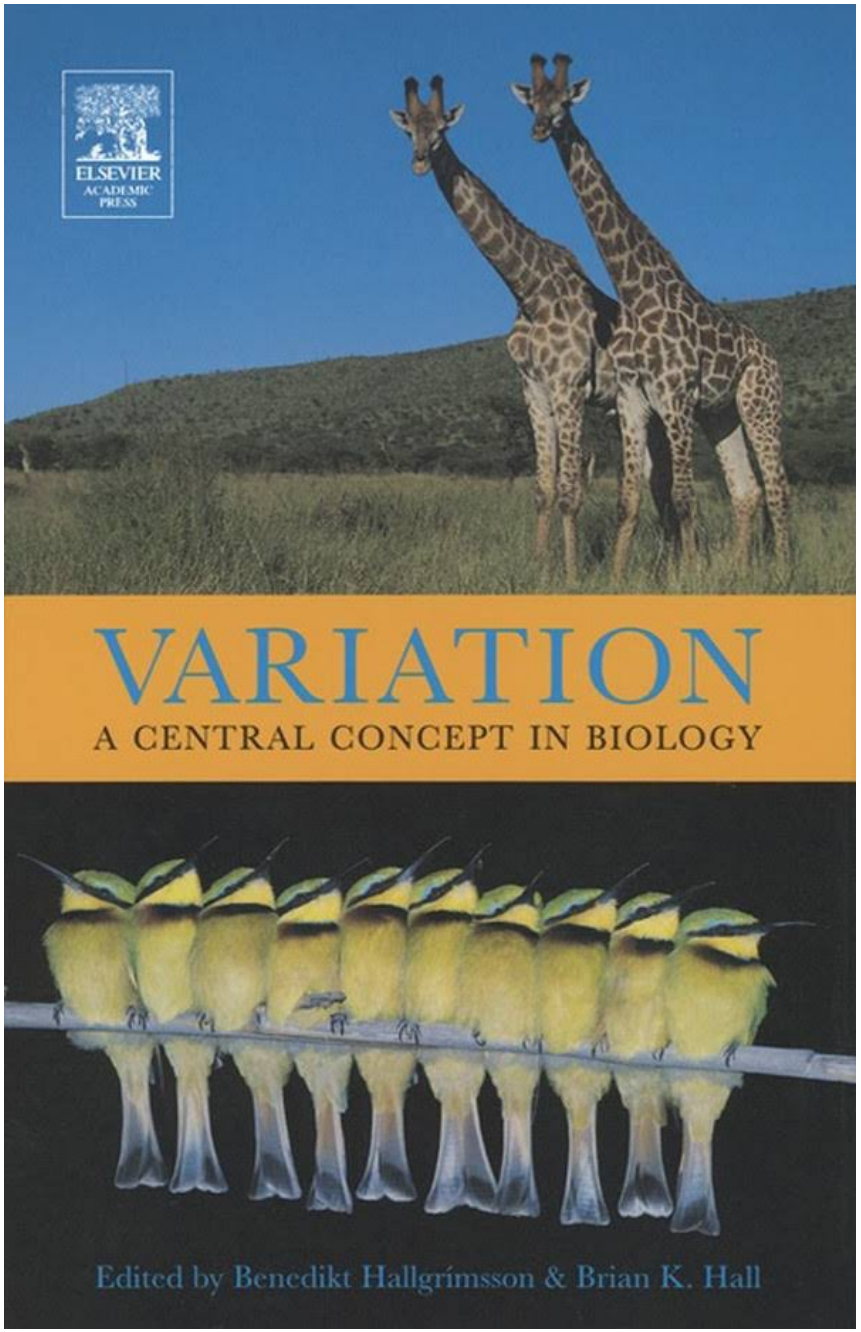
Séminaire CBGP
19 Septembre
2017

Antoine Fraimout

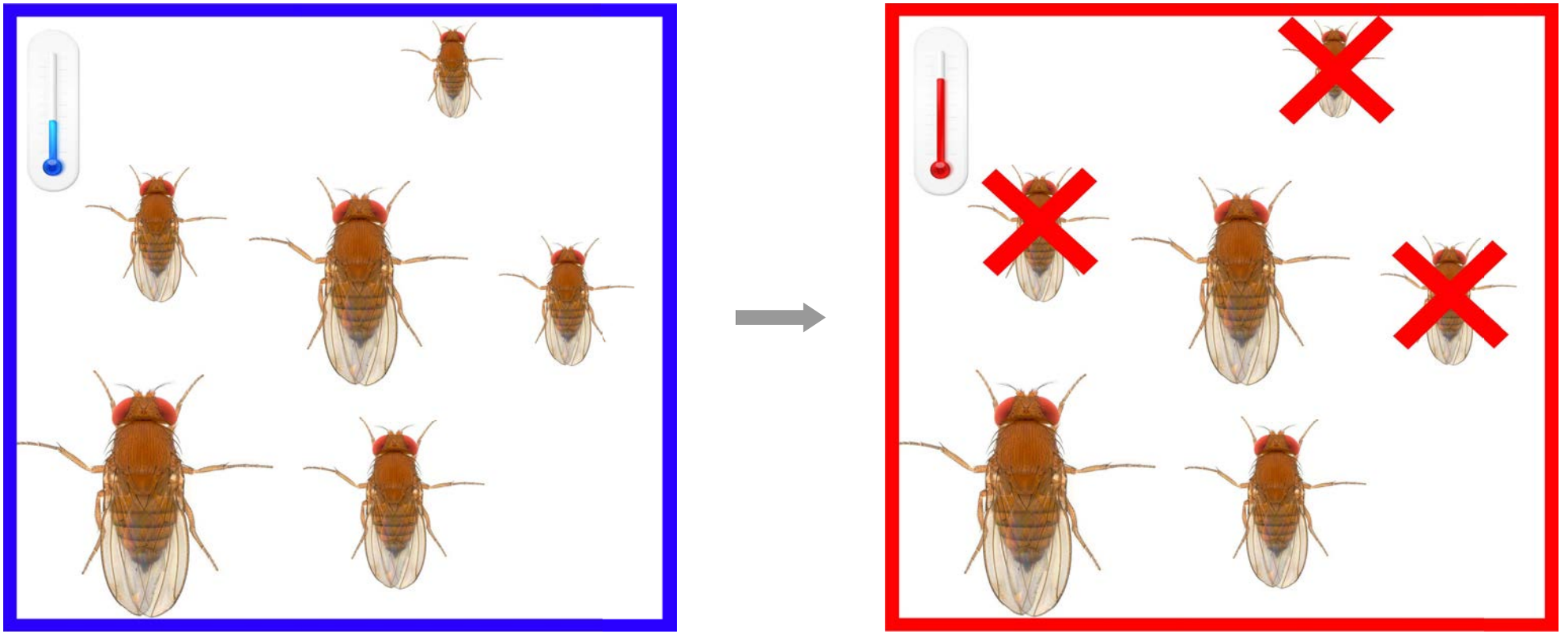
Evolution de la variation génétique et phénotypique au cours d'une invasion: le cas de *Drosophila suzukii*



Hallgrimsson & Hall 2005

Phenotypic variation is the raw material for evolution by natural selection

It determines the capacity of a population to respond to selection

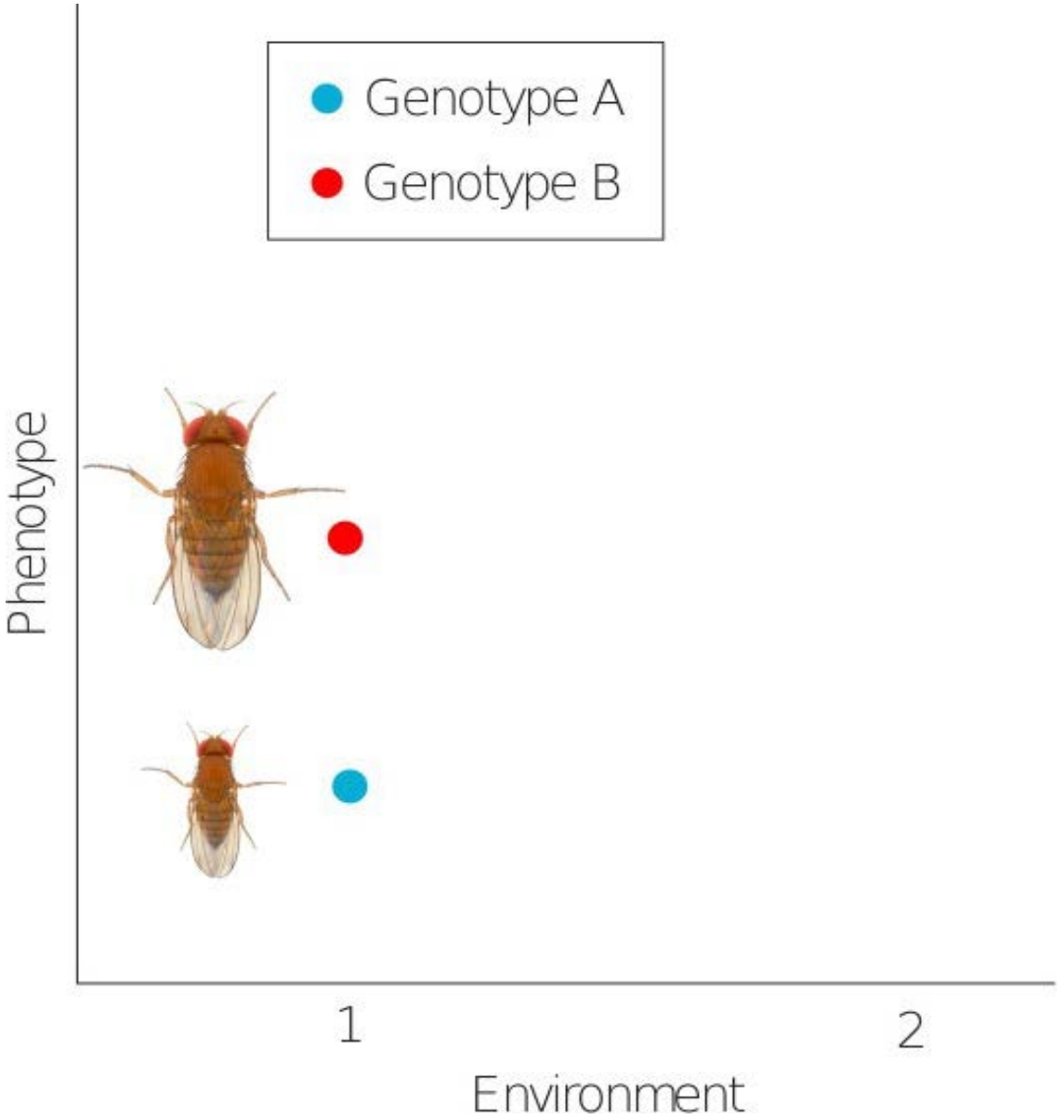


Environmental change

Phenotypic variation has different sources in a population

Phenotypic variation has different sources in a population

Genetic

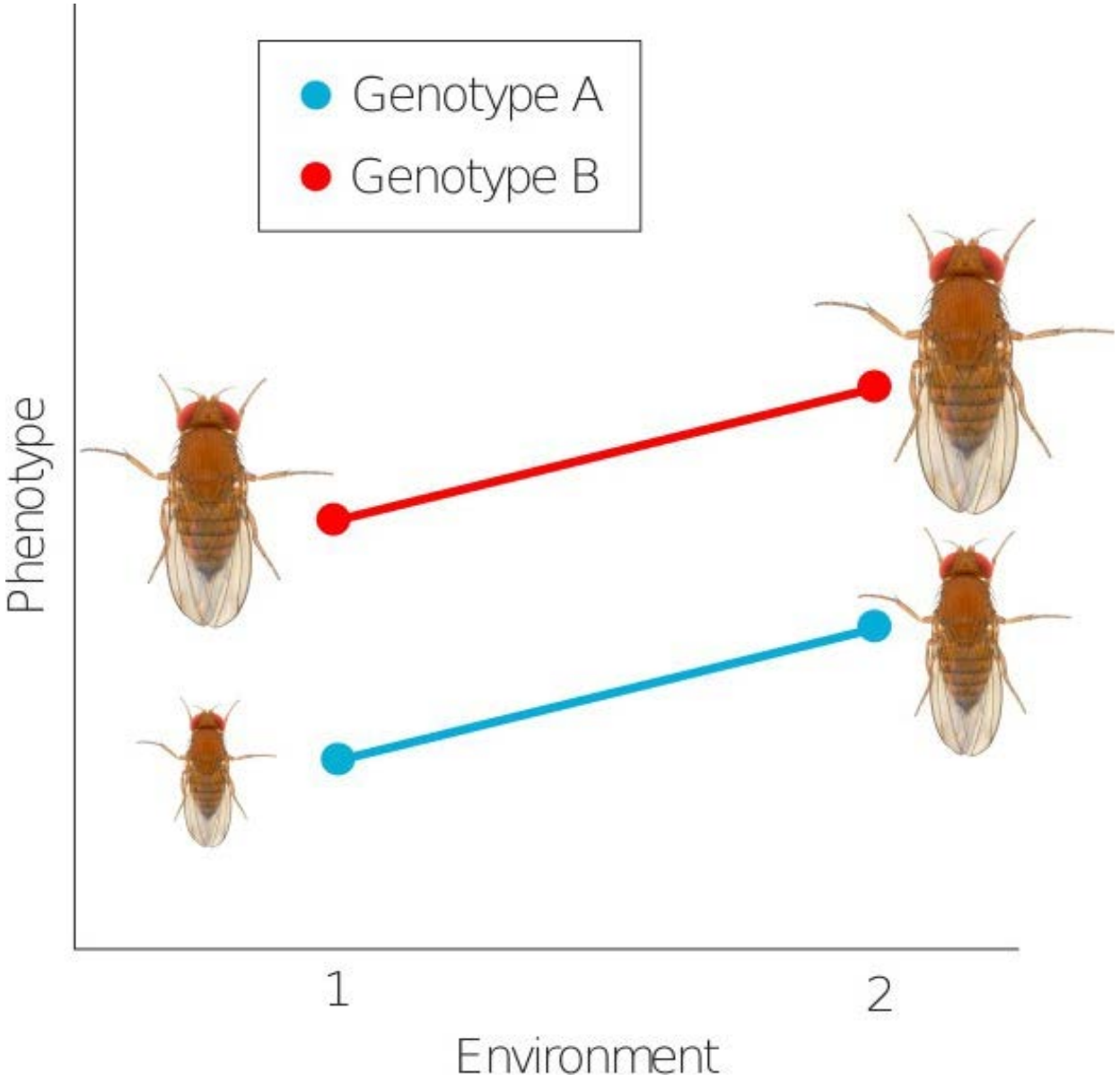


$V_P = V_G$

Modified from Anholt & Mackay 2004

Phenotypic variation has different sources in a population

Environmental

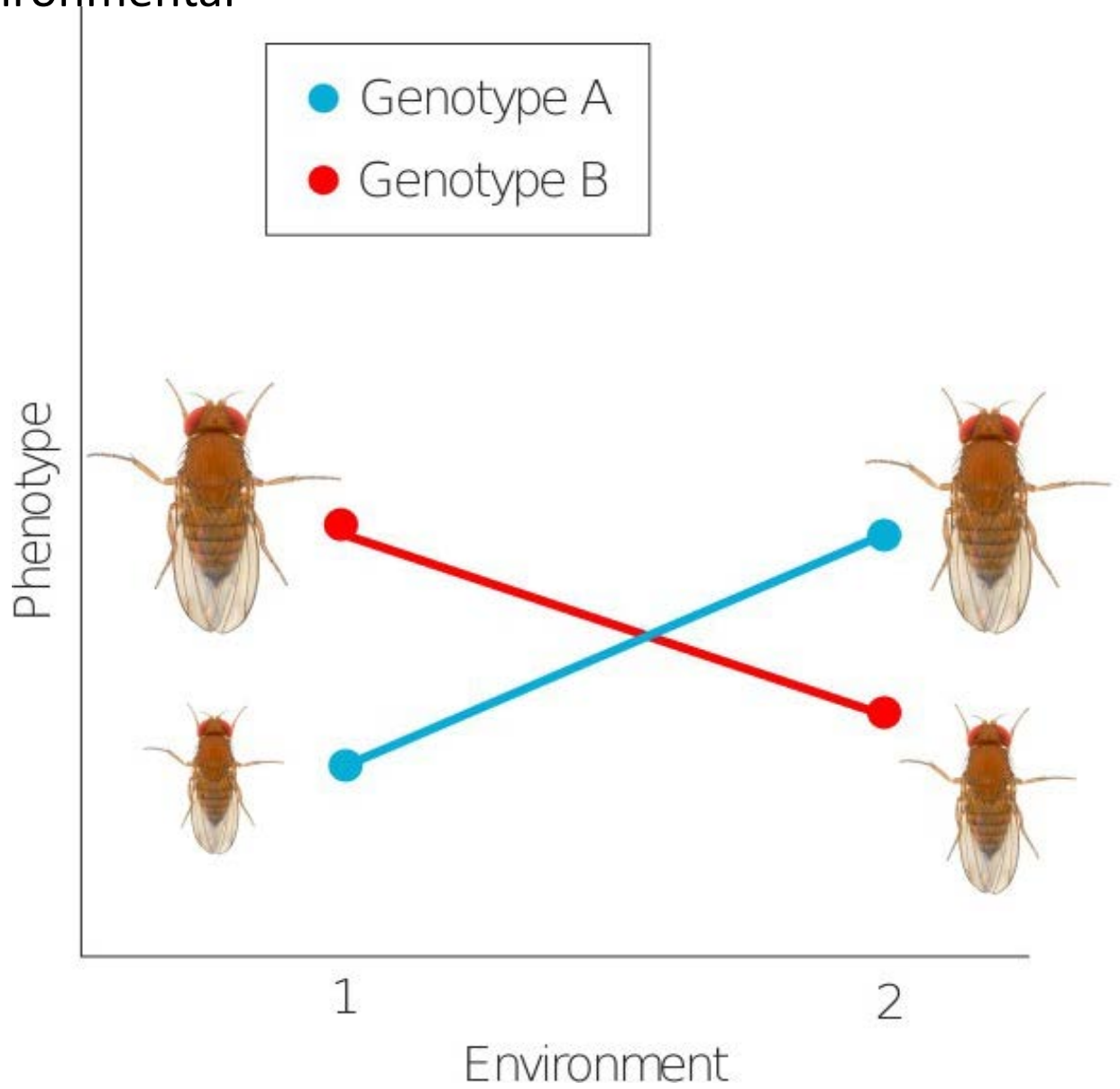


$$V_P = V_G + V_E$$

Modified from Anholt & Mackay 2004

Phenotypic variation has different sources in a population

Genetic and environmental

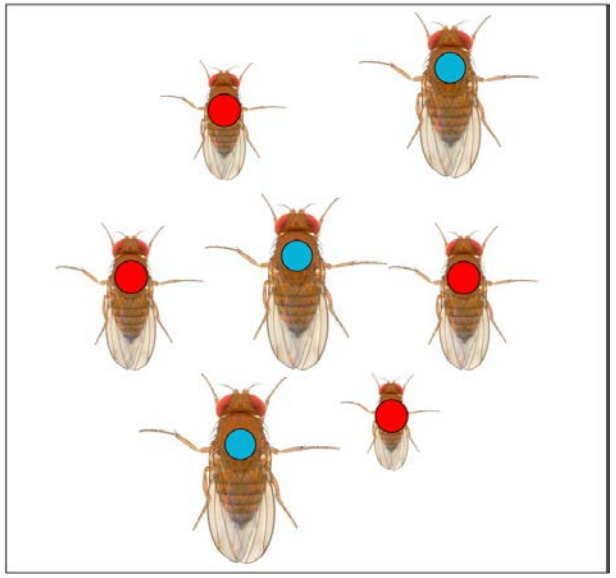


$$V_P = V_G + V_E + V_{GxE}$$

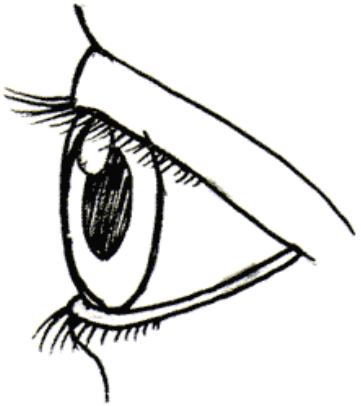
Modified from Anholt & Mackay 2004

A snapshot in the course of evolution

Observed variation

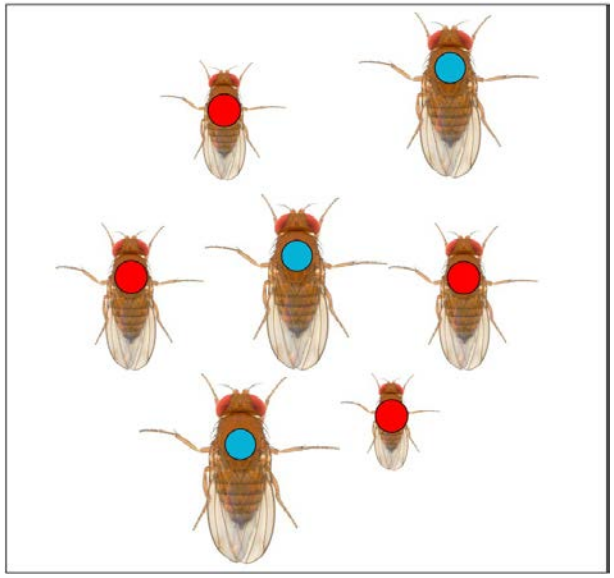


$(V_P = V_G + V_E + V_{GxE})$

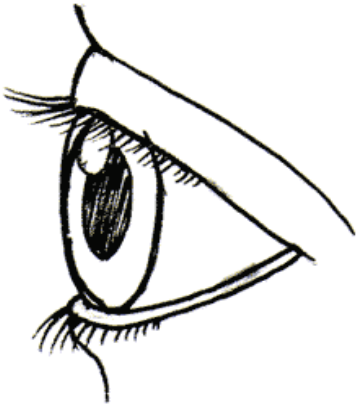


Ancestral variation

Observed variation

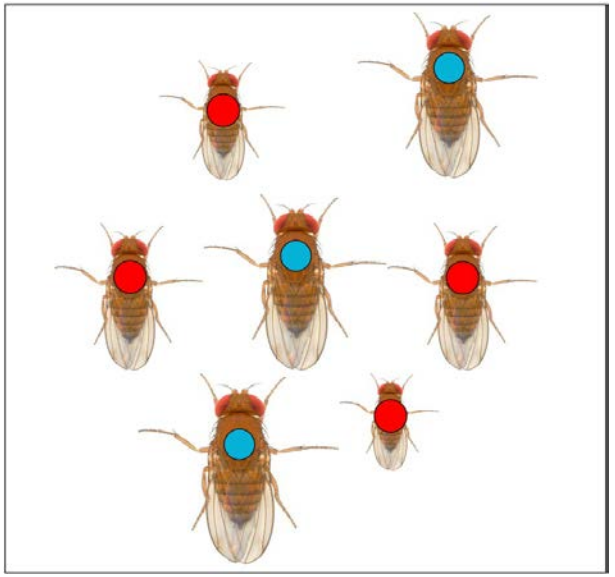


$(V_P = V_G + V_E + V_{GxE})$



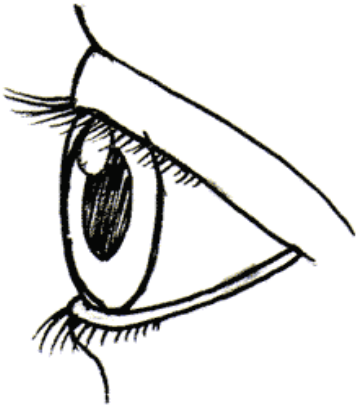
Ancestral variation

Observed variation



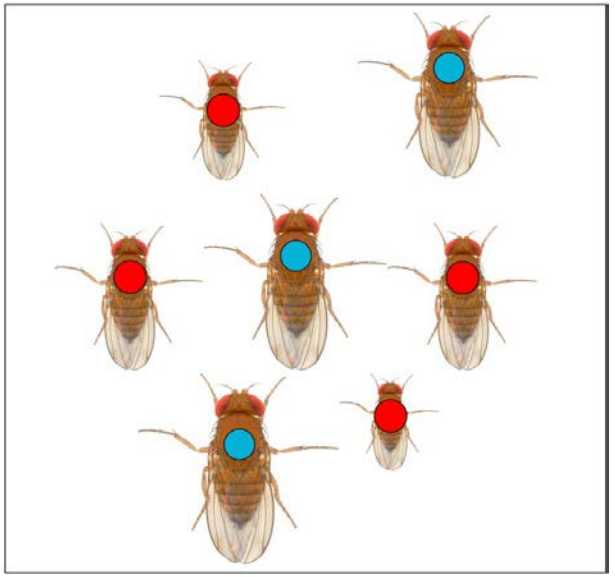
$(V_P = V_G + V_E + V_{GxE})$

Response to selection



Ancestral variation

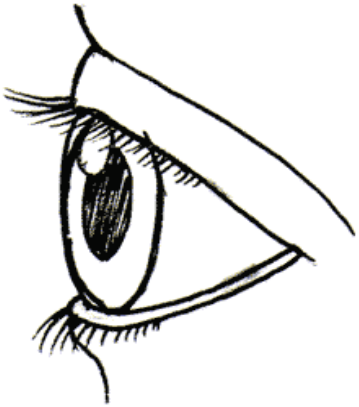
Observed variation



$(V_P = V_G + V_E + V_{GxE})$

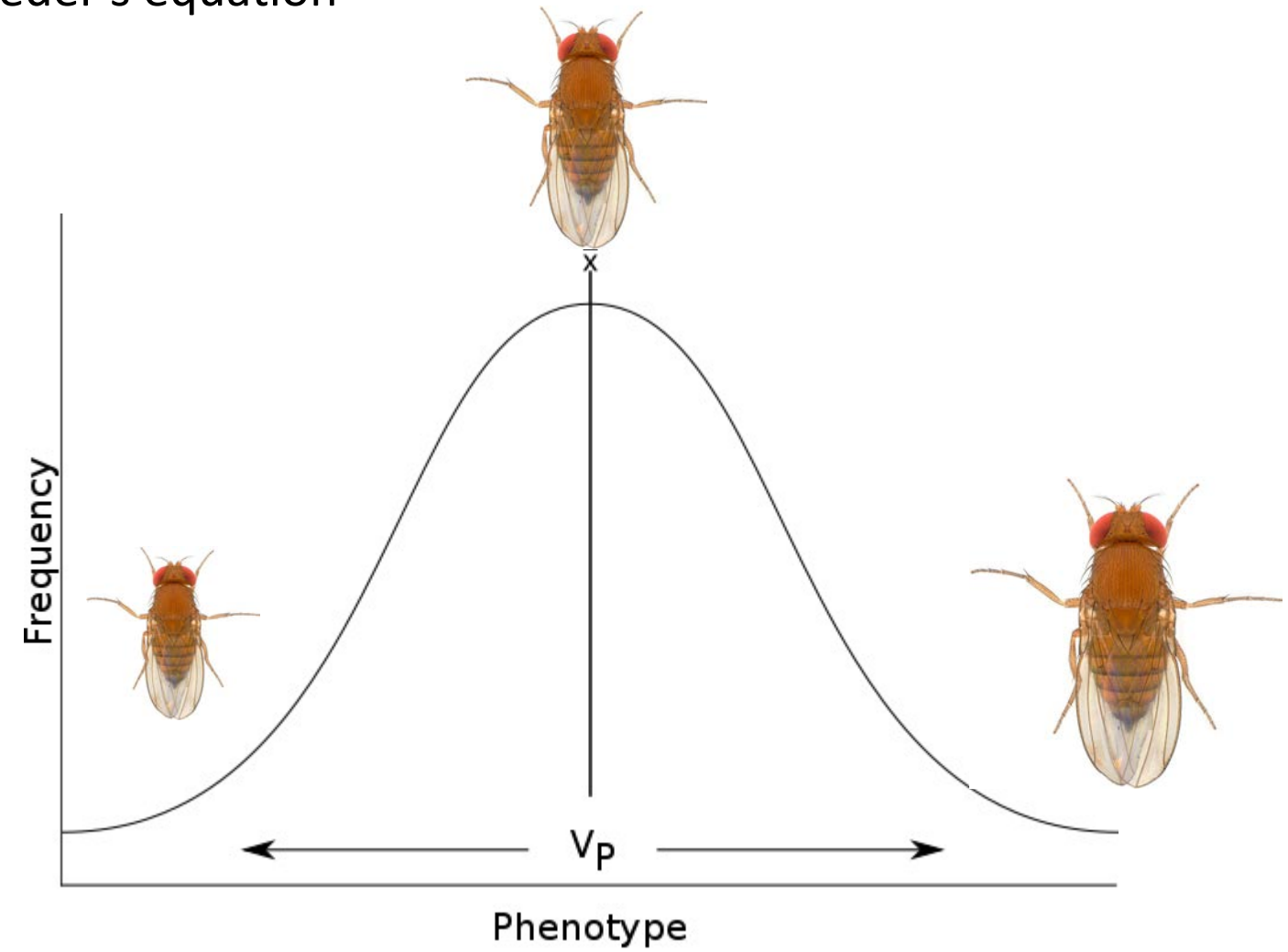
Response to selection

Can we predict response to selection?



Theoretical response to selection

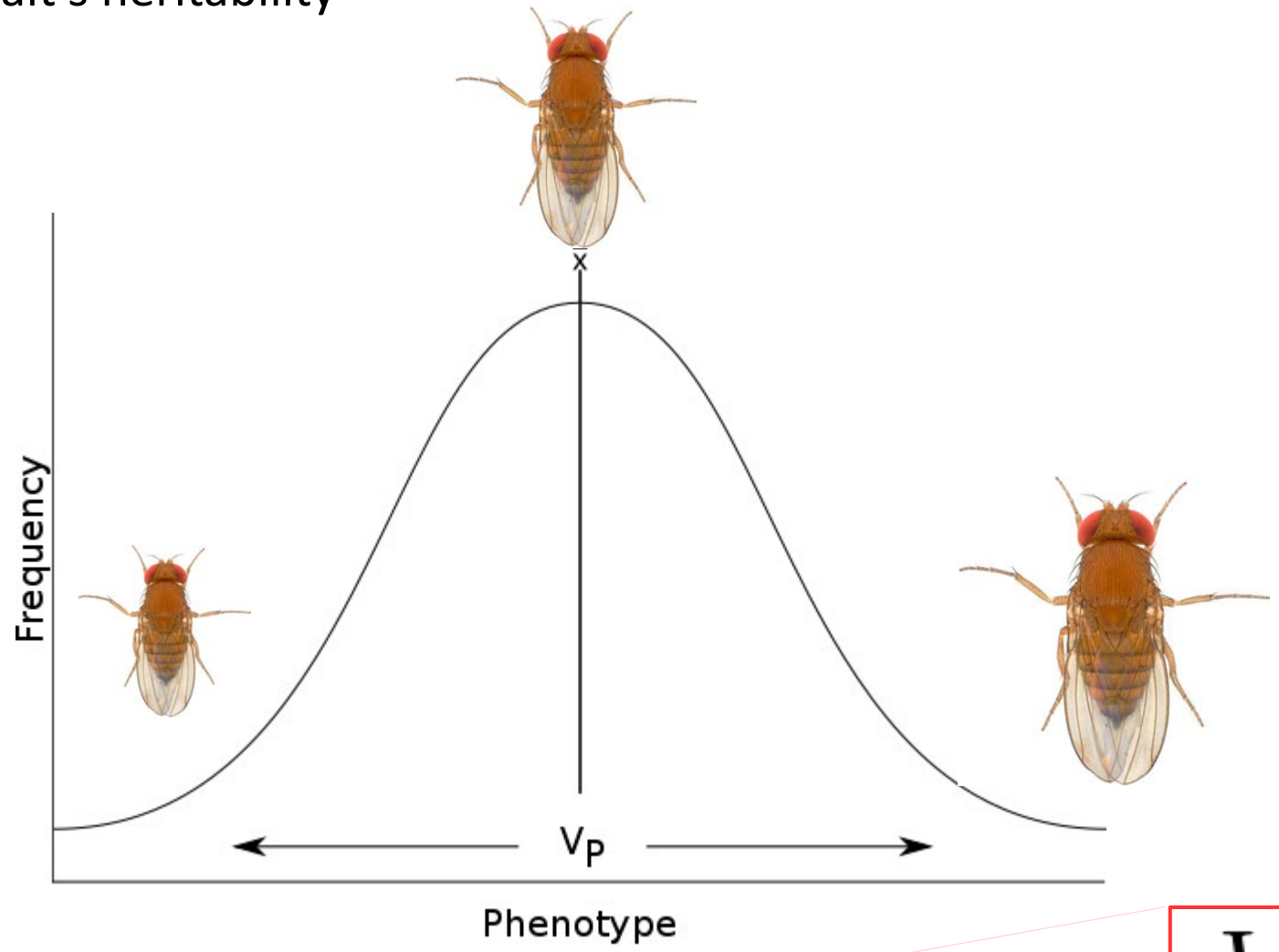
The univariate breeder's equation



$$R = h^2 S$$

Theoretical response to selection

The product of a trait's heritability

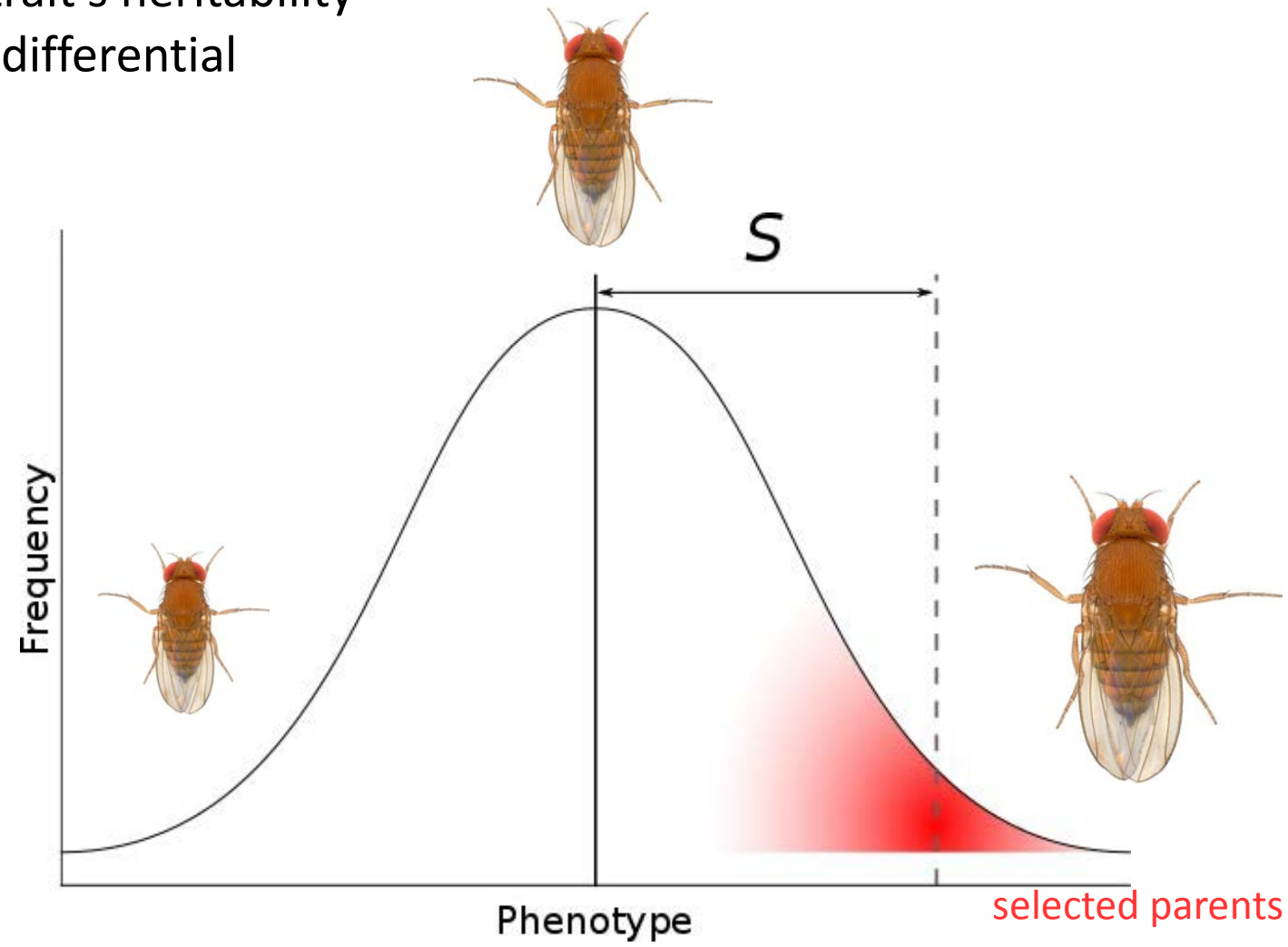


$$R = h^2 S$$

$$\frac{V_A}{V_P}$$

Theoretical response to selection

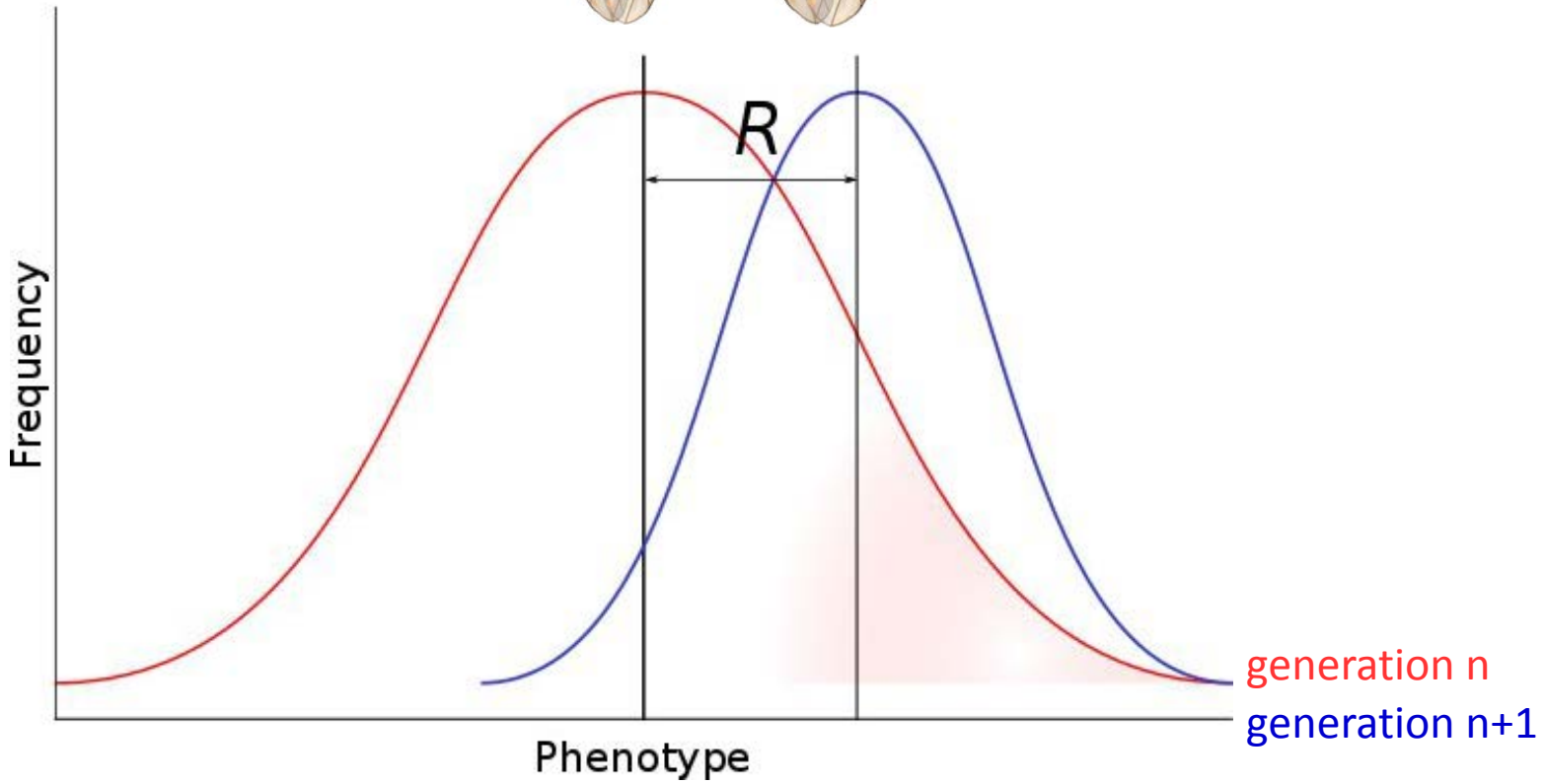
The product of a trait's heritability
and the selection differential



