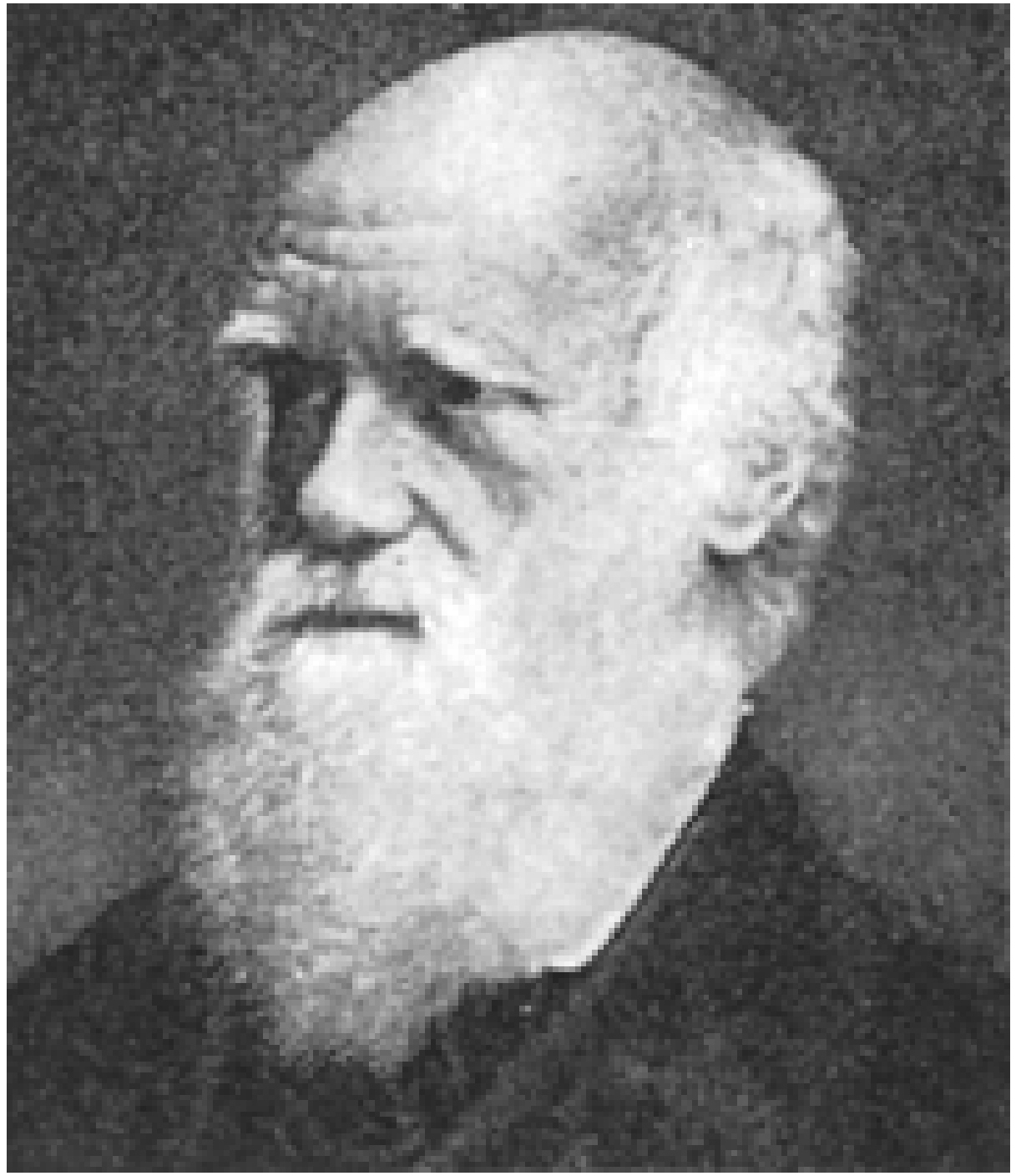
# The temporal separation of gender in flowering plants: An evolutionary analysis

Matthew B. Routley


C. Routley



# Inbreeding avoidance

B. Husband

# Dichogamy

B. Husband

Protandry

B. Husband

Protogyny

# Evaluating inbreeding avoidance

- Survey by Bertin 1993
  - 73% 160 SI species
  - 75% 673 SC species
  - 34% protogynous
- Seen as evidence against inbreeding avoidance

