are equal

mating disadvantage

- Some courtship signals may be inappropriate btw distinct genotypes due to genetic differentiation.

- An isolation based on quantitative differences.

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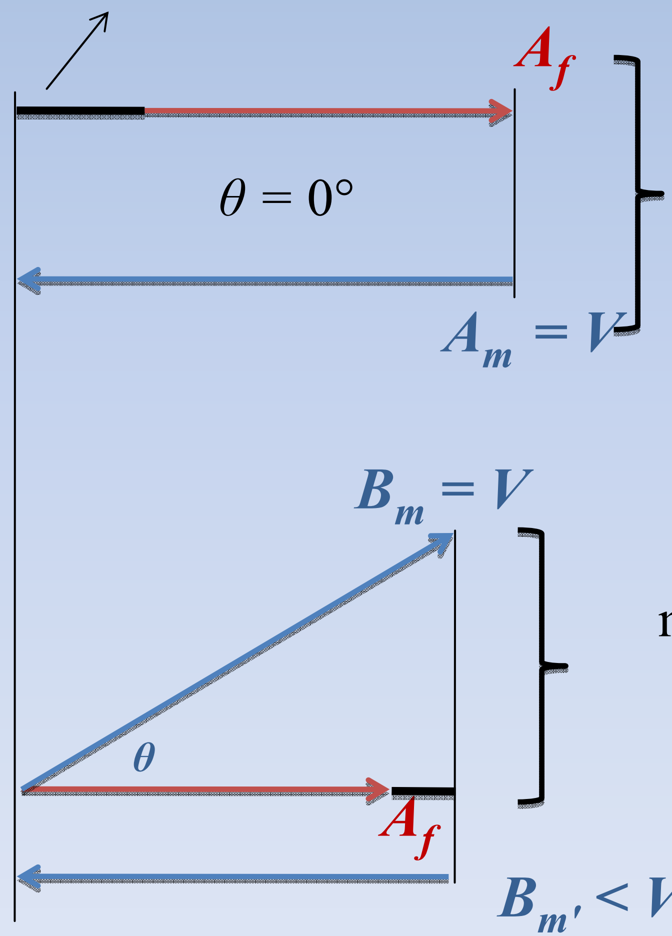
Positive assortative mating

- Isolation angle separates the vigor signals of distinct genotypes (partial)

effective excitation



$$\text{mating time} = \frac{1}{(A_m * cos(\theta) - A_f)}$$

$cos(0) = 1$

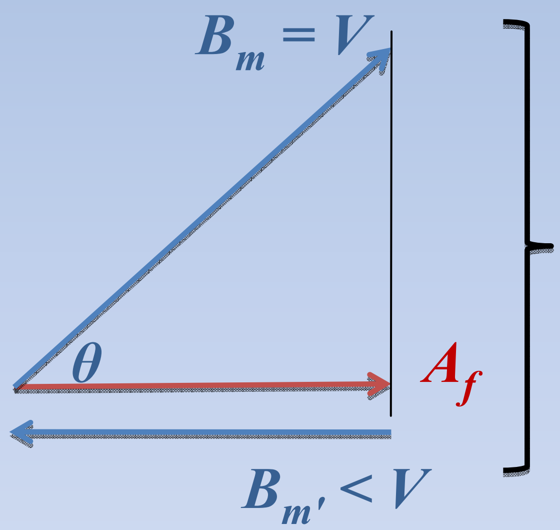
$$\text{mating time} = \frac{1}{(B_m * cos(\theta) - A_f)}$$

$B_{m'} < V$ *(for $0 < \theta <= 90$)*

Positive assortative mating

- Complete reproductive isolation

$$B_m * \cos(\theta) = A_f$$



$$\text{mating time} = \frac{1}{(B_m * \cos(\theta) - A_f)}$$

$B_{m'} =< A_f$ → ***effective excitation = 0*** → ***no mating!***

- *Assumption:* Matings are possible only when $A_m > A_f$

The Model

Additional components of the model

Offsprings

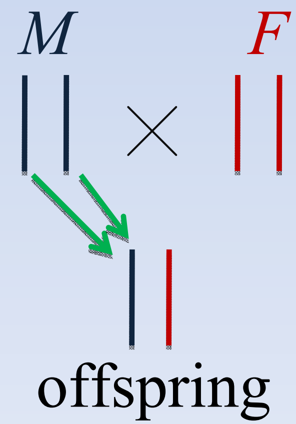
- observing changes (distribution of mating times, genetic diversity..etc.) among generations → speciation
- Poisson distribution, $\lambda = 2$

Progeny sex

- uniform numb.