$$R = h^2 S$$

Theoretical response to selection

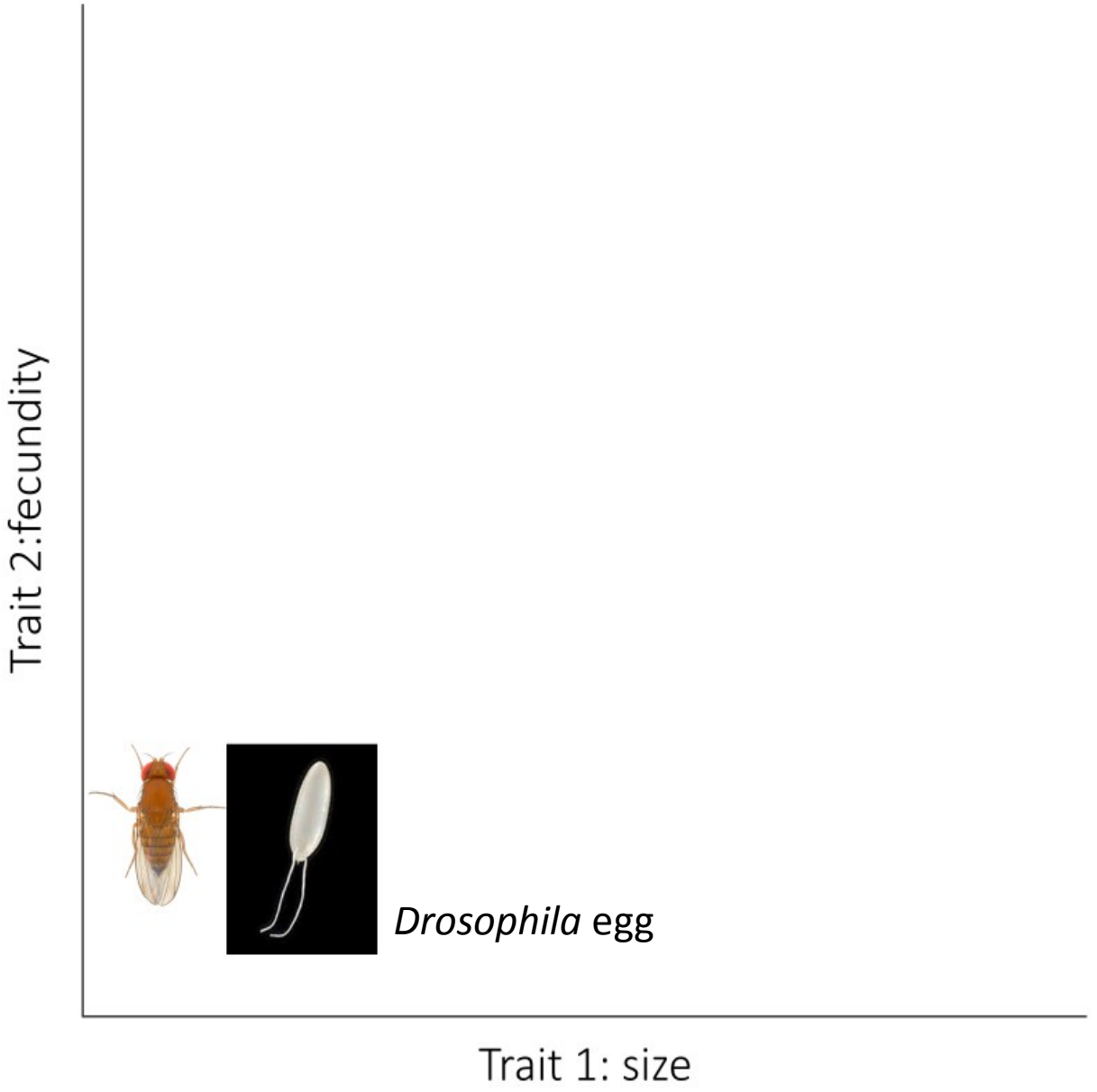
Evolution towards larger individuals



$$\boxed{R} = h^2 S$$

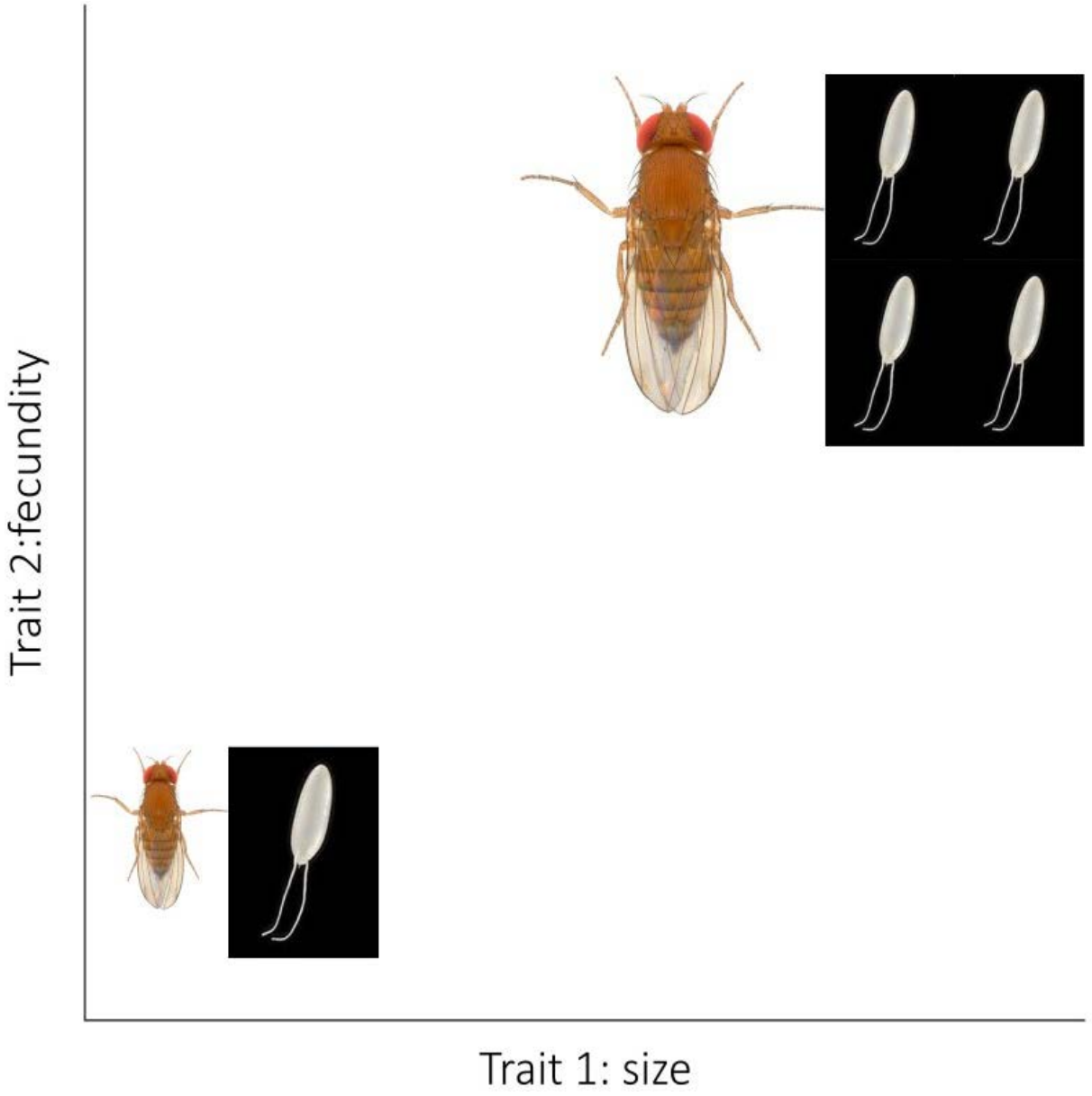
Practical issue

Selection acts on multiple traits



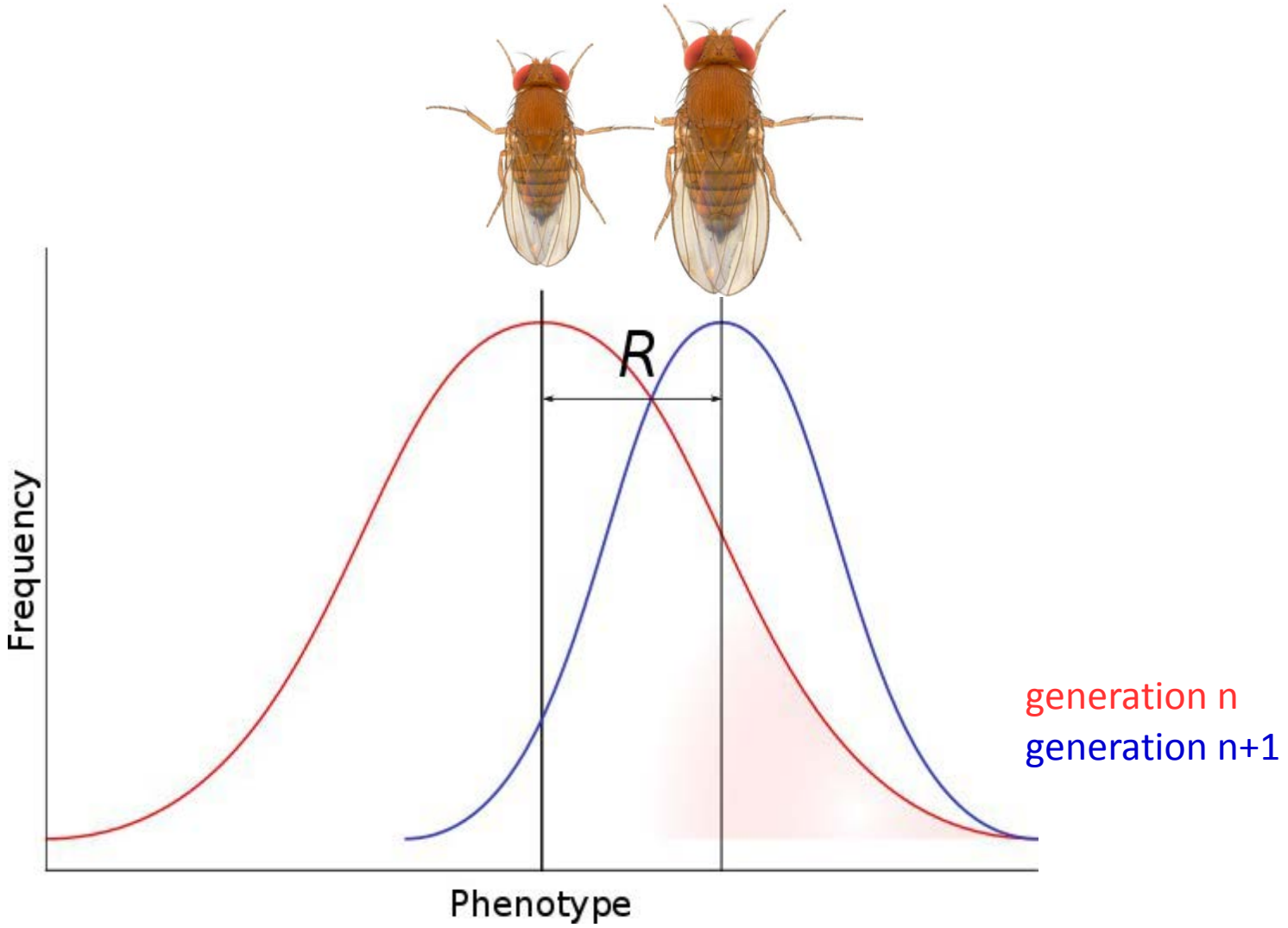
Practical issue

Traits can be genetically correlated and covary



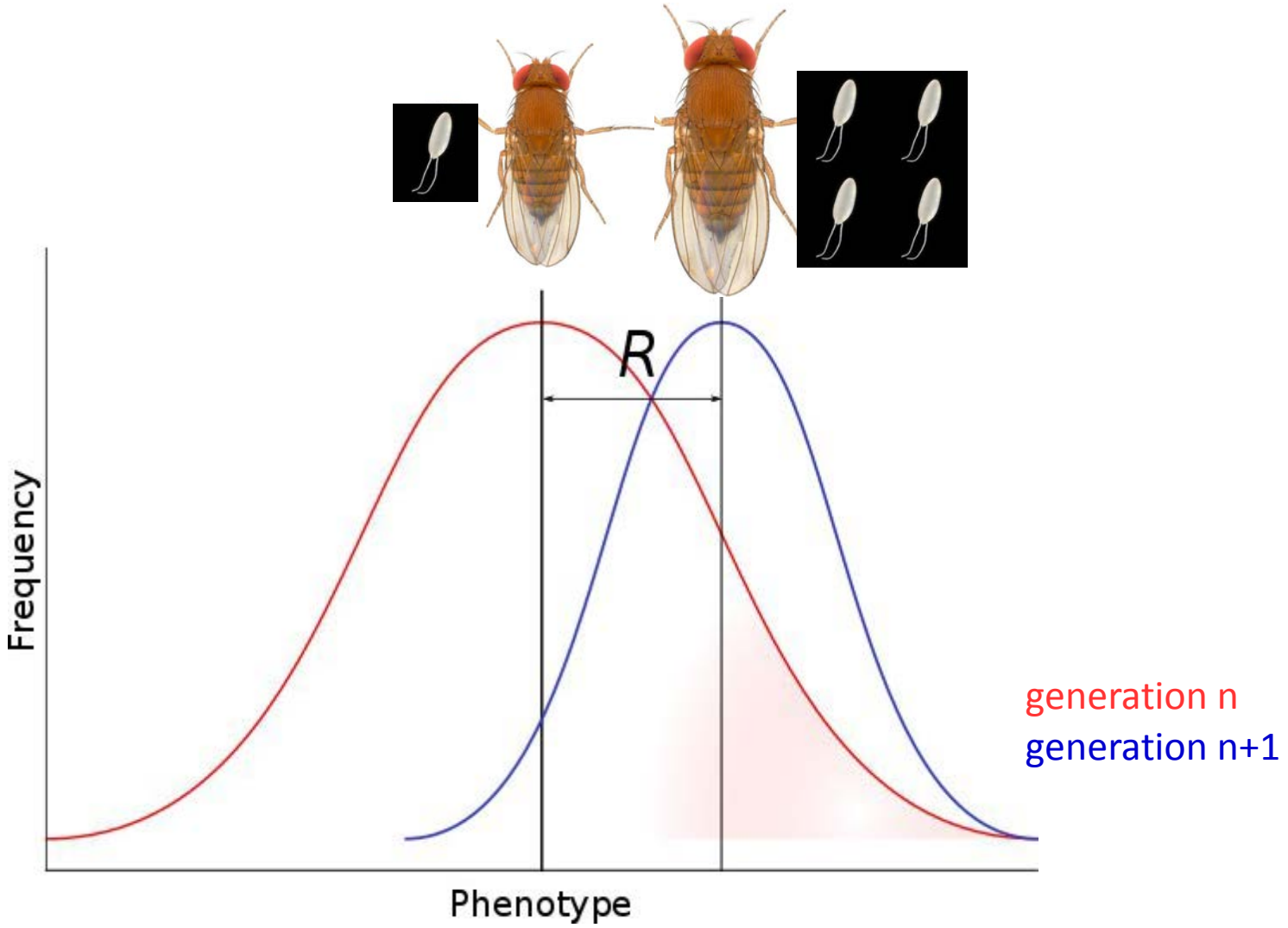
Response to selection

Evolution towards larger individuals



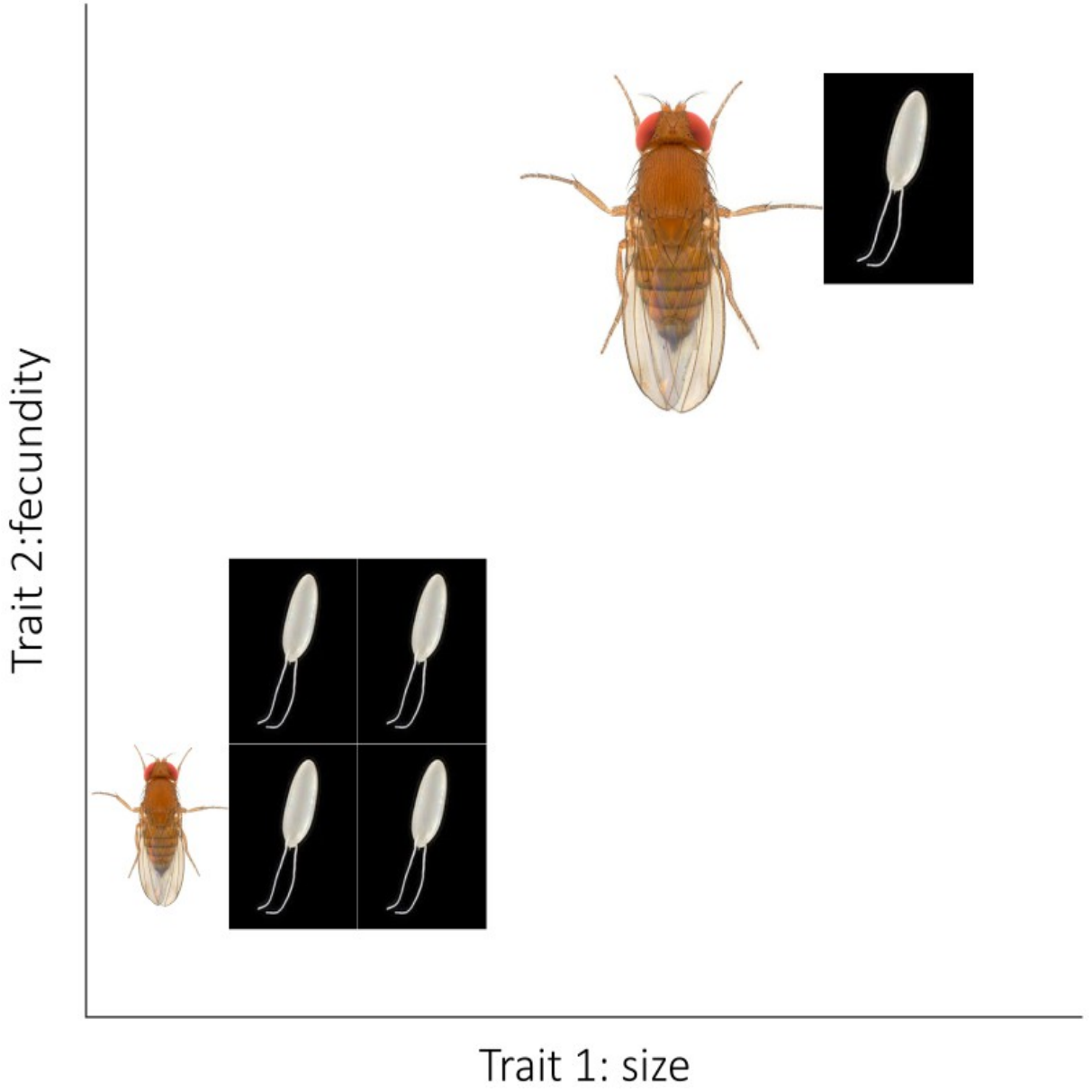
Response to selection

Evolution towards larger **and more fecund** individuals



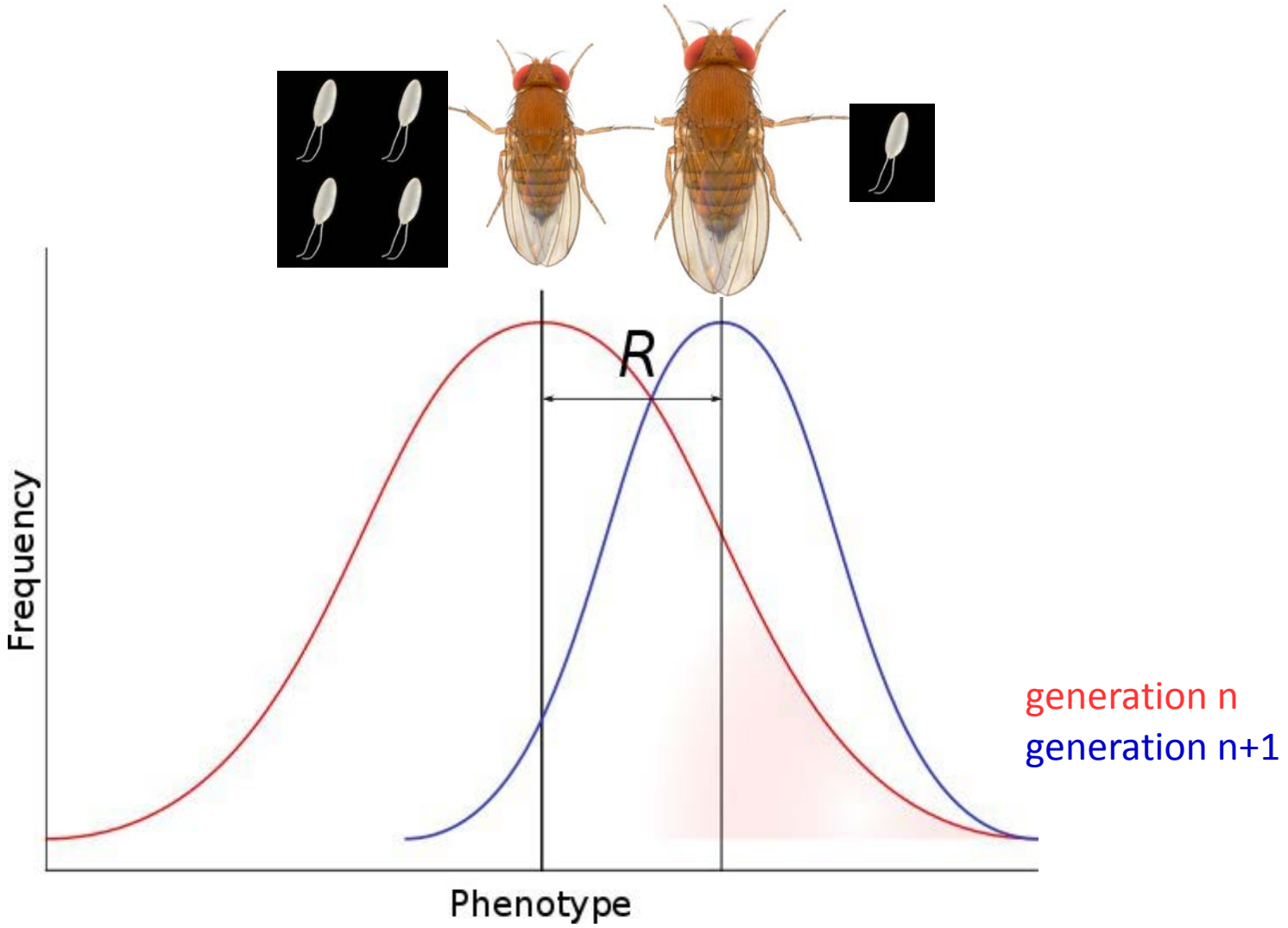
Practical issue

Traits can be genetically correlated and covary



Response to selection

Evolution towards larger **and LESS fecund** individuals



Theoretical response to selection

Multivariate breeder's equation

$$R = \mathbf{G}\mathbf{P}^{-1}S$$

Theoretical response to selection

Multivariate breeder's equation

$$R = \mathbf{GP}^{-1}S$$

Multivariate equivalent of h^2

Theoretical response to selection

Multivariate breeder's equation

$$R = \mathbf{G}\mathbf{P}^{-1}S$$

$$G = \begin{bmatrix} V_{G1} & Cov_{G12} \\ Cov_{G21} & V_{G2} \end{bmatrix}$$

Theoretical response to selection

Multivariate breeder's equation

$$R = \mathbf{G}\mathbf{P}^{-1}S$$

$$G = \begin{bmatrix} V_{G1} & Cov_{G12} \\ Cov_{G21} & V_{G2} \end{bmatrix}$$

Theoretical response to selection

Multivariate breeder's equation

$$R = \mathbf{G}\mathbf{P}^{-1}S$$

$$G = \begin{bmatrix} V_{G1} & Cov_{G12} \\ Cov_{G21} & V_{G2} \end{bmatrix}$$

Estimation of quantitative genetic variation

Family 1

Family 2

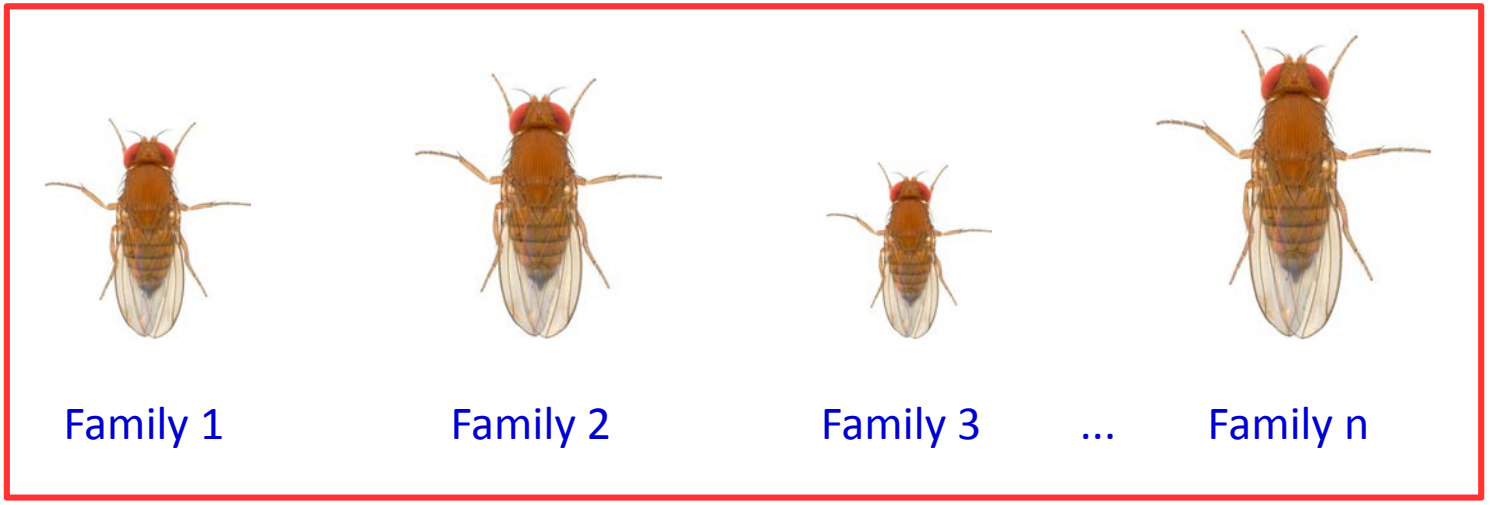
Family 3

...

Family n

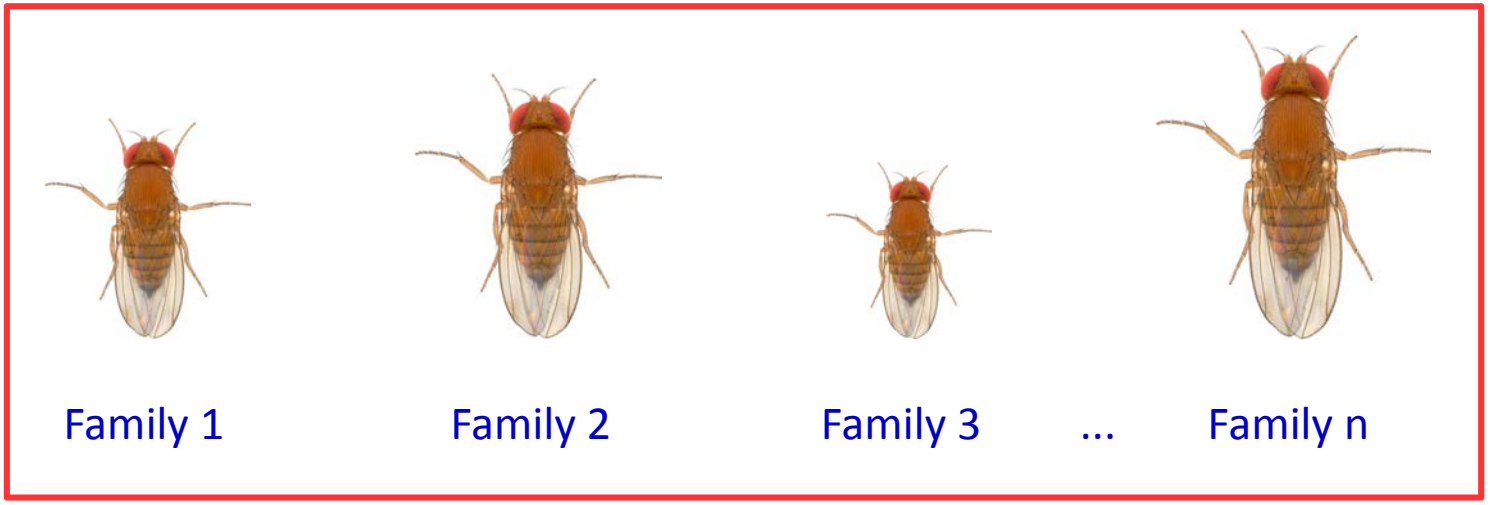
Estimation of quantitative genetic variation

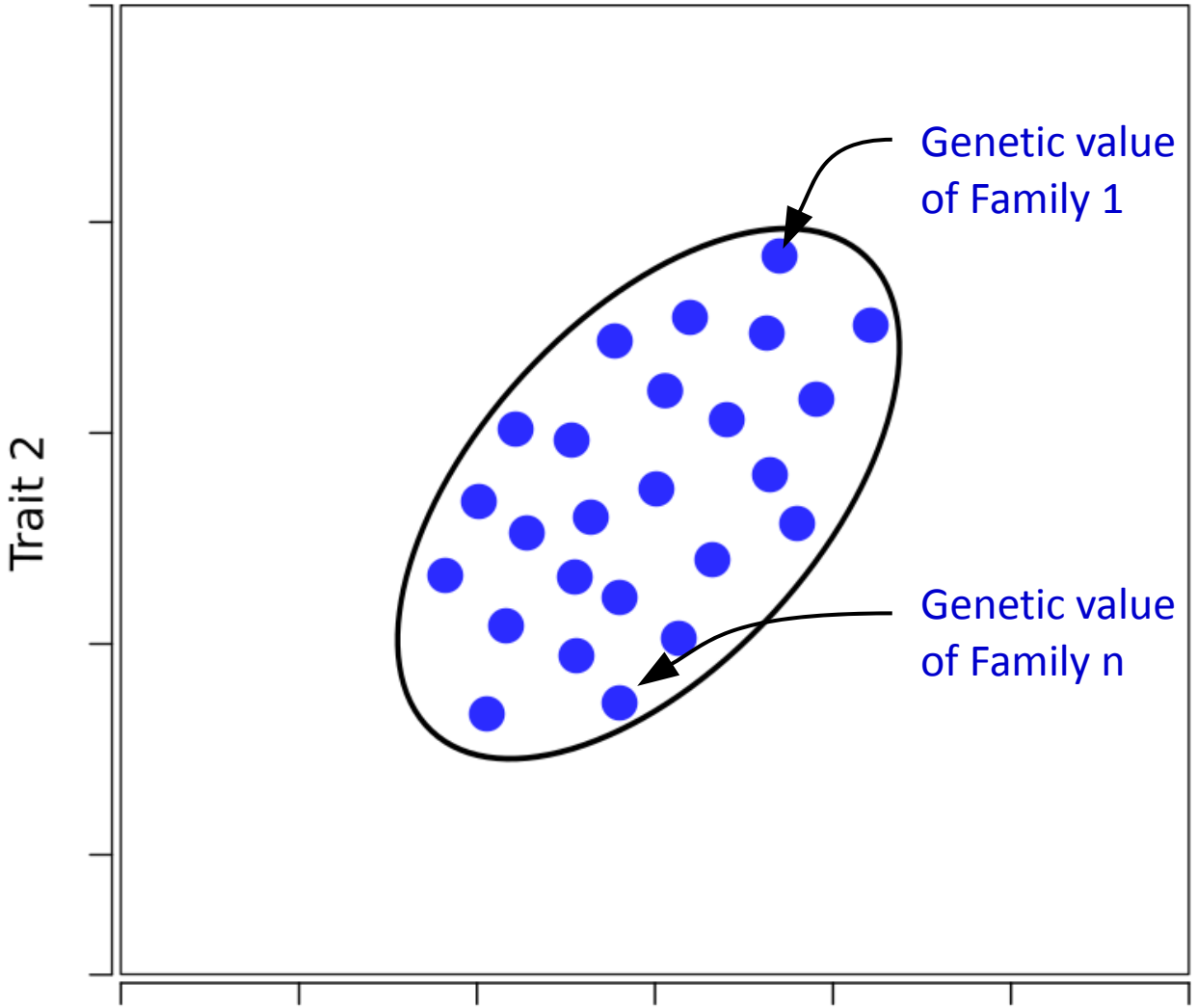
Common garden design

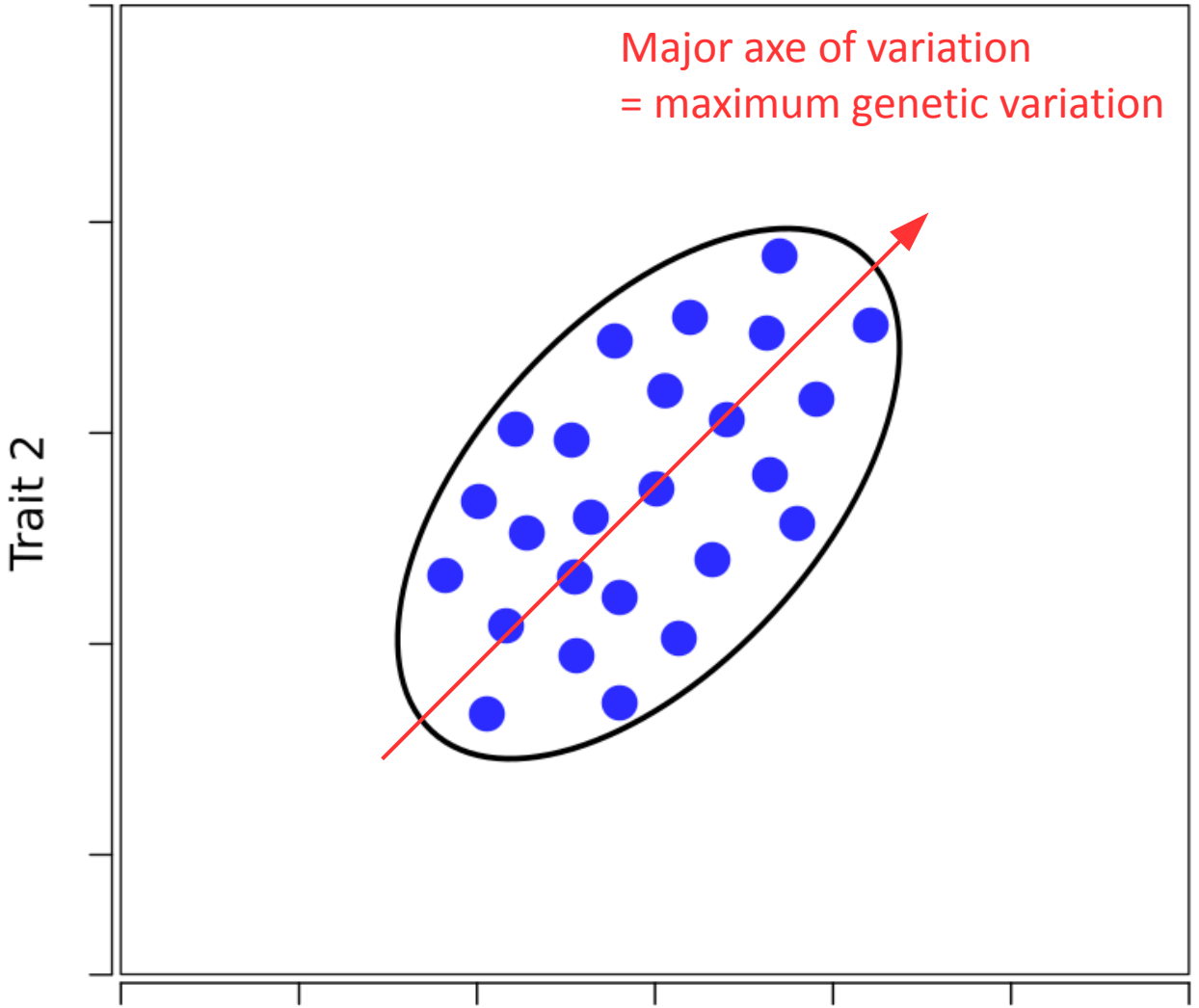


Estimation of quantitative genetic variation

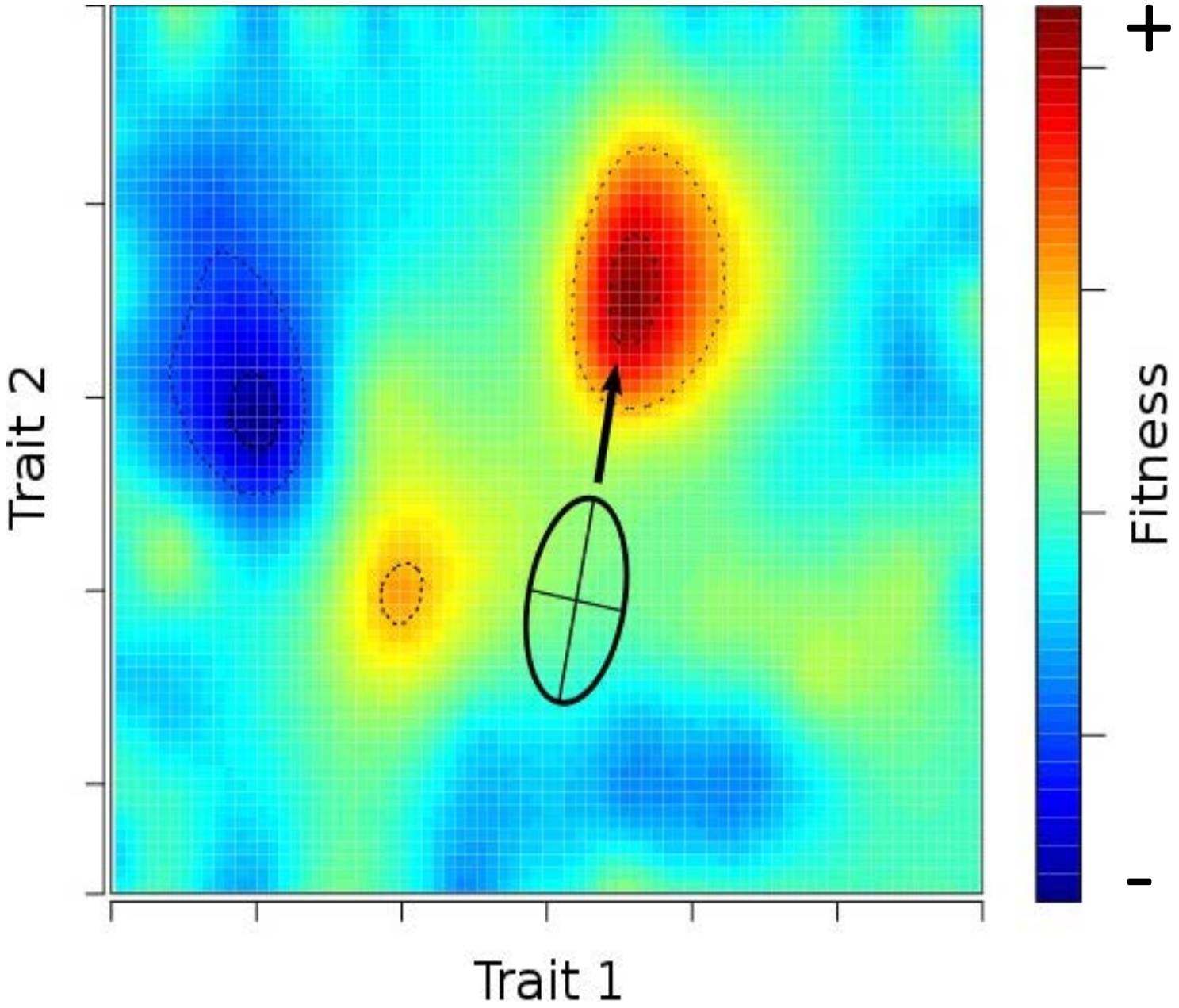
Phenotyping individuals within/between families