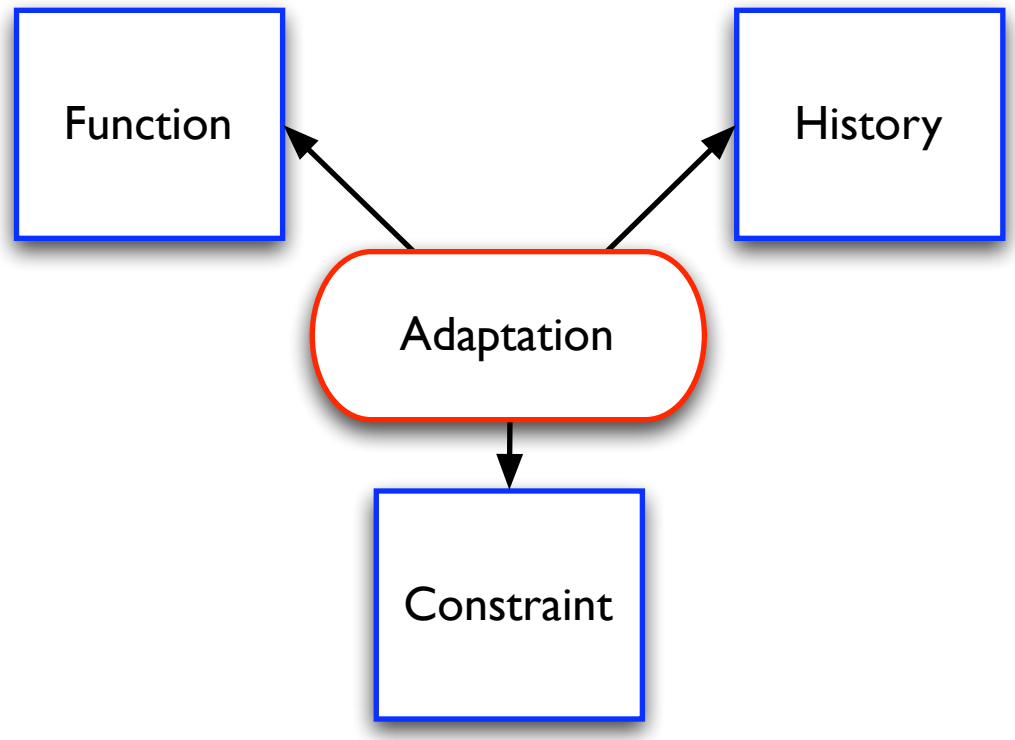
# Interference avoidance

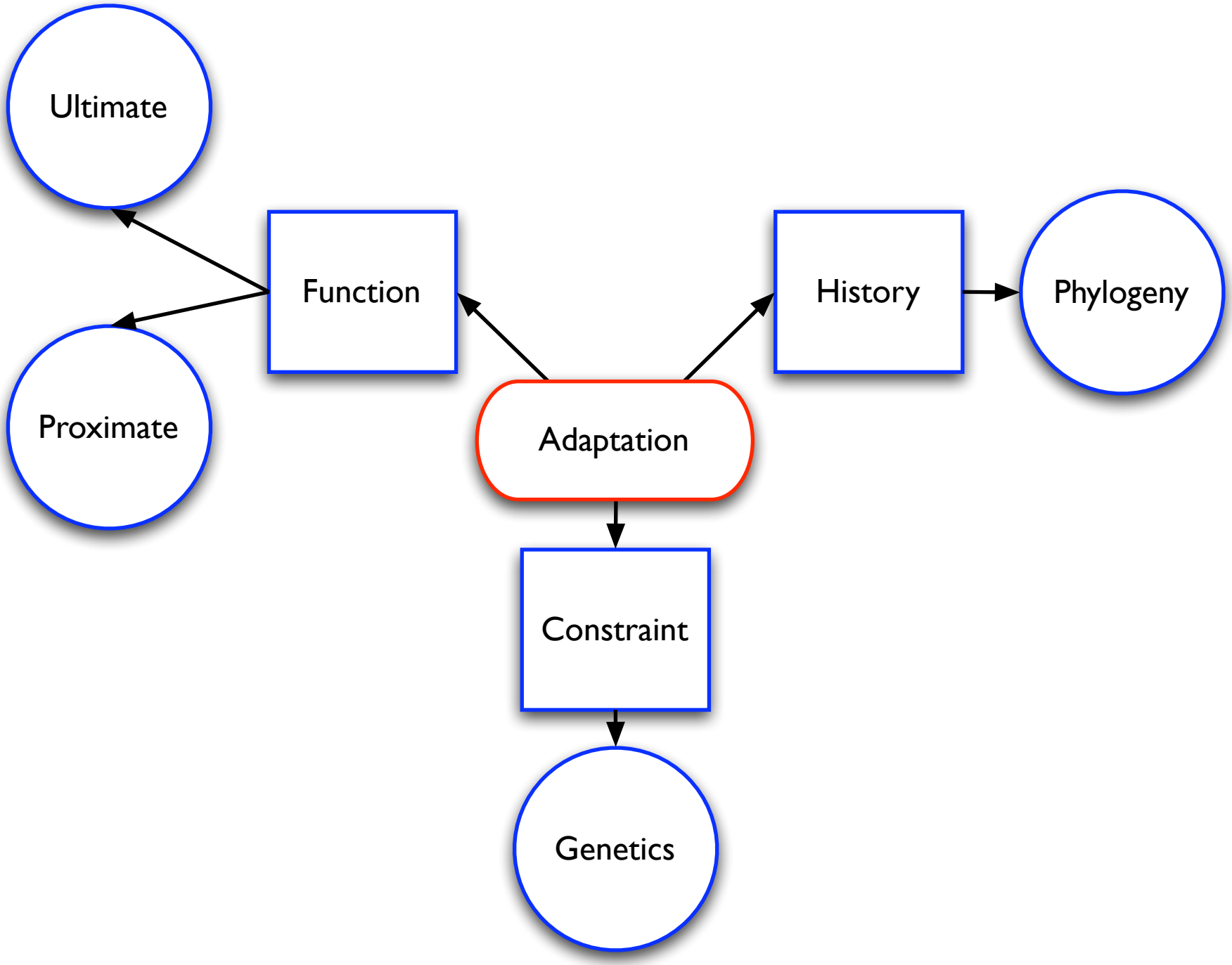
B. Husband

# Interference avoidance

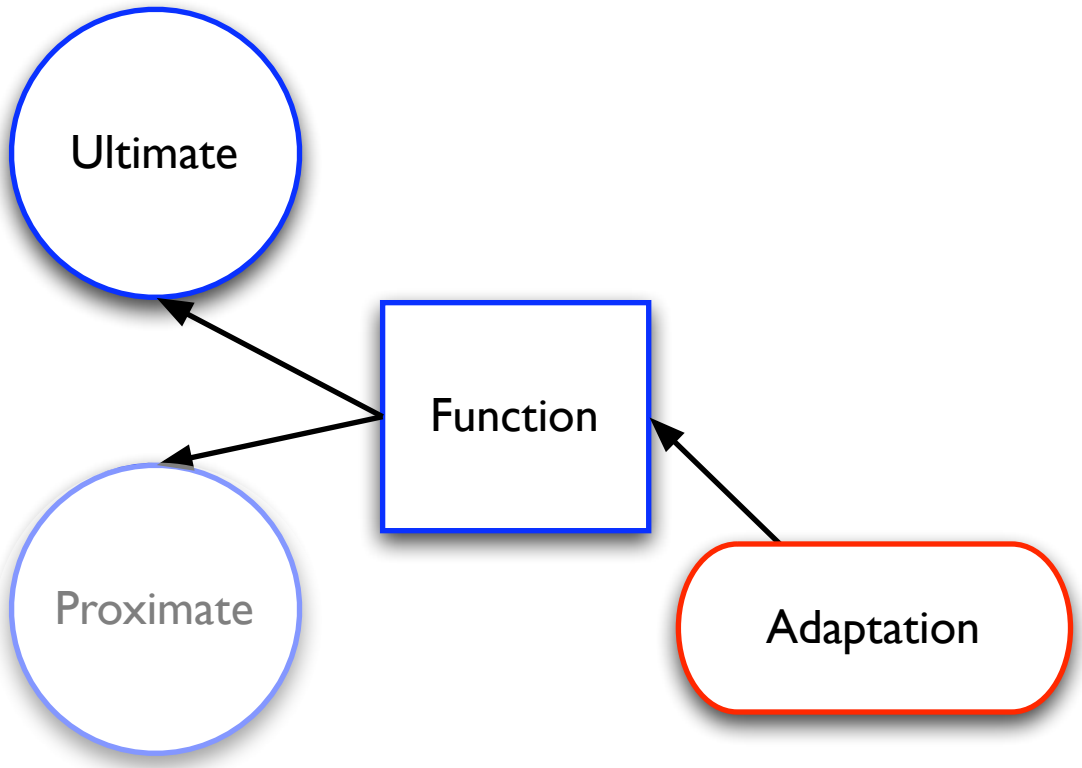
B. Husband


Adaptation


Function
History
Adaptation
Constraint


Ultimate
Proximate
Function
Adaptation
History
Phylogeny
Constraint
Genetics

# Functional Analysis: Ultimate



# Functional significance

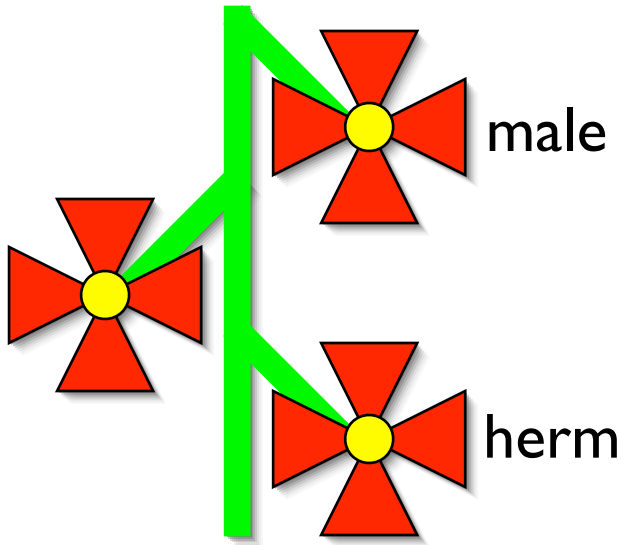
- Interference avoidance predicts:
  1. Protandry reduces interference
  2. Interference increases with inflorescence size
  3. Protandry enhances pollen export in large inflorescences
- Enhancement of male reproductive success provides selective advantage of protandry

# *Chamerion angustifolium*

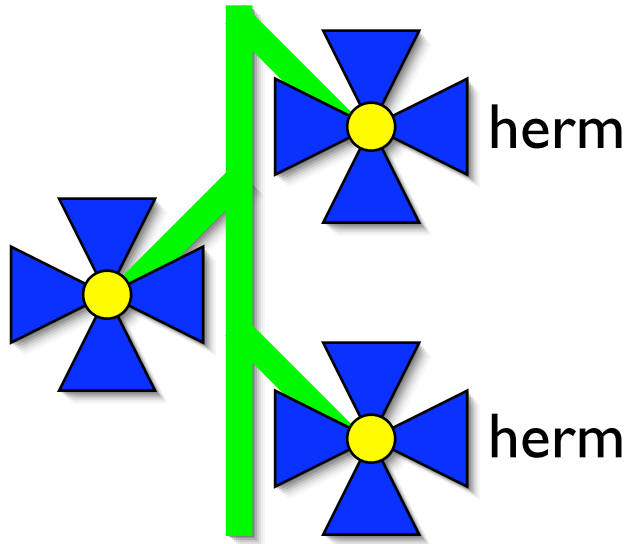
- 10-15 open flowers
- protandrous
- male phase ~2 days
- 45% ovules selfed
- $\delta = 0.945$

B. Husband

# Experimental design

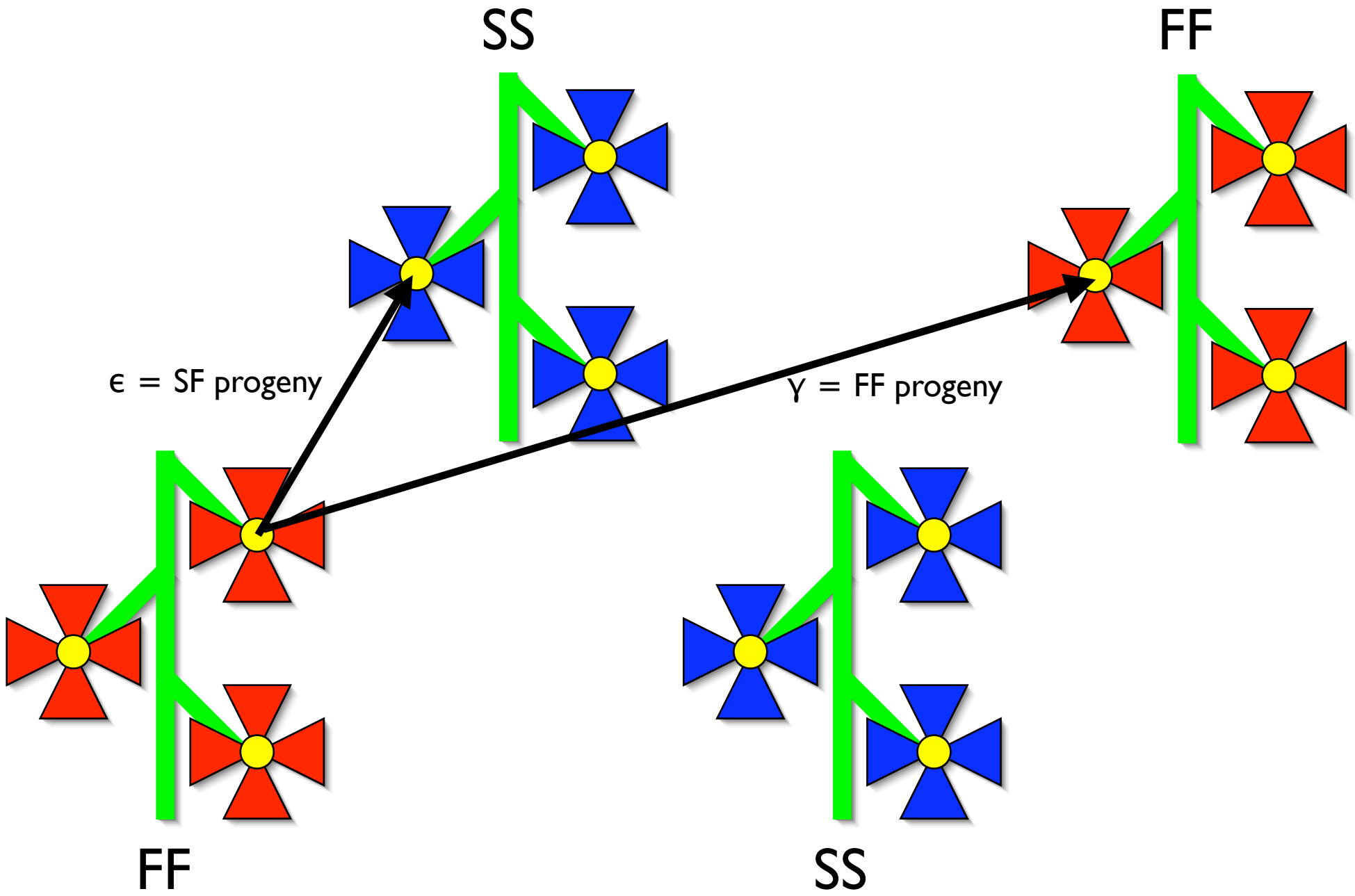



FF
Protandrous



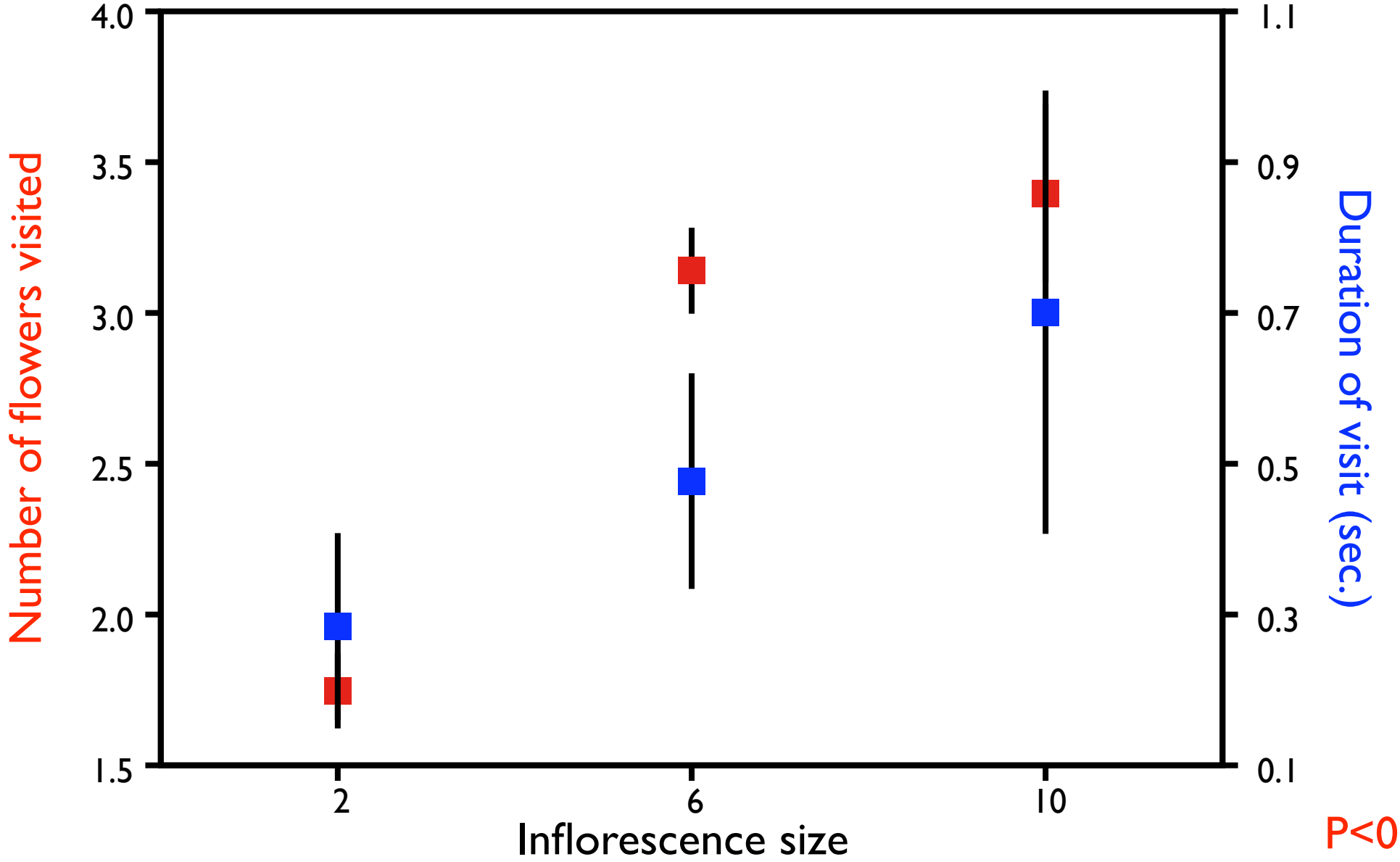

SS
Adichogamous

- Array of 16 plants with 2, 6, or 10 flowers/plant




$$\text{protandrous siring success} = \frac{\epsilon_{adichogamous}}{\gamma_{adichogamous} * t_{adichogamous}}$$