Inheritance of alleles

- Diploid; 2 alleles
- Uniform



The Model

Additional components of the model

Non-overlapping generations

More than one mating

- Males are free to court other females and mate upon completion of a copulation
- Females do not accept another male → female receptivity to other males is reduced by the transfer of sperm and seminal fluids

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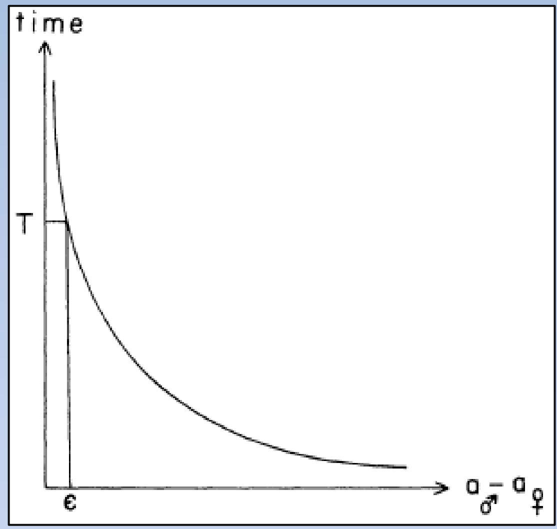
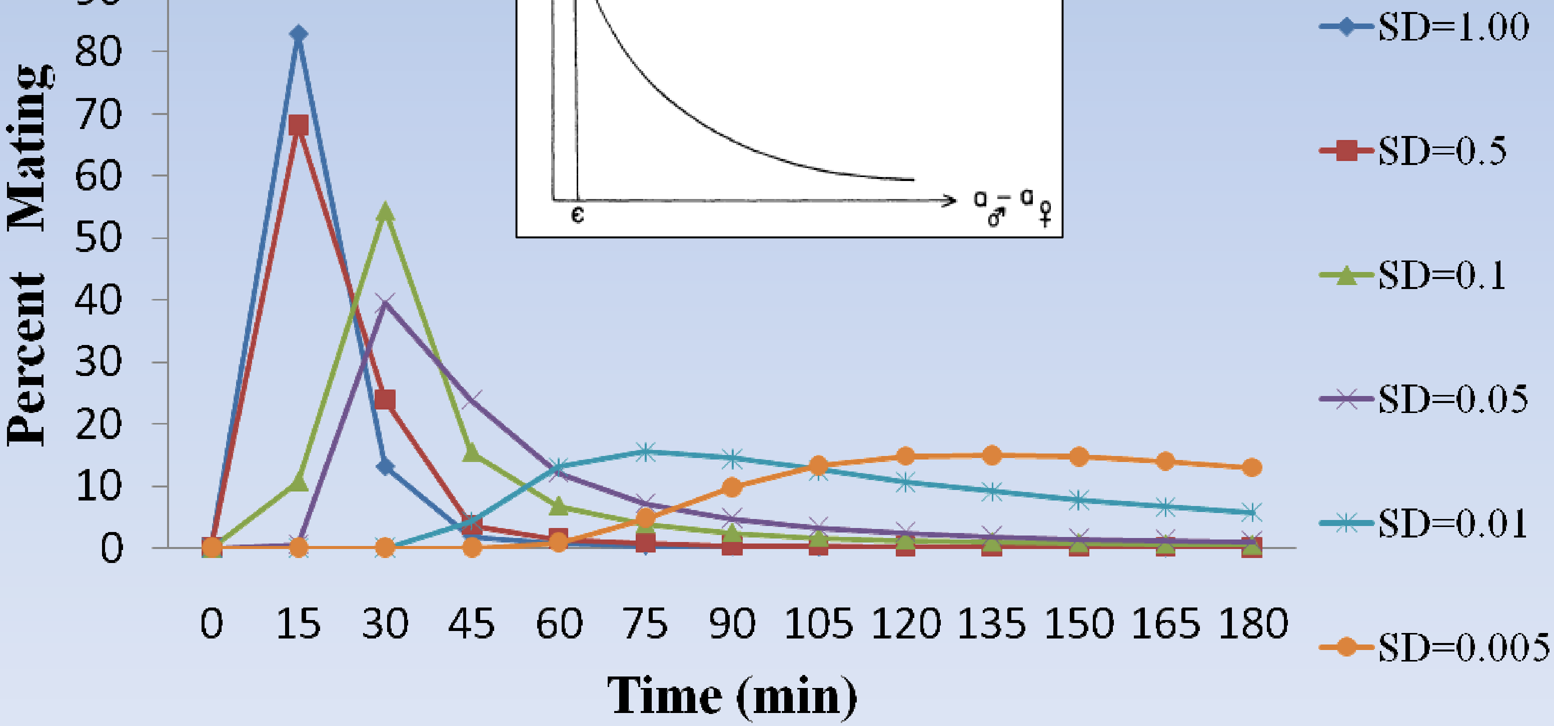
Simulation