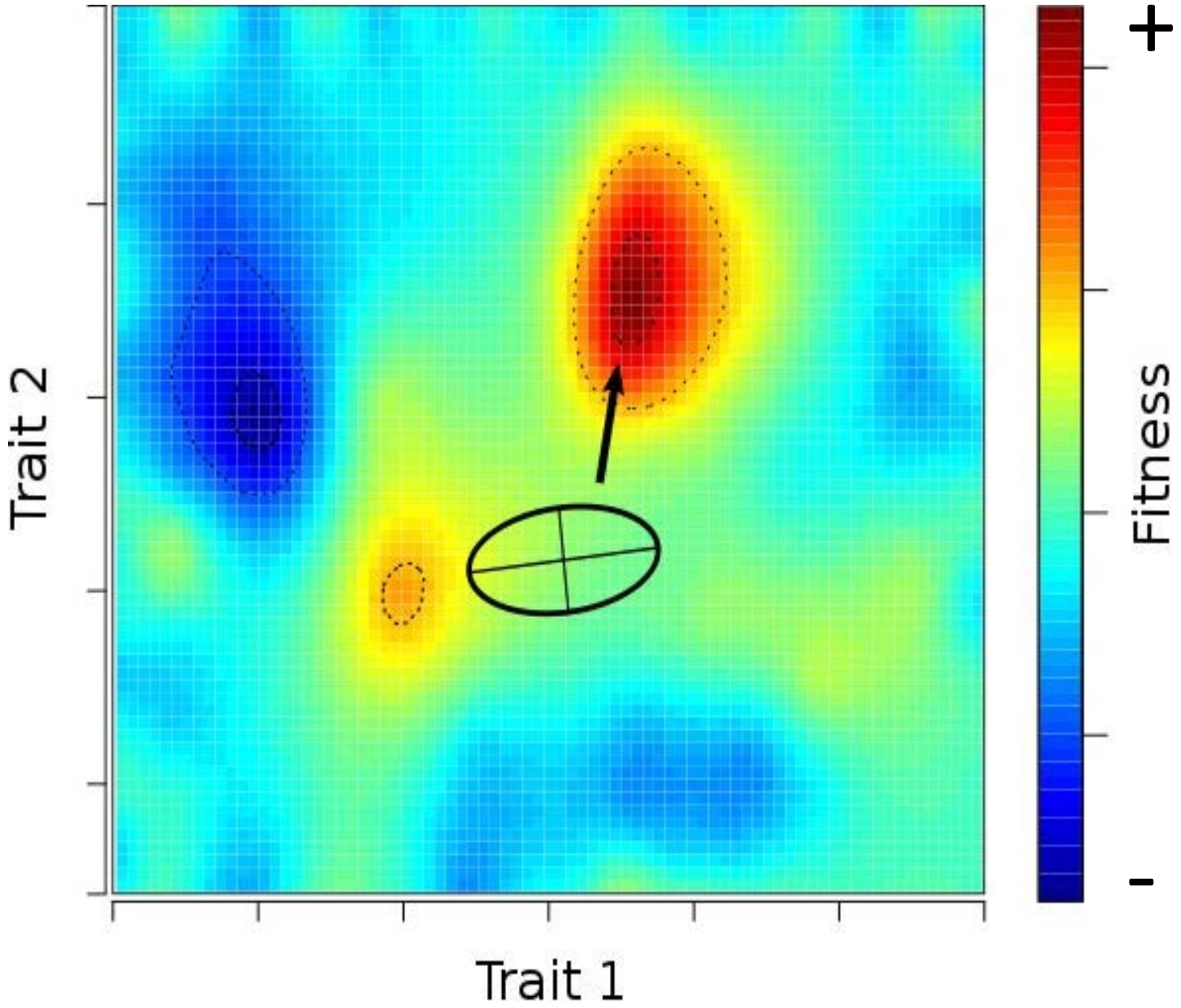

Genetic value
of Family 1
Genetic value
of Family n
Trait 2
Trait 1


Major axe of variation
= maximum genetic variation
Trait 2
Trait 1

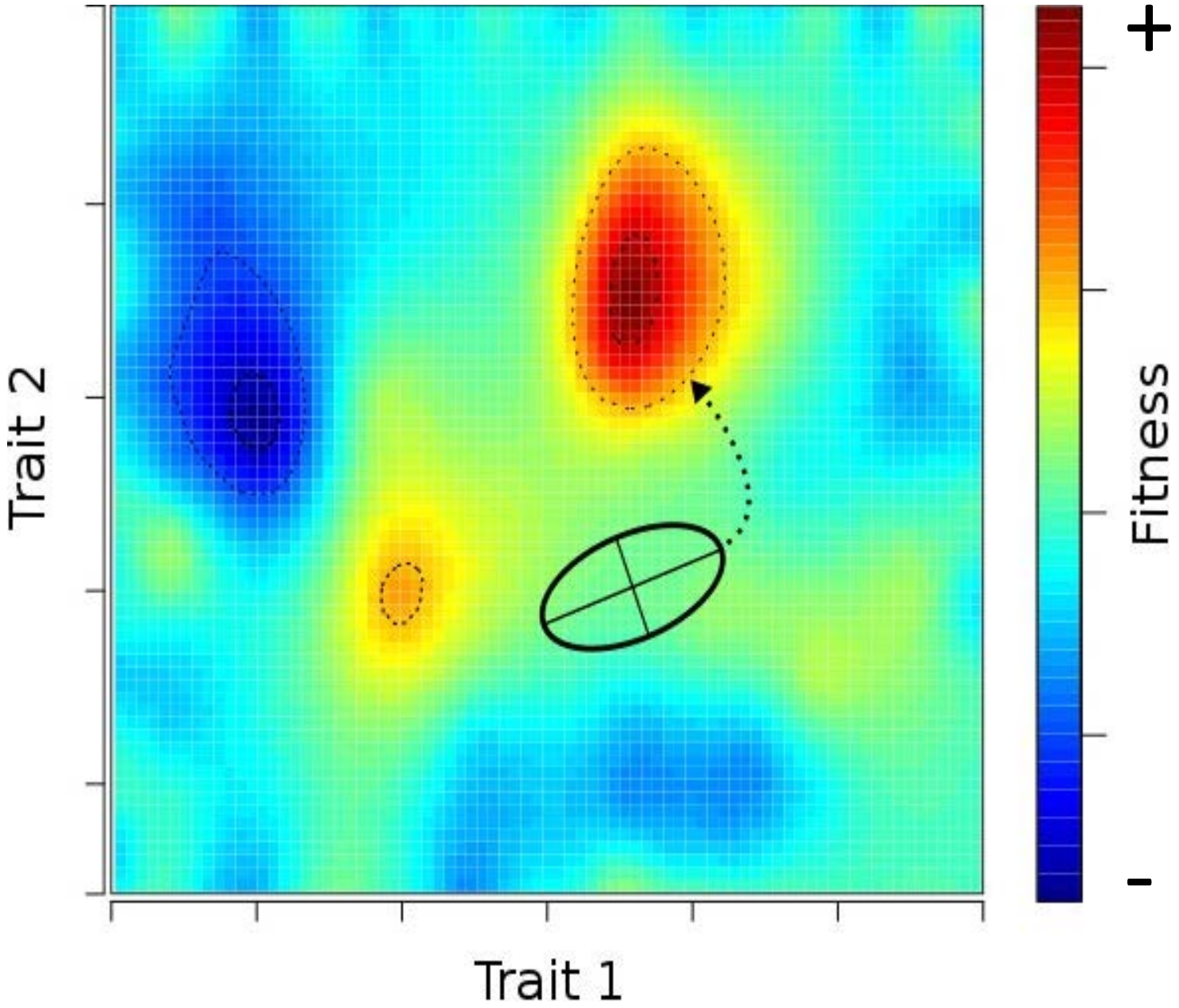
The **G** matrix and the adaptive landscape



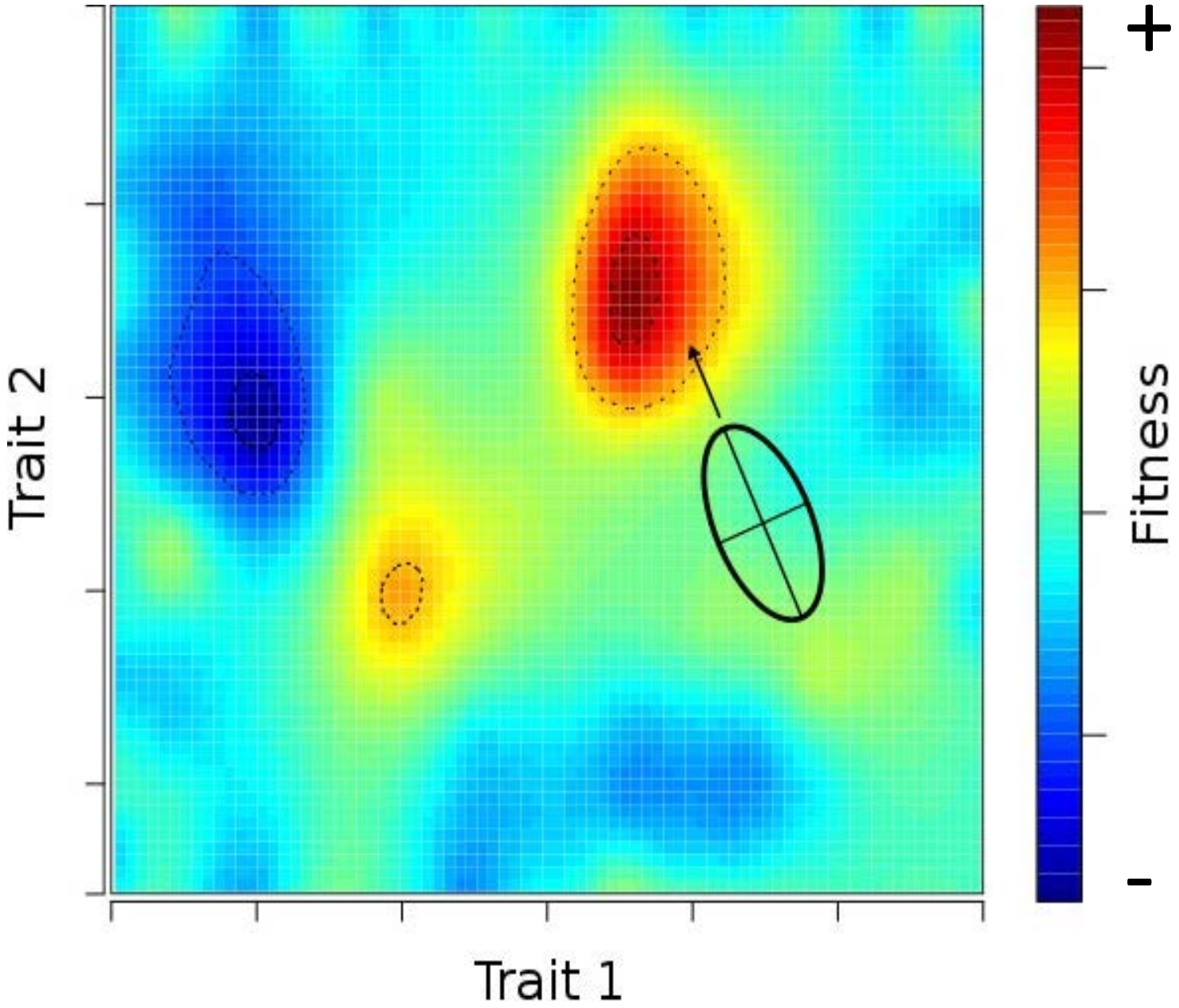
The **G** matrix and the adaptive landscape



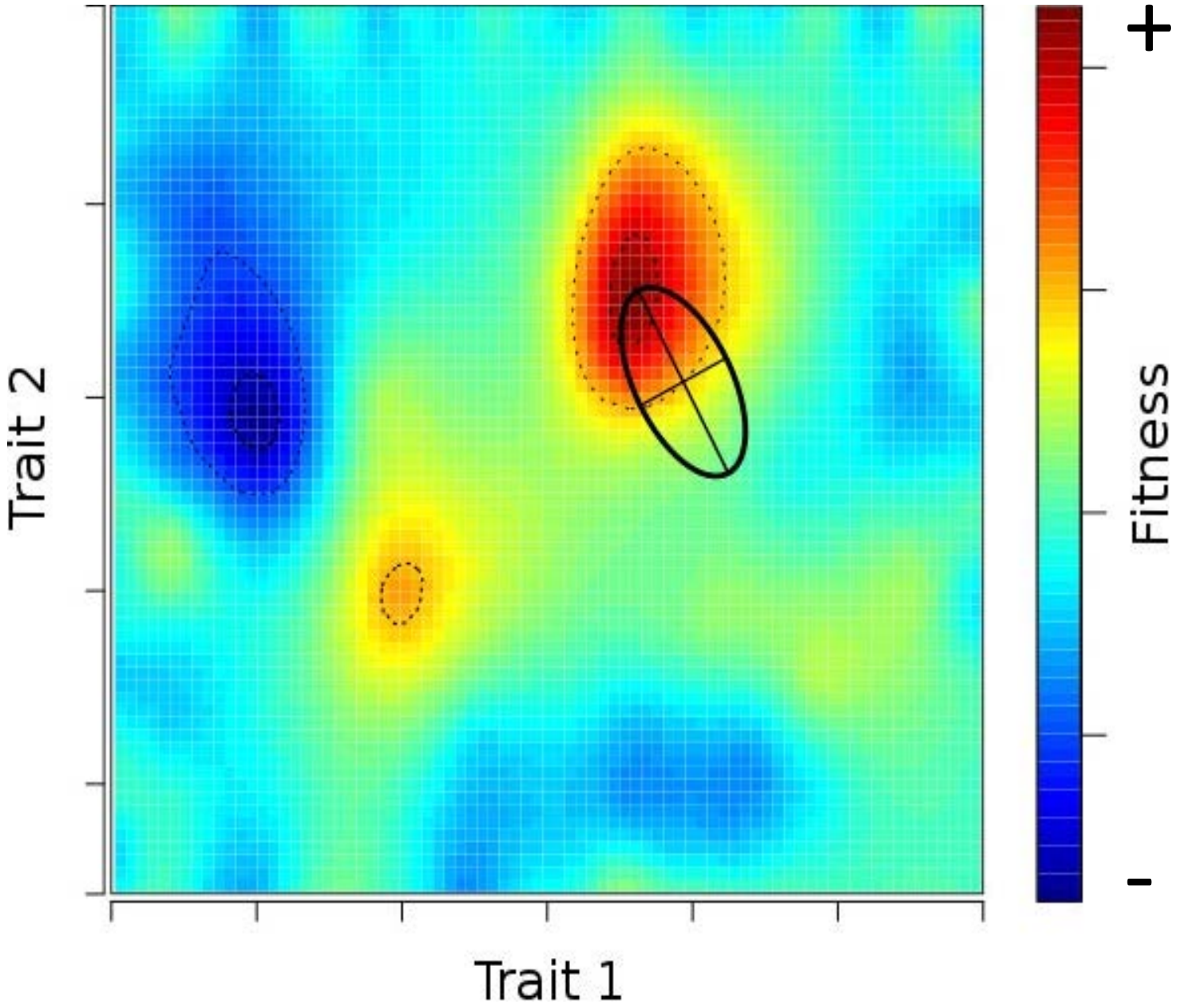
The **G** matrix and the adaptive landscape



The **G** matrix and the adaptive landscape



The **G** matrix and the adaptive landscape



The G matrix: a central object in evolutionary biology

It summarizes genetic variation in population

It contains the sign and strength of covariation

Used in predictive models of phenotypic evolution

Predictive models rely on the stability of the **G** matrix...

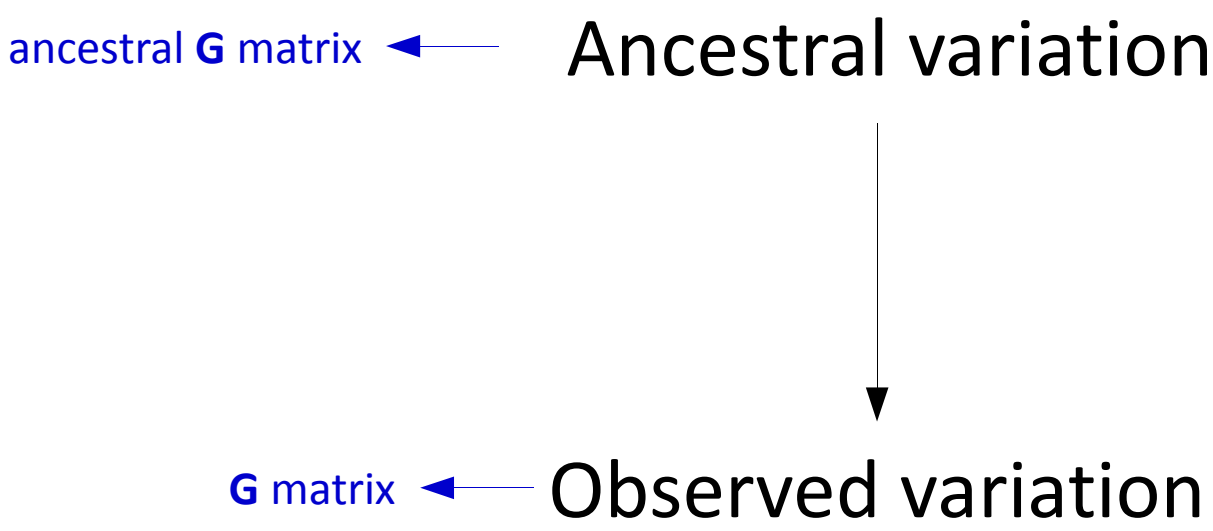
$$R = \mathbf{G}\mathbf{P}^{-1}S$$

Main questions

Is the **G** matrix stable?

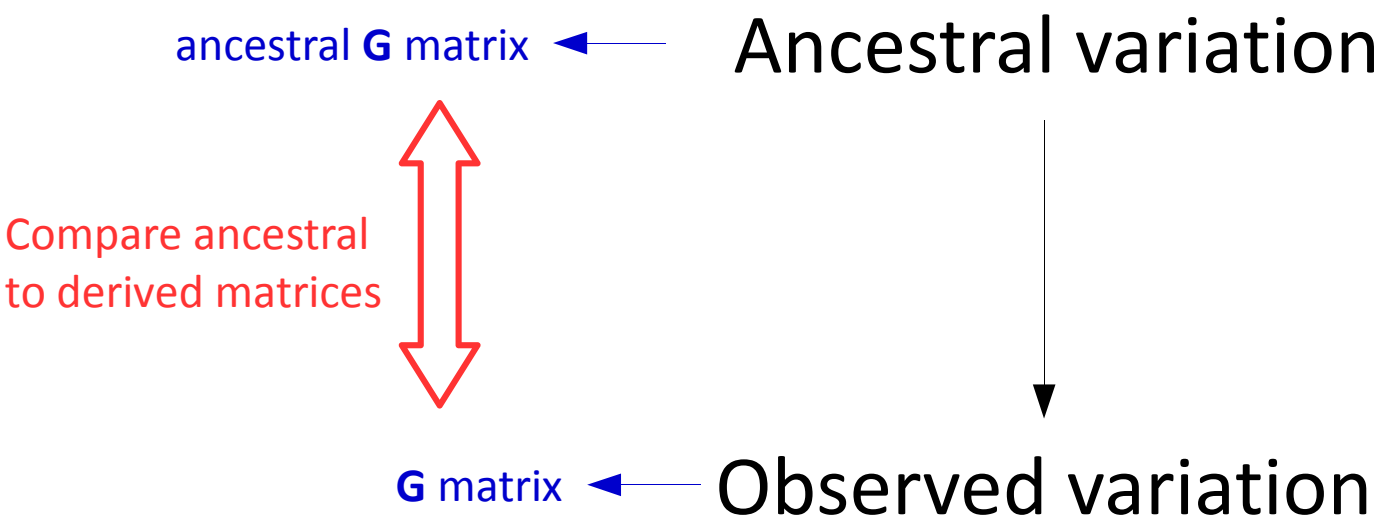
Main questions

Is the **G** matrix stable?



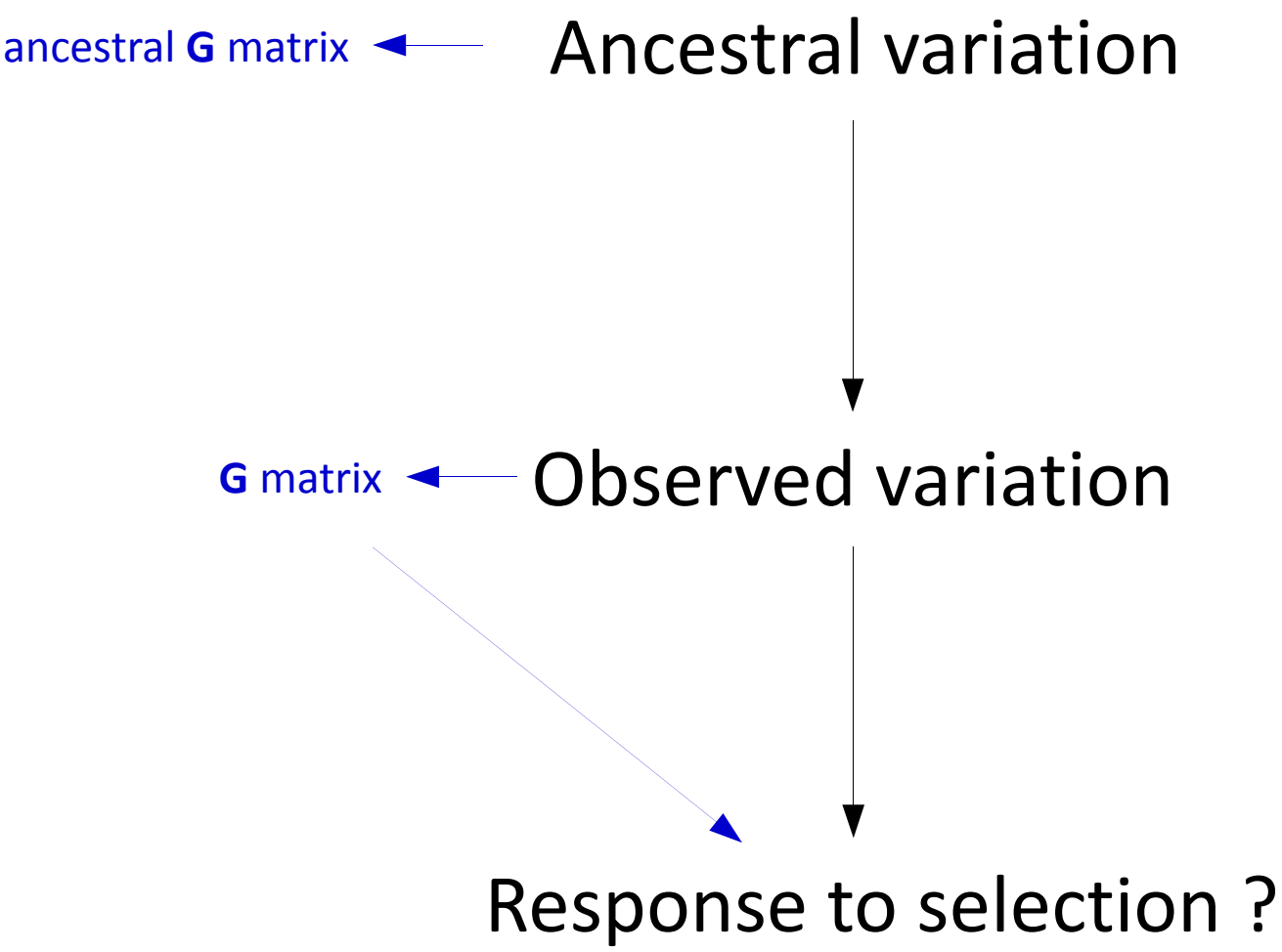
Main questions

Is the **G** matrix stable?



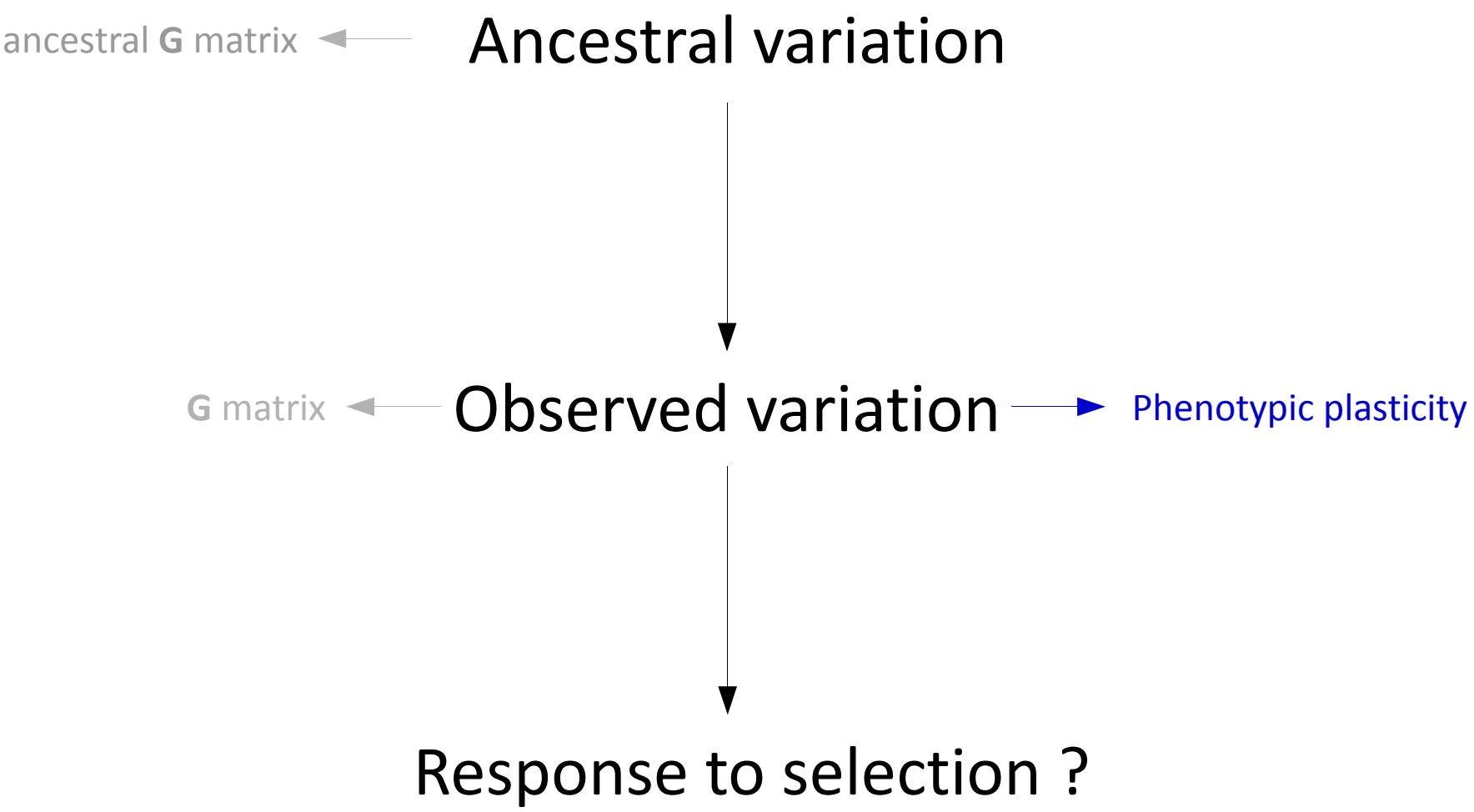
Main questions

Is the **G** matrix stable?



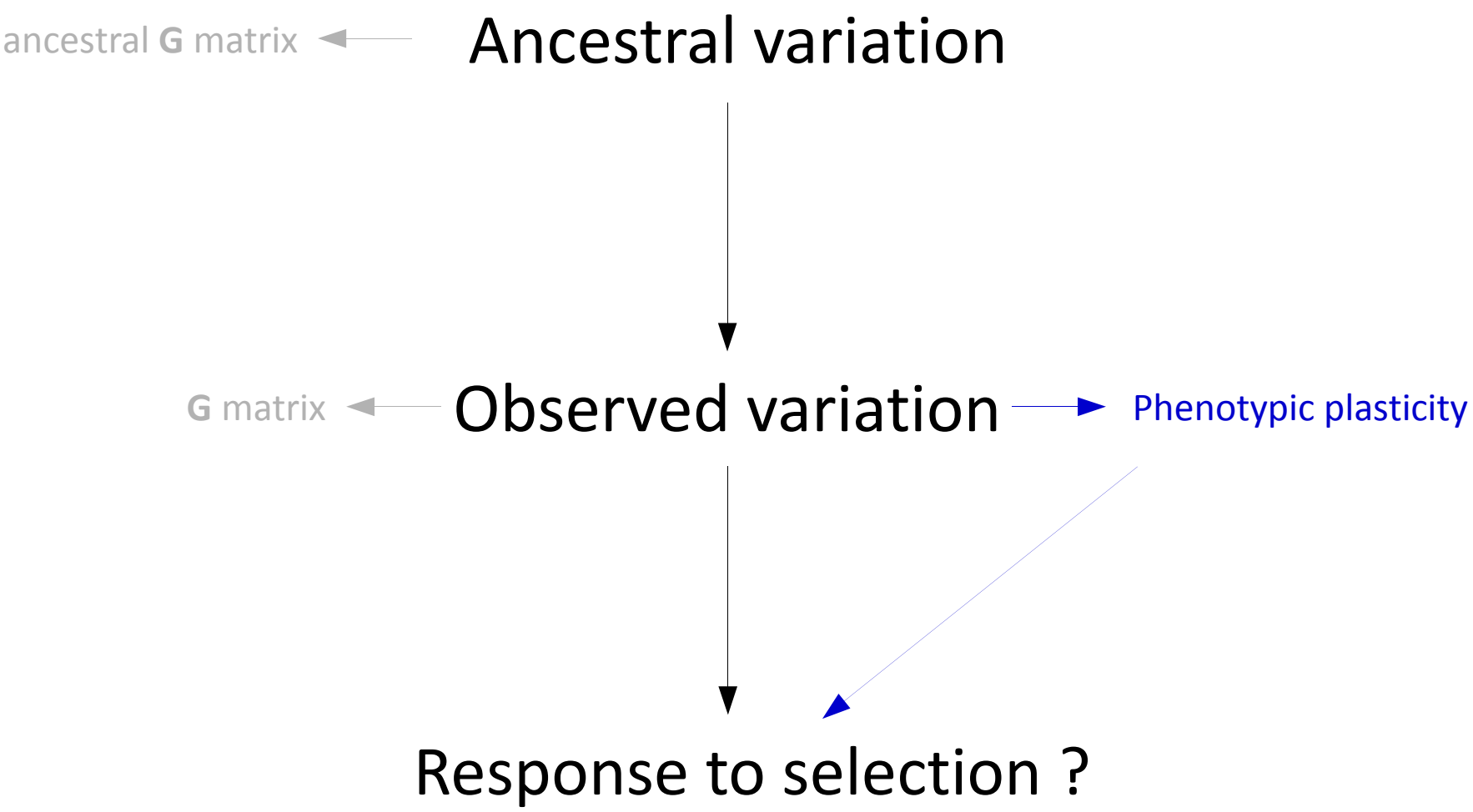
Main questions

The role of phenotypic plasticity?

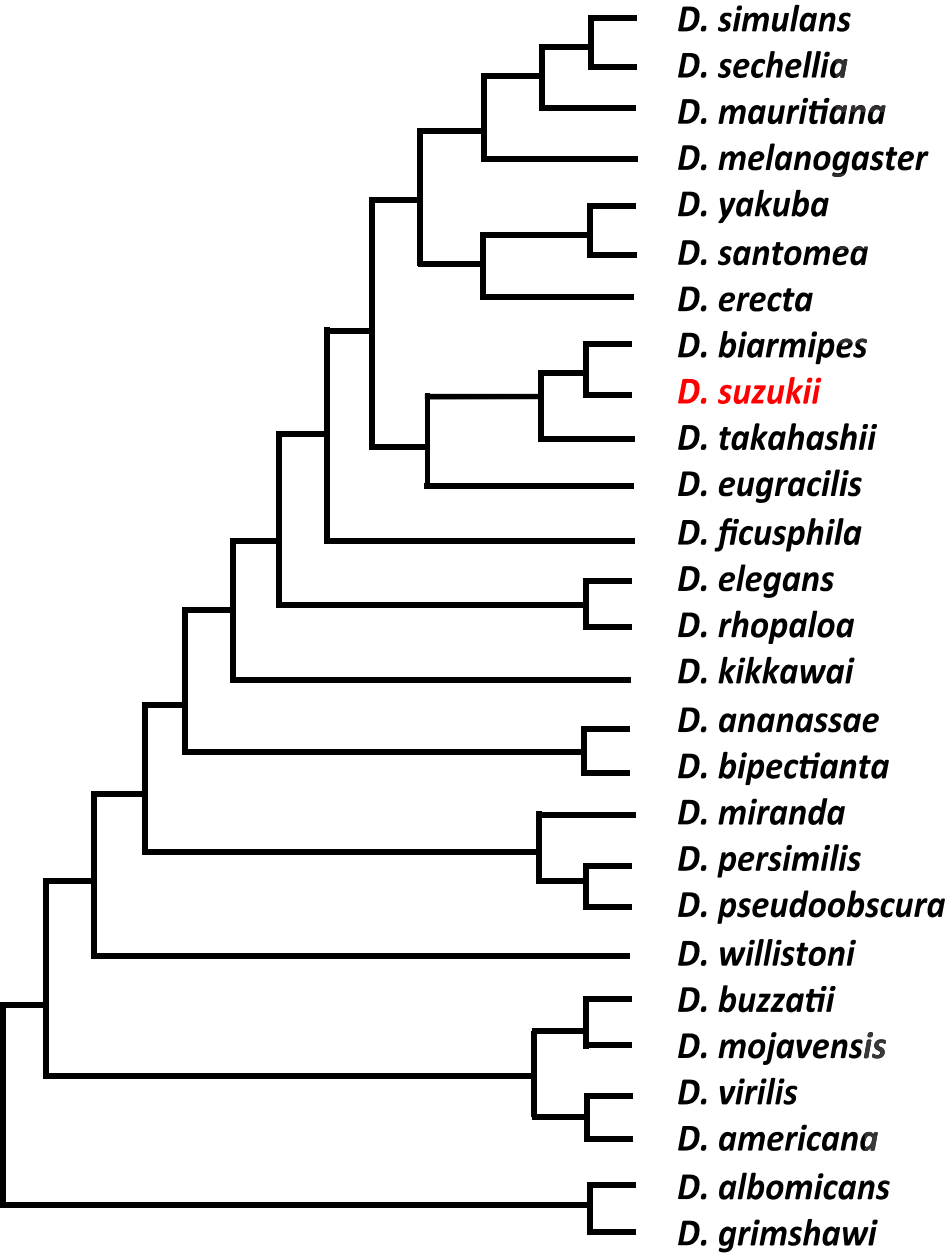


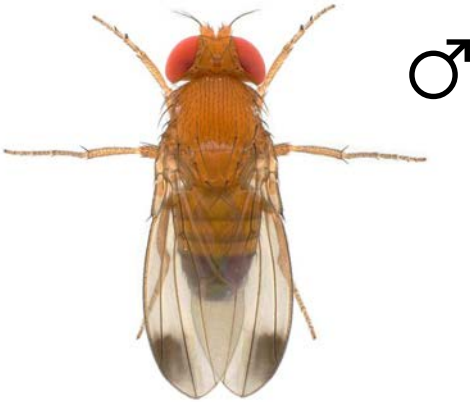
Main questions

The role of phenotypic plasticity?

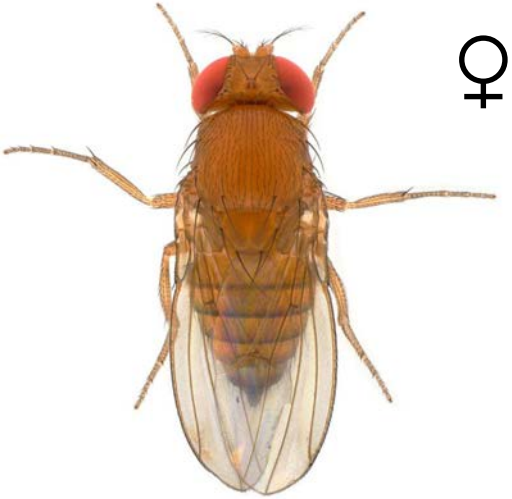


Drosophila suzukii





♂



♀

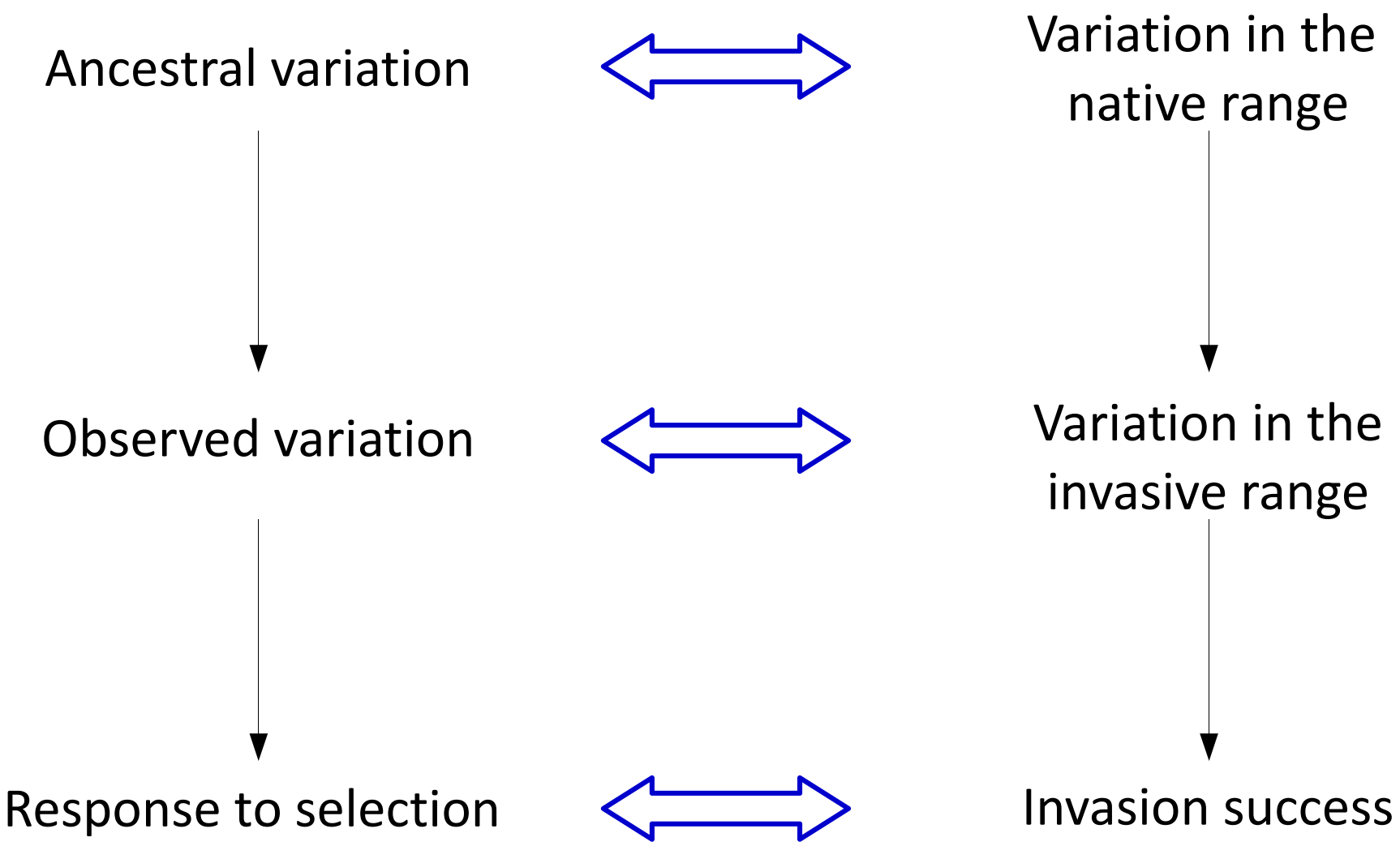
Phylogeny of the *melanogaster* species group (Markow 2015)

N. Gompel ©2015

Photo: Y. Le Poul & A. Fraimout

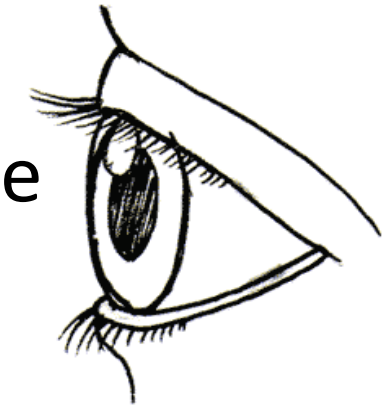
Larvae develop inside the fruit causing severe damages and allowing for secondary contaminations

An ideal study model



Variation in the native range

(ancestral variation)



Variation in the invasive range

(observed variation)

Invasion success

(response to selection)

Variation in the native range

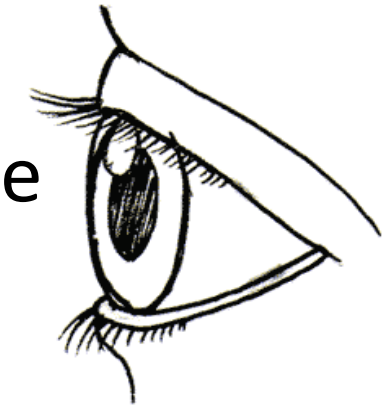
(ancestral variation)

1 . Invasion history

Links between populations

Variation in the invasive range

(observed variation)



Invasion success

(response to selection)

Variation in the native range

(ancestral variation)

1 . Invasion history

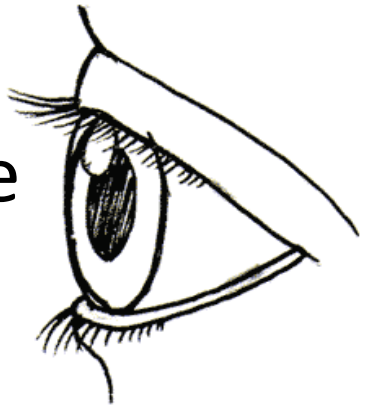
Links between populations

2. Evolution of **G**

Did **G** evolved during the invasion?