# Visitation

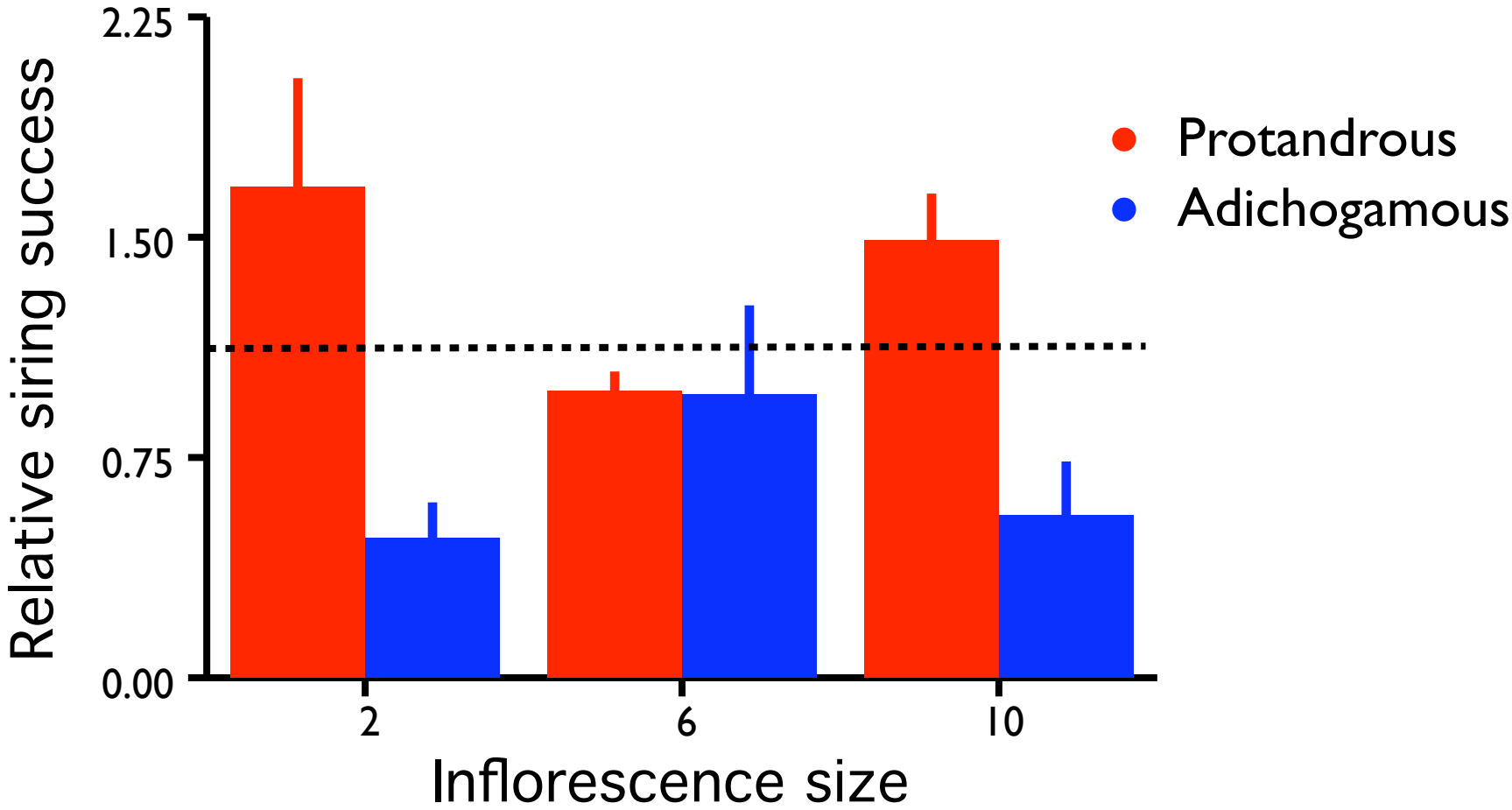



P<0.01
P<0.01

# Female outcrossing rate

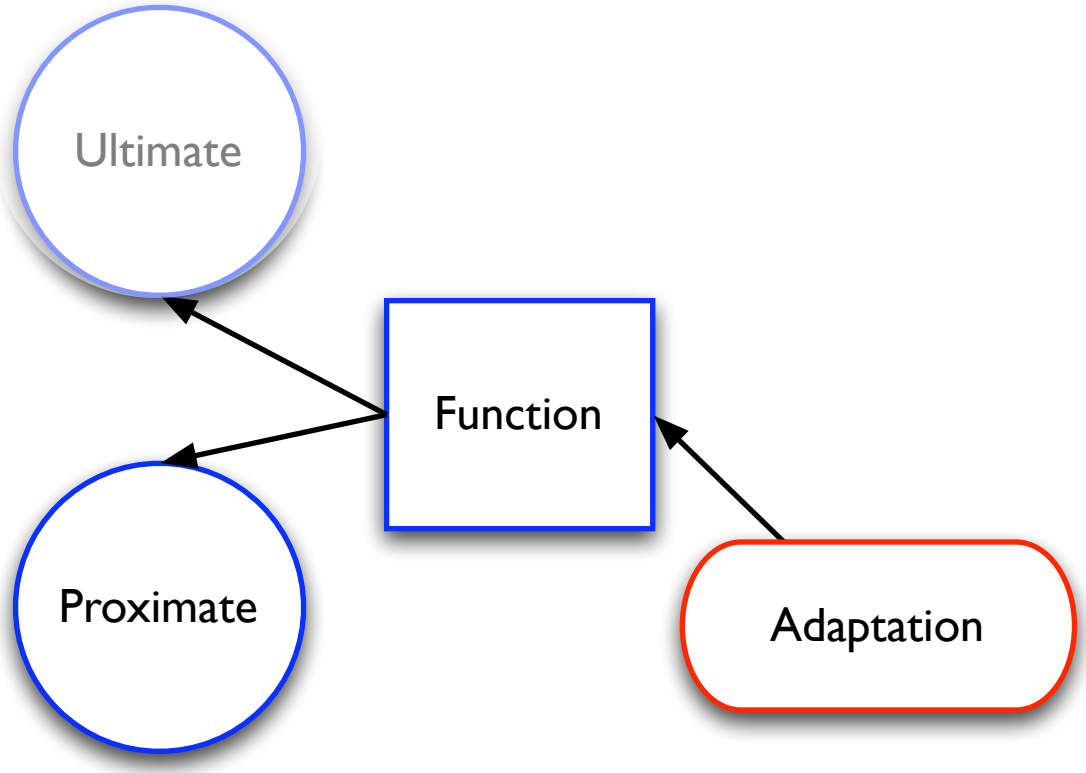
| Treatment | *t* |
|---|---|
| Dichogamy | |
| protandrous | 1.14 ± 0.40 |
| adichogamous | 0.92 ± 0.13 |
| Inflorescence size | |
| two-flowered | 0.84 ± 0.39 |
| six-flowered | 1.99 ± 0.07 |
| 10-flowered | 0.90 ± 0.25 |
| Position | |
| top | 0.84 ± 0.13 |
| bottom | 0.95 ± 0.10 |

# Siring success



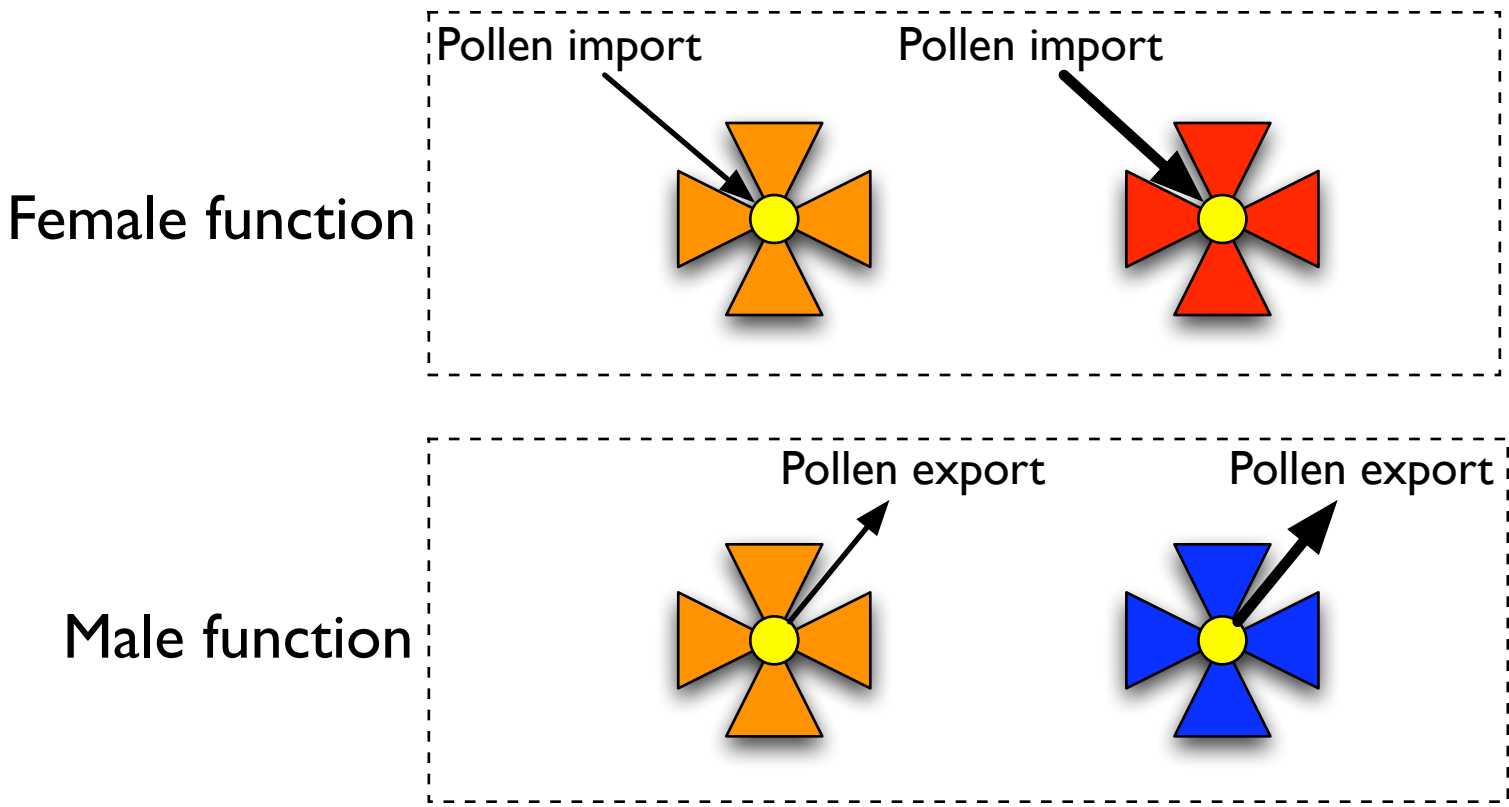

| Source | F ratio | P |
|---|---|---|
| Inflorescence size | 0.01 | >0.95 |
| Array (inflorescence size) | 1.15 | >0.90 |
| Dichogamy | 18.38 | <0.05 |
| Dichogamy X inflorescence size | 3.61 | <0.10 |