Sim. Experiments & Results



SD for vigor of males and females



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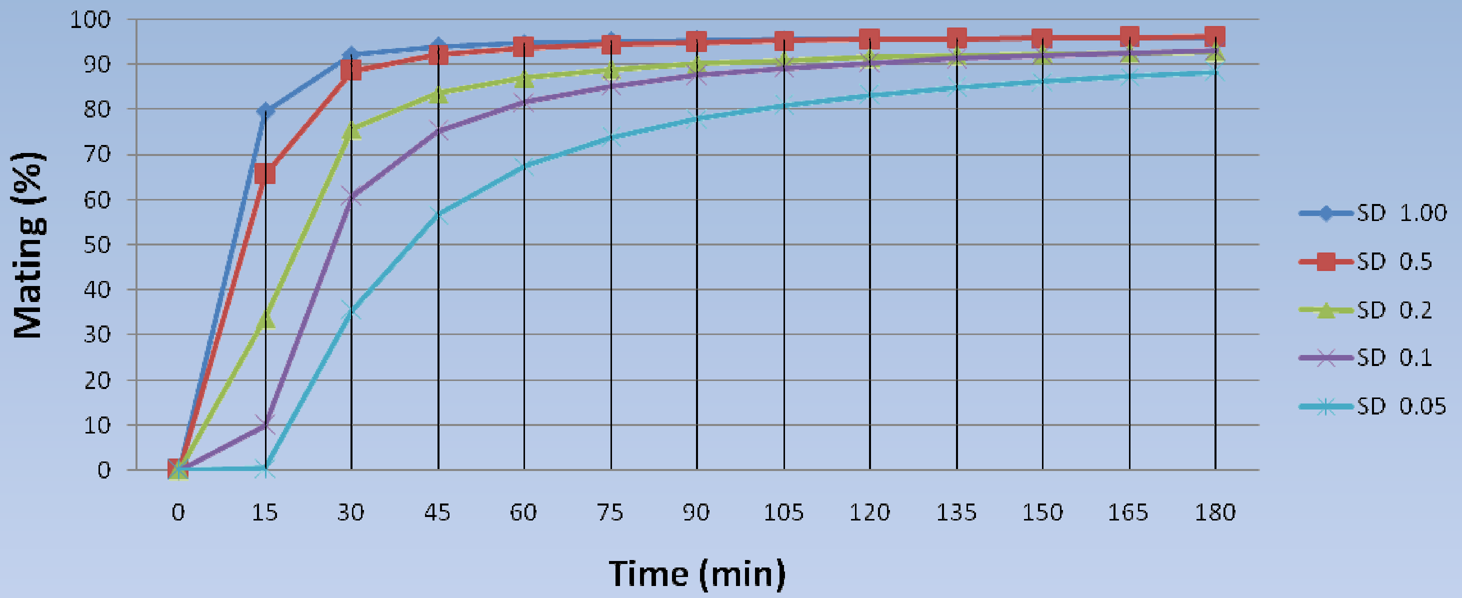
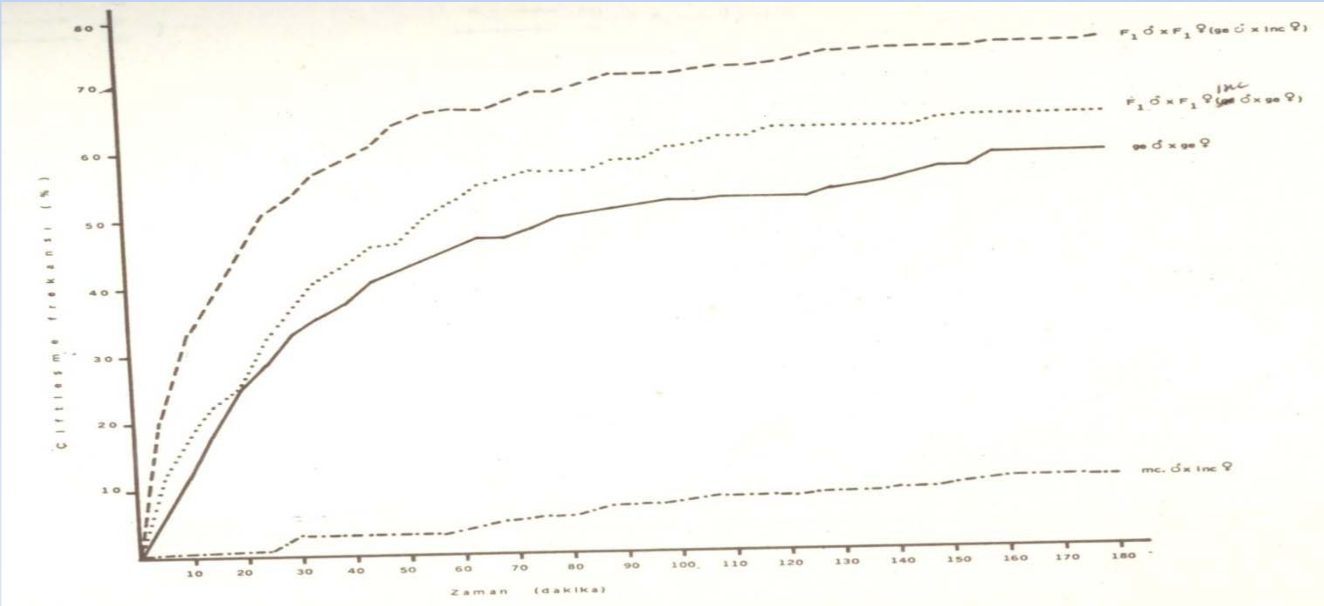
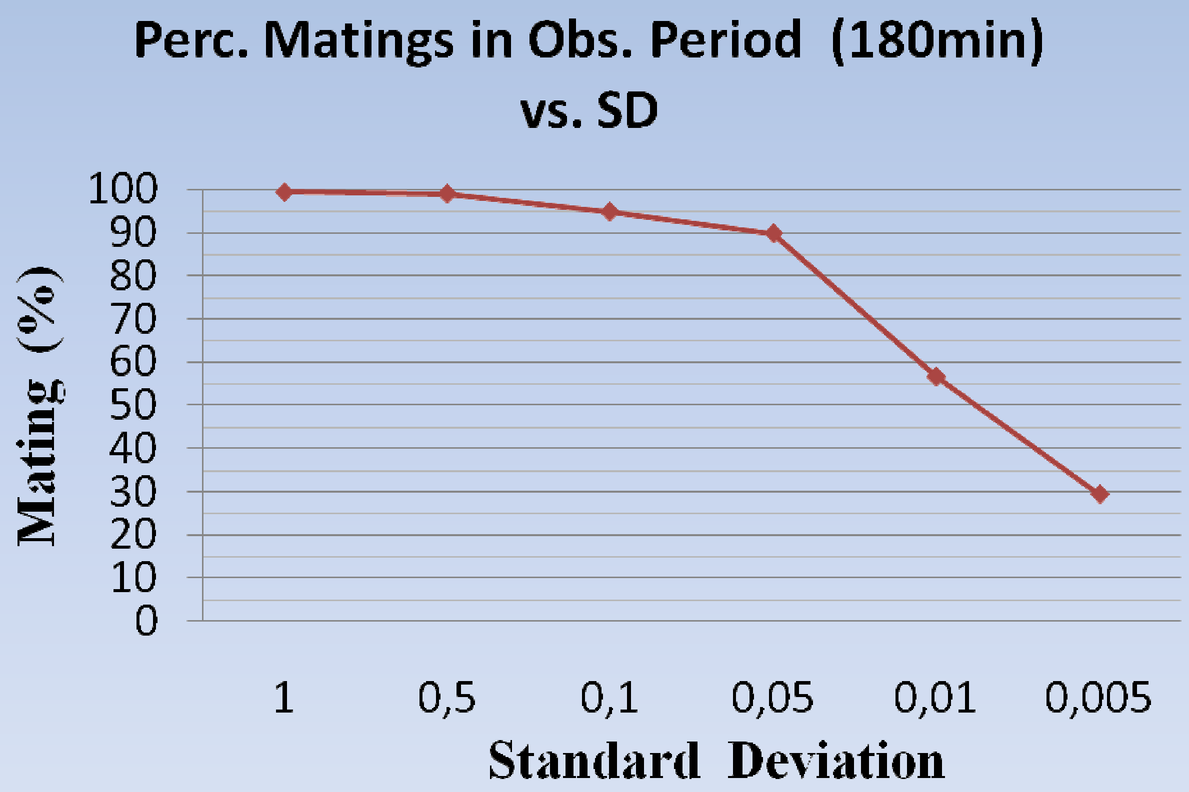