Variation in the invasive range

(observed variation)



Invasion success

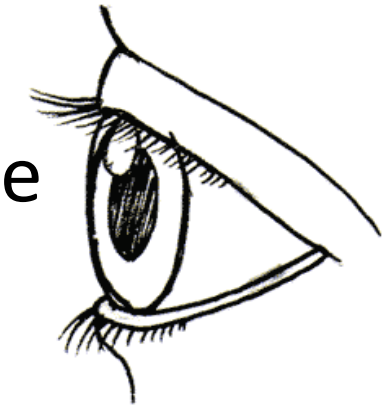
(response to selection)

Variation in the native range
(ancestral variation)

1 . Invasion history
Links between populations

2. Evolution of **G**
Did **G** evolved during the invasion?

Variation in the invasive range
(observed variation)



3. Phenotypic plasticity
Role in invasive success

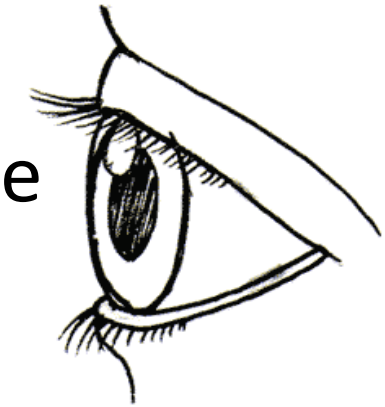
Invasion success
(response to selection)

Variation in the native range
(ancestral variation)

1 . Invasion history
Links between populations

2. Evolution of **G**
Did **G** evolved during the invasion?

Variation in the invasive range
(observed variation)



3. Phenotypic plasticity
Role in invasive success

4. Niche modeling
Link evolution to ecology

Invasion success
(response to selection)

Field sampling

native range


University of Tokyo


University of Hokkaido

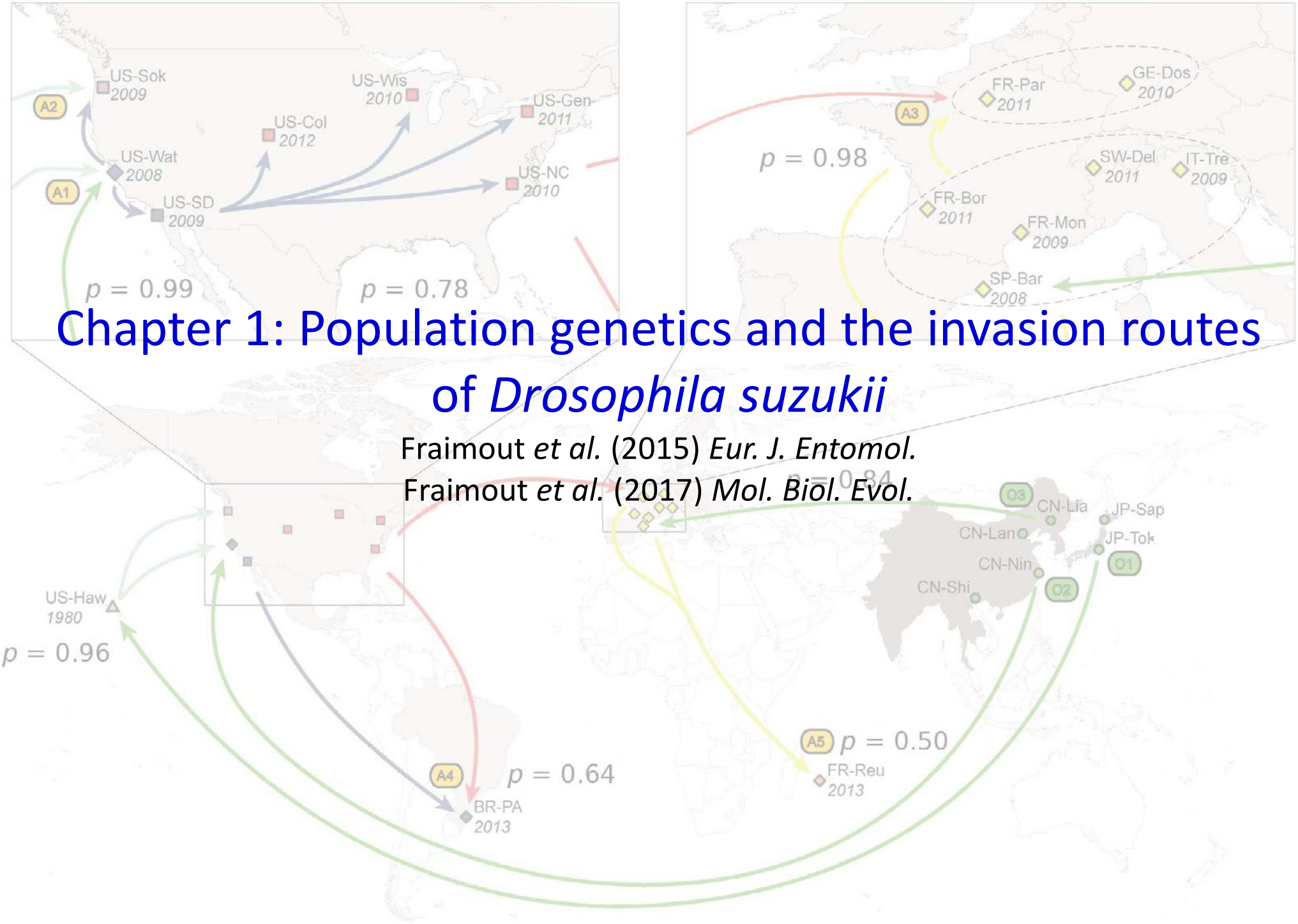

Vineyard in Oregon


Strawberry field in California

invasive range

Drosophila model “easy“ to rear in controled conditions

Allows for establishment of laboratory stock populations and families

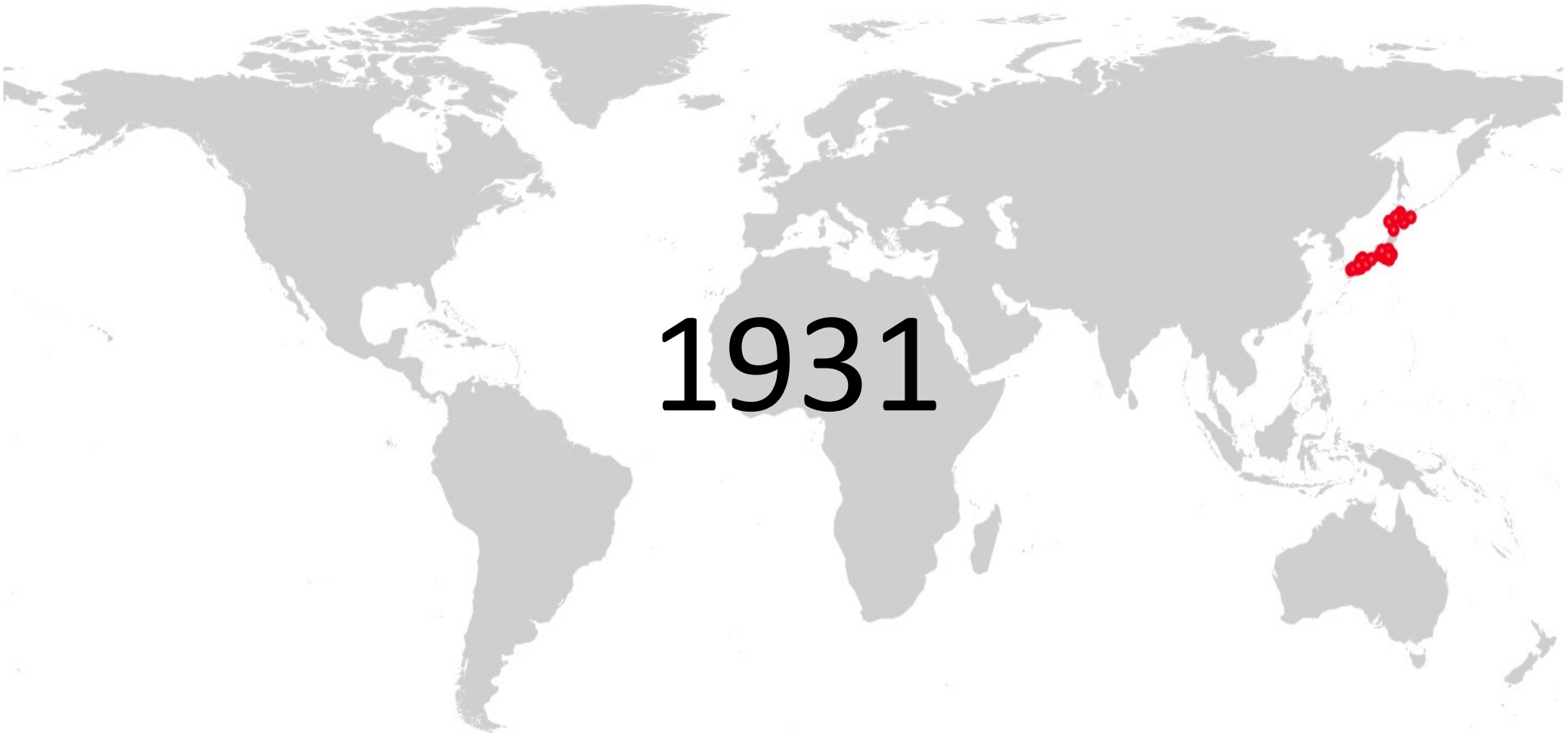


Chapter 1: Population genetics and the invasion routes of *Drosophila suzukii*

Fraimout *et al.* (2015) *Eur. J. Entomol.*

Fraimout *et al.* (2017) *Mol. Biol. Evol.*

An elusive invasion history

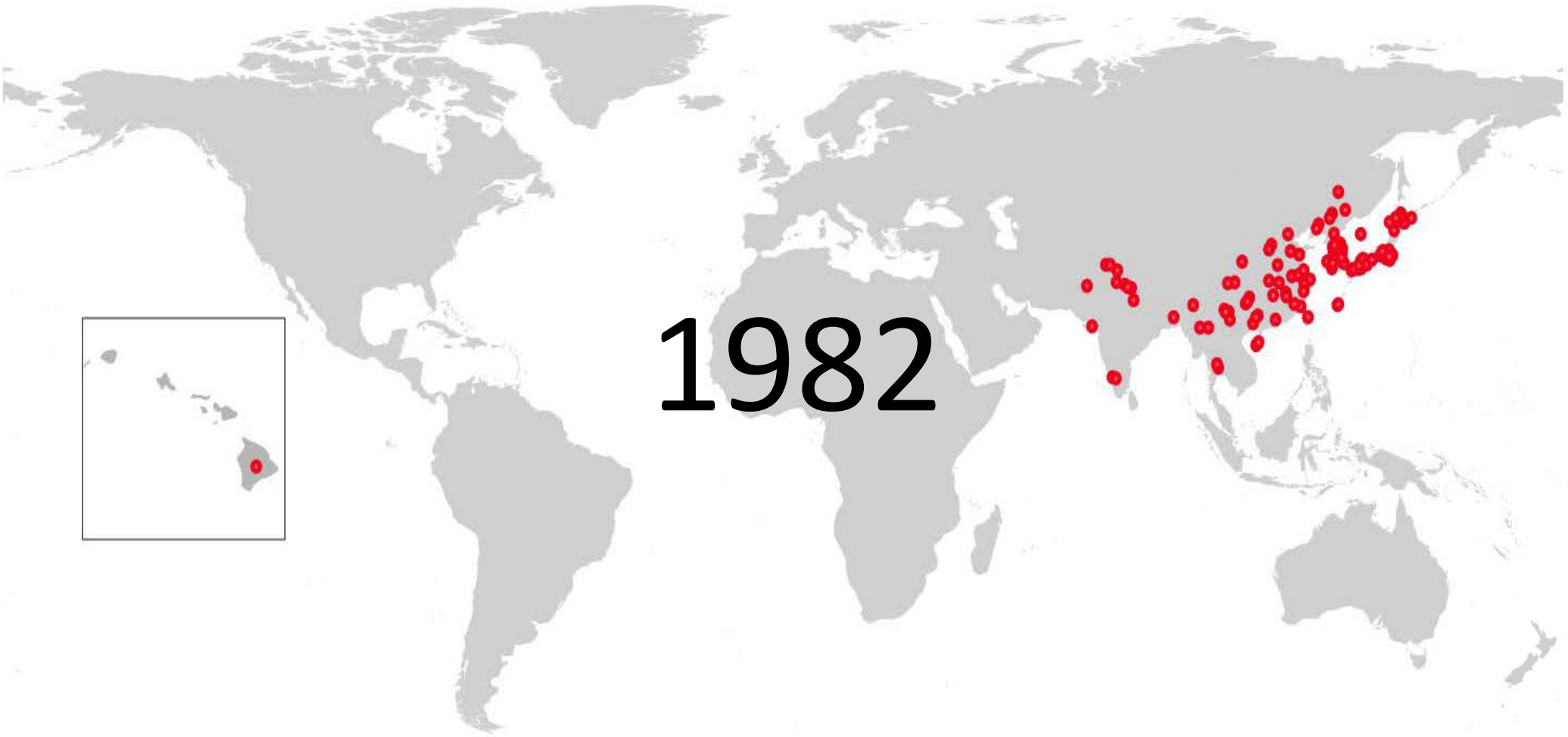


Worldwide distribution of *D. suzukii*

An elusive invasion history

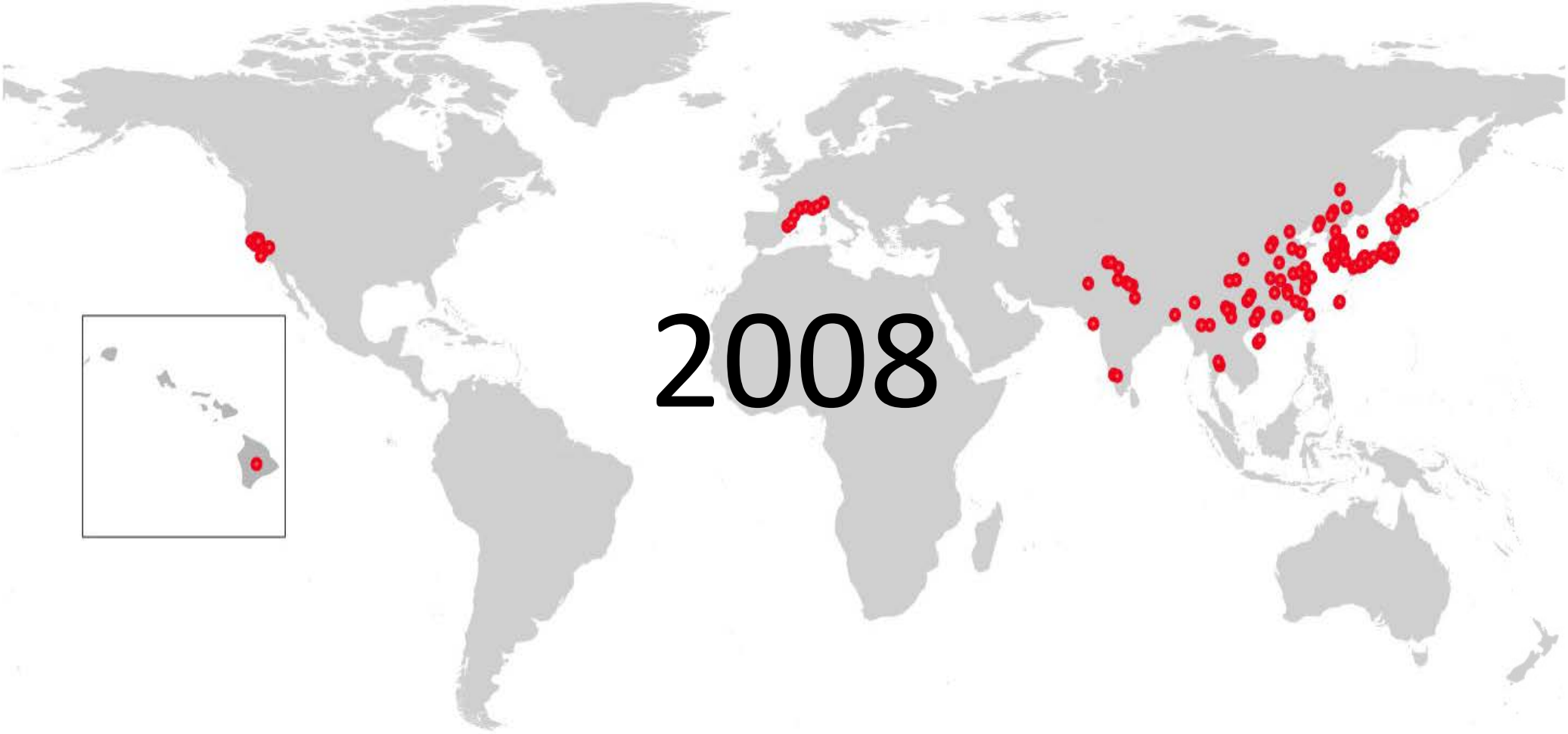
Worldwide distribution of *D. suzukii*

An elusive invasion history



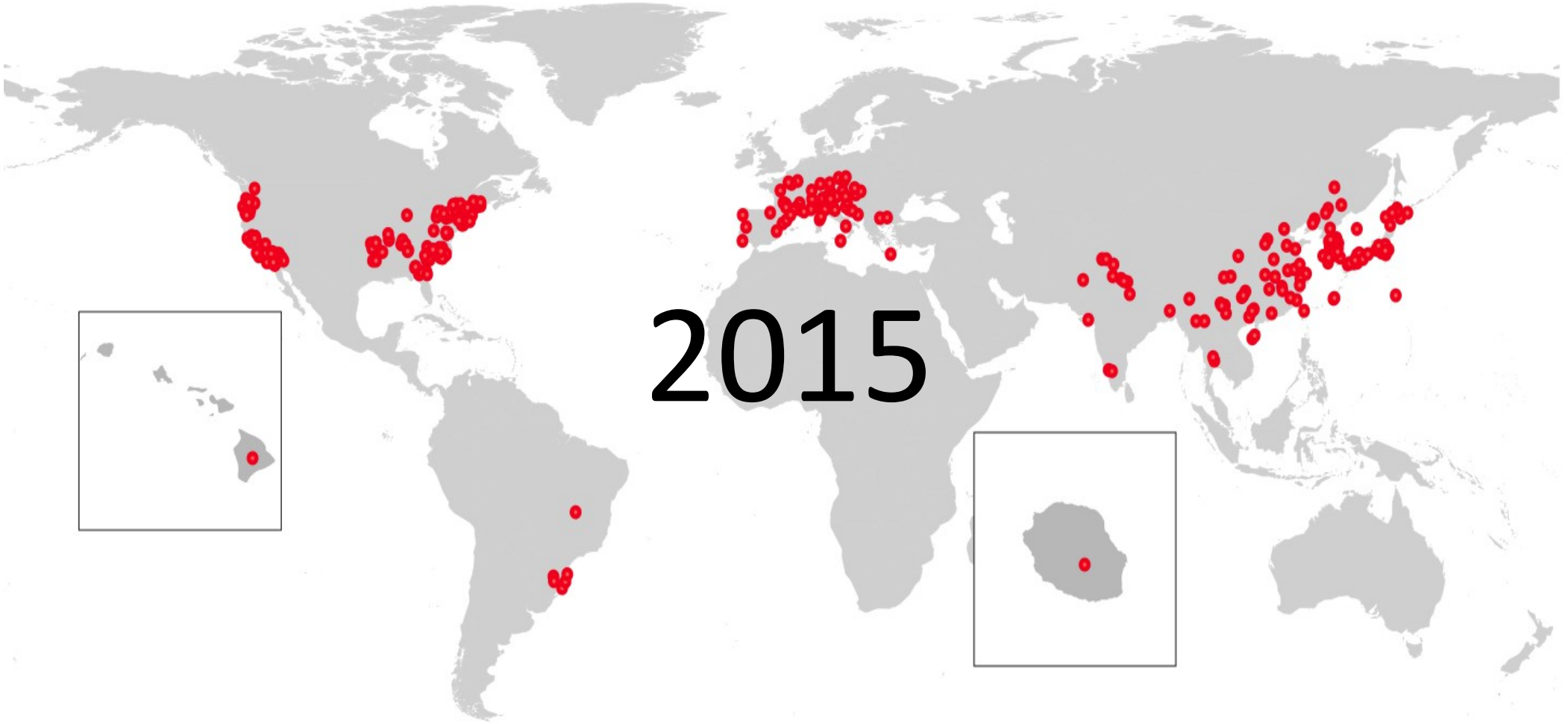
Worldwide distribution of *D. suzukii*

An elusive invasion history



Worldwide distribution of *D. suzukii*

An elusive invasion history



Worldwide distribution of *D. suzukii*

How to reconstruct invasion routes?

From molecular data

1.Sampling & Genotyping

Large sampling scheme in native and invasive ranges

Sampling of *D. suzukii* – 23 populations (6 native, 17 invasive, 684 individuals)

How to reconstruct invasion routes?

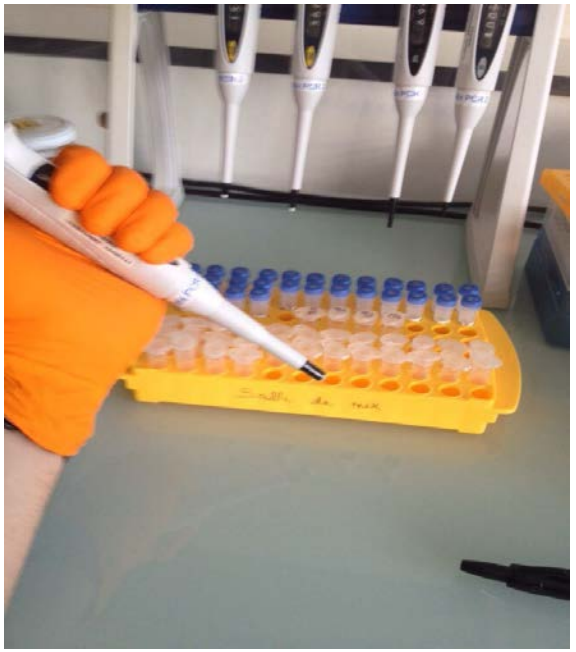
From molecular data

1.Sampling & Genotyping

Large sampling scheme in native and invasive ranges

Genotyping at polymorphic loci (Fraimout *et al.* 2015)

Development of 25 specific microsatellites markers



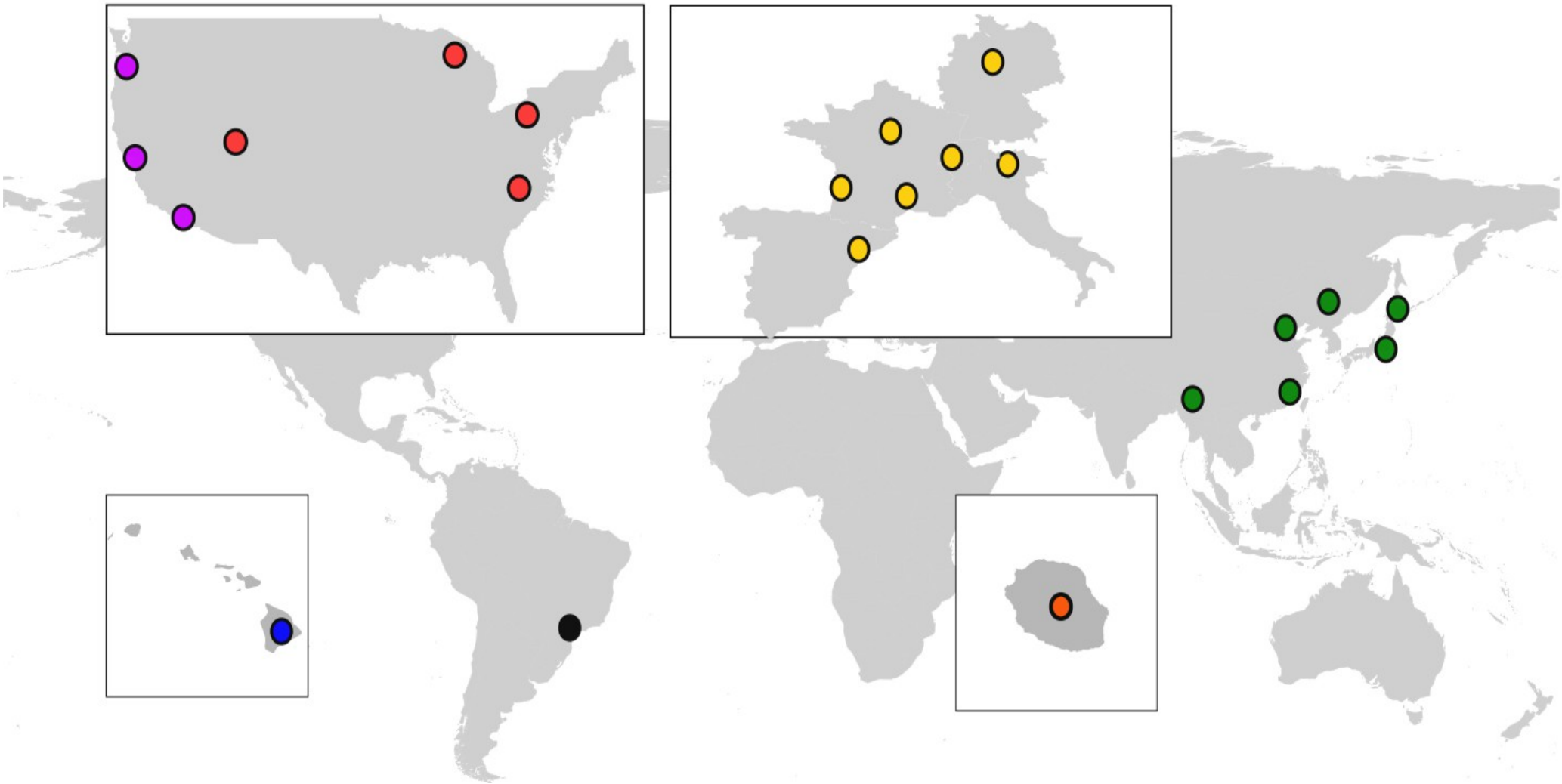
How to reconstruct invasion routes?

From molecular data

1.Sampling & Genotyping

- Large sampling scheme in native and invasive ranges
- Genotyping at polymorphic loci (Fraimout *et al.* 2015)
  - Development of 25 specific microsatellites markers
- Characterizing genetic variation among samples
  - To group samples in genetic clusters

Genetic clustering – 7 focal groups



Genetic groups of *D. suzukii* estimated with BAPS software (Corander *et al.* 2003)

How to reconstruct invasion routes?

From molecular data

2.Establish relationship among populations

Testing the origins of each invasive groups with invasion scenarios

Using representative samples

How to reconstruct invasion routes?

From molecular data

2.Establish relationship among populations

Testing the origins of each invasive groups with invasion scenarios

Using representative samples

Simulating datasets under competing invasion scenarios

approximate Bayesian computation (DIYABC v.2.0.1, Cornuet *et al.* 2014)

How to reconstruct invasion routes?

From molecular data

2.Establish relationship among populations

Testing the origins of each invasive groups with invasion scenarios

Using representative samples

Simulating datasets under competing invasion scenarios

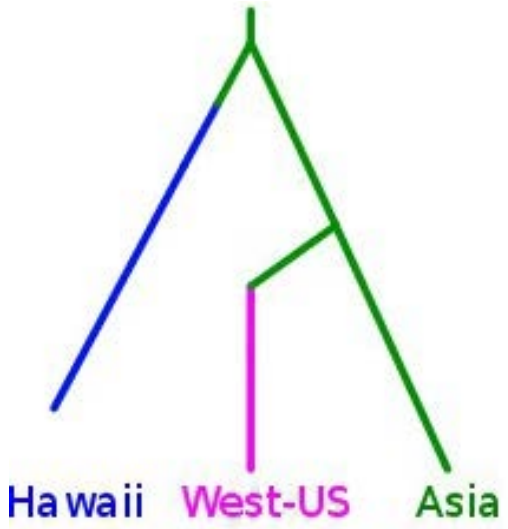
approximate Bayesian computation (DIYABC v.2.0.1, Cornuet *et al.* 2014)

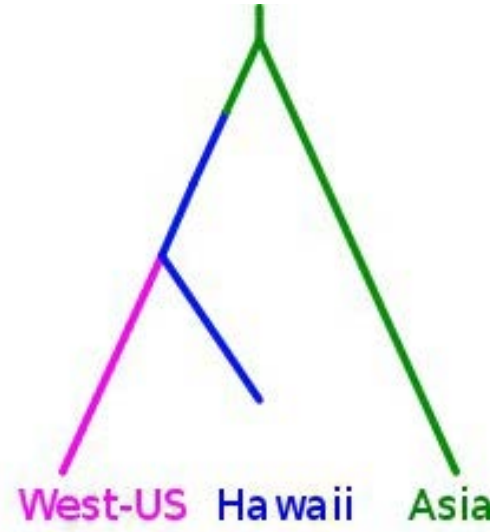
Performing model choice using Random forests

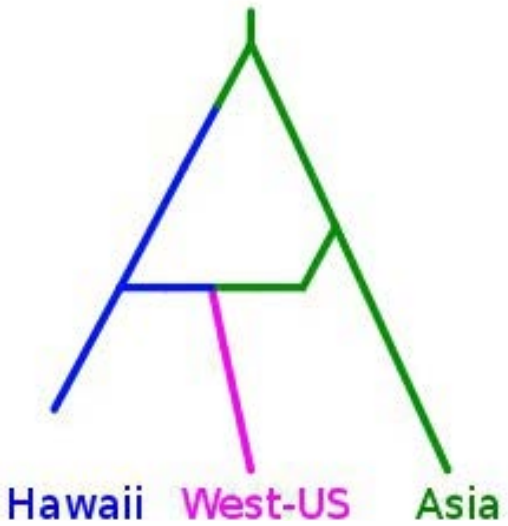
ABC-Random Forest (R package, Pudlo *et al.* 2015)

What are the origins of western USA populations?

Simulating datasets

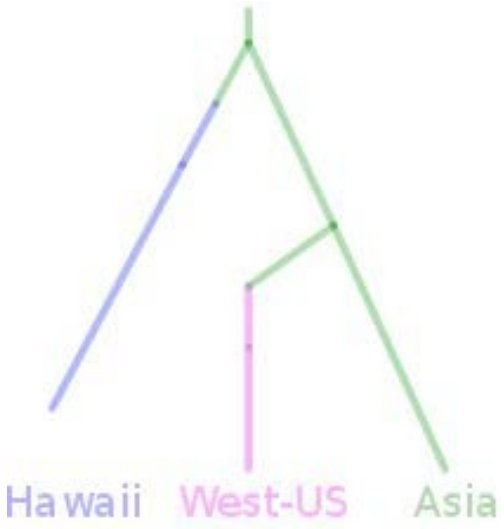


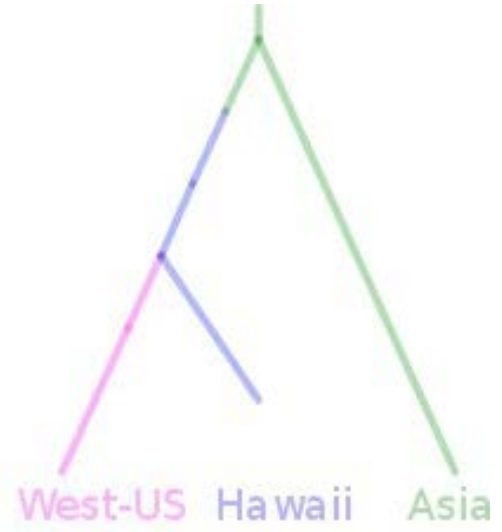




What are the origins of western USA populations?

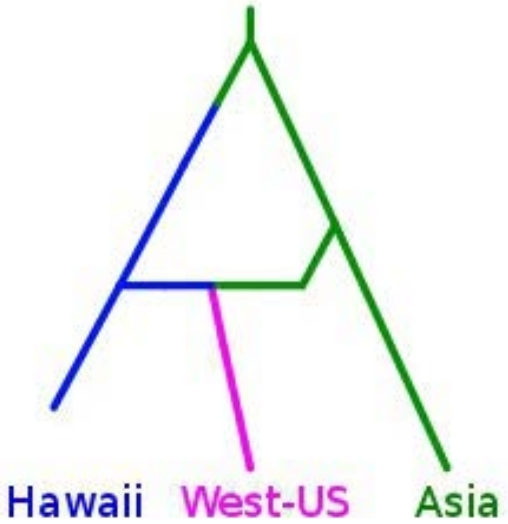
Performing model choice





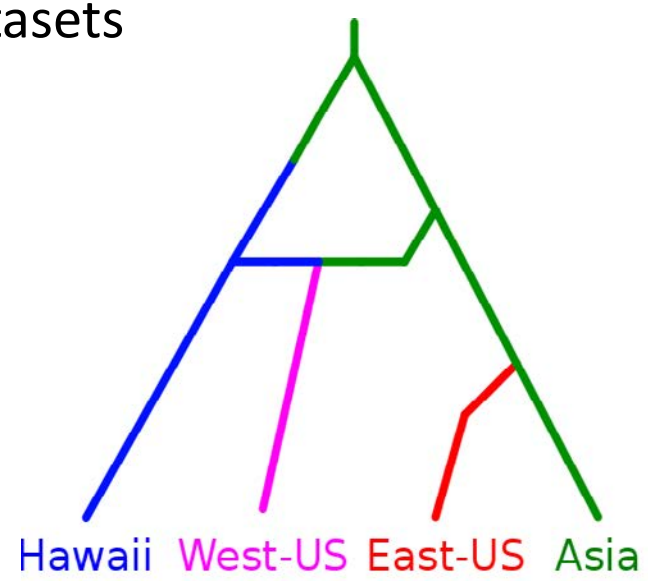
posterior probability of the best model $p = 0.99$

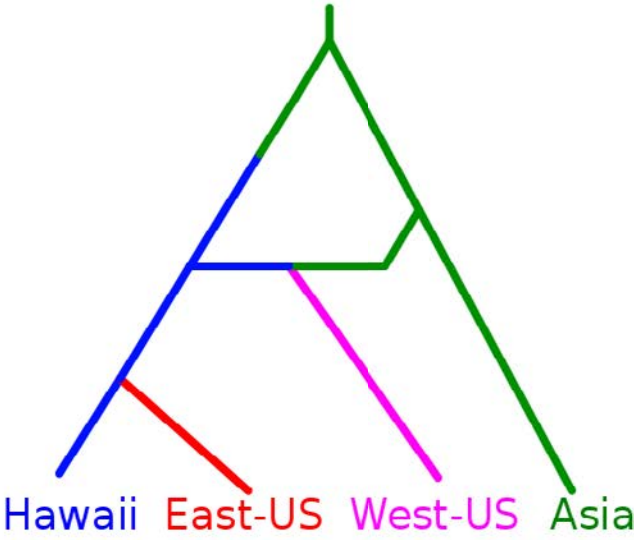
western USA admixed between Hawaii & Asia

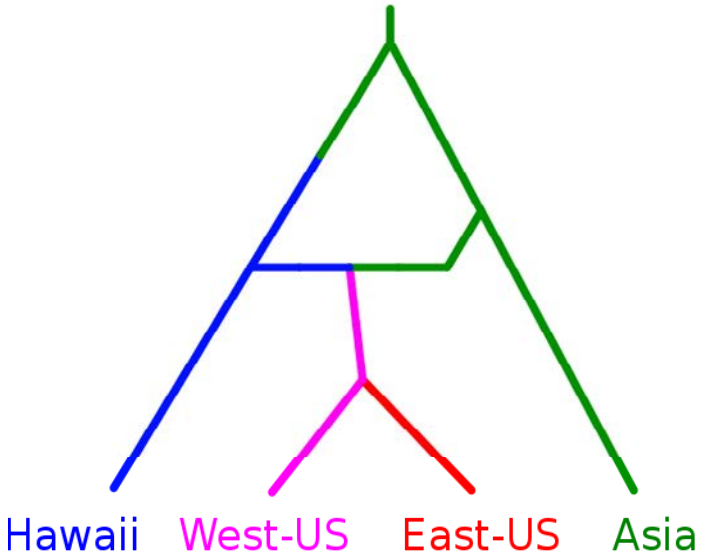


What are the origins of eastern USA populations?

Simulating datasets



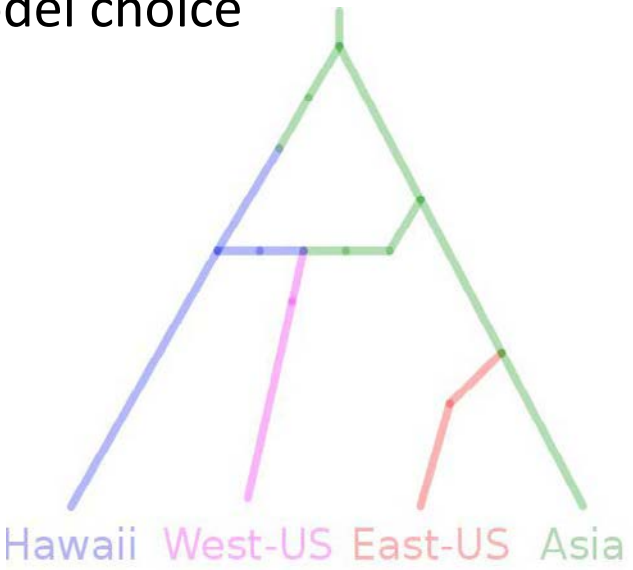


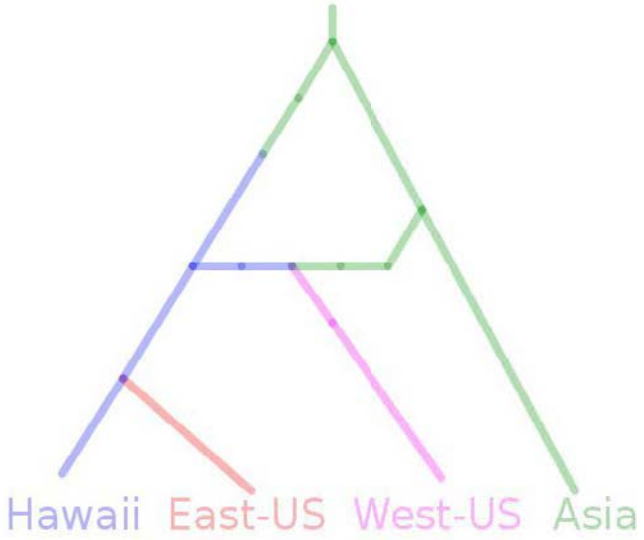


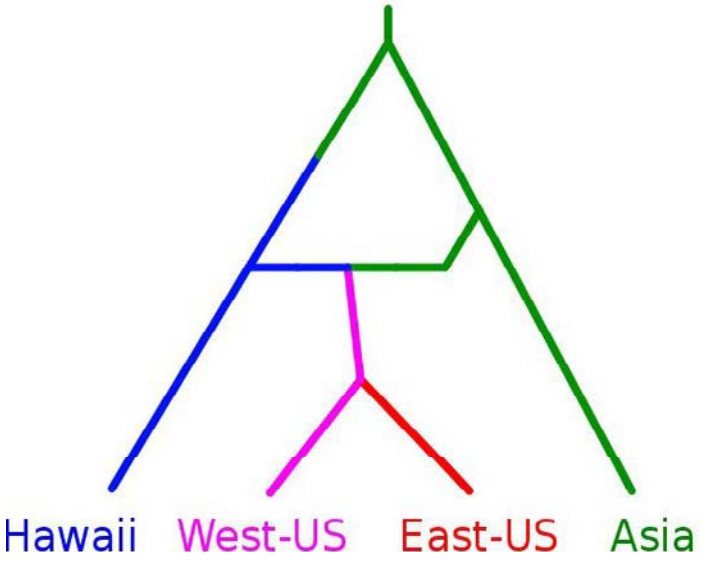
6 scenarios in total

What are the origins of eastern USA populations?

Performing model choice







posterior probability of the best model $p = 0.78$

eastern USA derived from western USA

How to deal with simultaneous introductions?

How to deal with simultaneous introductions?

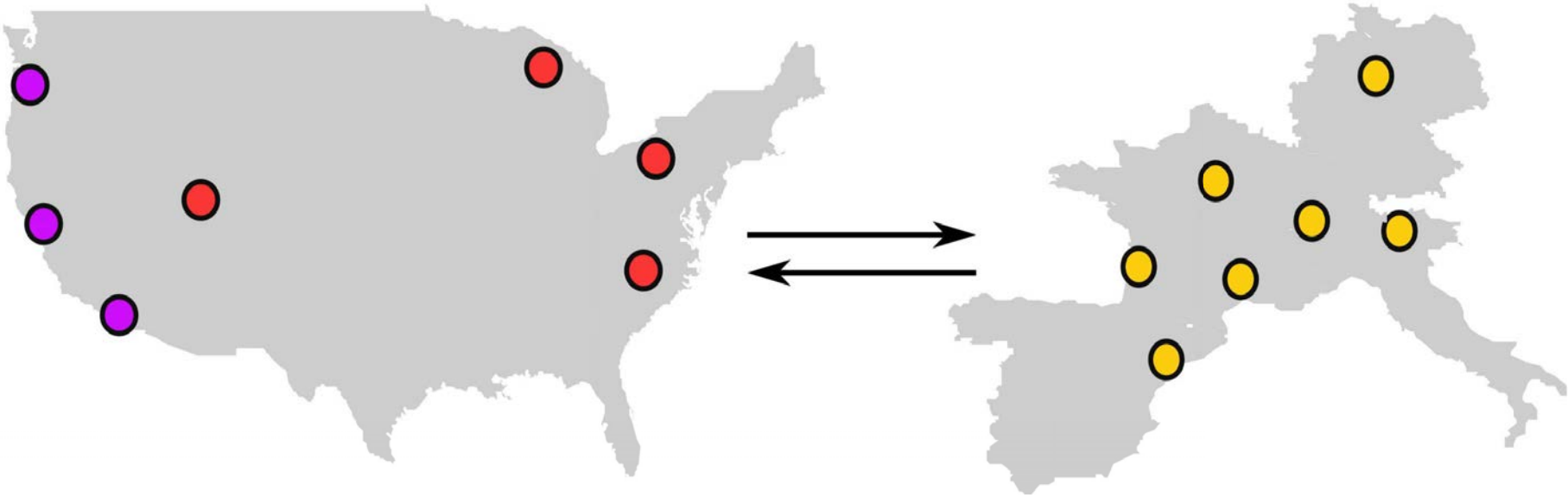
Introduction dates in USA and Europe overlap (2008)

How to deal with simultaneous introductions?