# Functional Analysis: Proximate



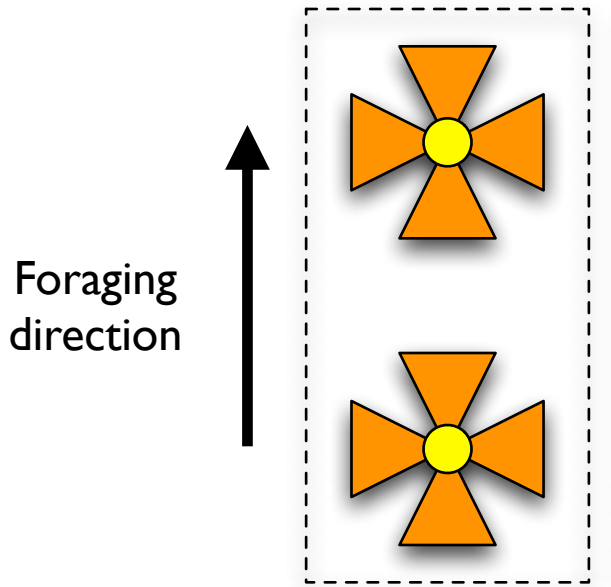
B. Husband

# Pollen dynamics

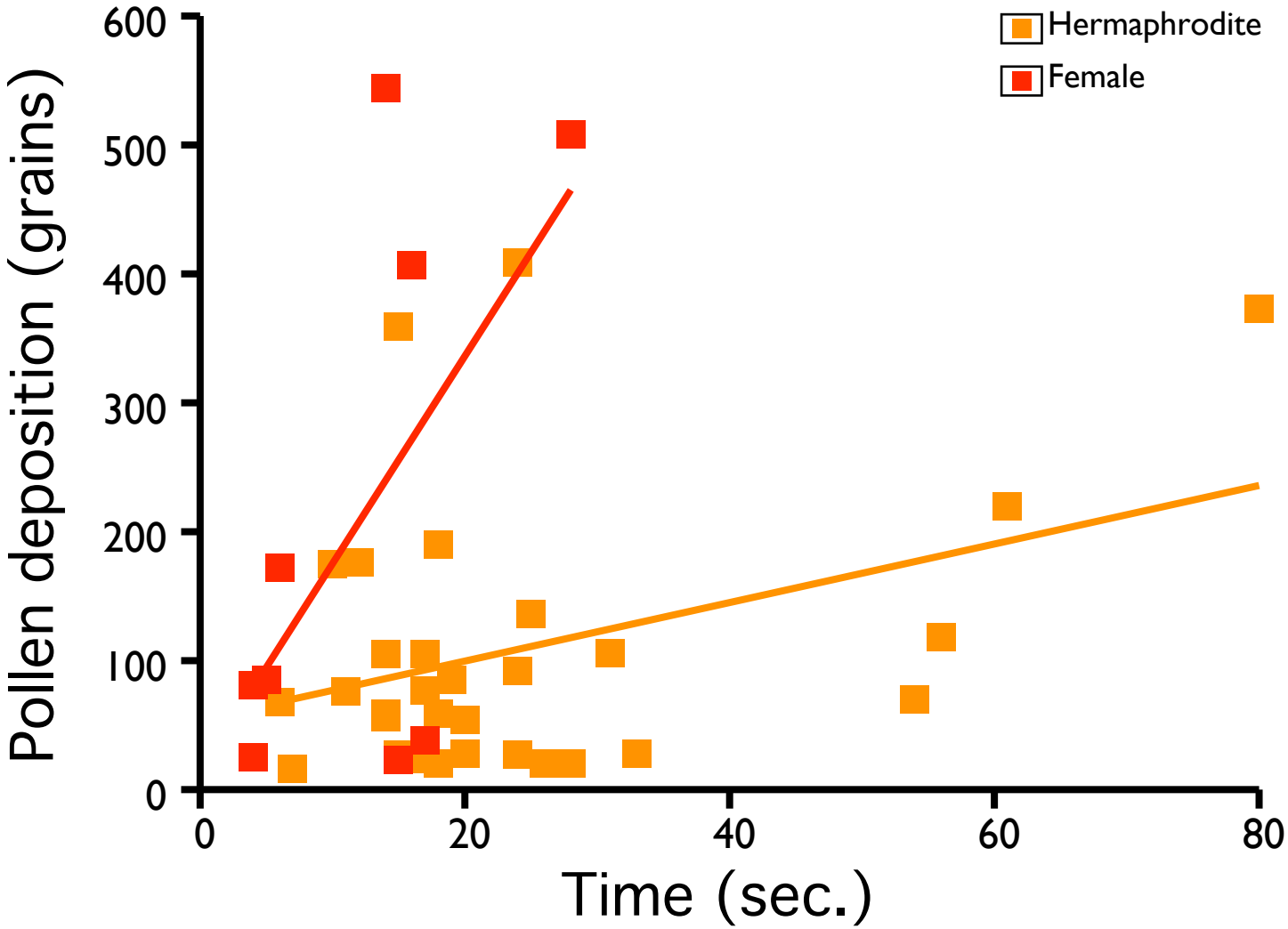



Caution!!
This room contains live bees.
Do NOT enter unless you
really want to.