Simulation

Sim. Experiments & Results

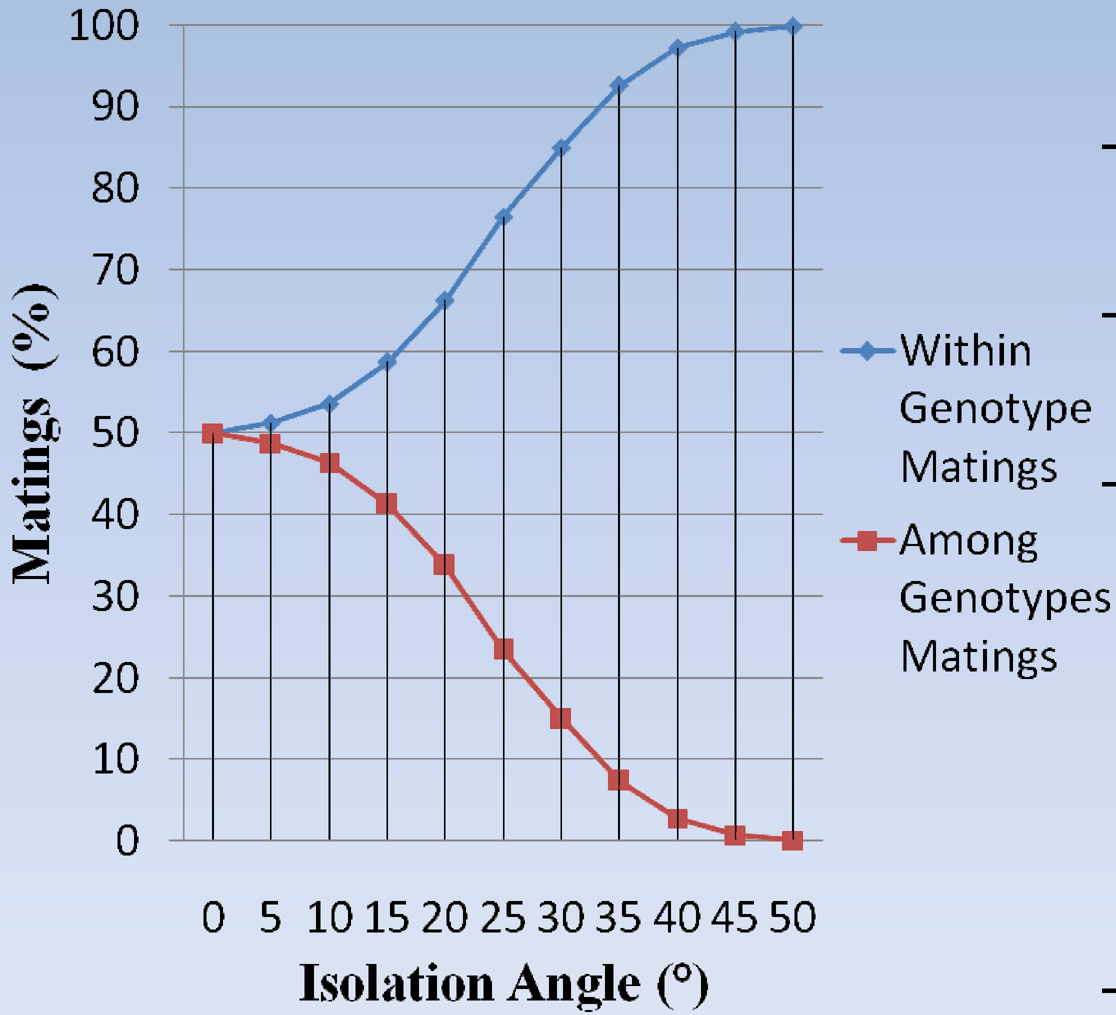


- Why are we interested in mating times and distributions?

-- unbalanced inheritance of alleles to the next generation (fitness)

Simulation

Sim. Experiments & Results



- n genotypes → n^2 matings
- A_m- A_f , B_m- B_f
- A_m- B_f , B_m- A_f
- Keeping other variables constant, increasing the isolation angle btw genotypes decreases matings among different genotypes (A_m- B_f or A_f- B_m).
- f(IntraG) + f(InterG) = 1

Simulation

Sim. Experiments & Results

Ethological Isolation Index

$$I = (M_{AA} + M_{BB} - M_{AB} - M_{BA})/N$$

- *Possible to quantify reproductive isolation*