Introduction dates in USA and Europe overlap

Europe as a source for USA?

USA as a source for Europe?

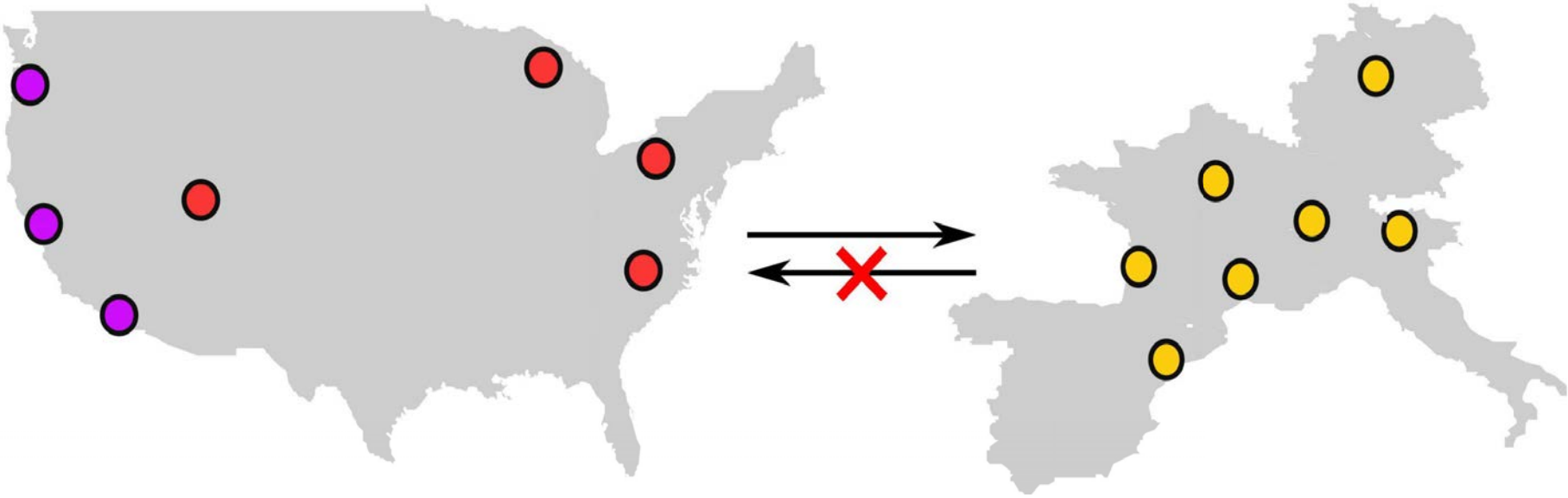


How to deal with simultaneous introductions?

Introduction dates in USA and Europe overlap

~~Europe as a source for USA?~~

USA as a source for Europe?

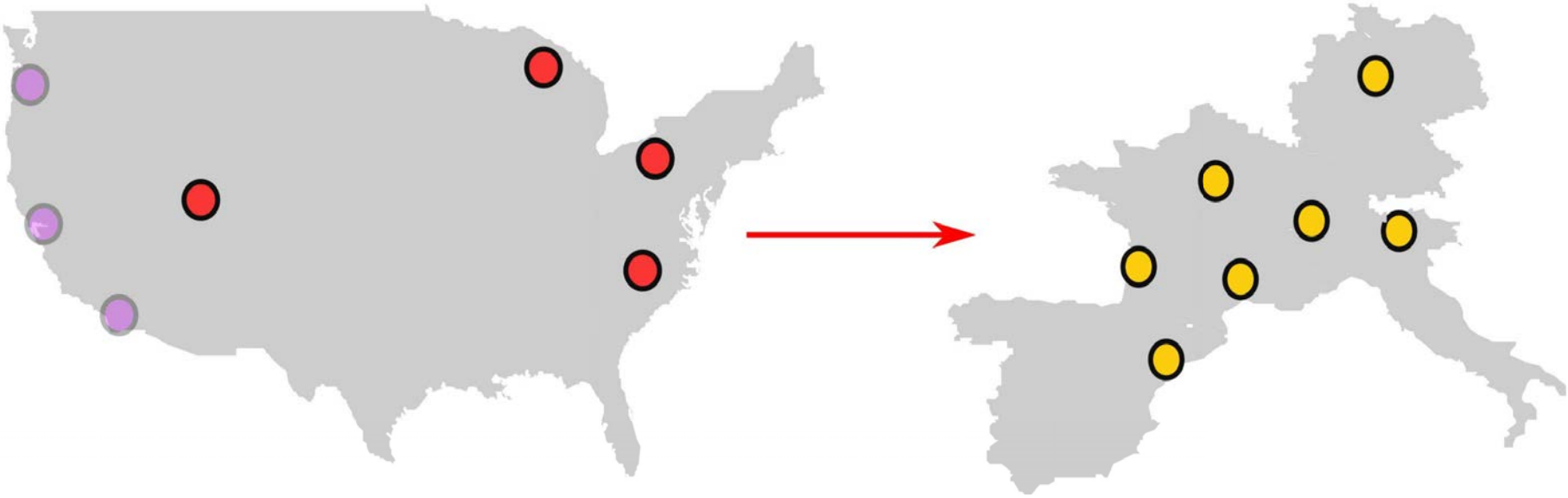


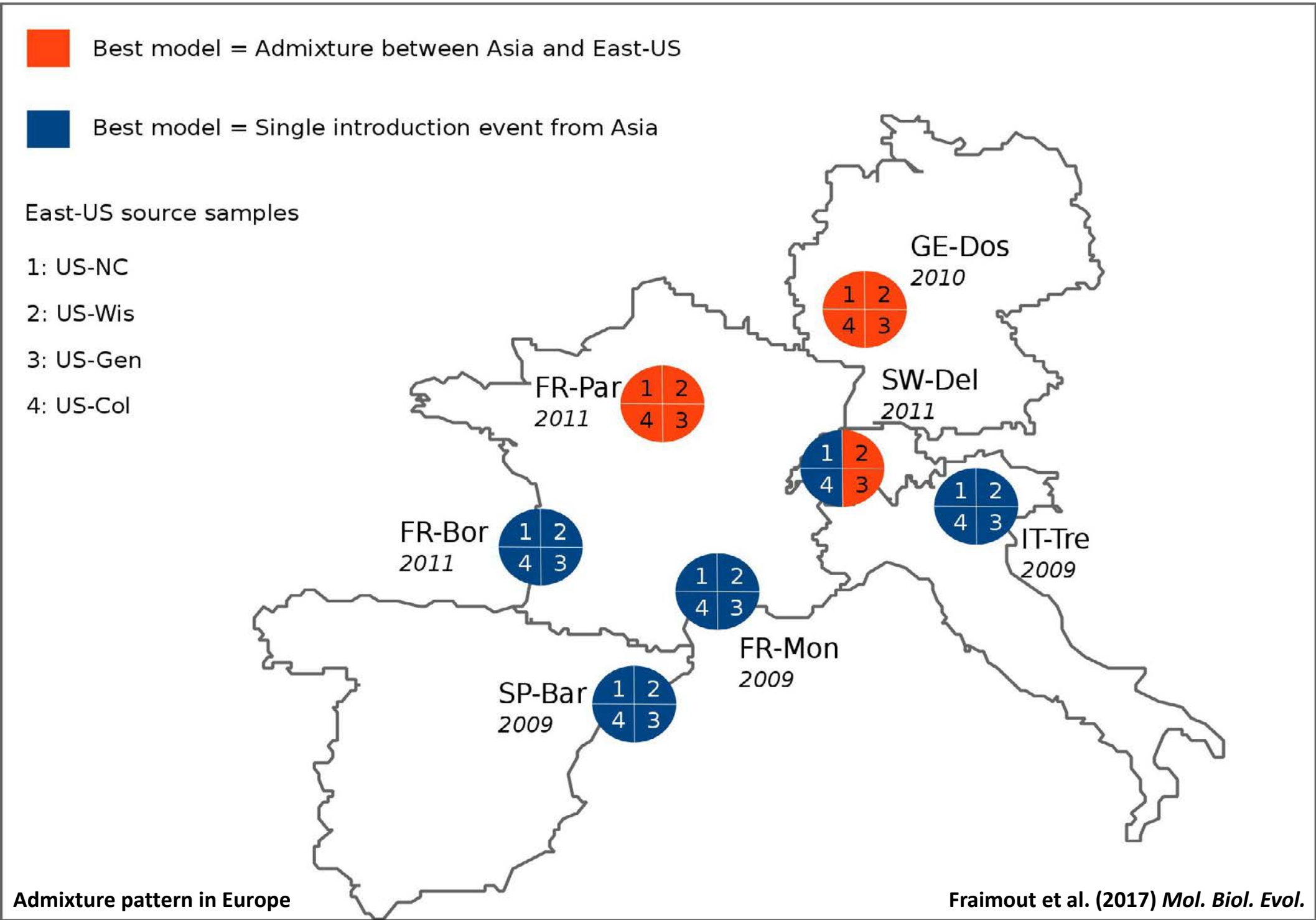
How to deal with simultaneous introductions?

Introduction dates in USA and Europe overlap

~~Europe as a source for USA?~~

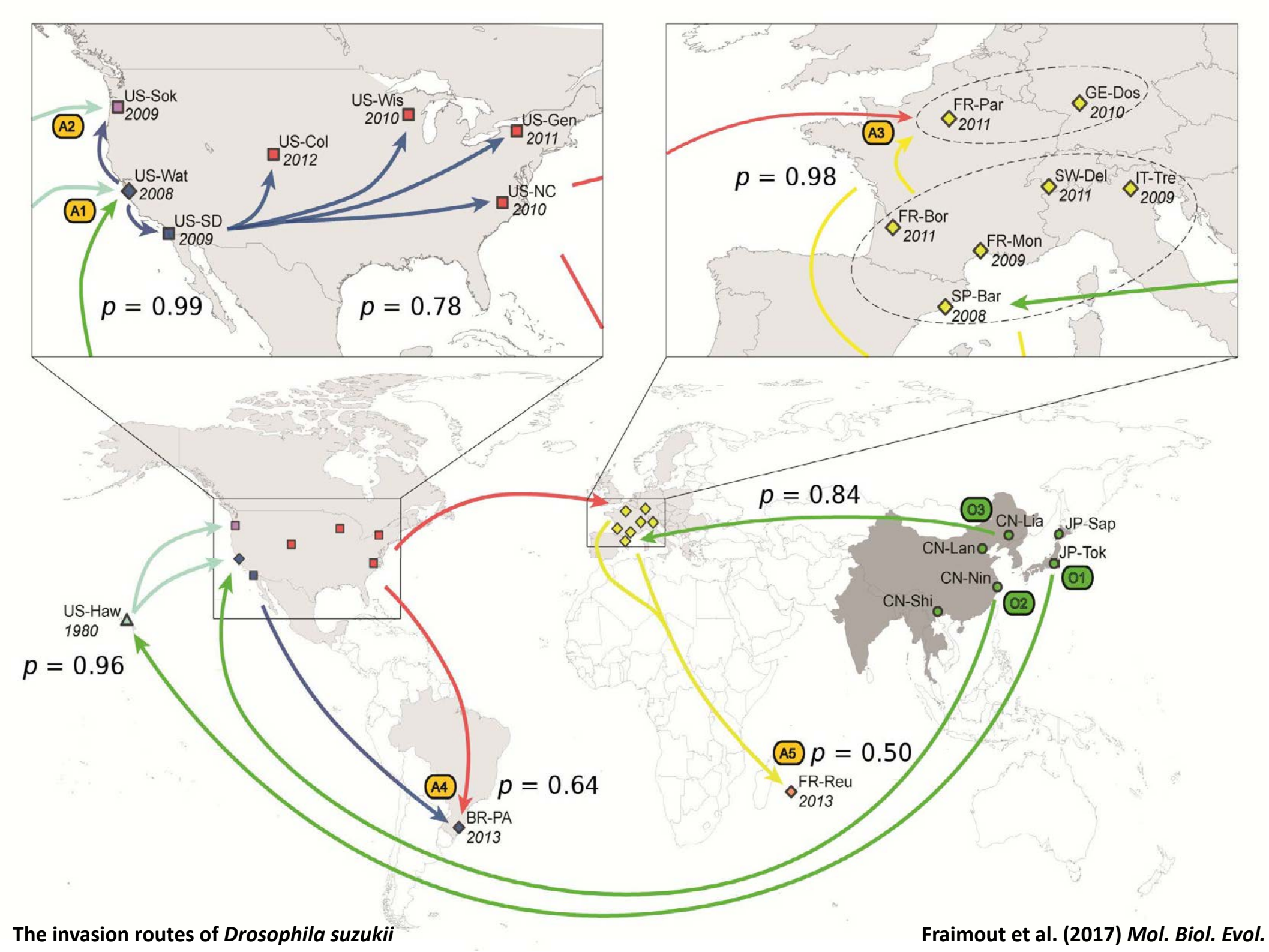
Eastern USA as a source for Europe!





Admixture pattern in Europe

Fraimout et al. (2017) *Mol. Biol. Evol.*



The invasion routes of *Drosophila suzukii*

Fraimout et al. (2017) *Mol. Biol. Evol.*

Conclusions on Chapter 1

A complex invasion history

- Multiple introductions event from different sources
- Most likely human-mediated on large scales (human migration, fruit-trade)

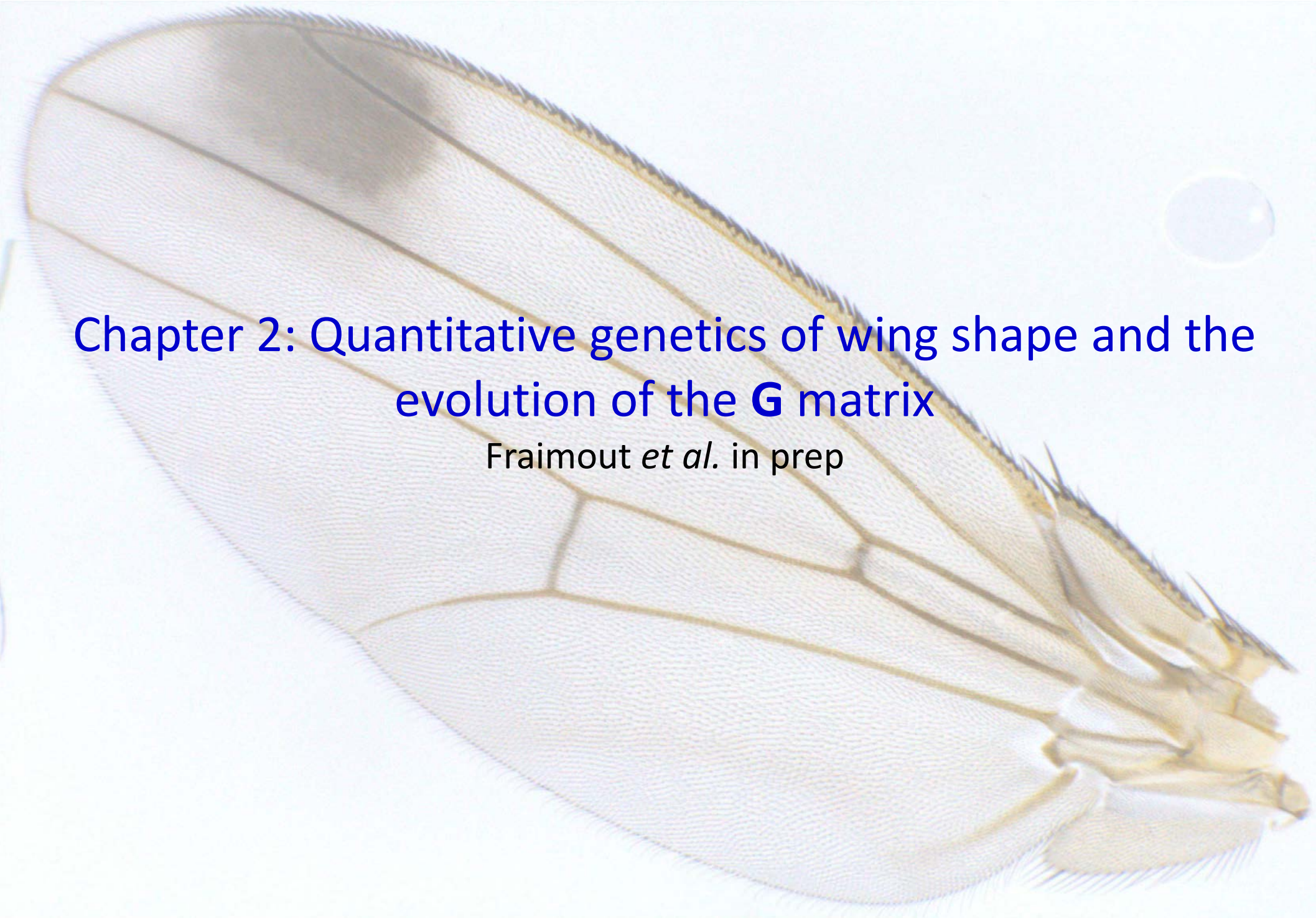
Conclusions on Chapter 1

A complex invasion history

- Multiple introductions event from different sources
- Most likely human-mediated on large scales (human migration, fruit-trade)

Genetic variation

- Overall loss of genetic variation in invasive populations
  - All invasive populations experienced bottlenecks (with different severity)
- Admixture in western USA
  - From two highly differentiated populations (Hawaii & Asia)

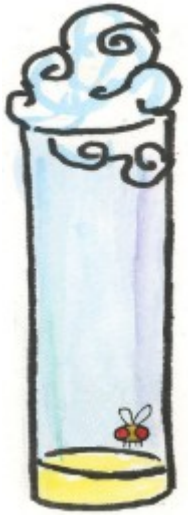


Chapter 2: Quantitative genetics of wing shape and the evolution of the **G** matrix

Fraimout *et al.* in prep

Breeding design: isofemale lines

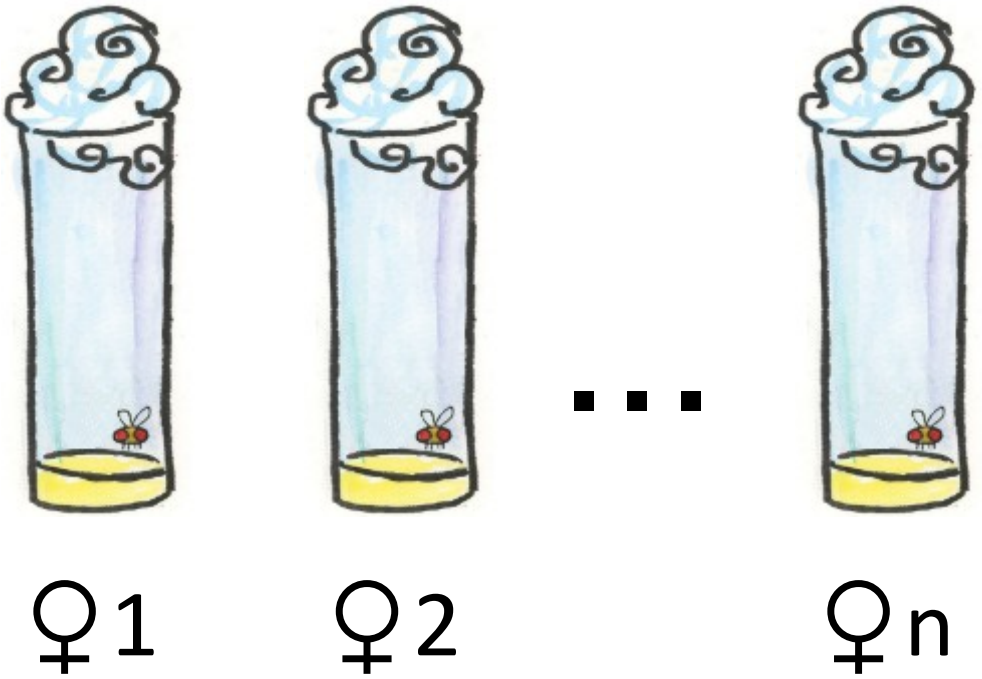
Established from single females caught in the field



1♀

Breeding design: isofemale lines

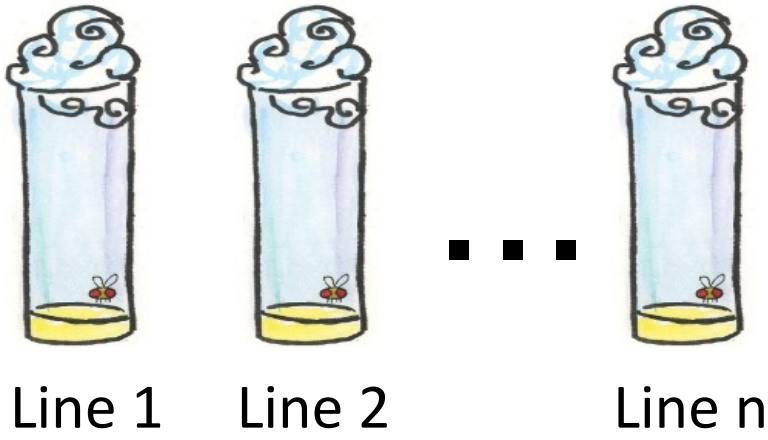
Multiple females caught at each localities



Line 1 Line 2 Line n

Rearing in the lab (5 generations)

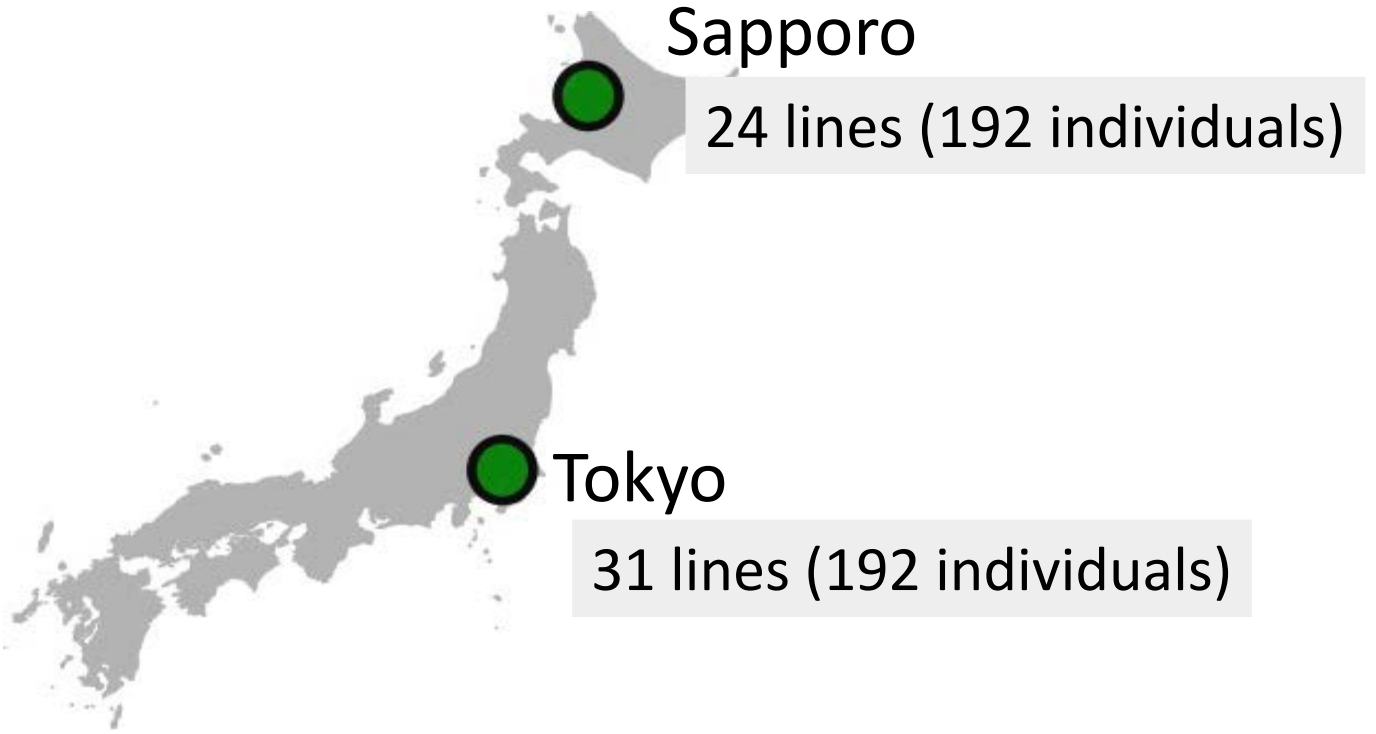
Line 1 Line 2 Line n



Generation 5 ready for phenotyping

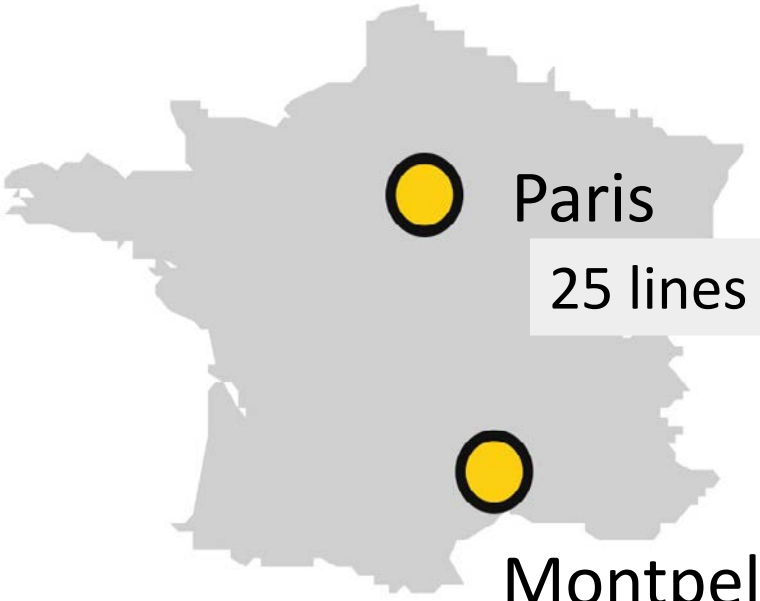
Study populations

Native range, Japan



Study populations

Invasive range, France



Paris

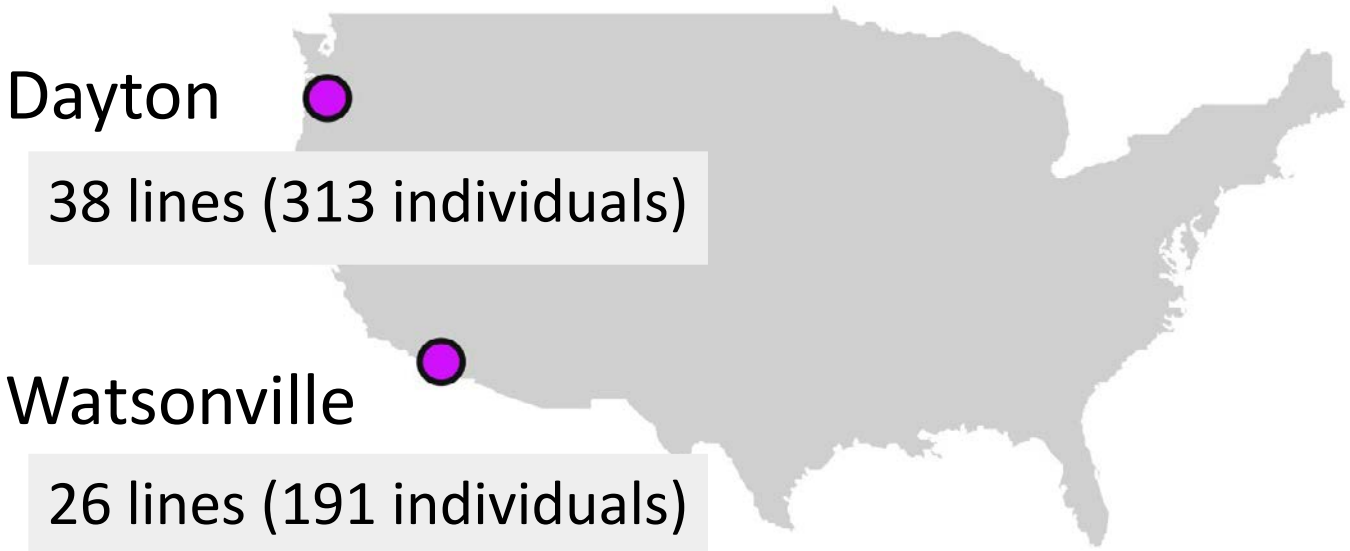
25 lines (209 individuals)

Montpellier

33 lines (226 individuals)

Study populations

Invasive range, USA



Study populations

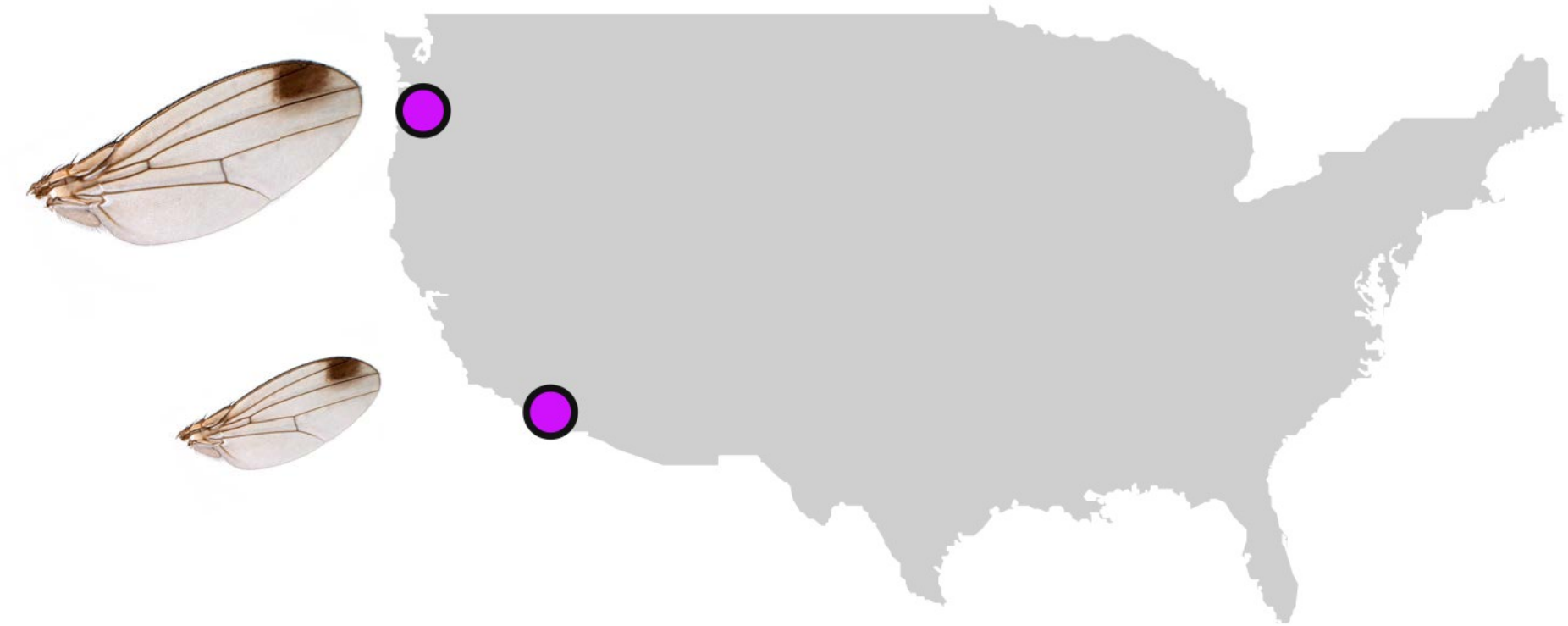
1323 individuals phenotyped

Sampling design: North/South gradient

Allows to test for latitudinal clines in morphology

Observed in other *Drosophila sp.*

Suggested to be adaptive, related to climate



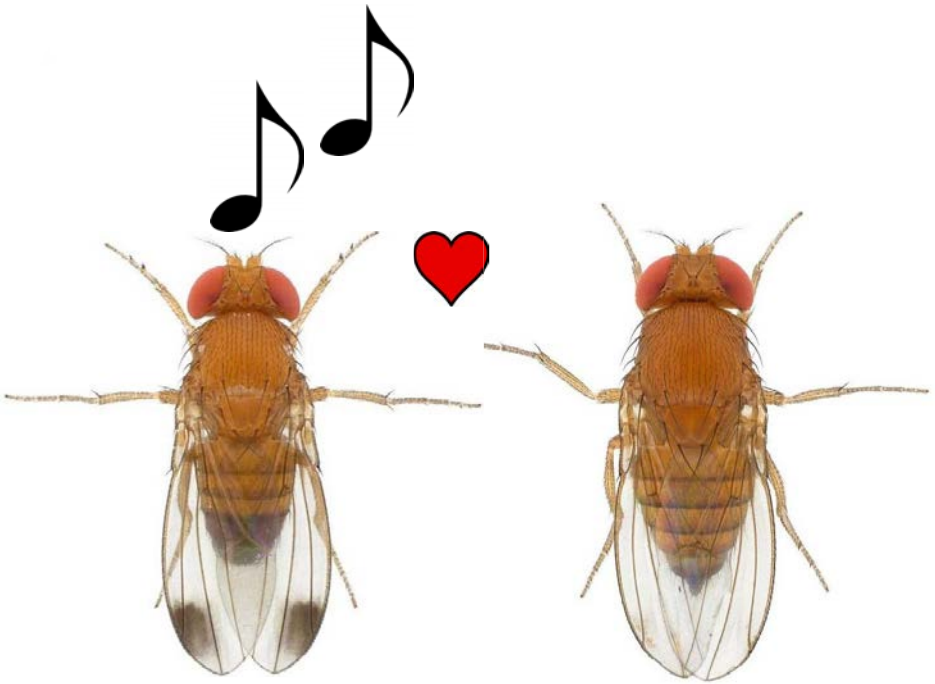
Focal trait: Wing

Focal trait: Wing

Flight and dispersion

Focal trait: Wing

Flight and dispersion

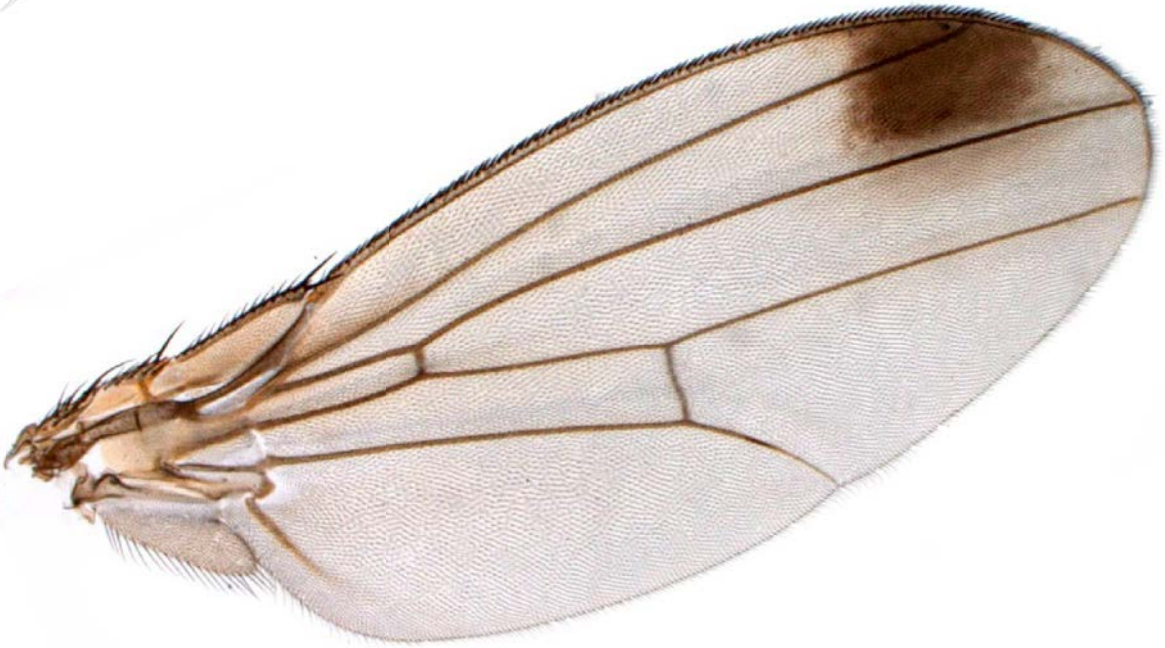


Phenotyping: wing shape

Extracting and mounting wings

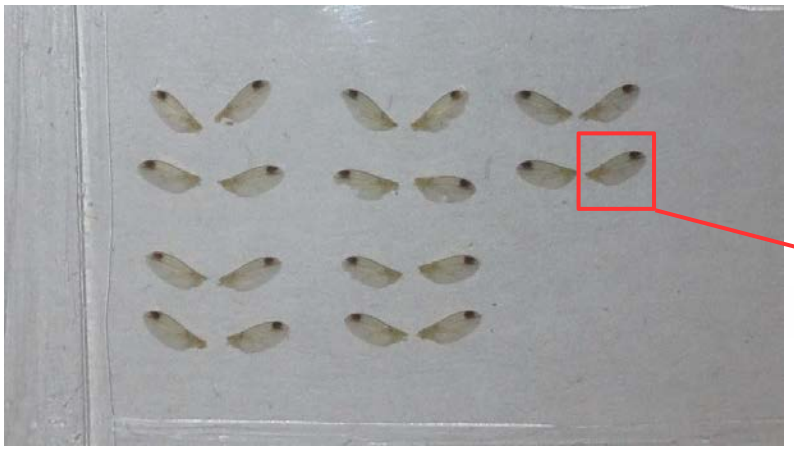
+

x 1323



Phenotyping: wing shape

Mounting and digitalizing wings

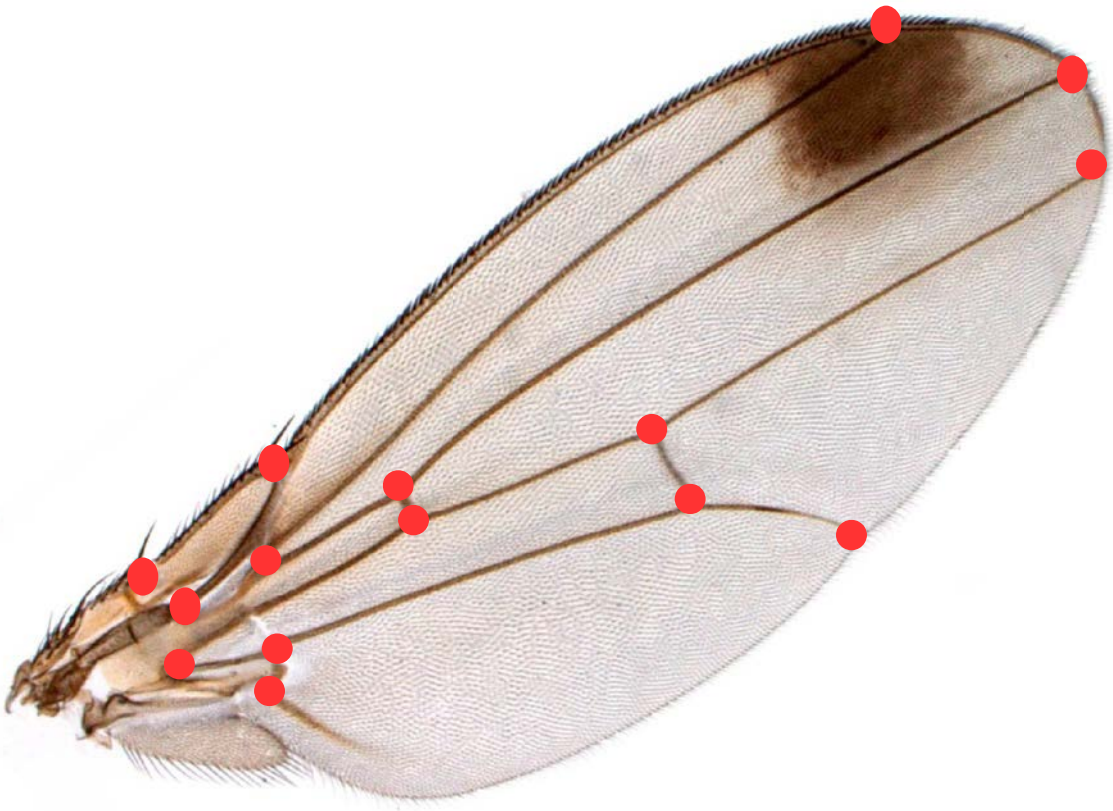


3mm

Phenotyping: wing shape

Geometric morphometrics

15 landmarks placed on the wing



Phenotyping: wing shape

Geometric morphometrics

15 landmarks placed on the wing

Extraction of wing shape subtle variation

Phenotyping: wing shape

Geometric morphometrics

15 landmarks placed on the wing

Extraction of wing shape subtle variation

Multivariate data

Comparative analyses

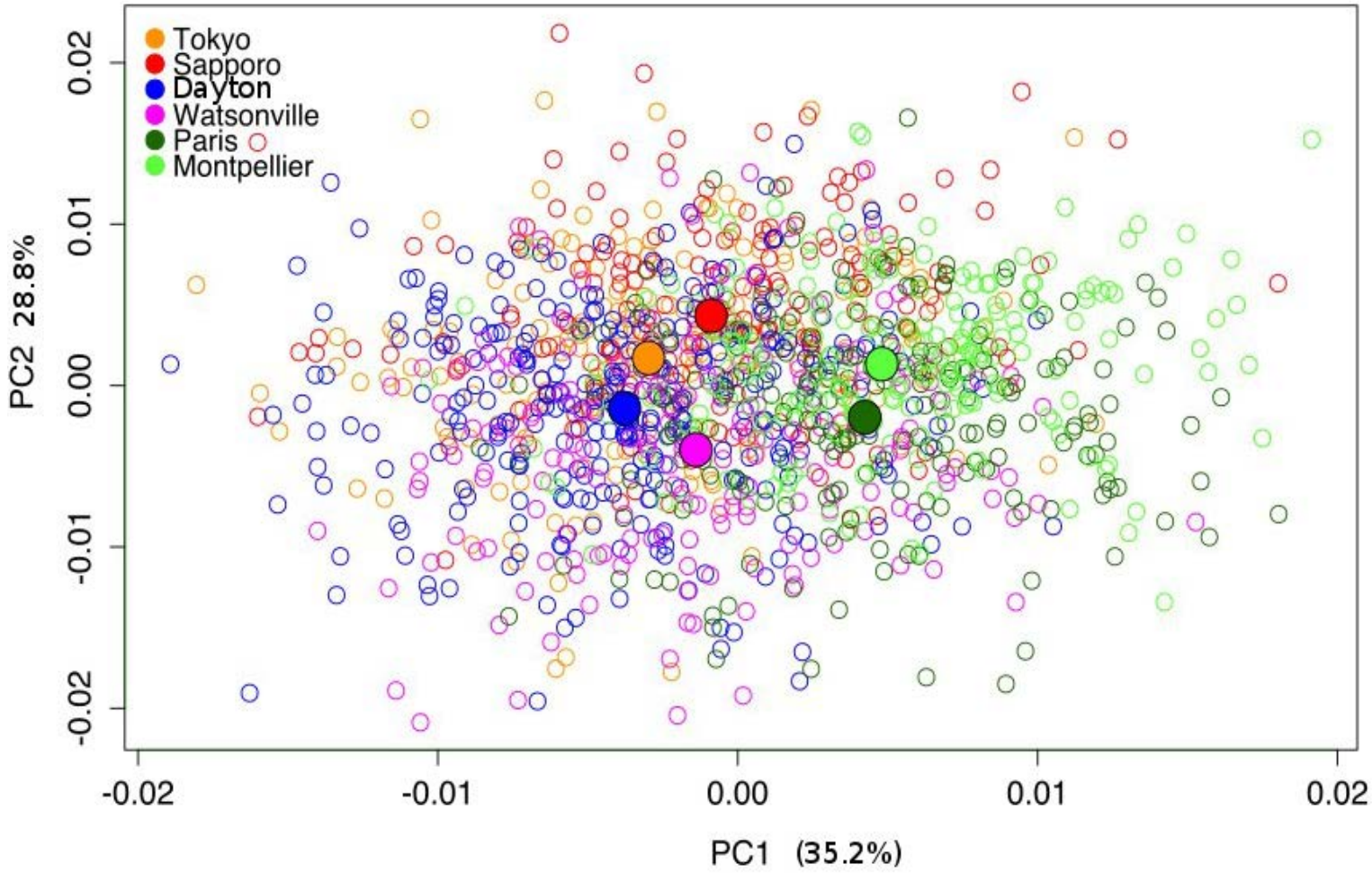
1. Estimating phenotypic divergence among populations