# Experimental design



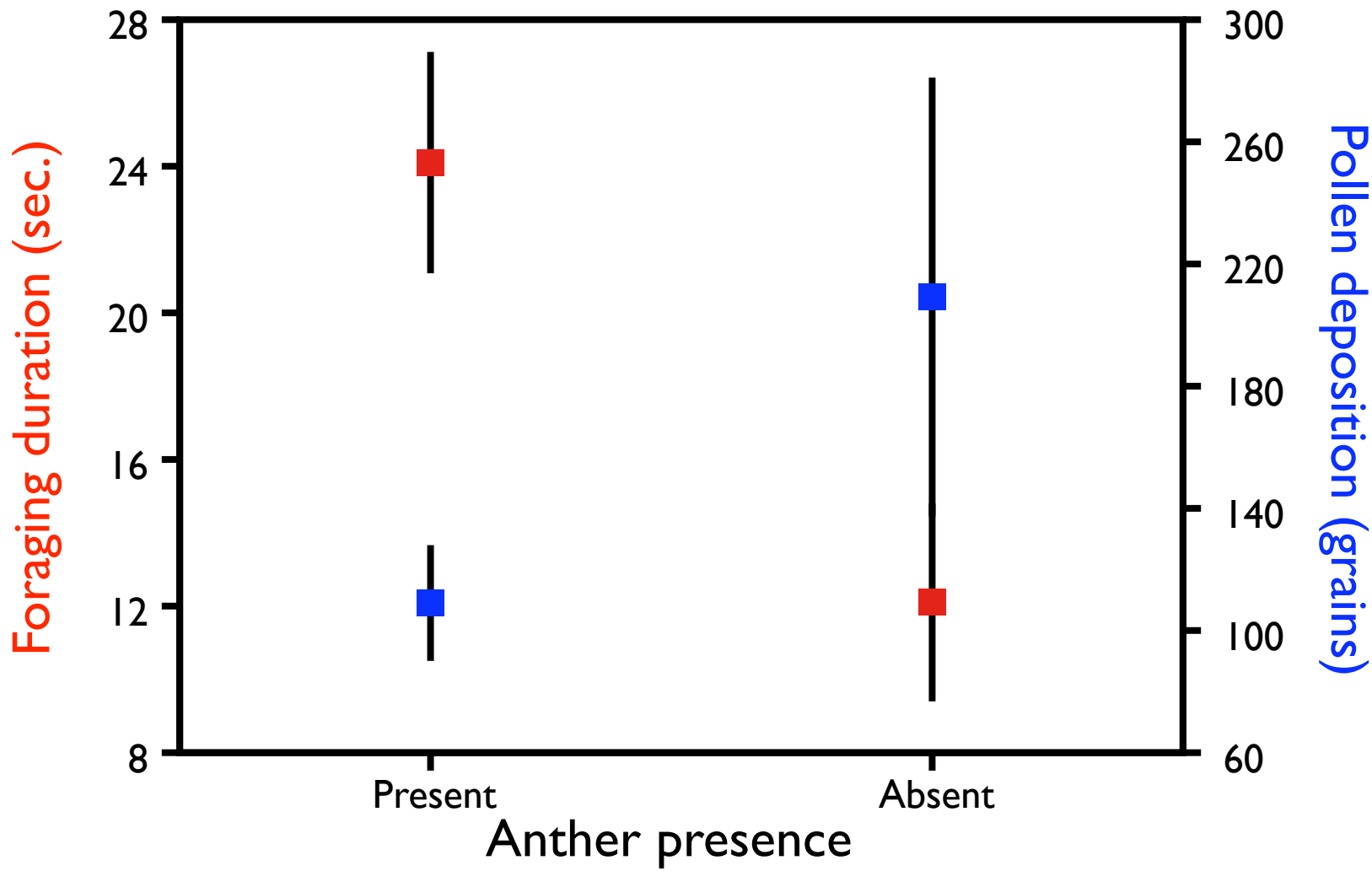
# Pollen deposition




Anthers: 67.6 (16.8–118.3) grains

Time: 3.0 (0.4–5.6) grains/second

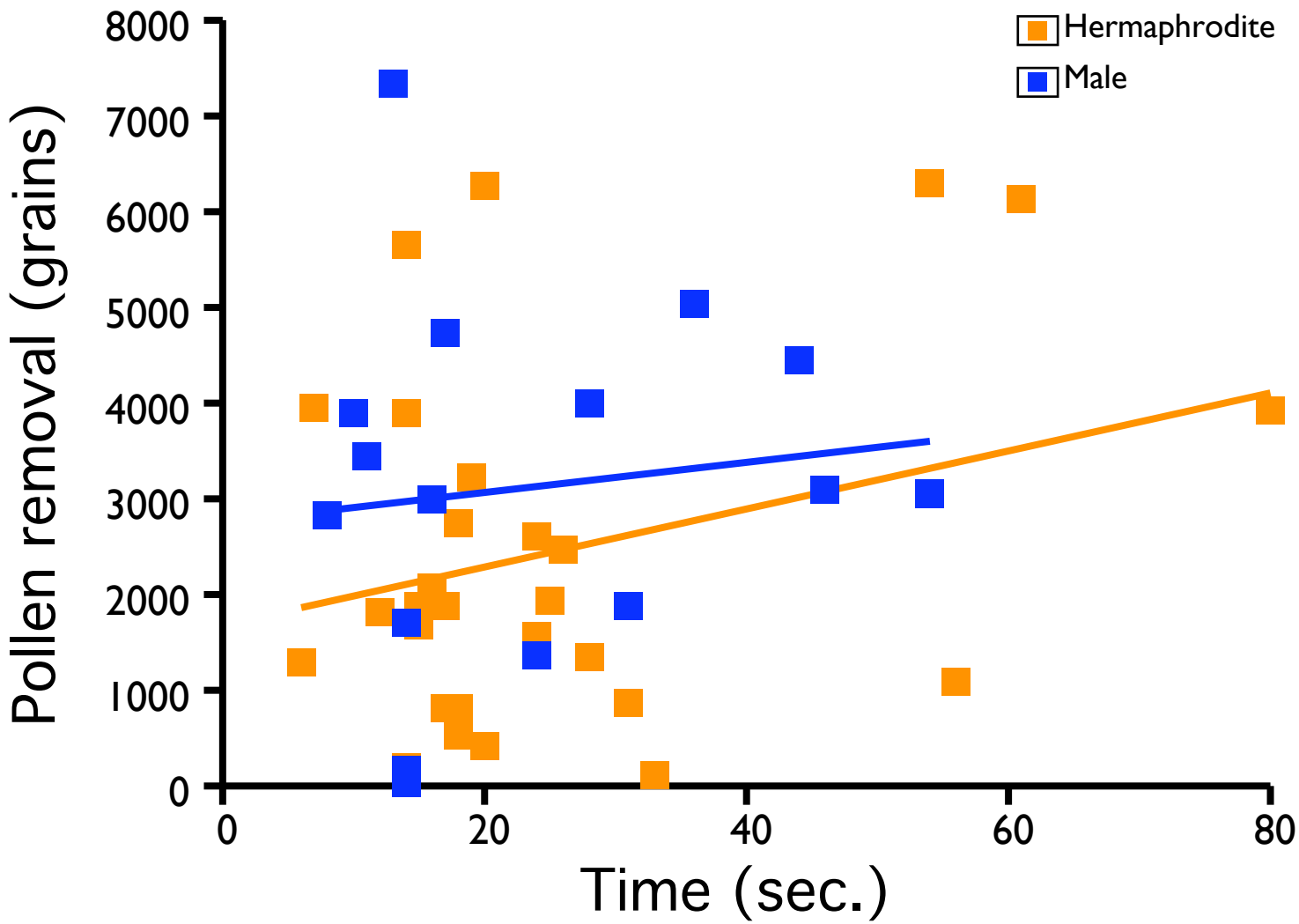
# Pollen deposition



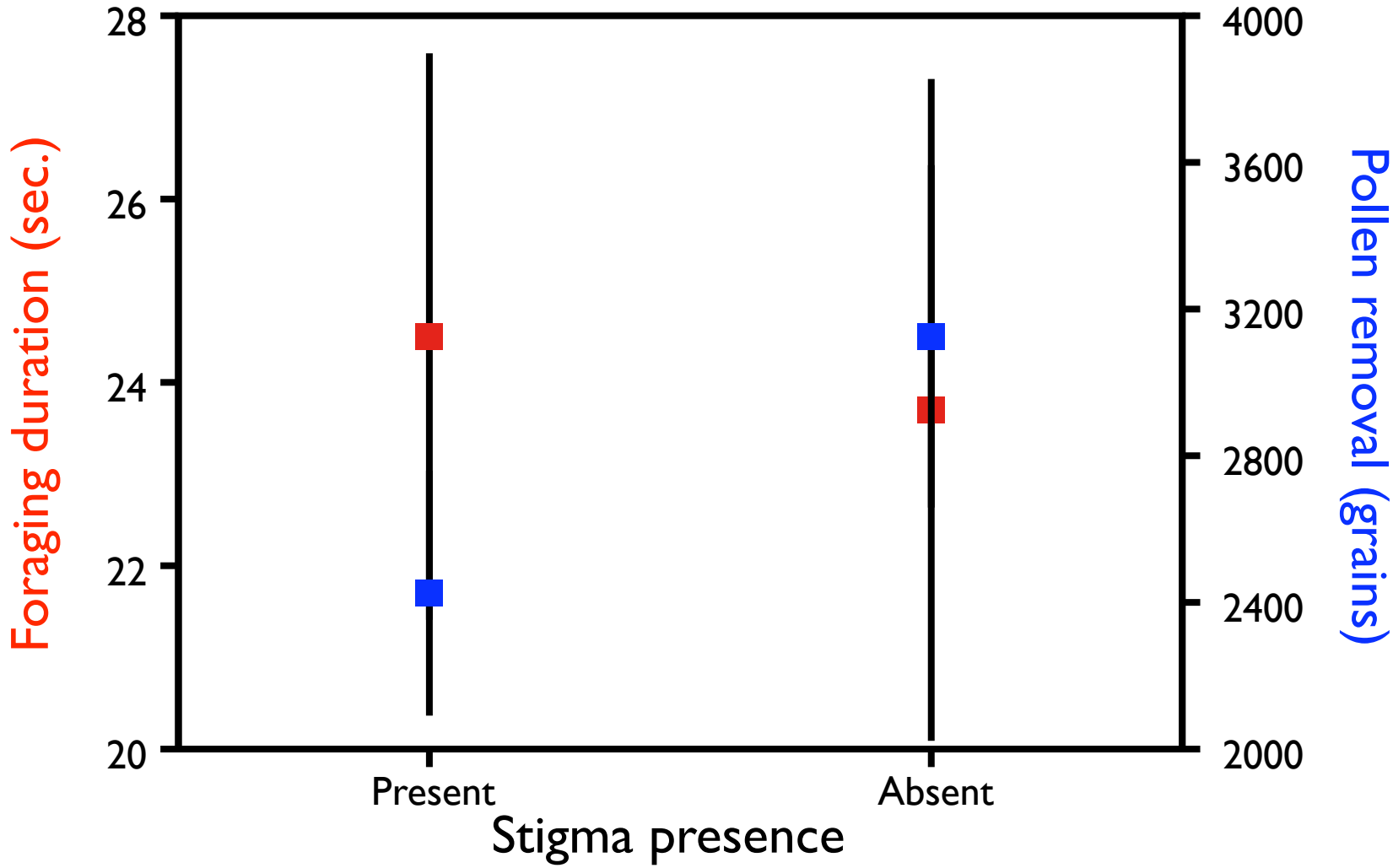

P<0.01

P<0.05

# Pollen removal



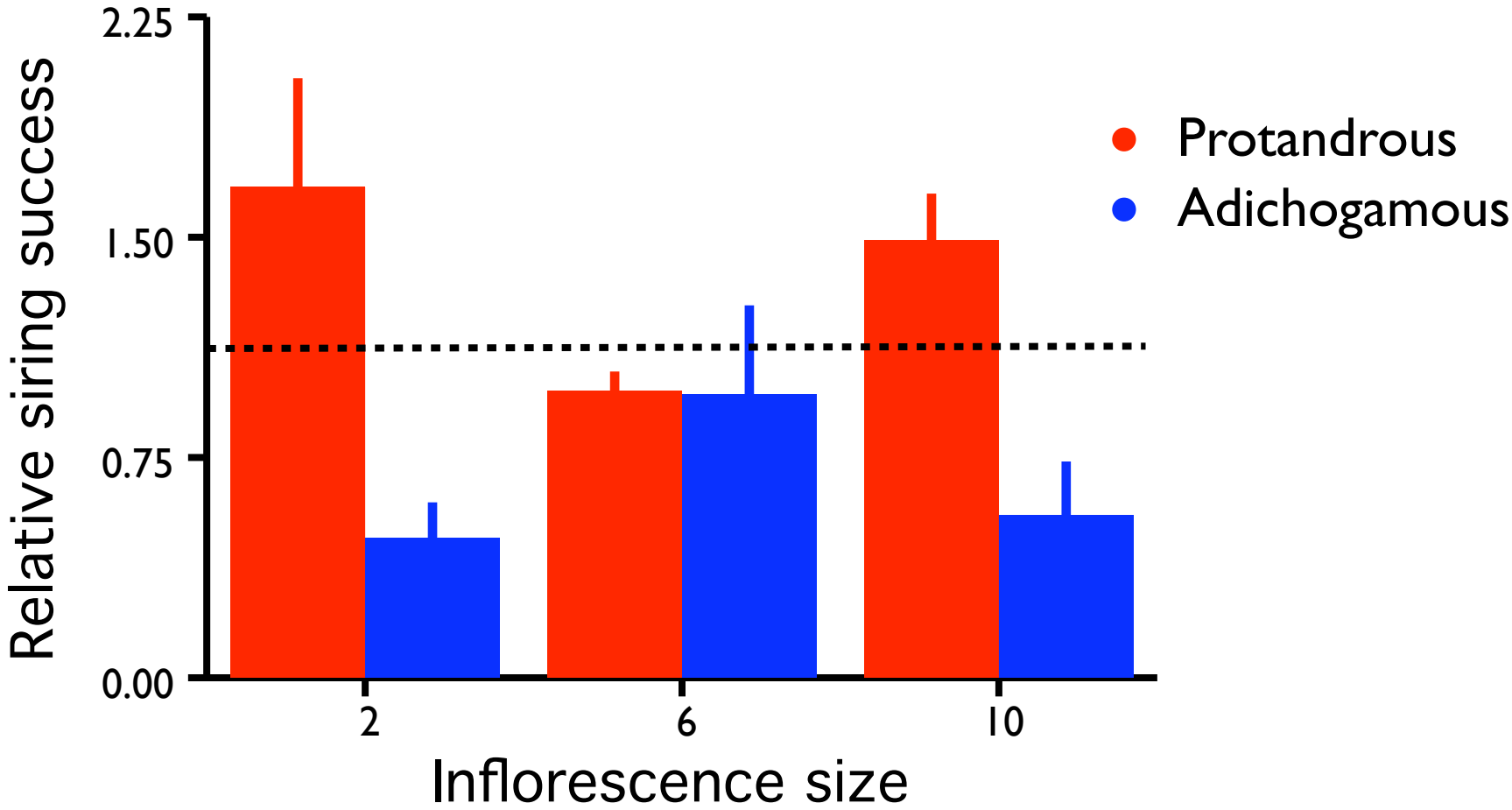
# Pollen removal



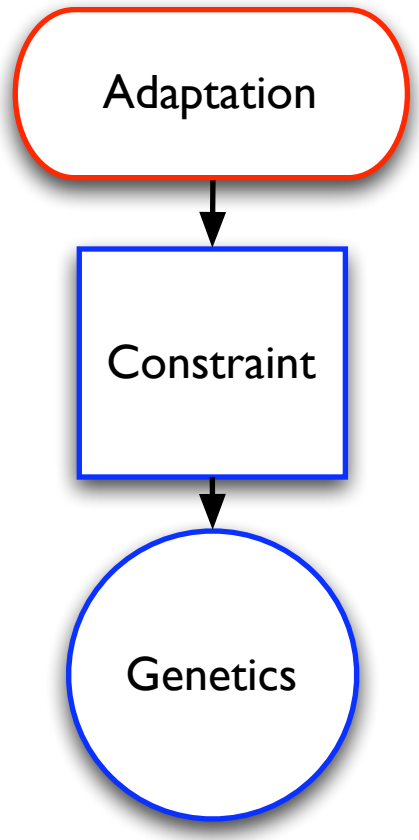

P>0.85

P>0.20

# Siring success



# Genetic analysis

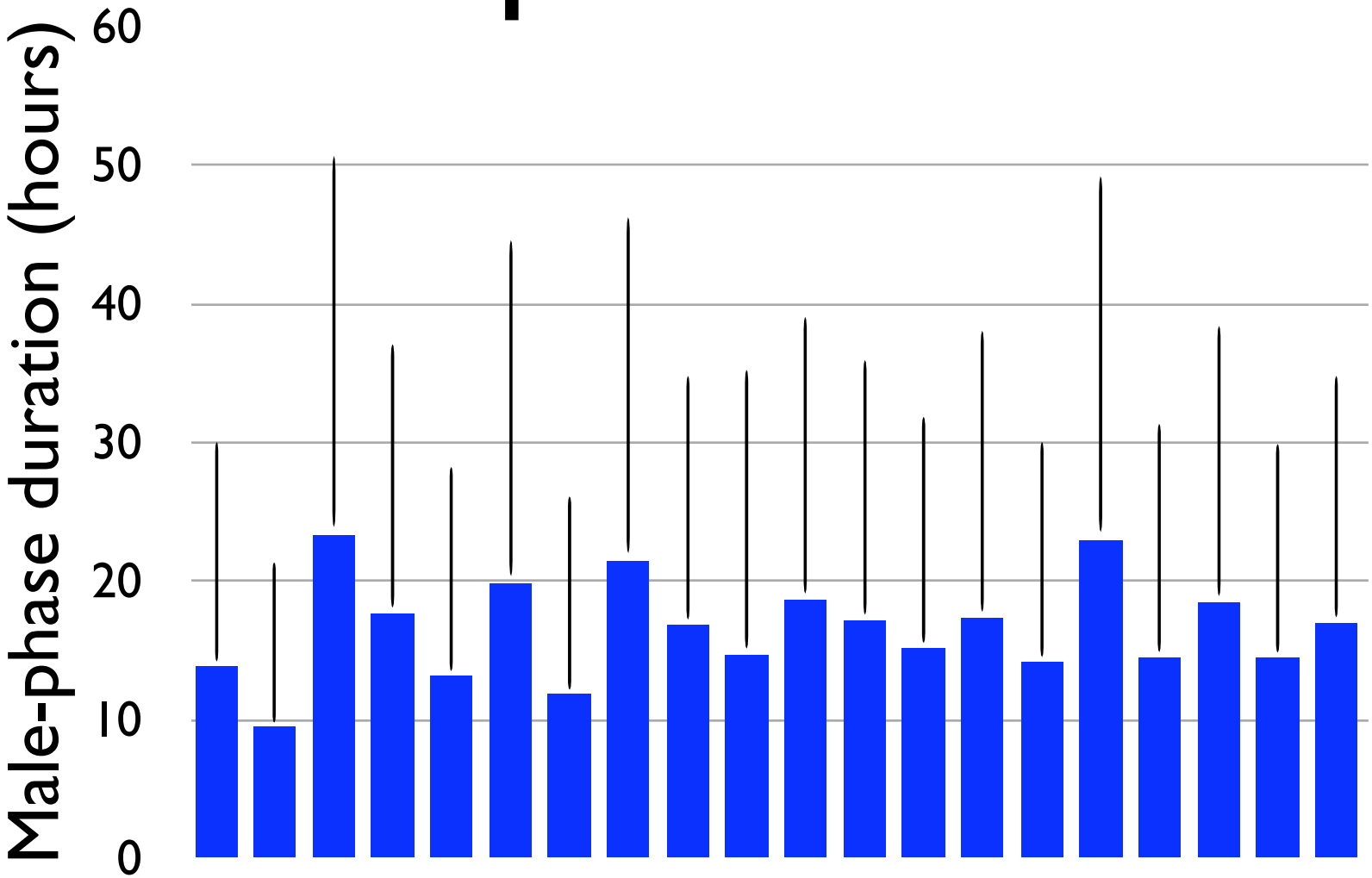


# Evolution of male-phase duration

- Influences of pollinator visitation & pollen removal
- Strong influence on male reproductive success
- Response to selection:
  - Heritability
  - Character correlations
  - Trade-offs