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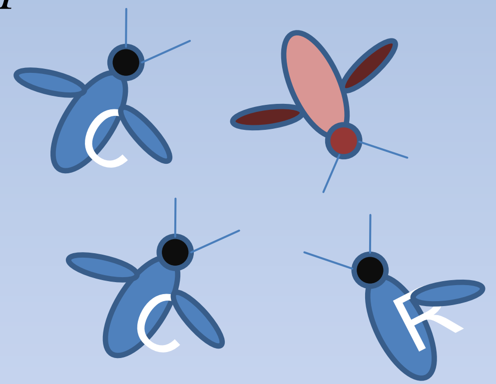
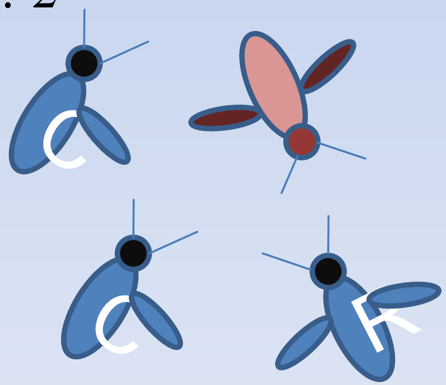
Simulation

Sim. Experiments & Results

Exp. 1



Exp. 2



- *Rare Male Advantage* is thought to be one of the most important factors that maintain genetic variation in natural populations.
- In experiments investigating this effect one wing of the males of one strain was clipped and clipping was alternated between rare and common strains.
- When we sum the results of these exp. an advantage favoring rare strain occurs. This is not because of any behavioral change in the rare strains but the result of clipping of wings.