2. Estimating G matrix from wing shape data for each population

3. Comparing G matrices between populations

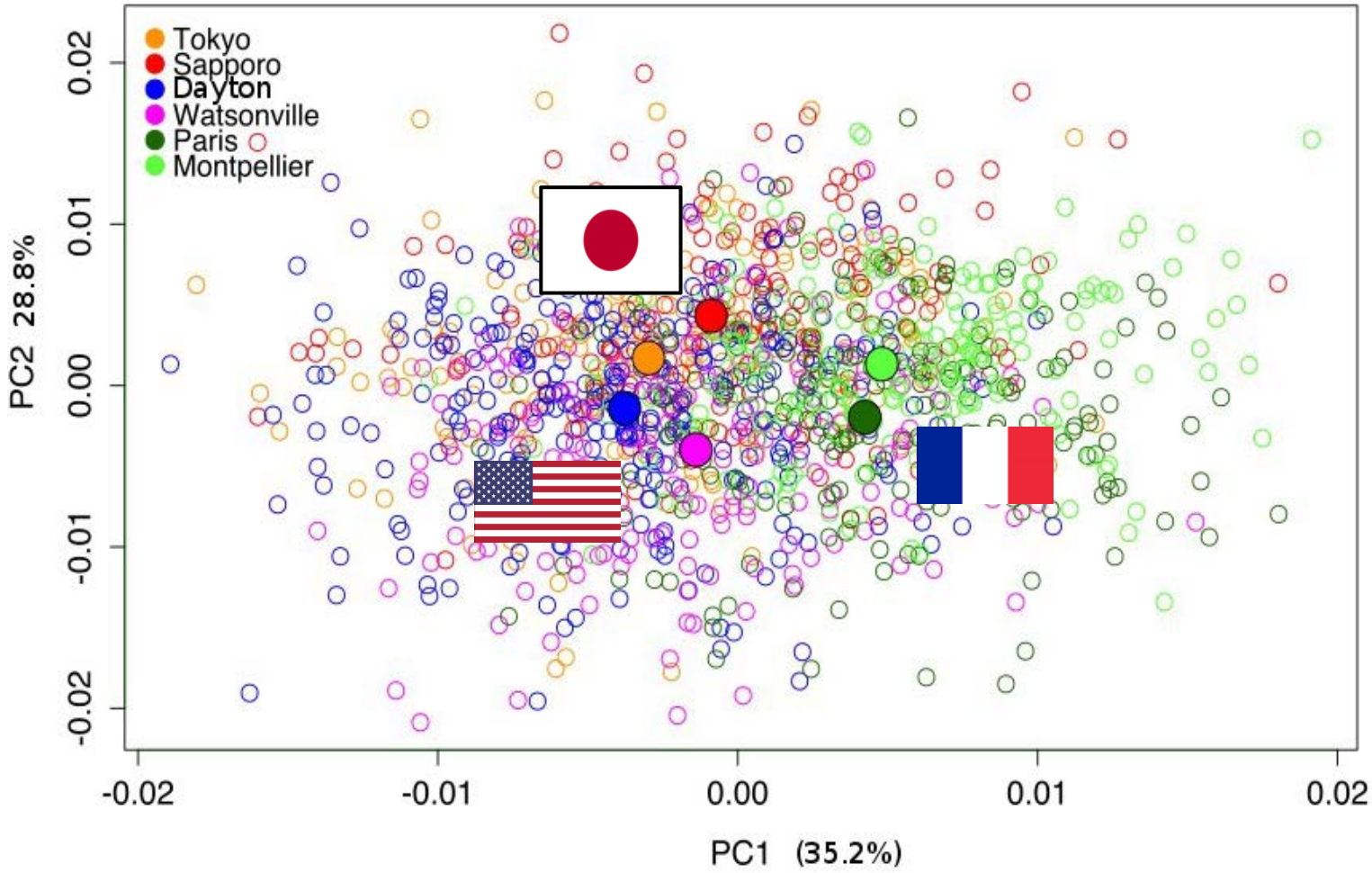
- Similarity (correlation between matrices)
- Volume (total genetic variance)
- Orientation
- Eccentricity (structuration of the variance)

Is there divergence in wing shape among populations?



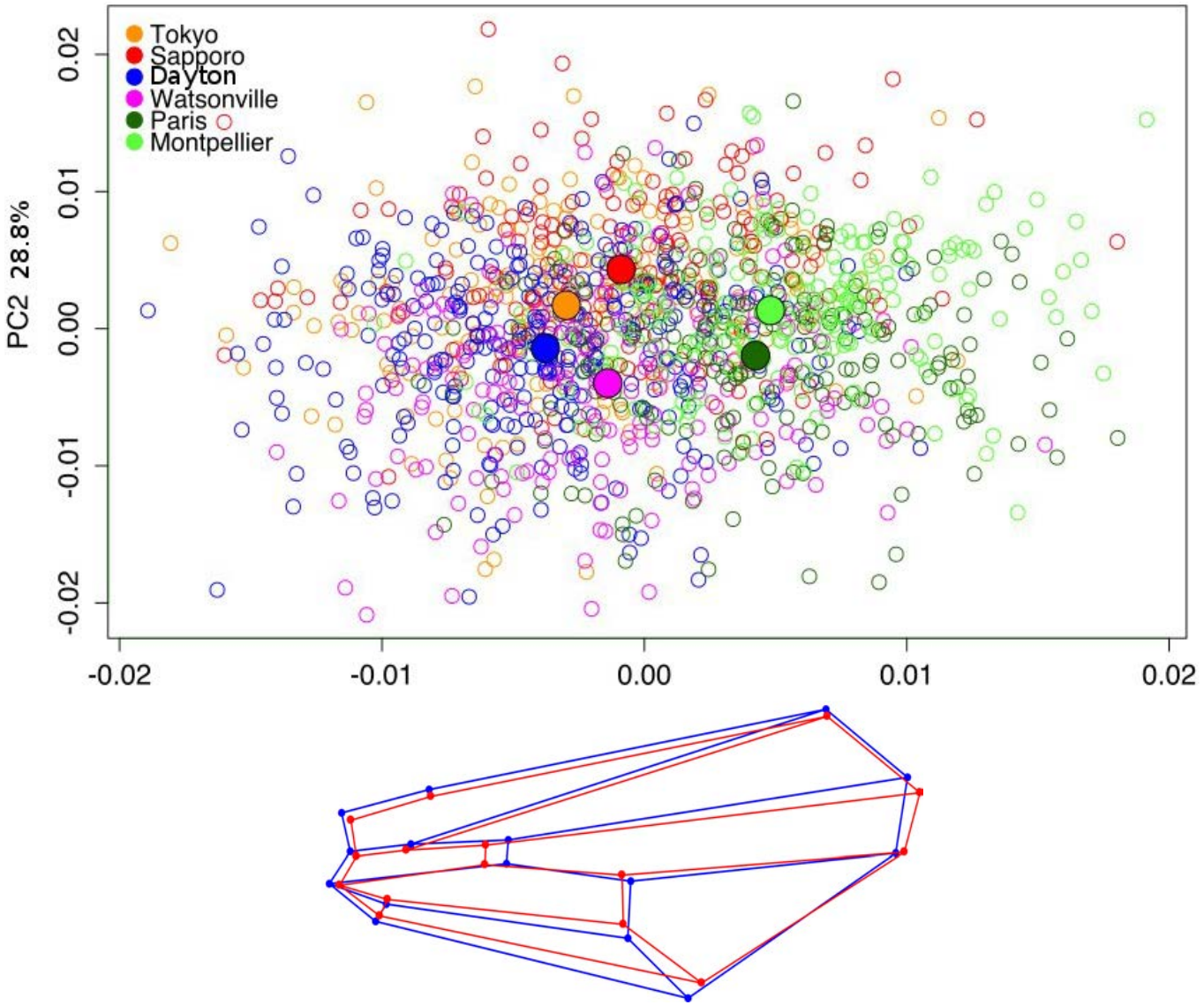
Divergence in wing shape among *D. suzukii* populations (MANOVA $p < 0.001$)

Is there divergence in wing shape among populations?



Divergence in wing shape among *D. suzukii* populations (MANOVA $p < 0.001$)

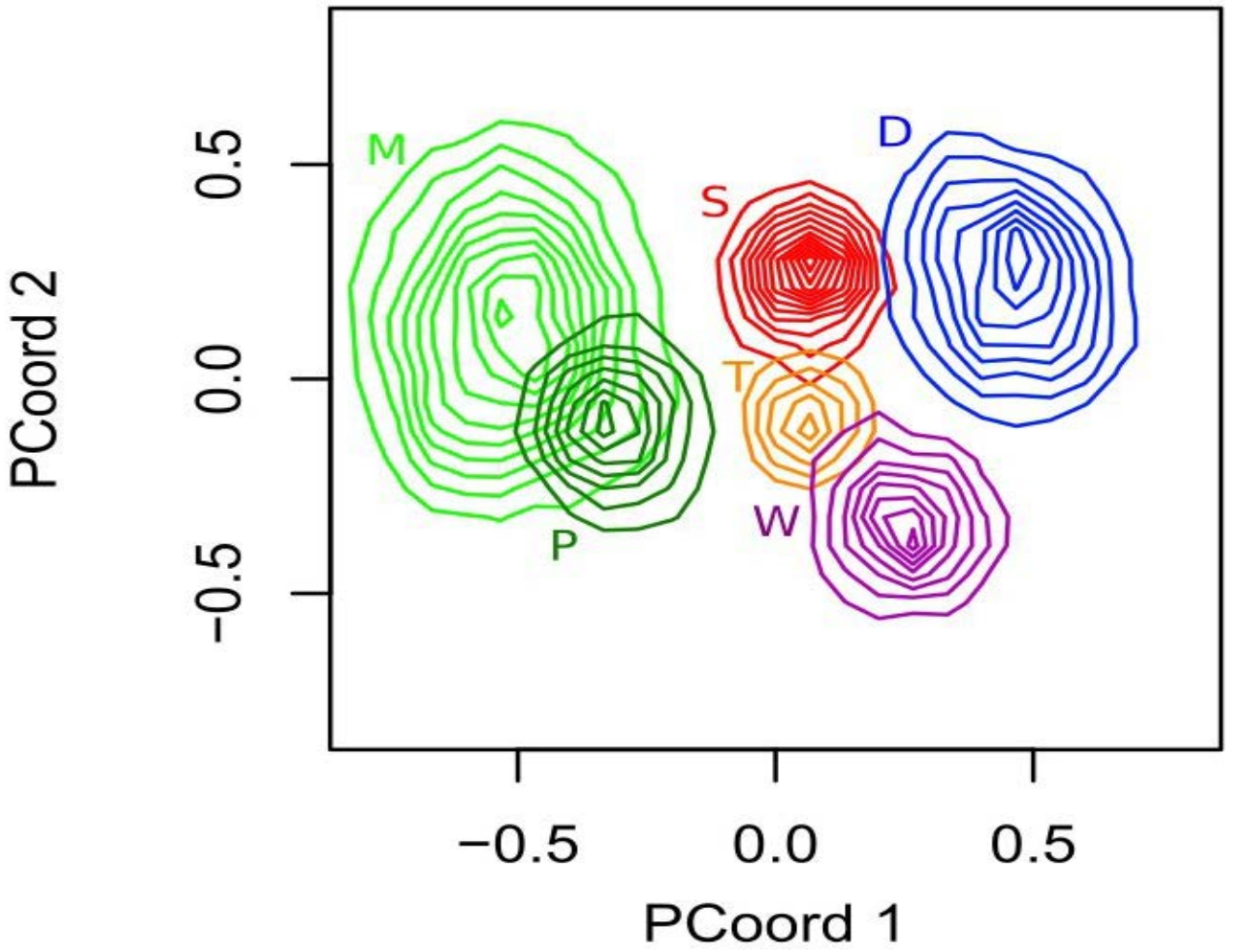
Is there divergence in wing shape among populations?



Vizualisation of shape change along PC1

Distance between **G** matrices

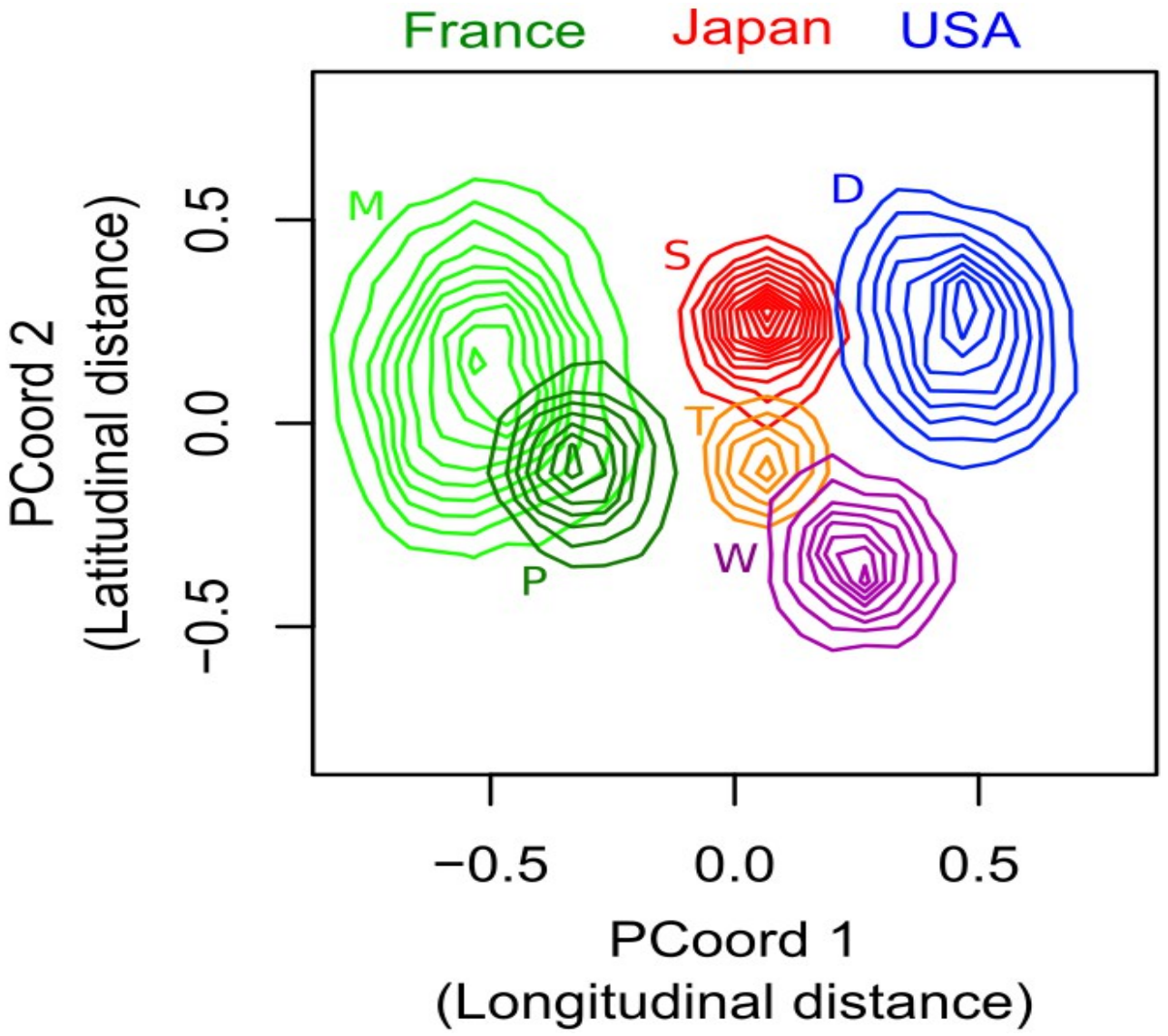
Matrices at the center of the confidence interval



Principal Coordinate Analysis (correlation coefficient)

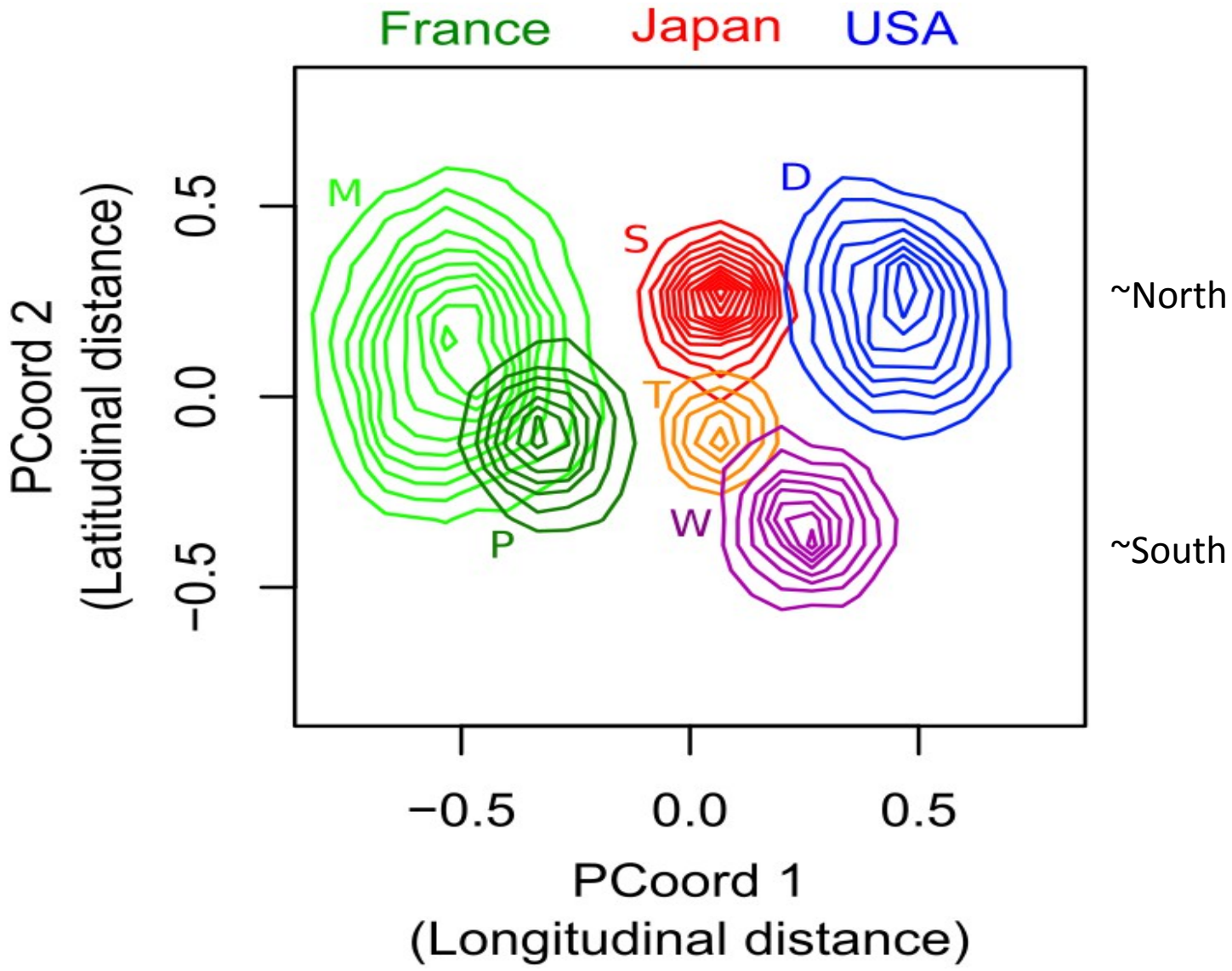
Distance between **G** matrices

Longitudinal signal (between continents)



Distance between **G** matrices

Latitudinal signal (North/South) but not consistent for France



Comparisons of **G** matrices

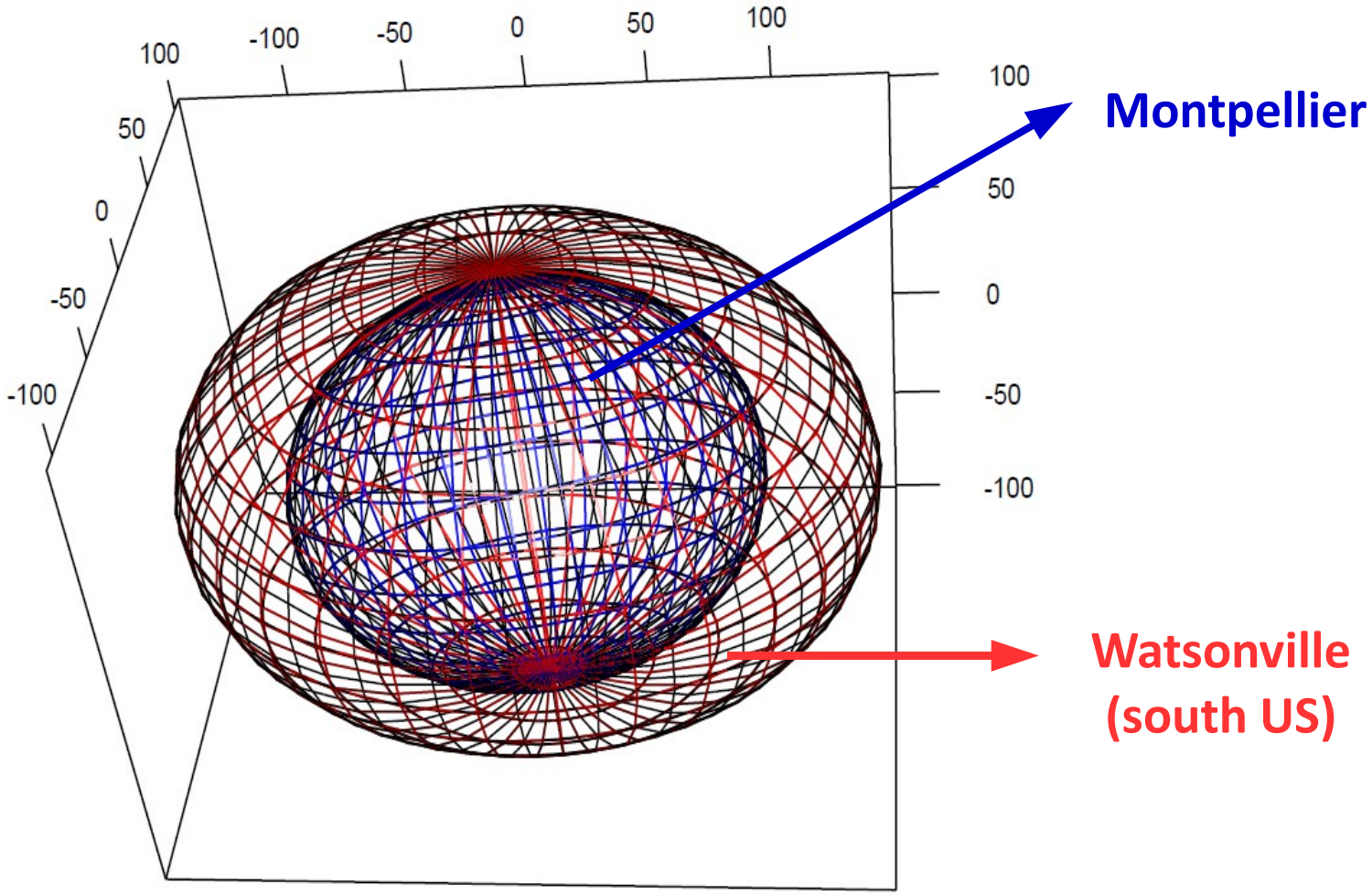
1. Volume: total genetic variance

Comparisons of **G** matrices

1. Volume: total genetic variance

southern USA population > France, northern USA

southern USA population = Japan

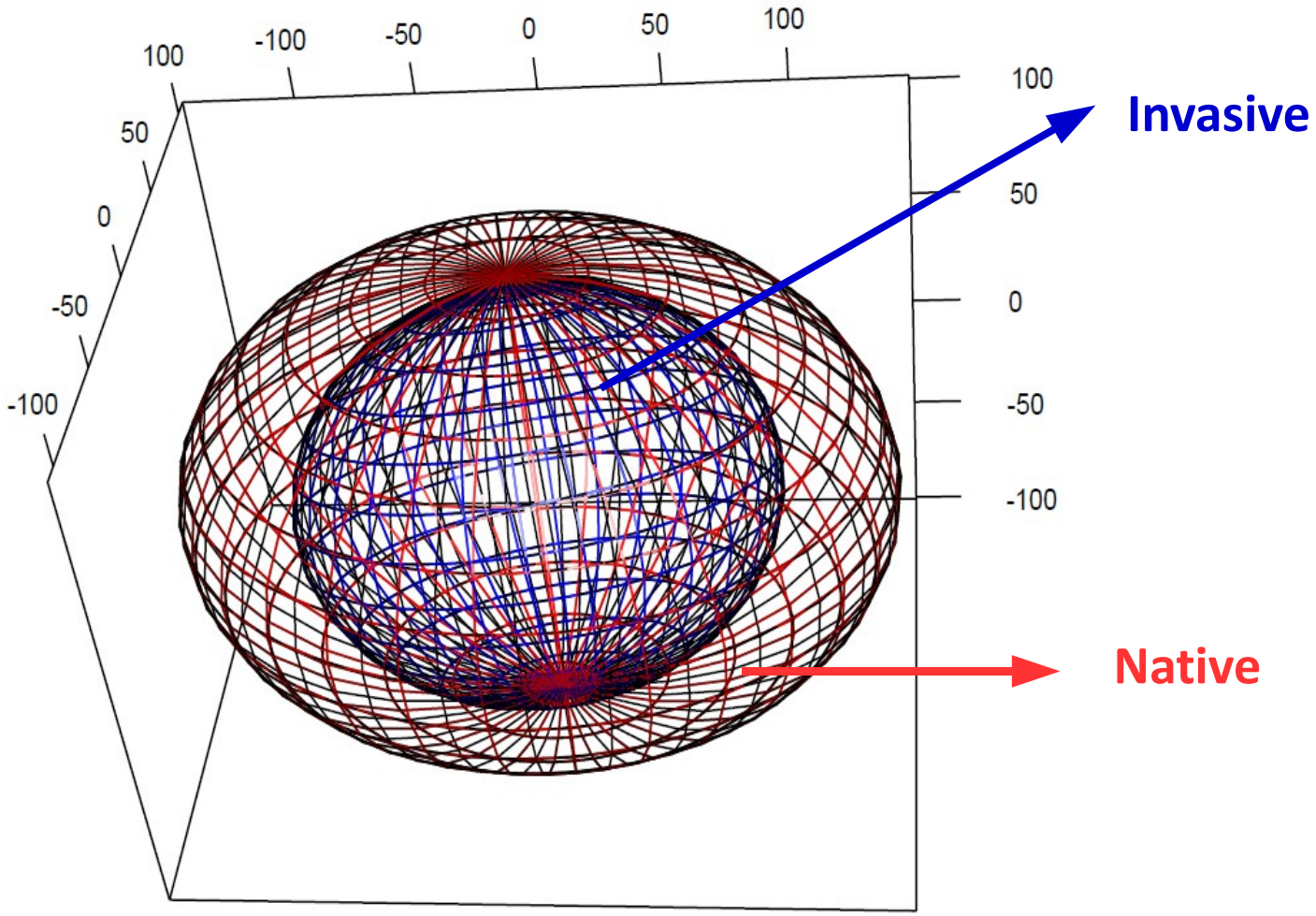


3D representation of matrices' volume differences

Comparisons of **G** matrices

1. Volume: total genetic variance

Trend for Native > Invasive (n.s)



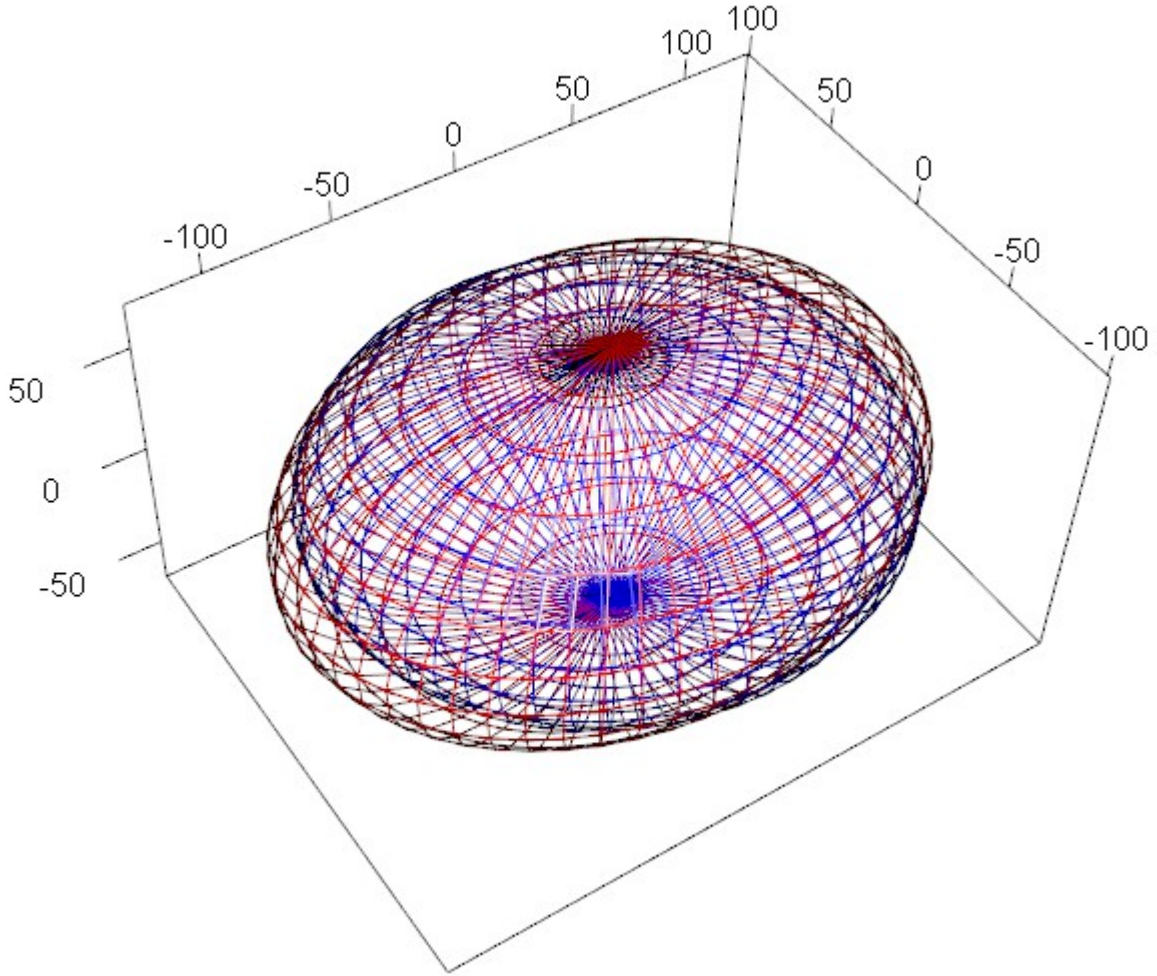
3D representation of matrices' volume differences

Comparisons of **G** matrices

2. Orientation and eccentricity

No significant differences or trend between populations

Matrices have the same orientation and the same shape



3D representation of matrices' shape differences

Conclusions on Chapter 2

Phenotypic divergence

Weak but non-random divergence in wing shape: geographic signal

Conclusions on Chapter 2

Phenotypic divergence

Weak but non-random divergence in wing shape: geographic signal

Evolution of G during the invasion

Weak but non-random divergence among matrices: geographic signal

Conclusions on Chapter 2

Phenotypic divergence

- Weak but non-random divergence in wing shape: geographic signal

Evolution of G during the invasion

- Weak but non-random divergence among matrices: geographic signal
- Changes in the volume of **G**
  - Populations experiencing bottleneck tend to have smaller volumes
  - Admixed southern USA population has greater volume

Conclusions on Chapter 2

Phenotypic divergence

- Weak but non-random divergence in wing shape: geographic signal

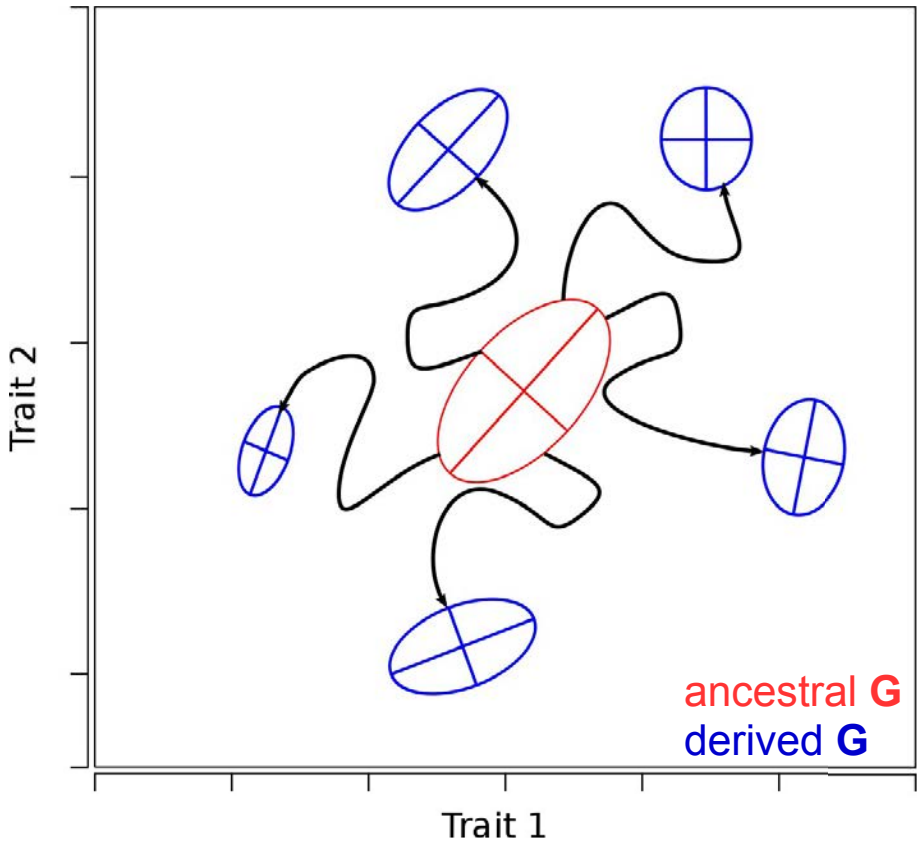
Evolution of G during the invasion

- Weak but non-random divergence among matrices: geographic signal
- Changes in the volume of **G**
  - Populations experiencing bottleneck tend to have smaller volumes
  - Admixed southern USA population has greater volume
- Dominant role of neutral evolution in the divergence?