8/5

# Male-phase variation

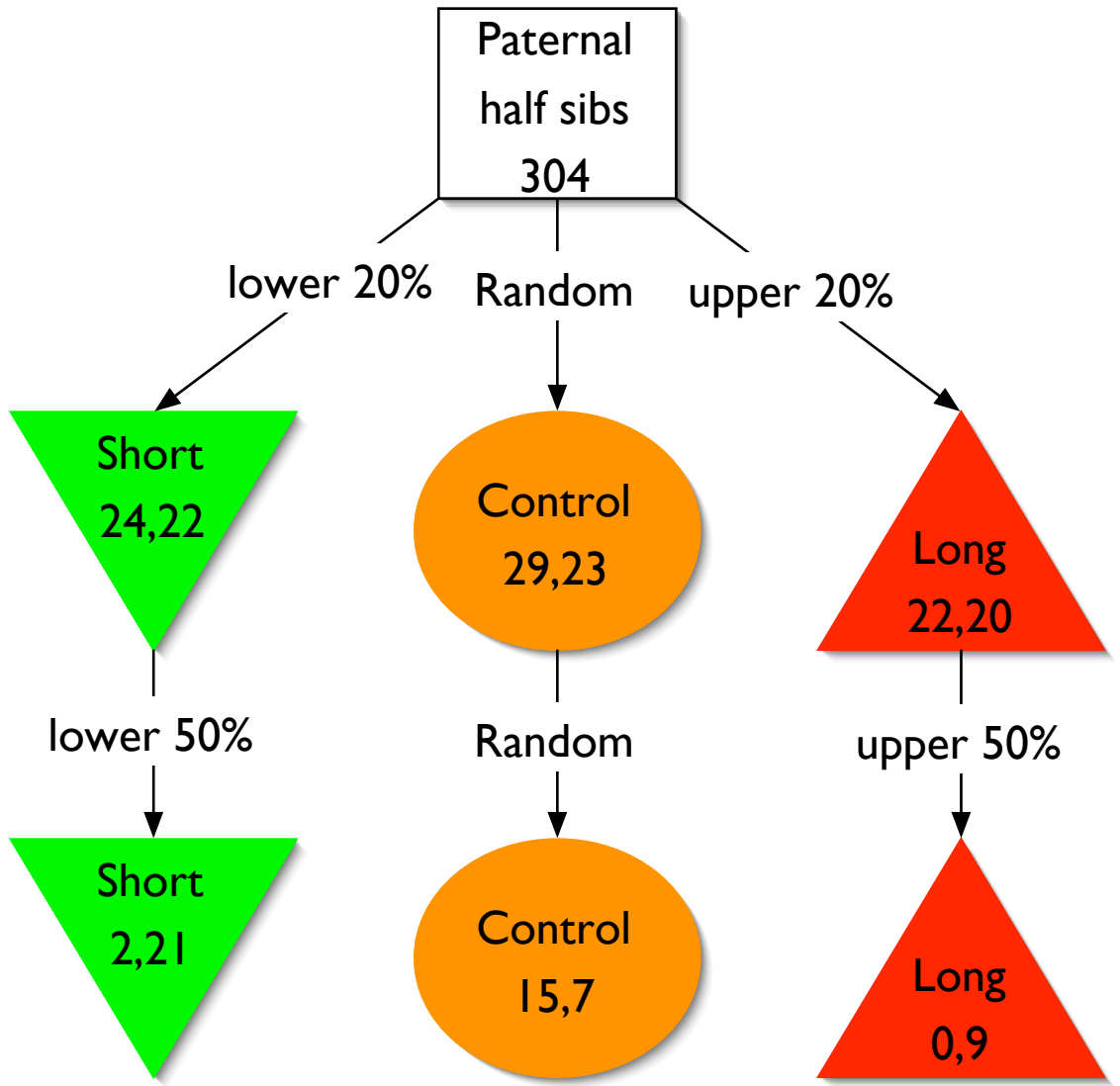



$h^2$=0.27 (0.54–0.05)

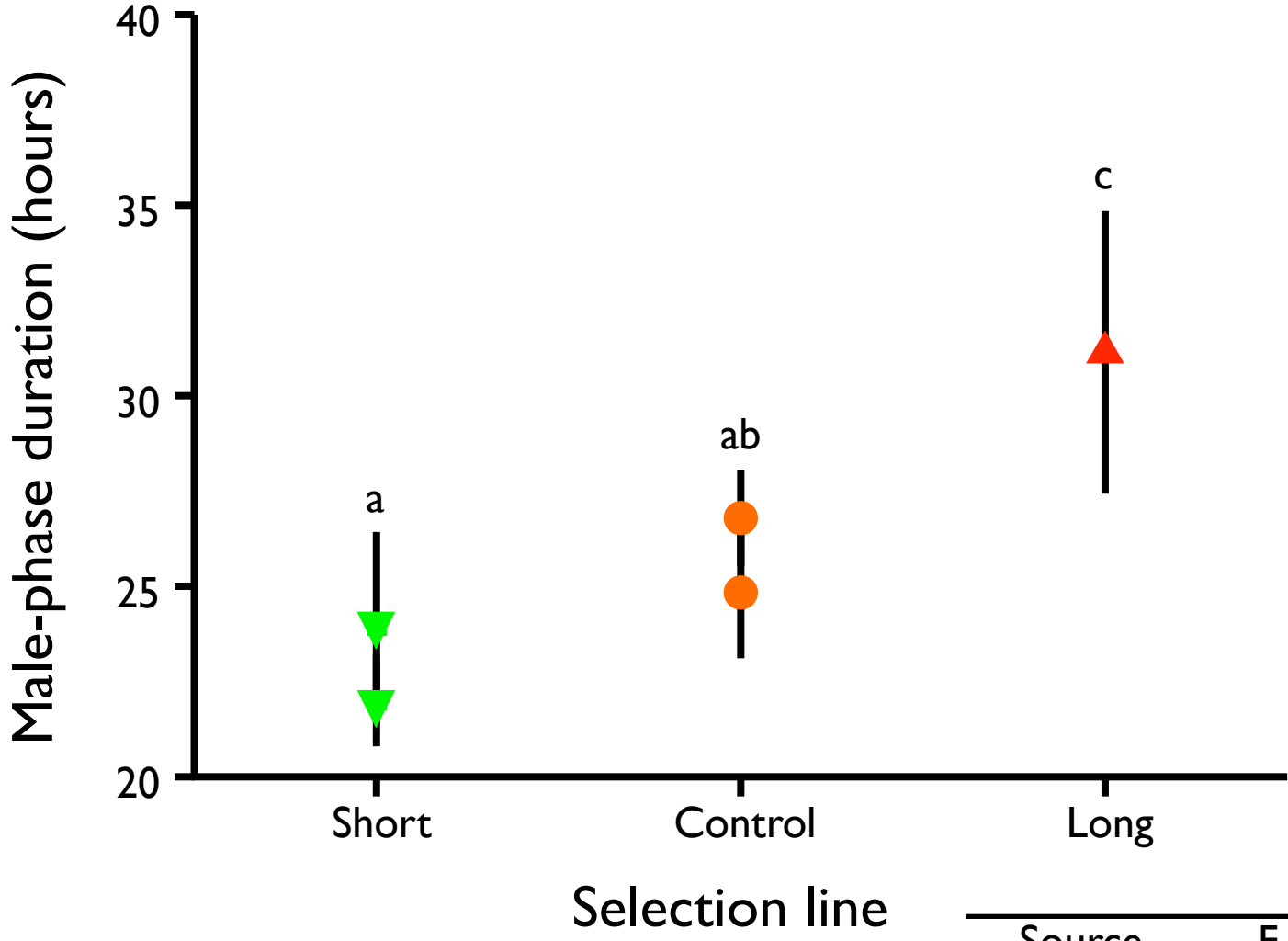
# Genetic architecture

| Male duration | Female duration | Floral width | Floral separation | Display length | Display size |
|---|---|---|---|---|---|
| 0.23±0.04 | -0.17±0.14 | -0.13±0.12 | 0.49±0.22 | 0.68±0.12 | 0.22±0.32 |
| | 0.17±0.04 | 0.04±0.11 | -0.26±0.22 | -0.18±0.15 | 0.38±0.29 |
| | | 0.19±0.04 | 0.26±0.21 | 0.47±0.16 | -0.13±0.10 |
| | | | 0.07±0.03 | 0.89±0.13 | 0.68±0.24 |
| | | | | 0.18±0.04 | 0.46±0.23 |
| | | | | | 0.39±0.18 |

# Artificial selection

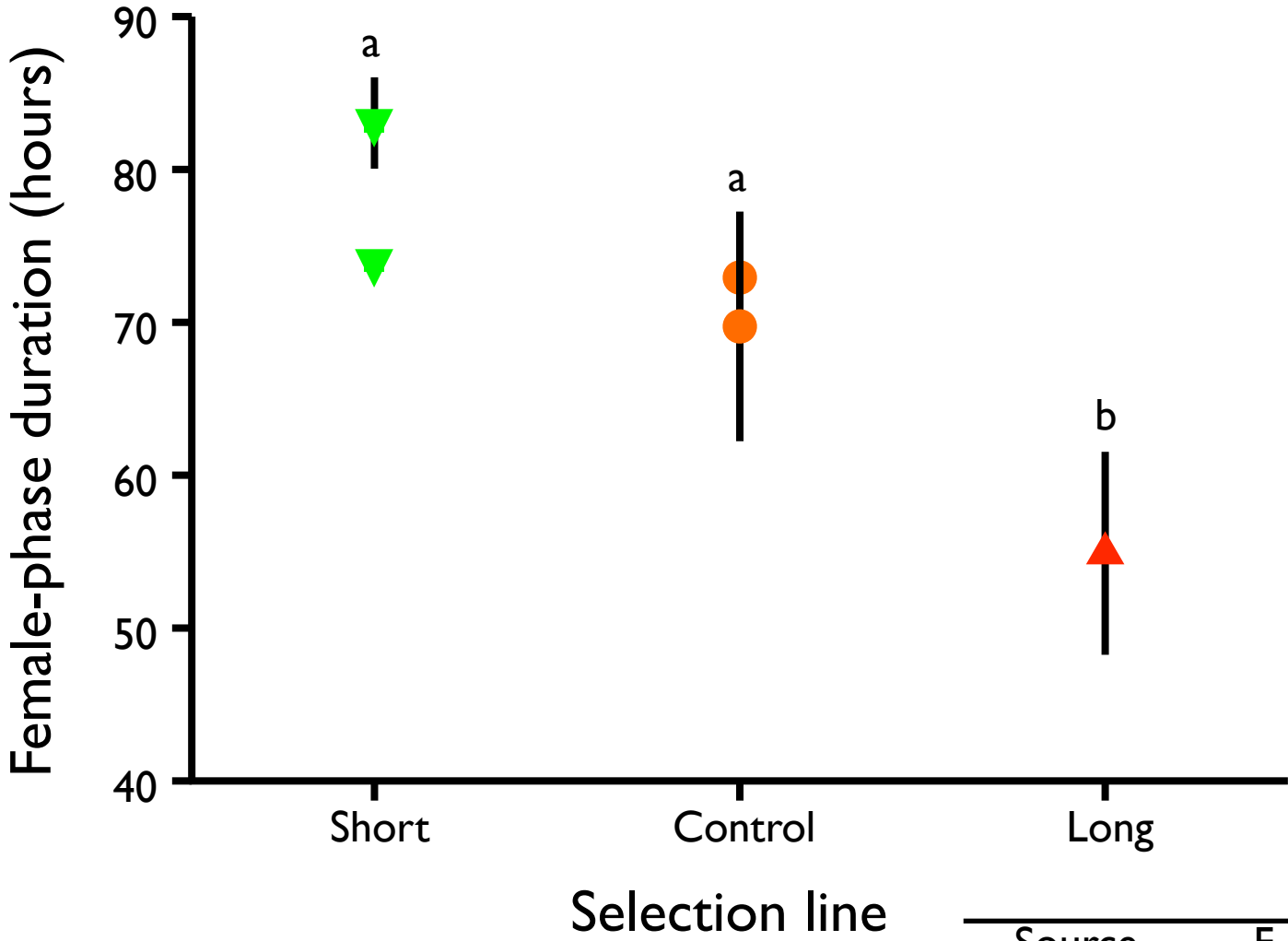


# Response to selection




| Source | F ratio | P |
|---|---|---|
| Generation | 22.39 | <0.0001 |
| Cross | 10.35 | <0.0001 |
| Replicate | 0.70 | >0.40 |