Simulation

Sim. Experiments & Results

#	genotypes	percentage	vigor
2	rare	11,7	10
18	common	88,3	10

Sim. Exp.	marked	# flies	genotypes	percentage	vigor
1	*	2	rare	9,52	7
		18	common	89,47	10

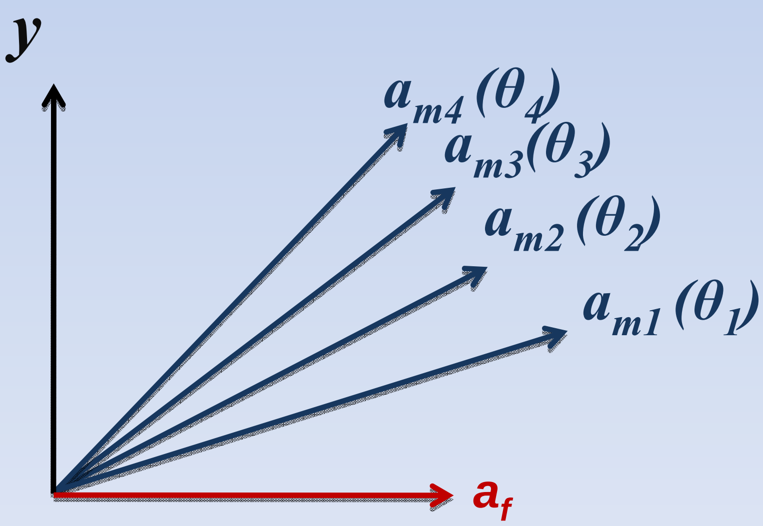
2		2	rare	45,00	10
	*	18	common	55,00	7

- *Instead of 11.7% - 90% (~1/9)*

  27.85% - 72.15% (~4/9) → shown as a proof for rare male advantage

New features

- *Overlapping generations*
  - Fly populations show very little overlapping of generations
- *Isolation angles* btw the ind. of the same genotype



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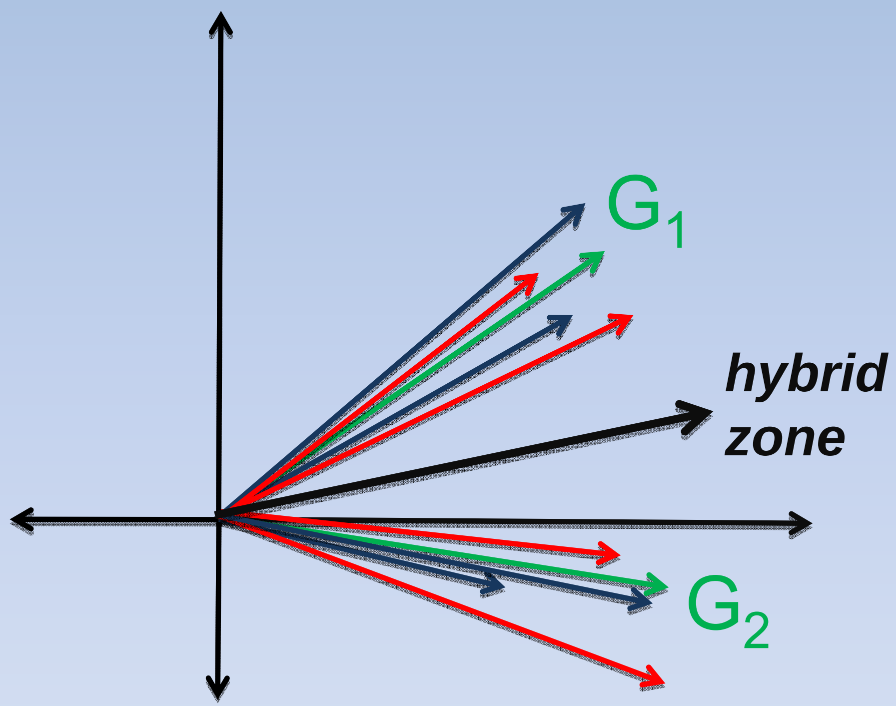
New features



– *Initial threshold level (H) is not the same for all females in a population.*

Thank you for your attention…

References:

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