Conclusions on Chapter 2

Evolution of G during the invasion

Under drift **G** should have diverge randomly

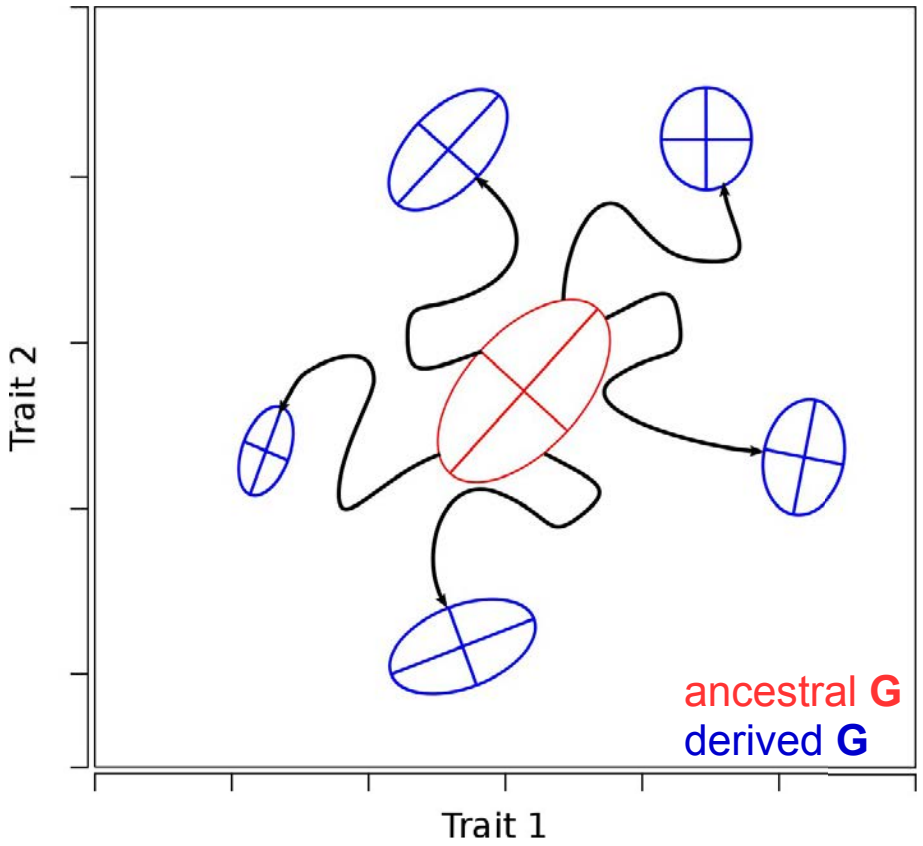


Conclusions on Chapter 2

Evolution of G during the invasion

Under drift **G** should have diverge randomly

Here stability of **G** on several aspects (orientation and shape)



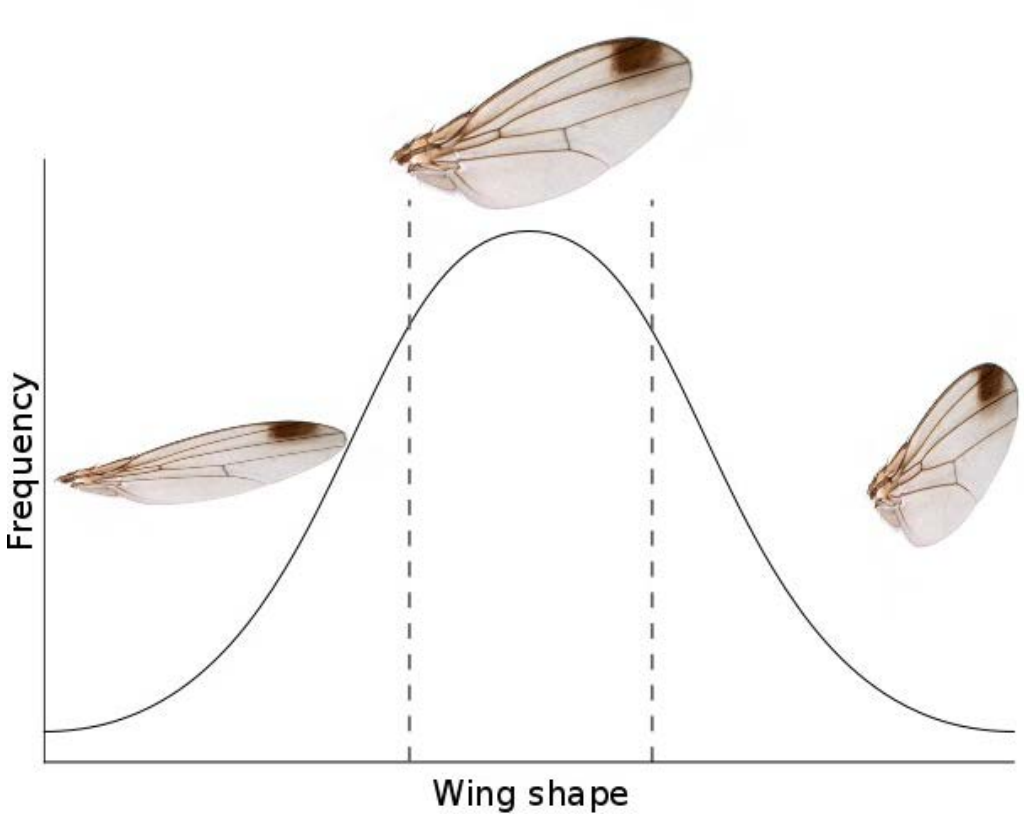
Conclusions on Chapter 2

Evolution of G during the invasion

Under drift **G** should have diverge randomly

Here stability of **G** on several aspects

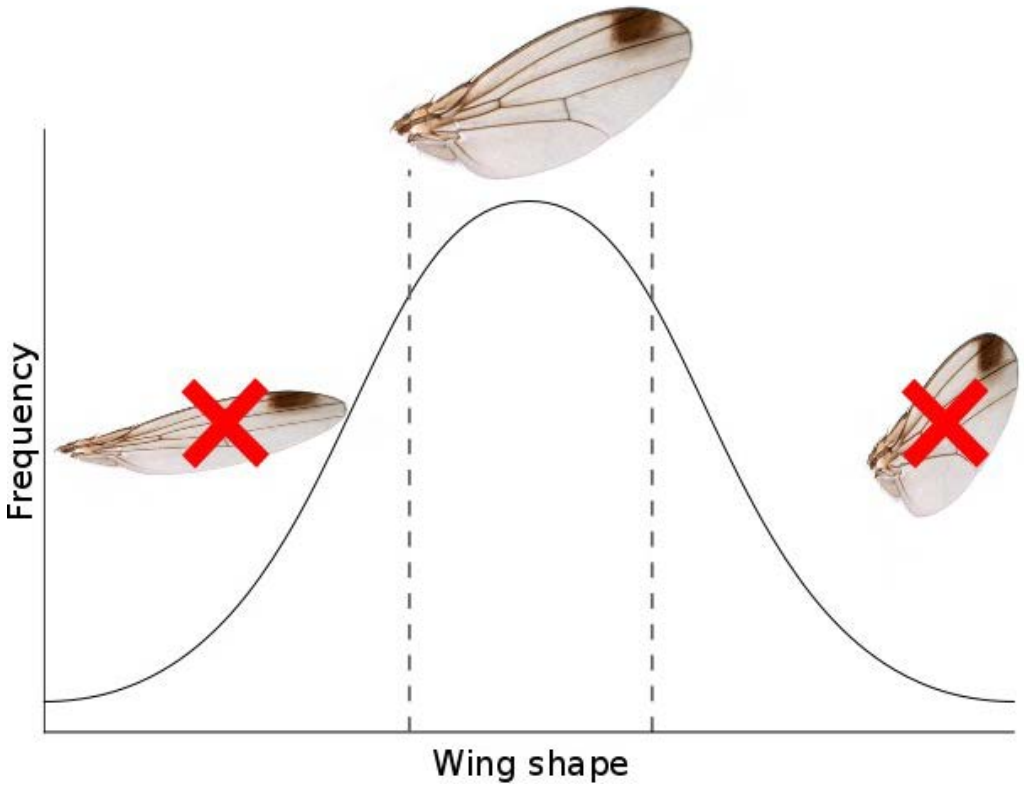
Stabilizing selection on the wing?



Conclusions on Chapter 2

Stabilizing selection on the wing?

Wing shape may be under strong stabilizing selection

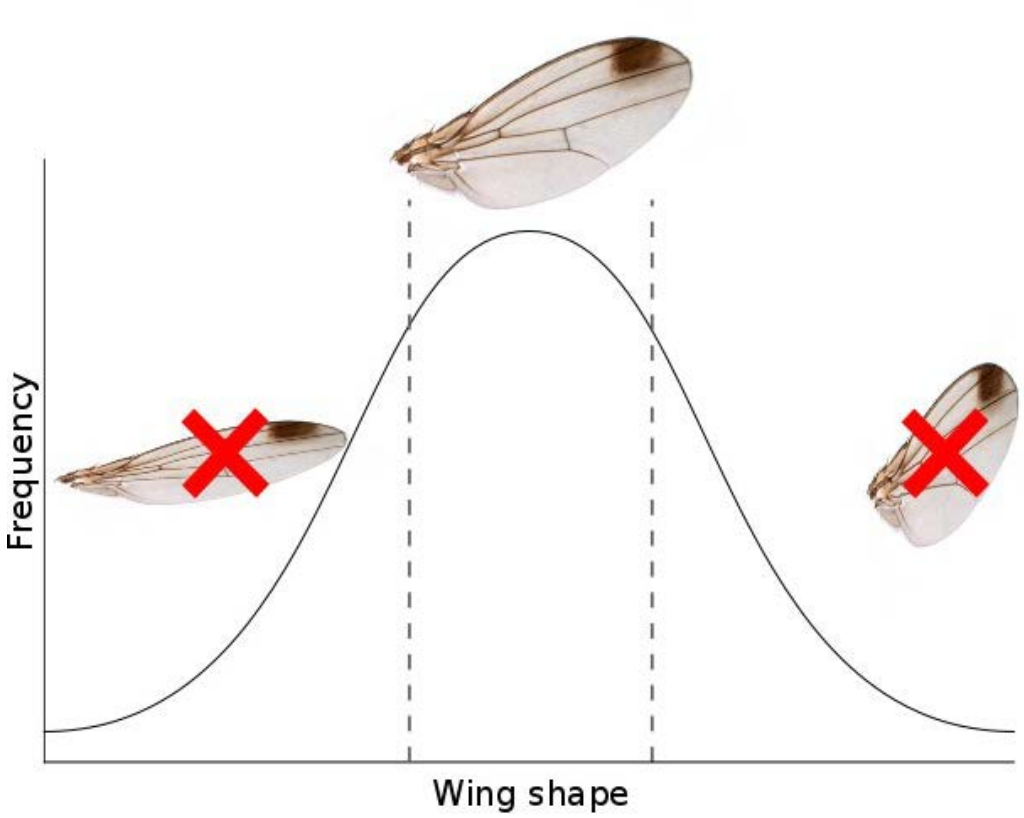


Conclusions on Chapter 2

Stabilizing selection on the wing?

Wing shape may be under strong stabilizing selection

Close to an adaptive peak



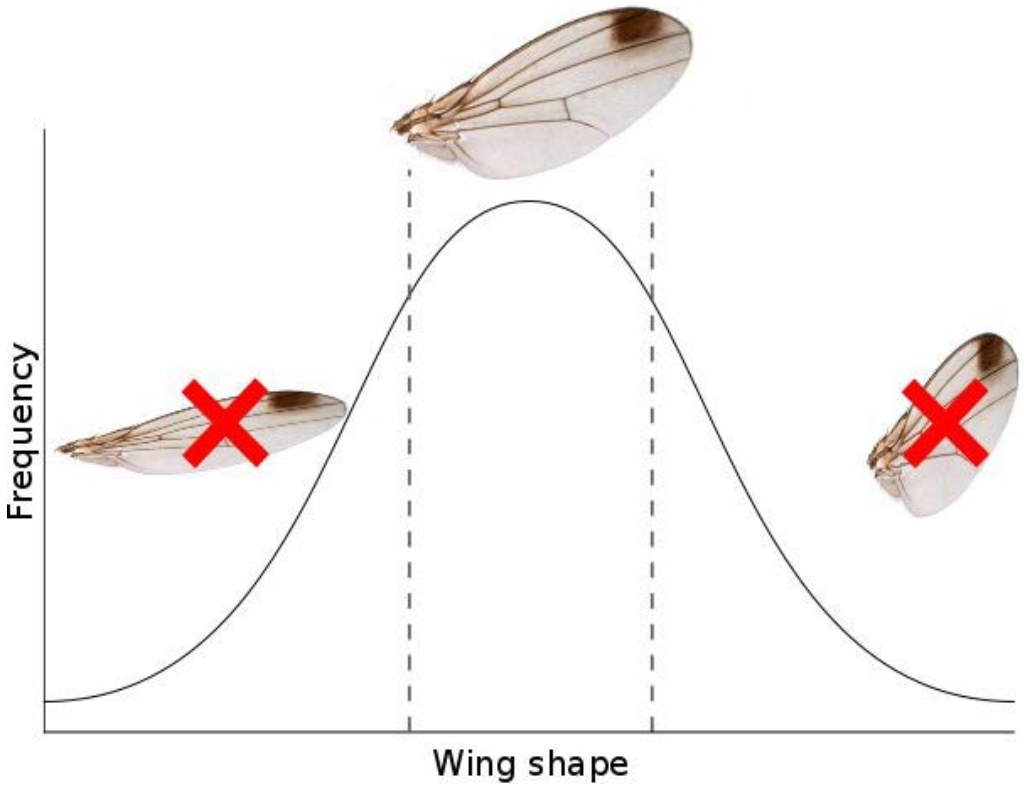
Conclusions on Chapter 2

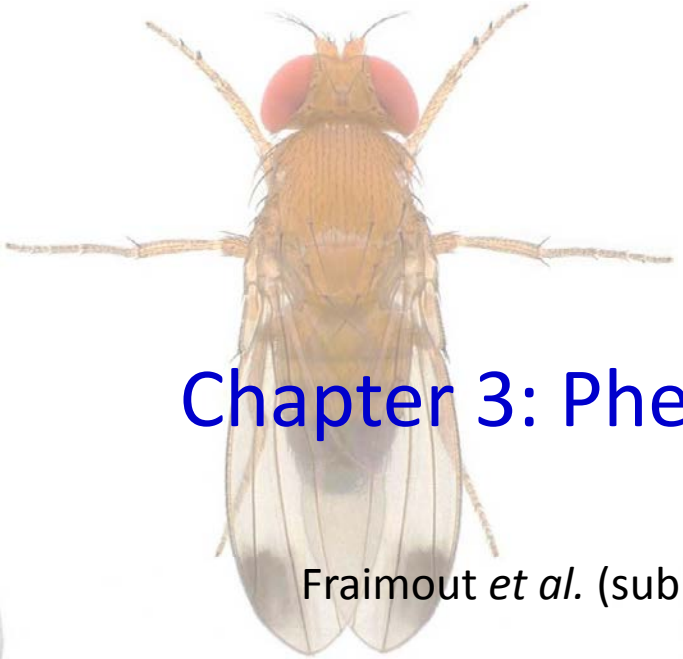
Stabilizing selection on the wing?

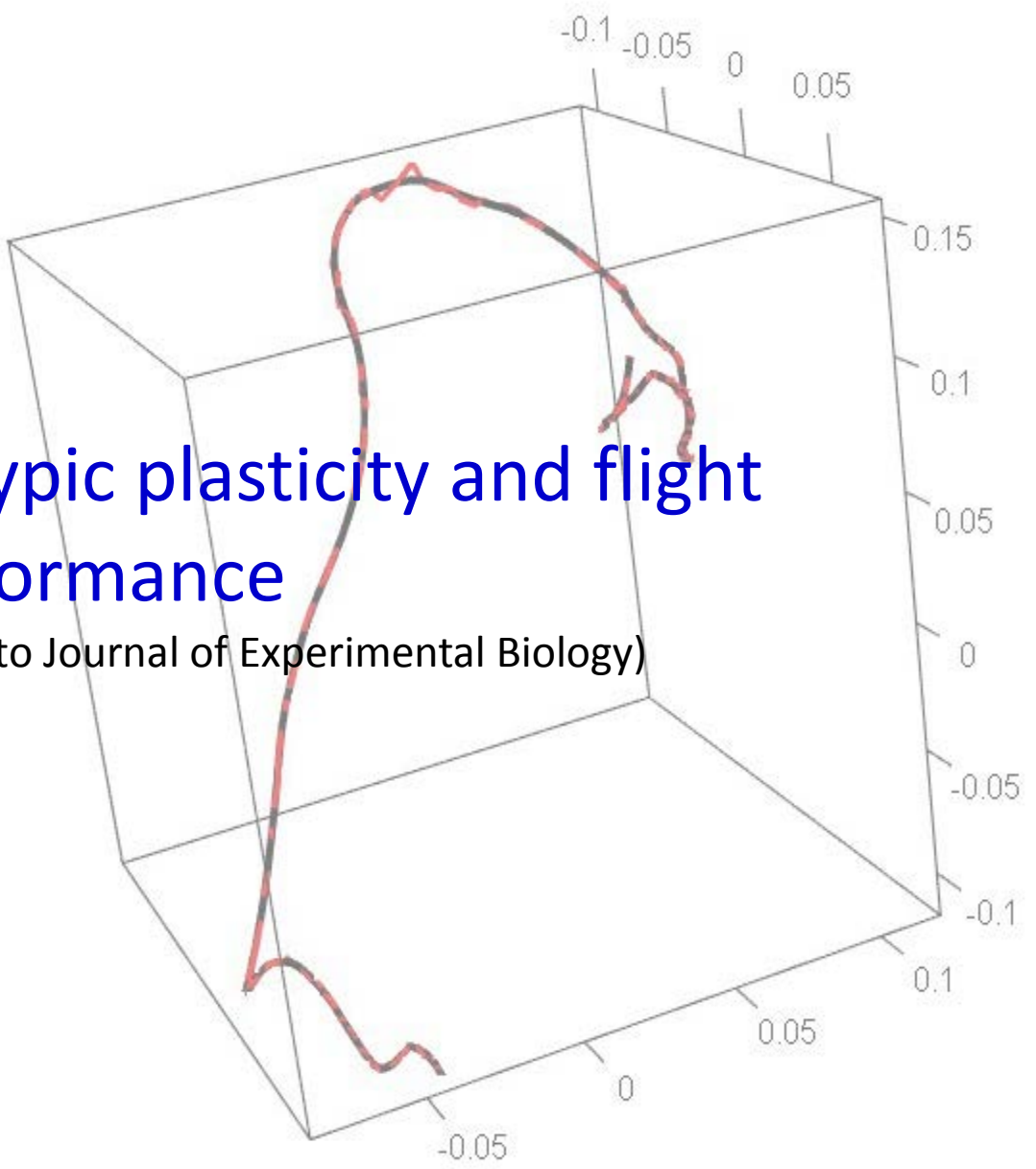
Wing shape may be under strong stabilizing selection

Close to an adaptive peak

Because of its role in flight performance (and foraging, courtship etc.)

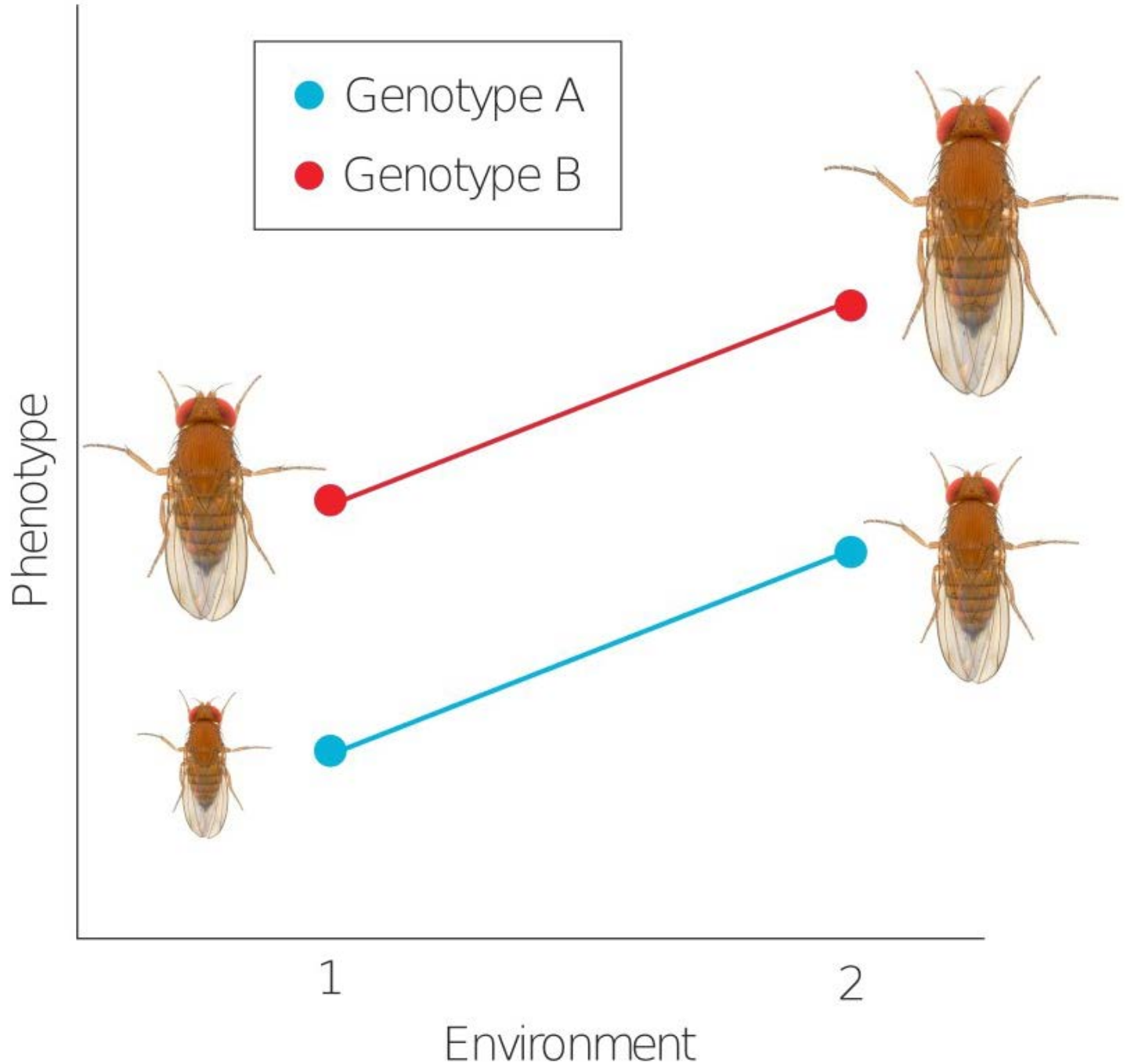






Chapter 3: Phenotypic plasticity and flight performance

Fraimout *et al.* (submitted to Journal of Experimental Biology)


Genotype A
Genotype B
Phenotype
1
2
Environment

The role of phenotypic plasticity in biological invasions

Does phenotypic plasticity facilitate invasion?

Invasive species are thought to be more plastic

The role of phenotypic plasticity in biological invasions

Does phenotypic plasticity facilitate invasion?

Invasive species are thought to be more plastic

Phenotypic plasticity could *"counteract"* loss of genetic variation and increase fitness in a new environment

The role of phenotypic plasticity in biological invasions

Does phenotypic plasticity facilitate invasion?

Invasive species are thought to be more plastic

Phenotypic plasticity could *"counteract"* loss of genetic variation and increase fitness in a new environment

Are invasive populations more plastic?

Invasive populations are predicted to be more plastic

The role of phenotypic plasticity in biological invasions

Does phenotypic plasticity facilitate invasion?

- Invasive species are thought to be more plastic
- Phenotypic plasticity could *"counteract"* loss of genetic variation and increase fitness in a new environment

Are invasive populations more plastic?

- Invasive populations are predicted to be more plastic
- Invasive populations are predicted to perform better than their native counterparts

The role of phenotypic plasticity in biological invasions

Does phenotypic plasticity facilitate invasion?

- Invasive species are thought to be more plastic
- Phenotypic plasticity could *"counteract"* loss of genetic variation and increase fitness in a new environment

Are invasive populations more plastic?

- Invasive populations are predicted to be more plastic
- Invasive populations are predicted to perform better than their native counterparts
- Link between plastic response and performance rarely tested empirically

The role of phenotypic plasticity in *D. suzukii*'s invasion

1. Comparing phenotypic plasticity between native and invasive populations

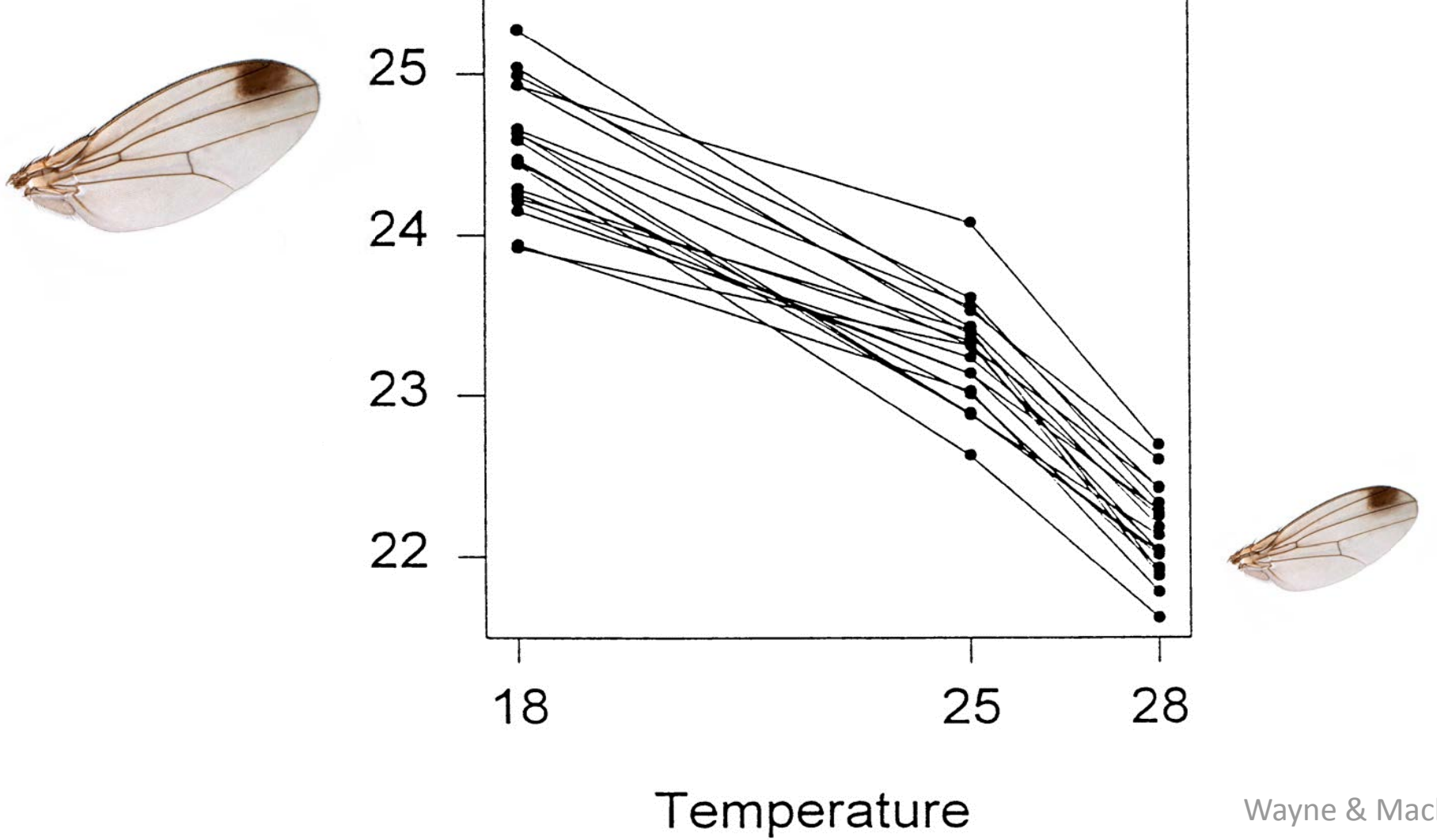
2. Estimating effect of plasticity on phenotype's performance

3. Comparing performances between native and invasive populations

Environmental cue: developmental temperature

Major component of ectotherm's biology

Affects morphology in *Drosophila* (cf. adaptive latitudinal clines)

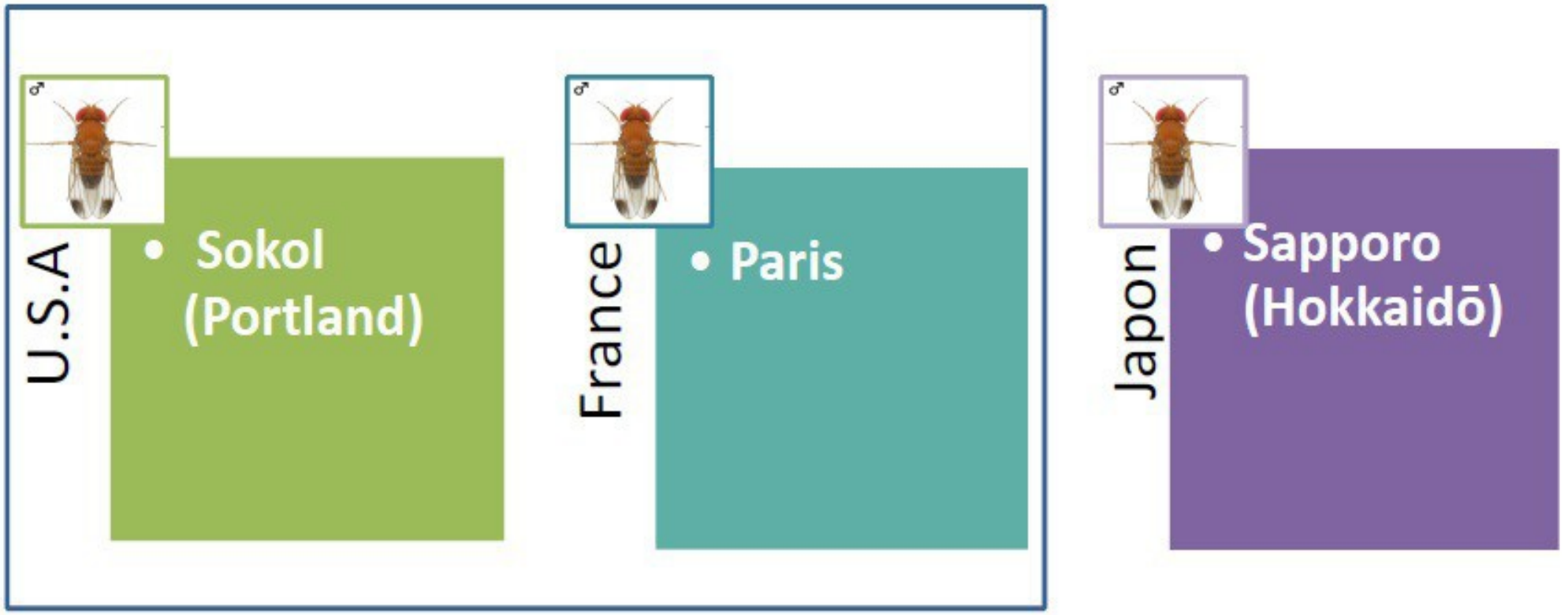


Wayne & Mackay 1998

Is there a relationship between wing plasticity and flight performance?

Testing the effect of developmental temperature on 3 populations of *D. suzukii*

From northern localities within continents



Invasive

Native

Testing the effect of developmental temperature on 3 populations of *D. suzukii*

3 experimental temperatures per population

Sokol

U.S.A

- 16°C *n=10*
- 22°C *n=9*
- 28°C *n=9*

Paris

France

- 16°C *n=6*
- 22°C *n=13*
- 28°C *n=9*

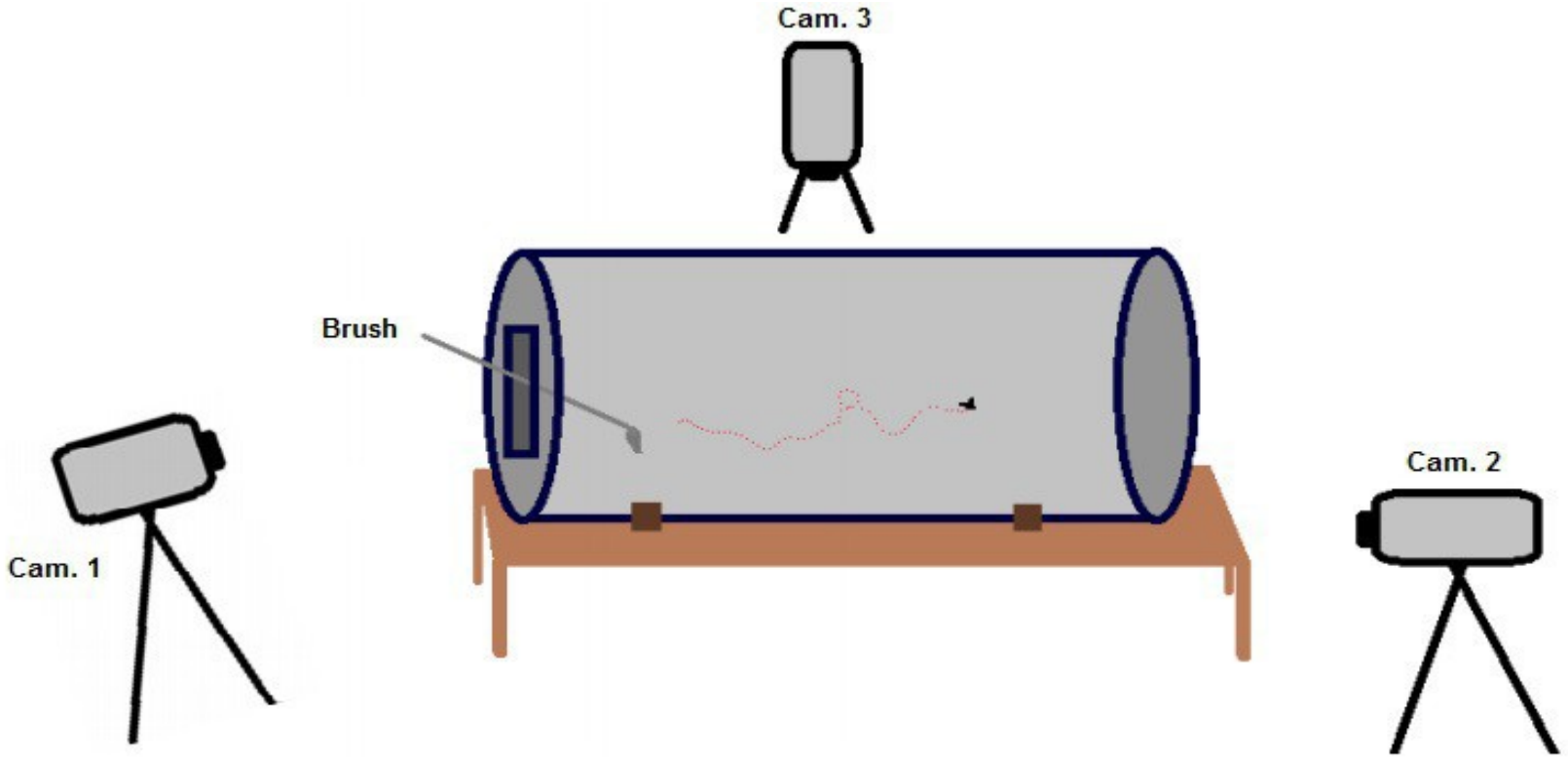
Sapporo

Japon

- 16°C *n=10*
- 22°C *n=12*
- 28°C *n=10*

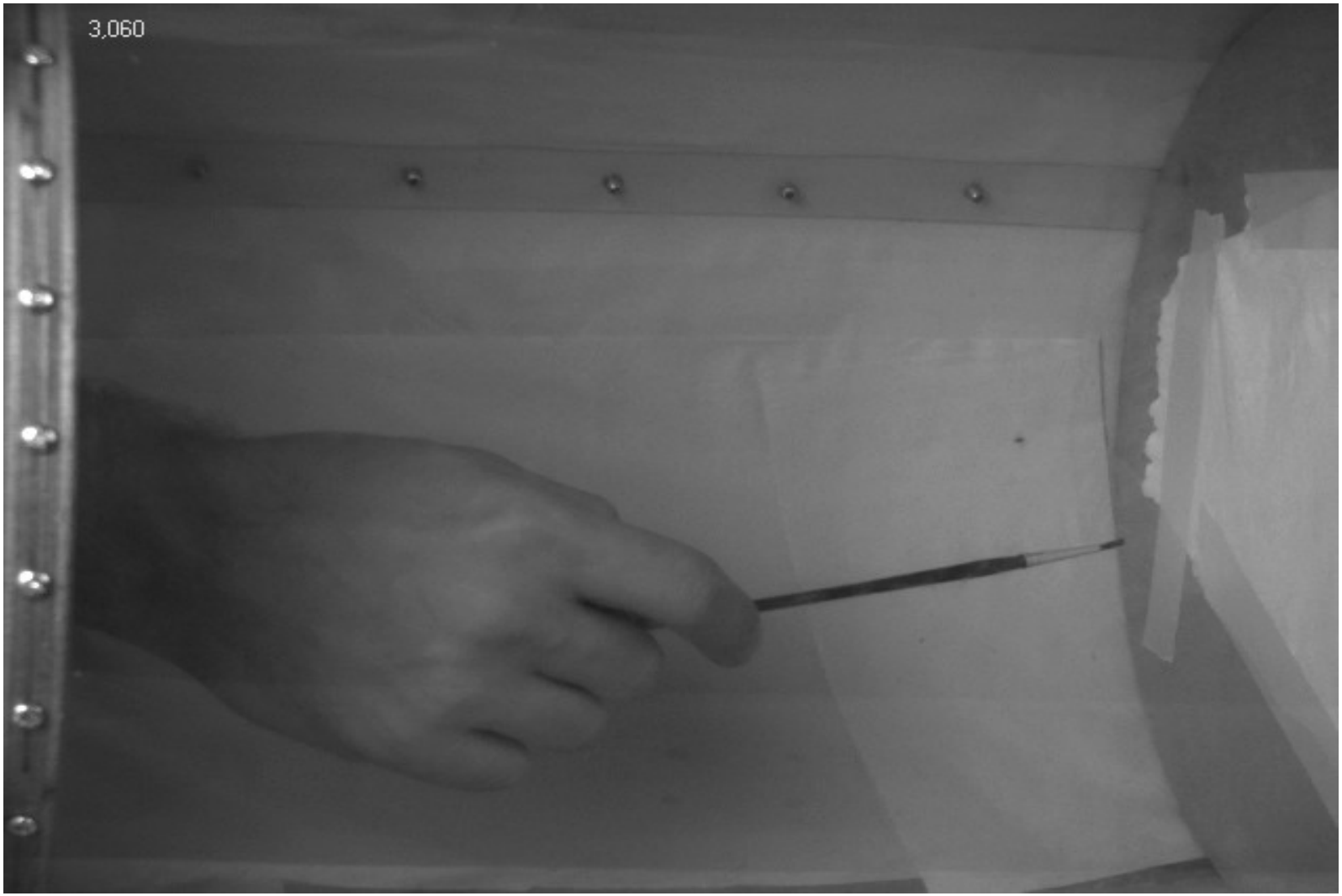
Total = 88

Flight acquisition



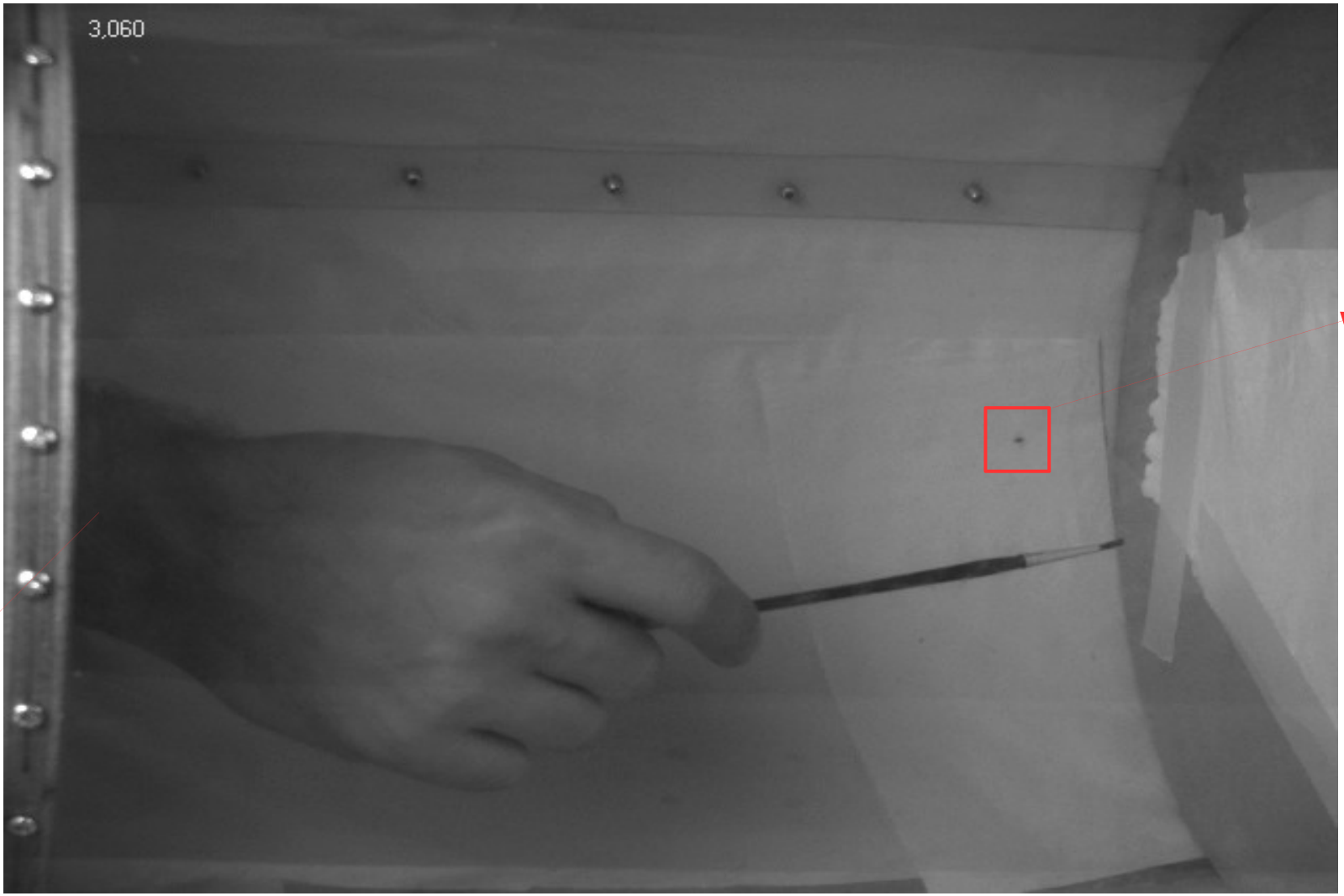
High speed cameras
Temperature constant but not controlled (~22°C)
1 male/line
3 flight/male