# Response to selection

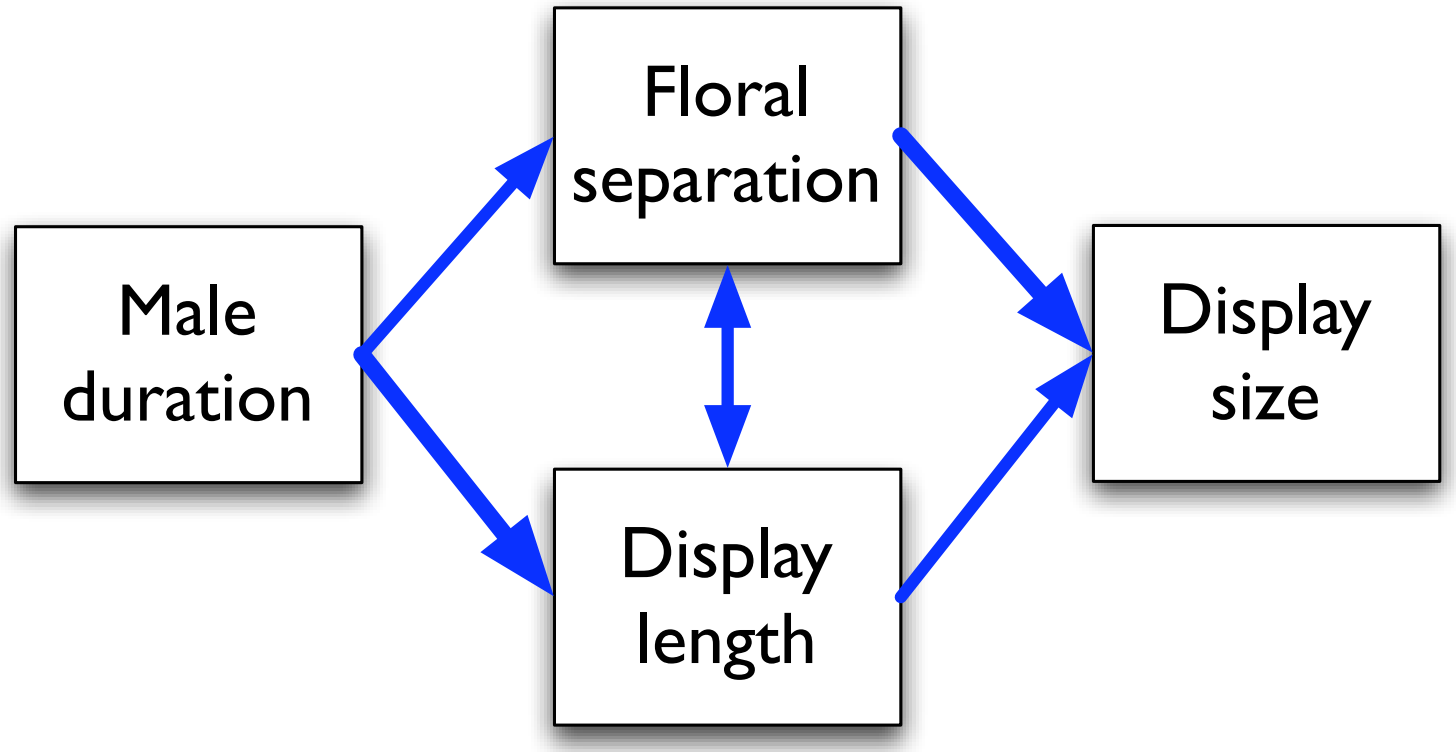



| Source | F ratio | P |
|---|---|---|
| Generation | 15.13 | <0.0001 |
| Cross | 3.71 | <0.05 |
| Replicate | 3.73 | >0.05 |

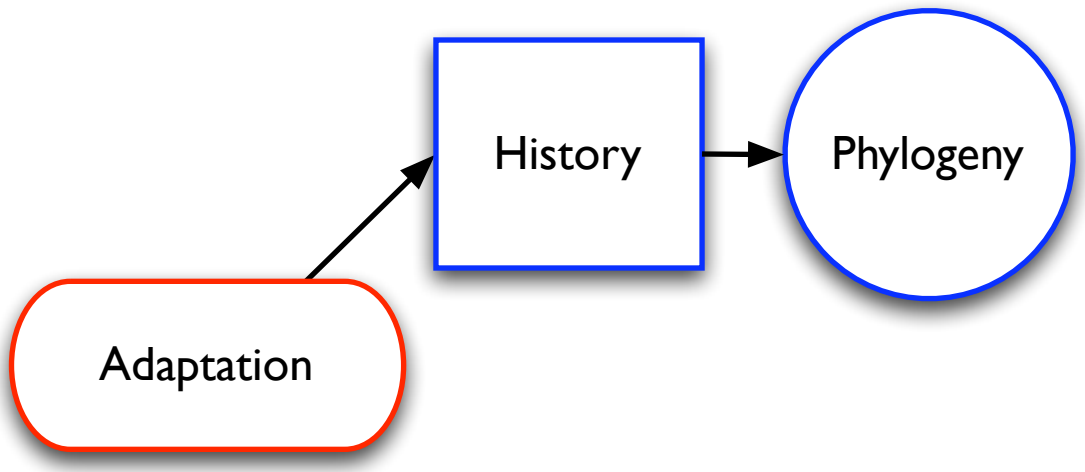
# Correlated characters

| Source | F ratio | df | P |
|---|---|---|---|
| Floral width | 0.71 | 2, 45 | >0.45 |
| Floral separation | 0.02 | 2, 45 | >0.95 |
| Inflorescence length | 0.73 | 2, 44 | >0.45 |
| Display size | 1.31 | 2, 51 | >0.25 |

# Character evolution



# Phylogenetic analysis



Considering phylogeny, are dichogamy and self-incompatibility correlated?

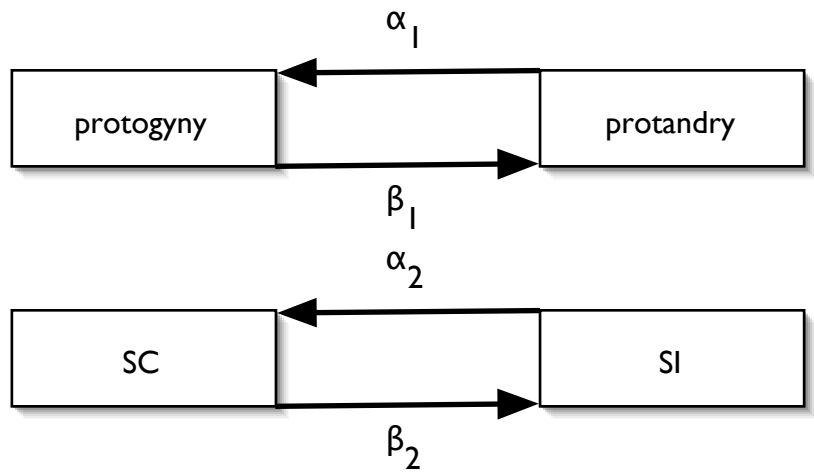
- Protogyny reduces inbreeding
  - ✦ associated with SC
- Protandry reduces interference
  - ✦ associated with SI

# Phylogenetic methods

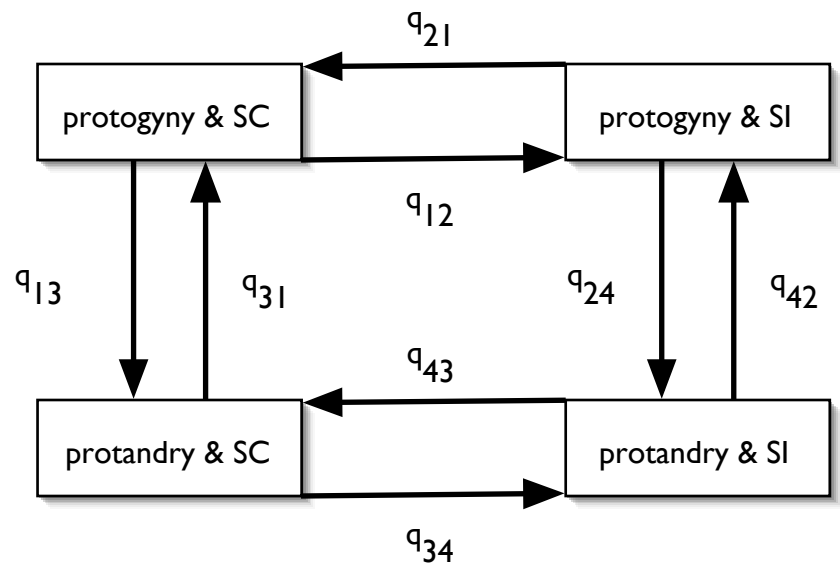
- Expanded Bertin's database:
  - ✦ 5,641 species
  - ✦ 244 families
- Protandry index
- SI index
- Soltis et al. 2000 phylogeny

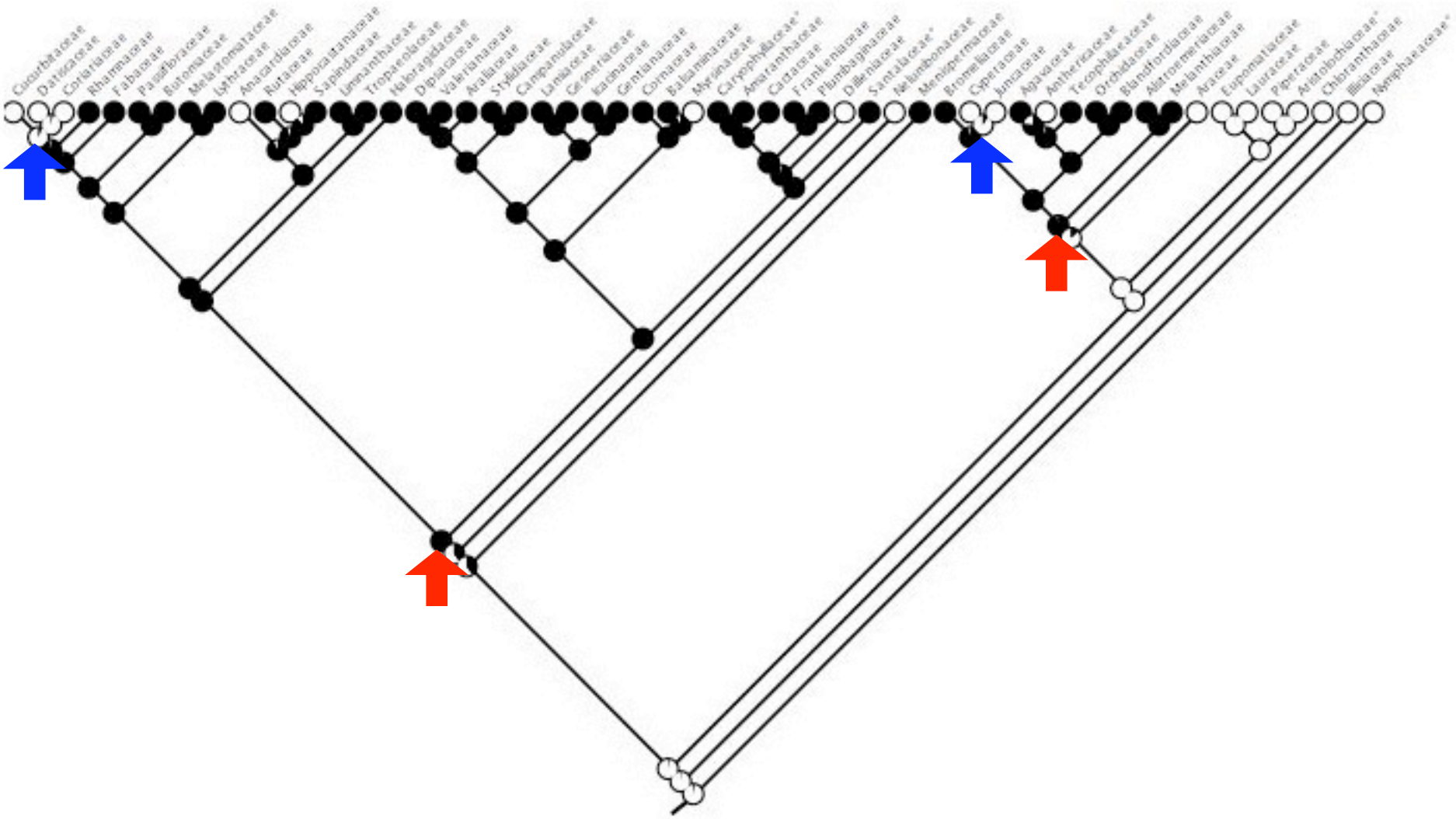
# Correlated evolution

Independent

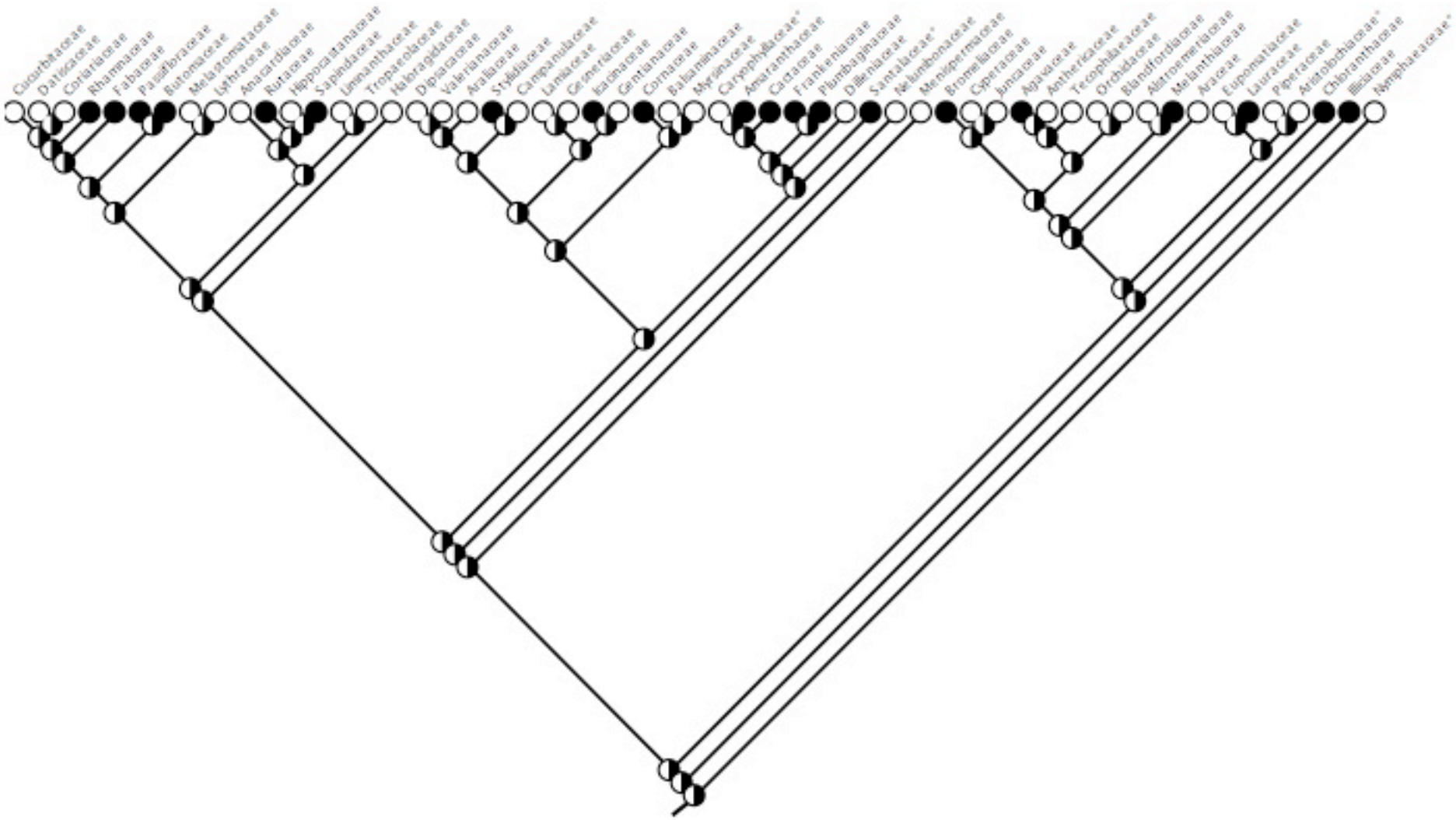



Dependent

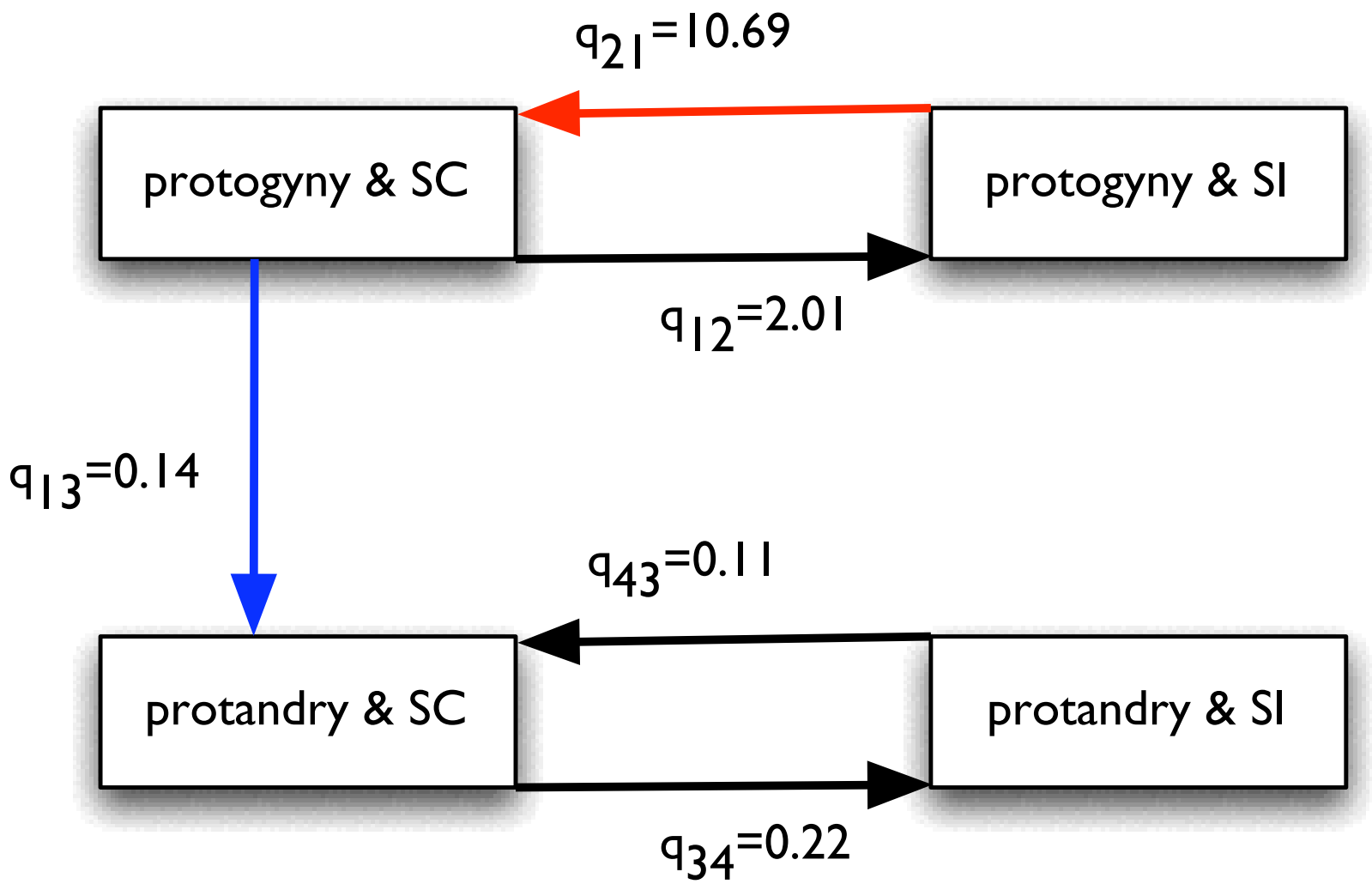





- Protandry
- Protogyny


Cucurbitaceae
Datiscaceae
Coriariaceae
Rhamnaceae
Fabaceae
Passifloraceae
Begoniaceae
Melastomataceae
Lythraceae
Anacardiaceae
Rutaceae
Hippocastanaceae
Sapindaceae
Limnanthaceae
Tropaeolaceae
Halmagidaceae
Dipsacaceae
Valerianaceae
Araliaceae
Stylidiaceae
Campanulaceae
Lamiaceae
Gesneriaceae
Icacinaceae
Gentianaceae
Cornaceae
Balaninaceae
Myrsinaceae
Caryophyllaceae*
Amaranthaceae
Cactaceae
Frankeniaceae
Plumbaginaceae
Dilleniaceae
Santalaceae*
Nelumbonaceae
Menispermaceae
Bromeliaceae
Cyperaceae
Juncaceae
Agavaceae
Anthericaceae
Tecophilaceae
Orchidaceae
Blandfordiaceae
Alstroemeriaceae
Melanthiaceae
Araceae
Eupomatiaceae
Lauraceae
Piperaceae
Aristolochiaceae*
Chloranthaceae
Illiciaceae
Nymphaeaceae*

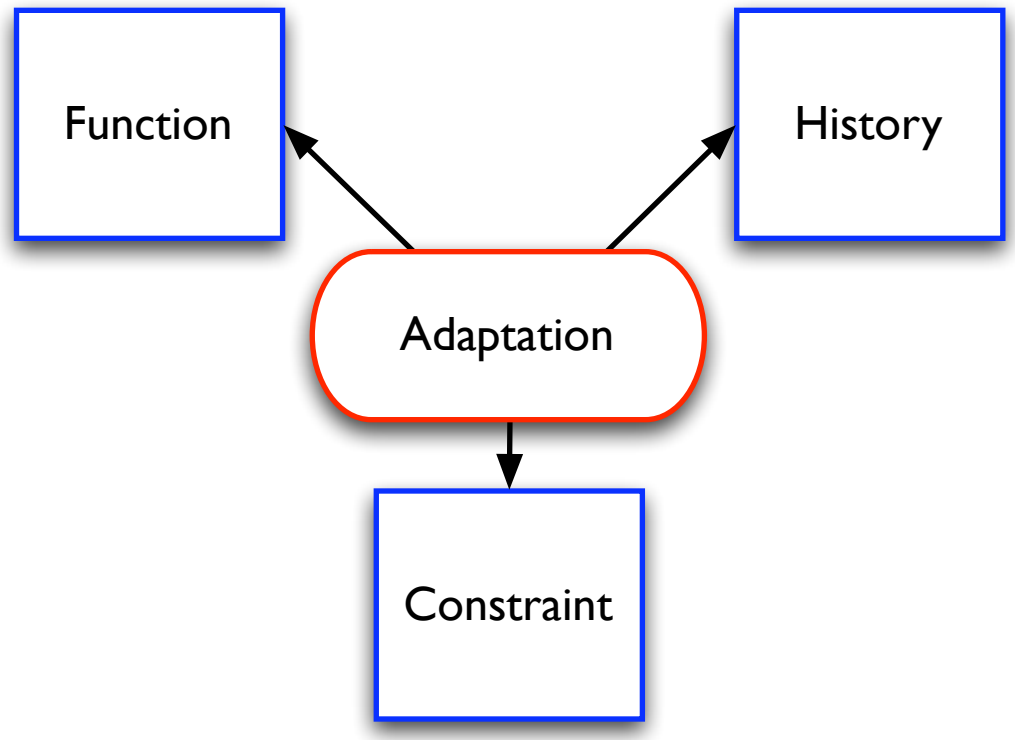
- SI
- SC




LR = 8.6

P < 0.05

κ = 0.20


Function
History
Adaptation
Constraint

# Acknowledgements

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