Flight acquisition



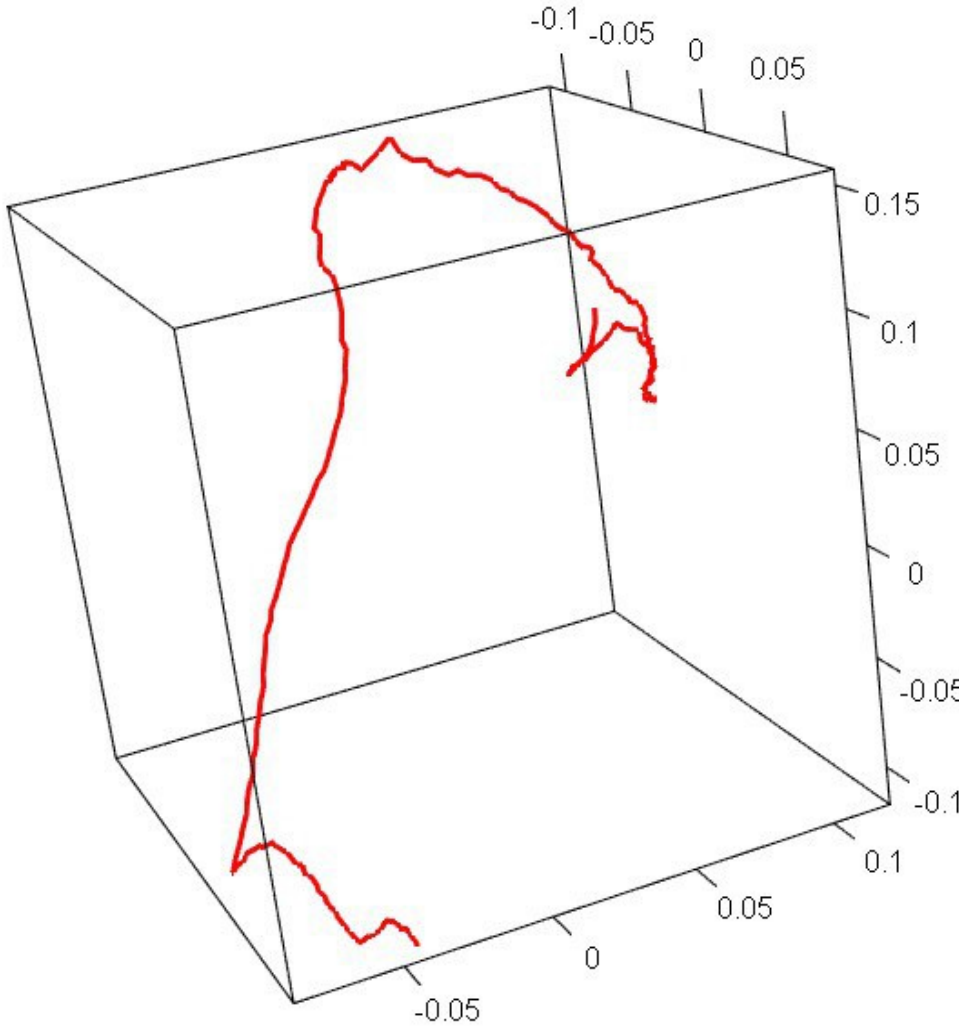
Tracking flight for 2D coordinates

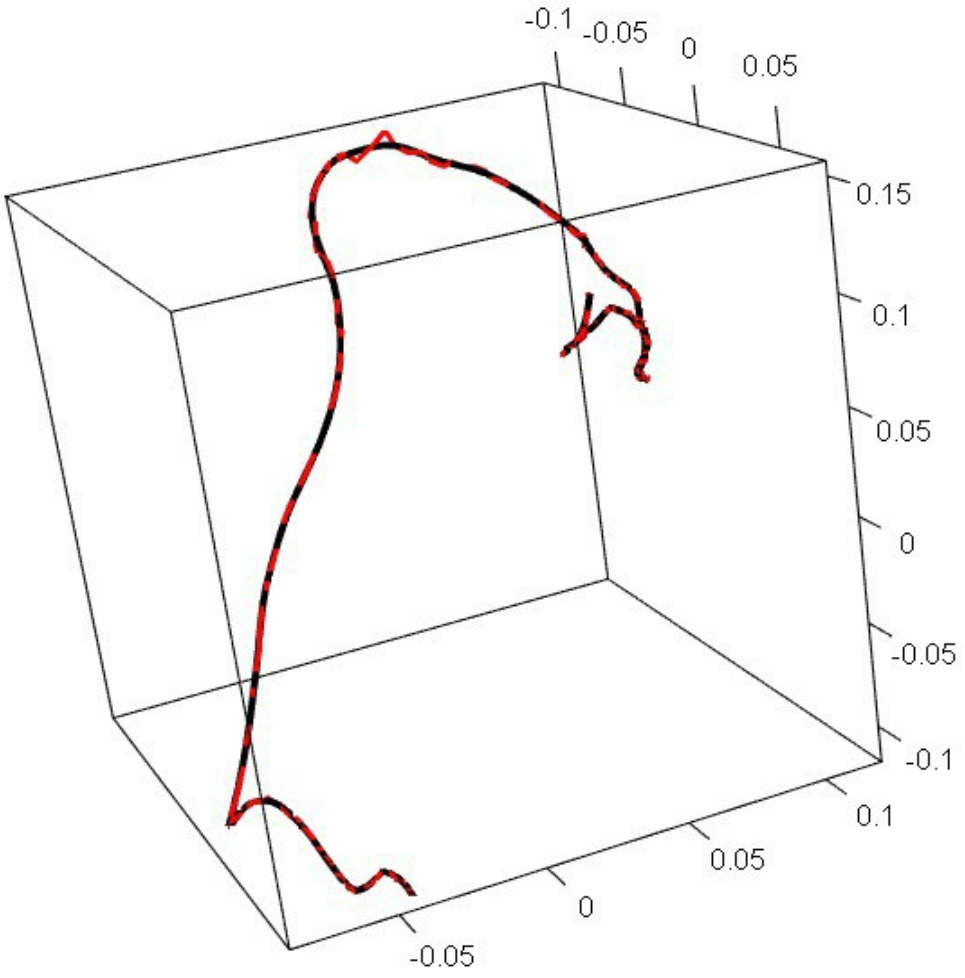
Flight acquisition



Tracking flight for 2D coordinates

Estimating 3D trajectories and flight parameters



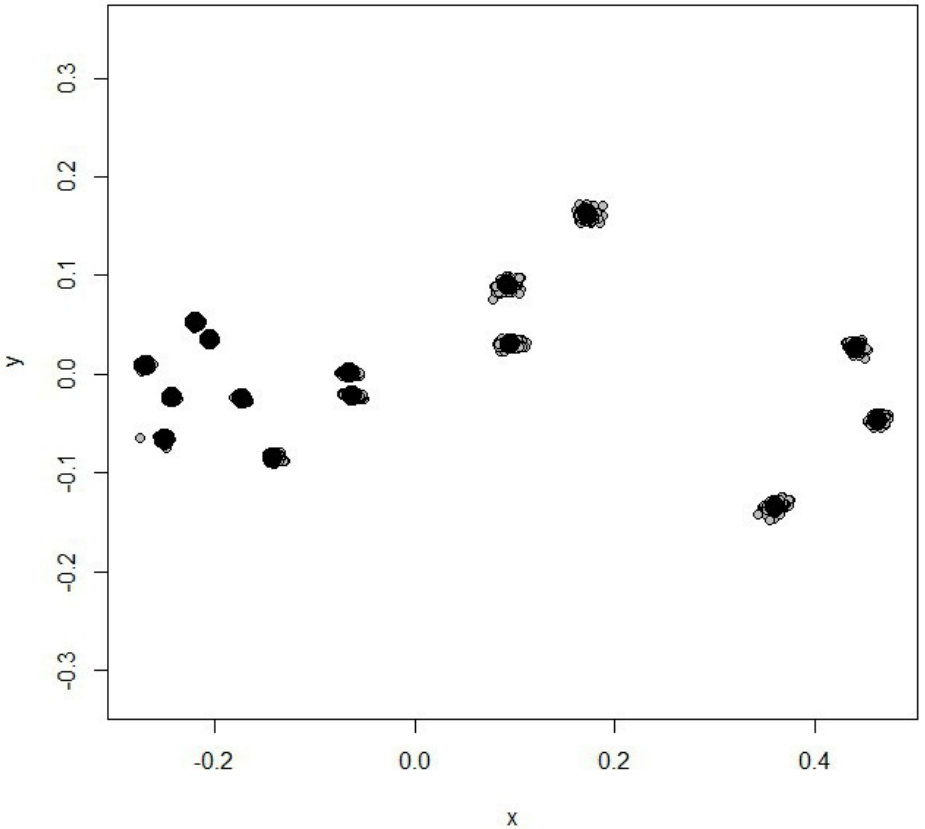


Trajectory smoothing (reducing noise/measurement error)
Flight parameters extraction: velocity, acceleration, sinuosity, angular changes and speed

Wing morphology

Geometric morphometrics

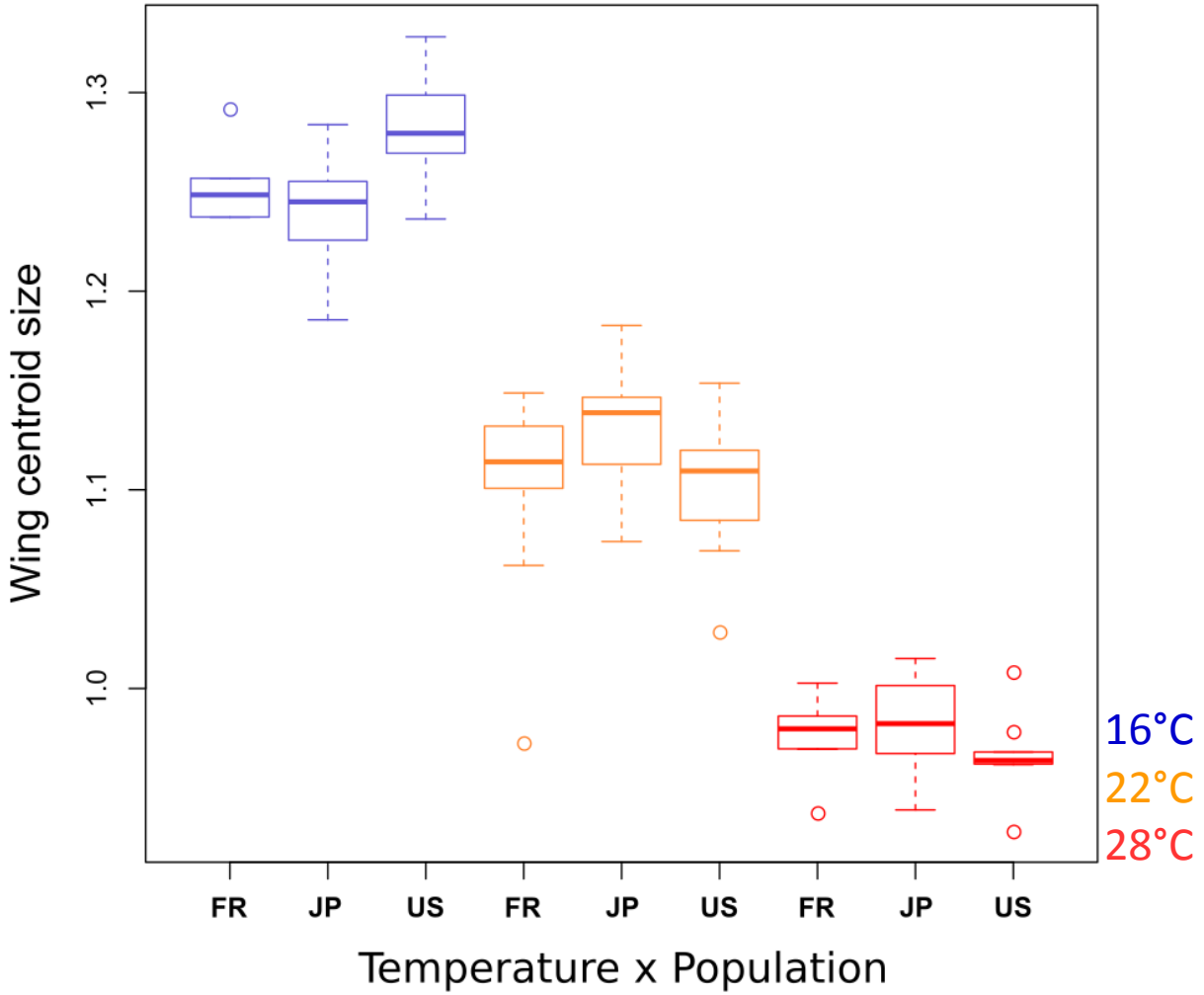
D. suzukii male wing



Procrustes superimposition – from Morpho R package

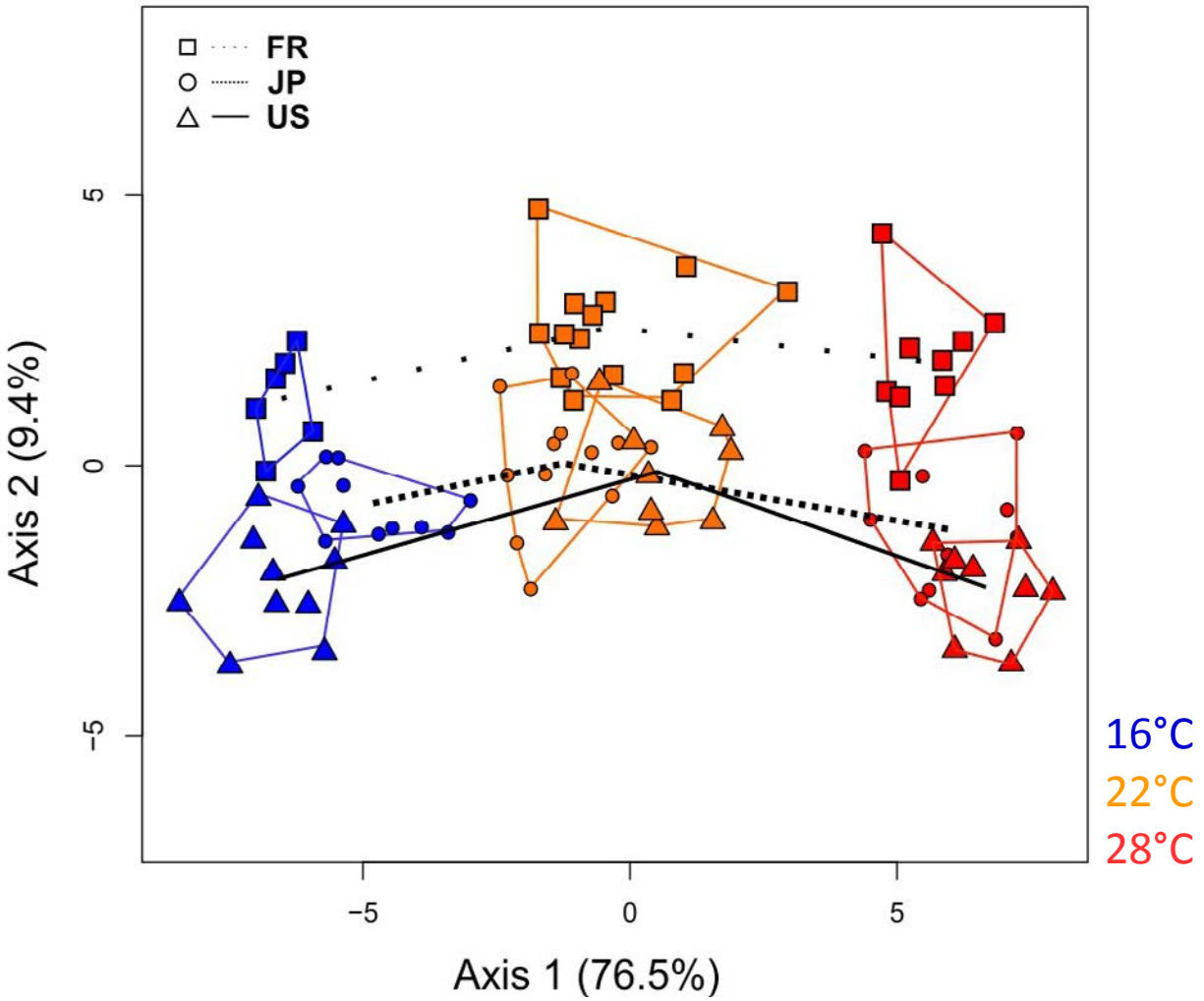
Effect of temperature on wing morphology: wing size

Strong effect of temperature on wing size



Effect of temperature on wing morphology: wing shape

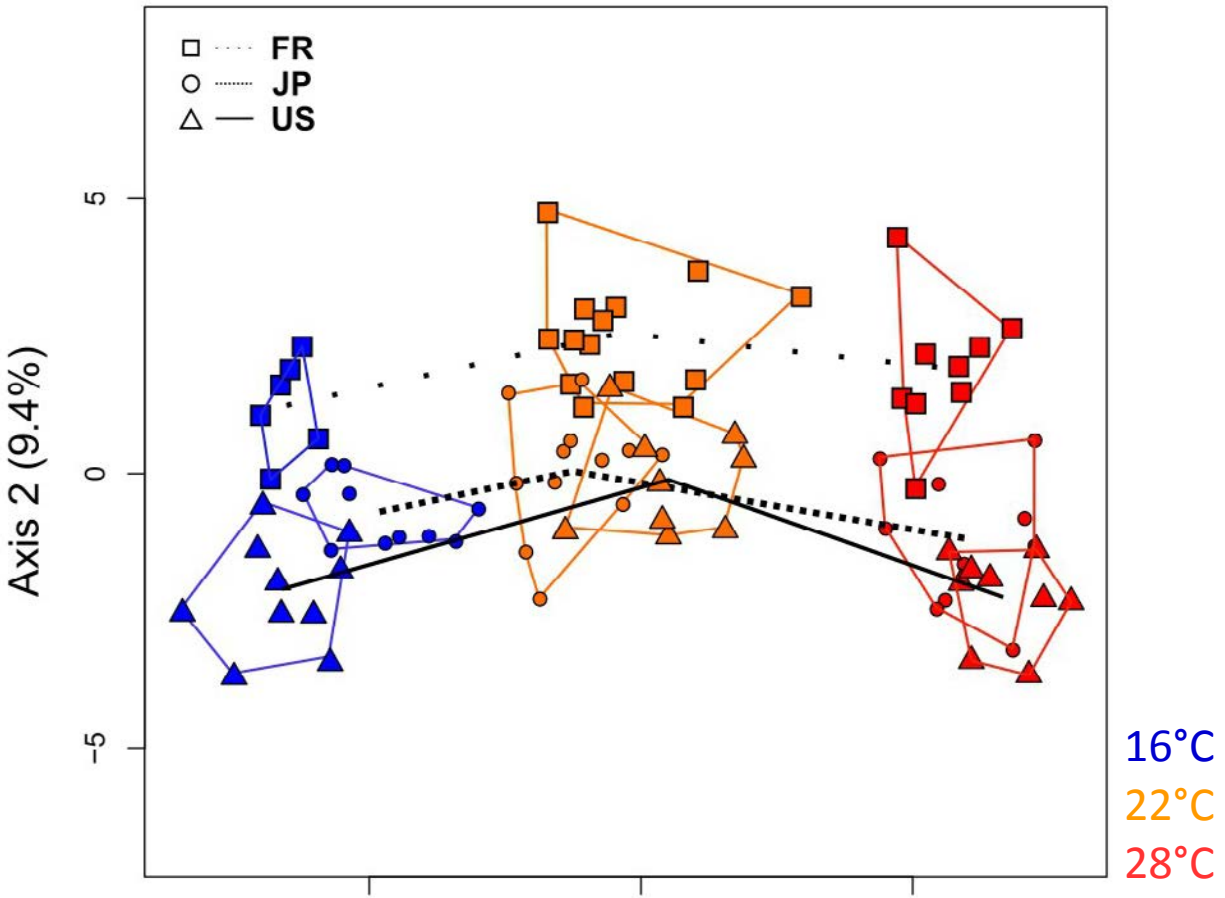
Strong effect of temperature on wing shape (MANOVA p <0.001)

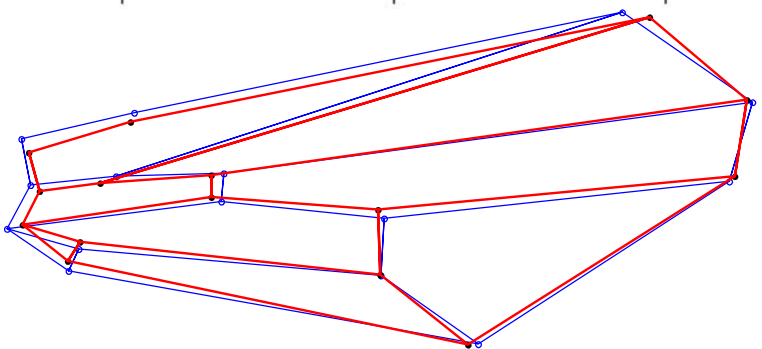


Linear Discriminant Analysis on temperature and population effects

Effect of temperature on wing morphology: wing shape

Strong effect of temperature on wing shape (MANOVA p <0.001)

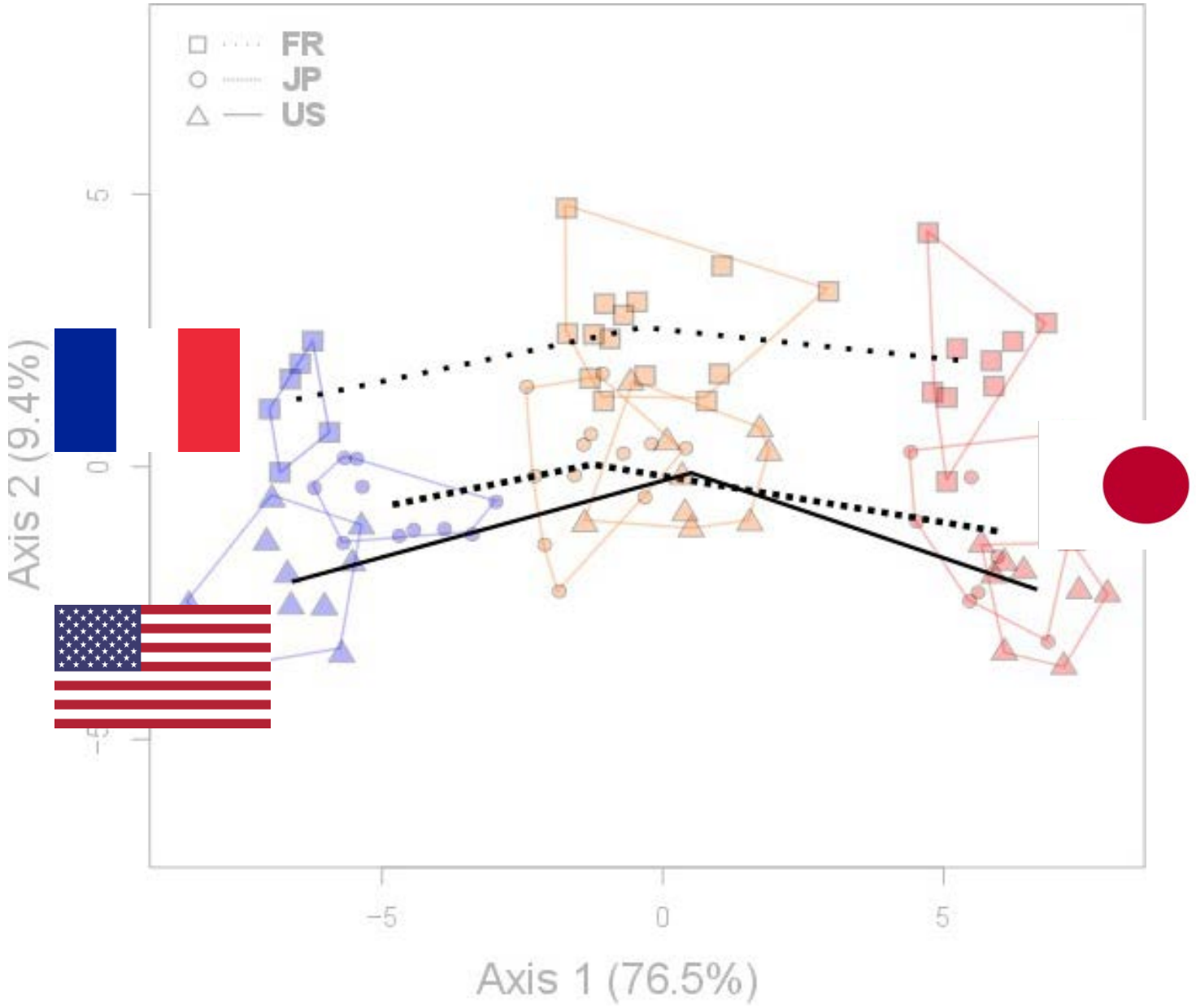




Visualization of shape change (PC1)

Effect of temperature on wing morphology: wing shape

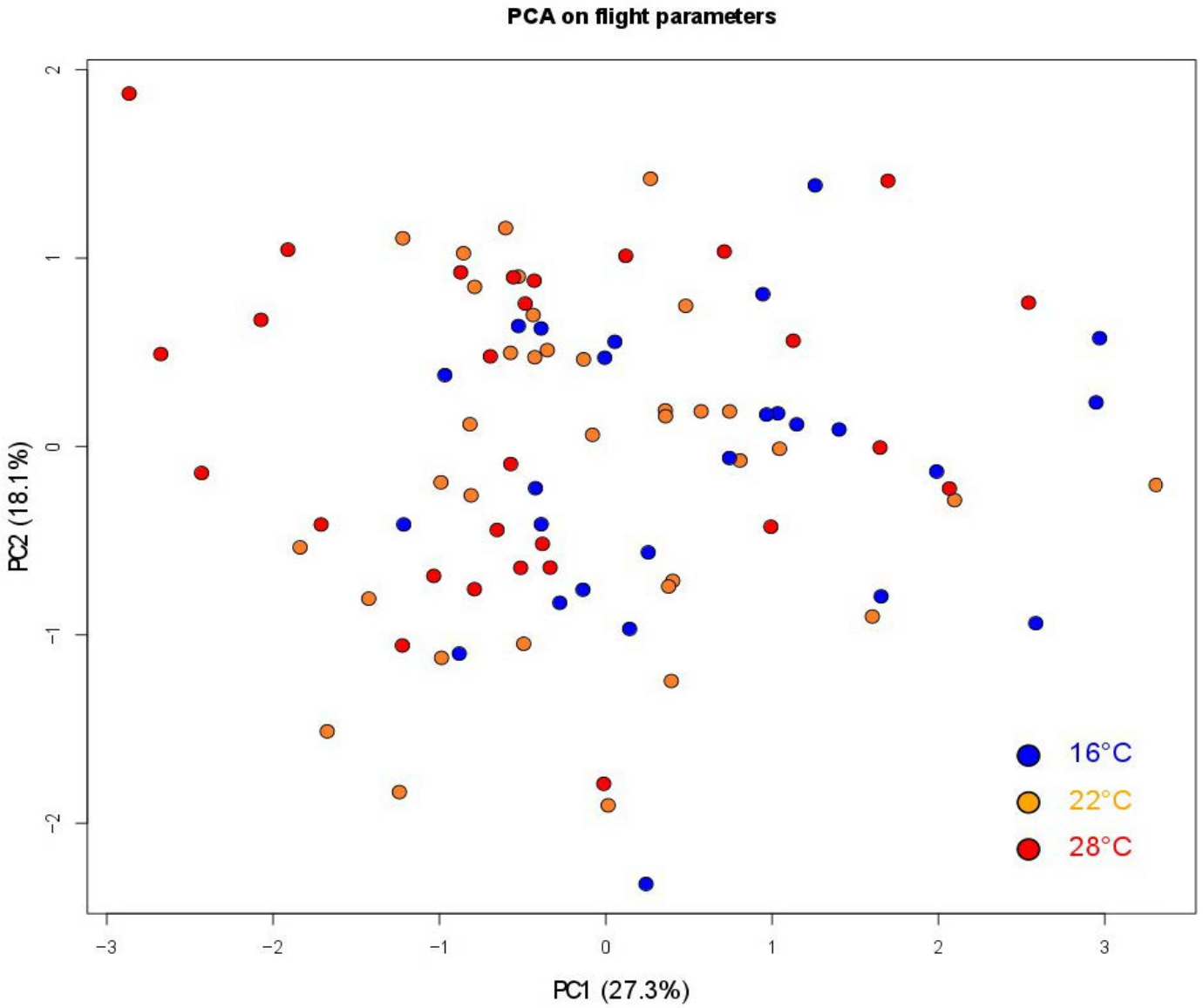
Paralel reaction norms – no difference in phenotypic plasticity

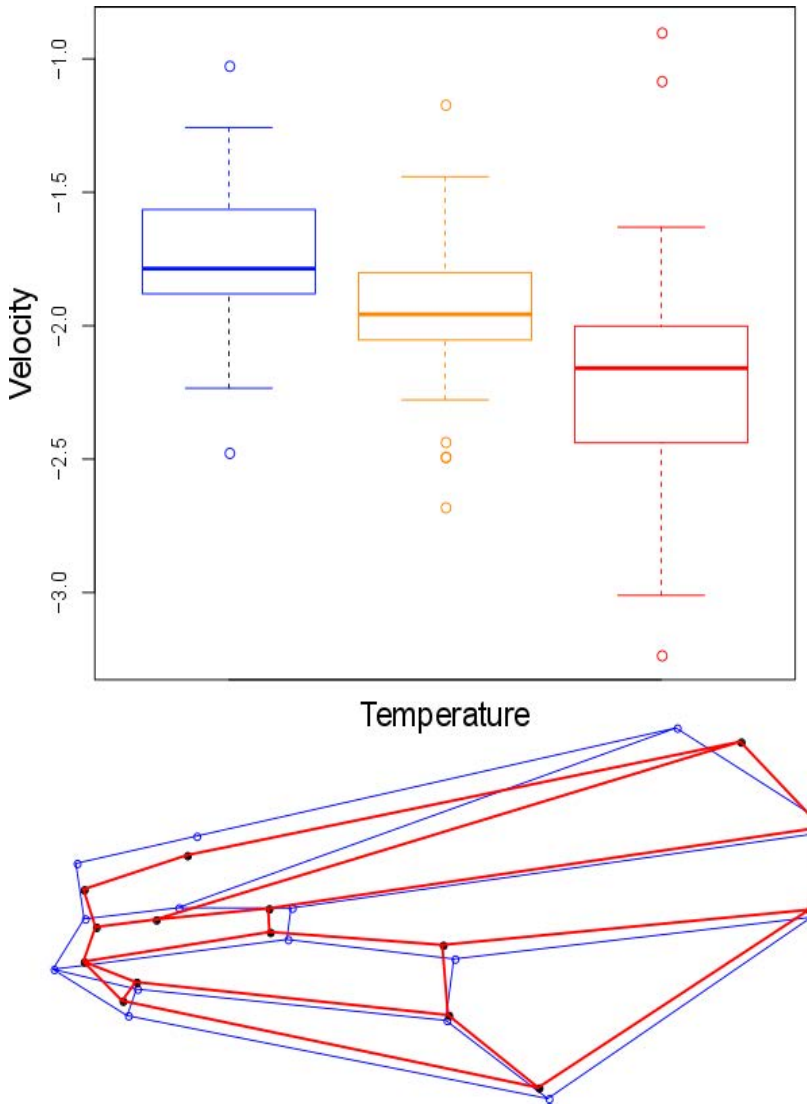


Parallel reaction norm → no difference in plasticity

Effect of temperature on flight

Effect of temperature on global flight (MANOVA $p<0.001$), but no differences between populations





Effect of temperature on particular flight parameters: velocity and acceleration

Conclusions on Chapter 3

Phenotypic plasticity in *D. suzukii*'s invasion

No difference in wing plasticity between native and invasive

Nor in flight performance

Conclusions on Chapter 3

Phenotypic plasticity in *D. suzukii*'s invasion

No difference in wing plasticity between native and invasive

Nor in flight performance

Phenotypic plasticity did not seem to facilitate *D. suzukii*'s invasion

Conclusions on Chapter 3

Phenotypic plasticity in *D. suzukii*'s invasion

- No difference in wing plasticity between native and invasive
- Nor in flight performance
- Phenotypic plasticity did not seem to facilitate *D. suzukii*'s invasion

Association between wing morphology and flight

- Flies reared at 16°C capable of faster flights

Conclusions on Chapter 3

Phenotypic plasticity in *D. suzukii*'s invasion

- No difference in wing plasticity between native and invasive
- Nor in flight performance
- Phenotypic plasticity did not seem to facilitate *D. suzukii*'s invasion

Association between wing morphology and flight

- Flies reared at 16°C capable of faster flights
- Adaptive plasticity?

Conclusions on Chapter 3

Phenotypic plasticity in *D. suzukii*'s invasion

- No difference in wing plasticity between native and invasive
- Nor in flight performance
- Phenotypic plasticity did not seem to facilitate *D. suzukii*'s invasion

Association between wing morphology and flight

- Flies reared at 16°C capable of faster flights
- Adaptive plasticity?
- Is 16°C an optimal temperature for *D. suzukii* ?

Conclusions on Chapter 3

Phenotypic plasticity in *D. suzukii*'s invasion

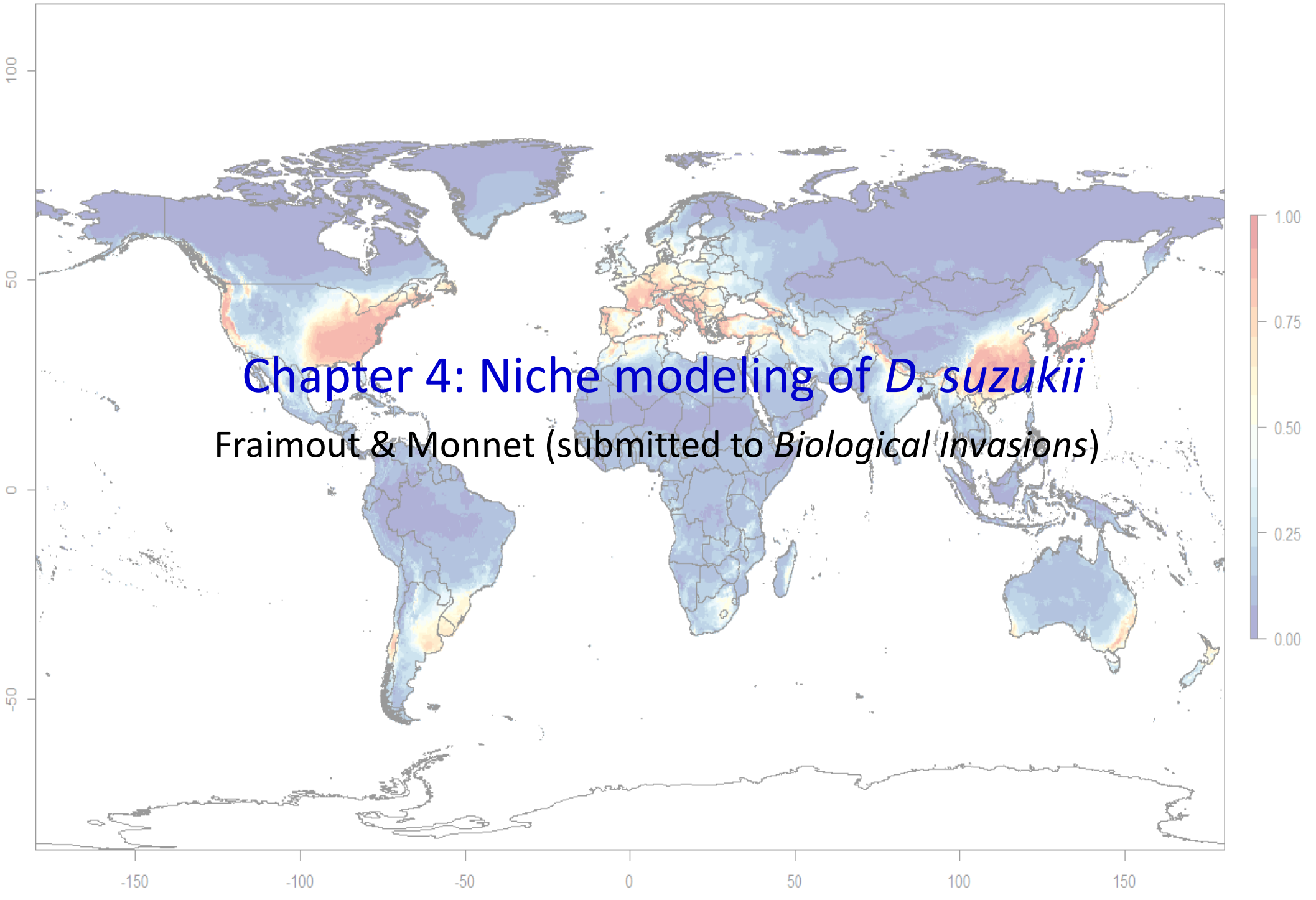
- No difference in wing plasticity between native and invasive
- Nor in flight performance
- Phenotypic plasticity did not seem to facilitate *D. suzukii*'s invasion

Association between wing morphology and flight

- Flies reared at 16°C capable of faster flights
- Adaptive plasticity?
- Is 16°C an optimal temperature for *D. suzukii* ?
- Need to characterize the climatic niche of the species

Chapter 4: Niche modeling of *D. suzukii*

Fraimout & Monnet (submitted to *Biological Invasions*)



Linking evolution to ecology

Invasive species are thought to experience rapid evolution in response to environmental changes

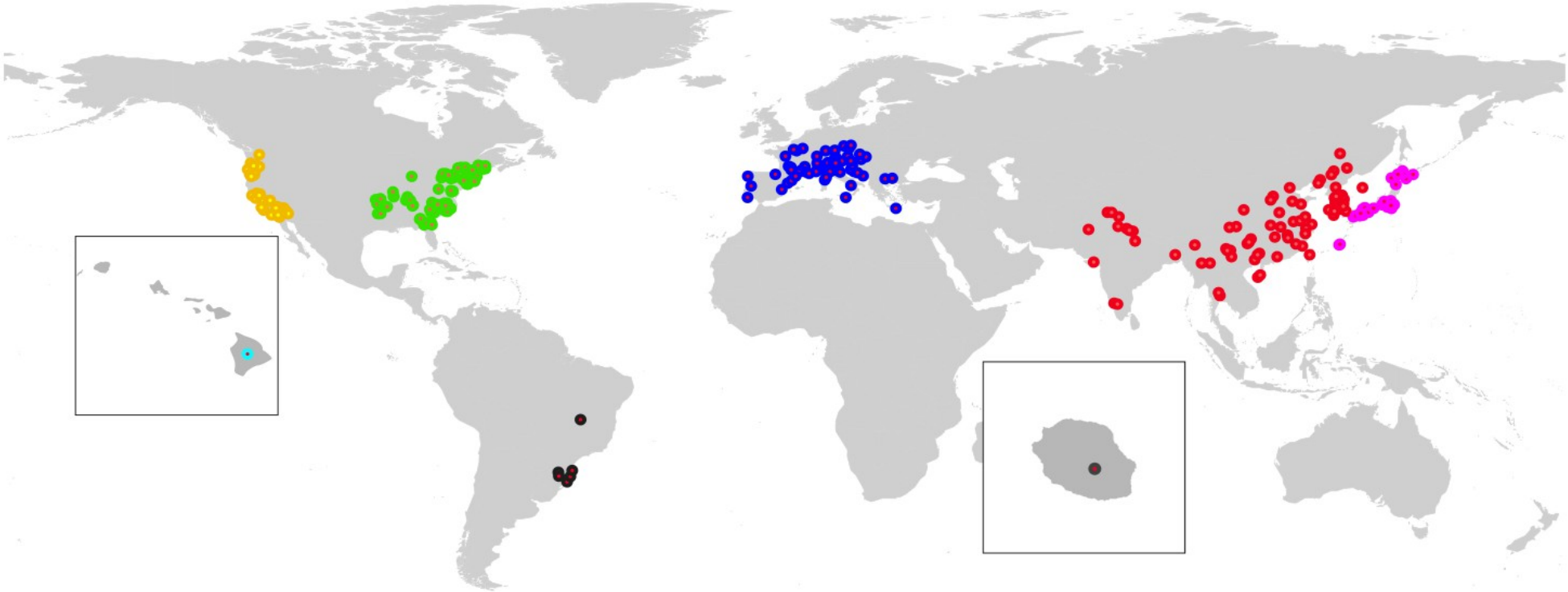
How much environmental change did *D. suzukii* experience?

Can previous result be explained by environmental changes?

What is the climatic optimum for *D. suzukii* ?

Estimation of the climatic niche of *D. suzukii* from presence data

Occurence data worldwide from field, litterature and databases



Estimation of the climatic niche of *D. suzukii* from presence data

Climatic variables from the worldclim database

Annual mean temperature

Temperature seasonality

Temperature of the coldest month

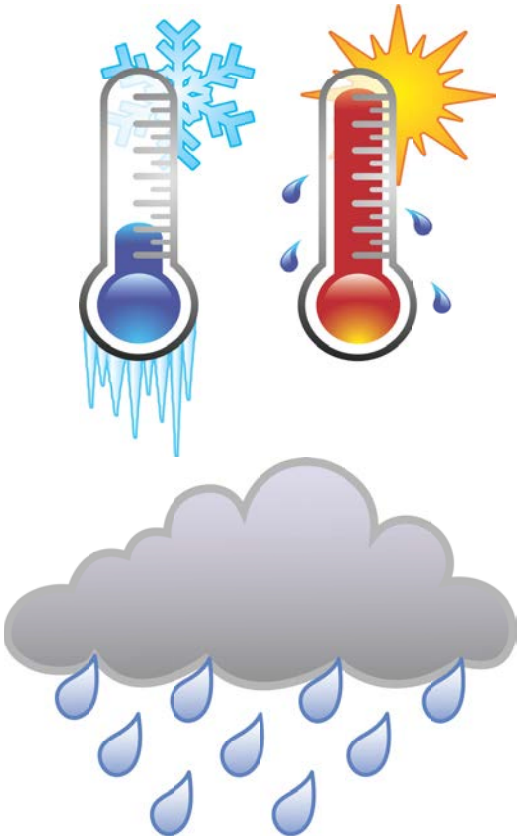
Temperature of the warmest month

Annual mean precipitation

Precipitation seasonality

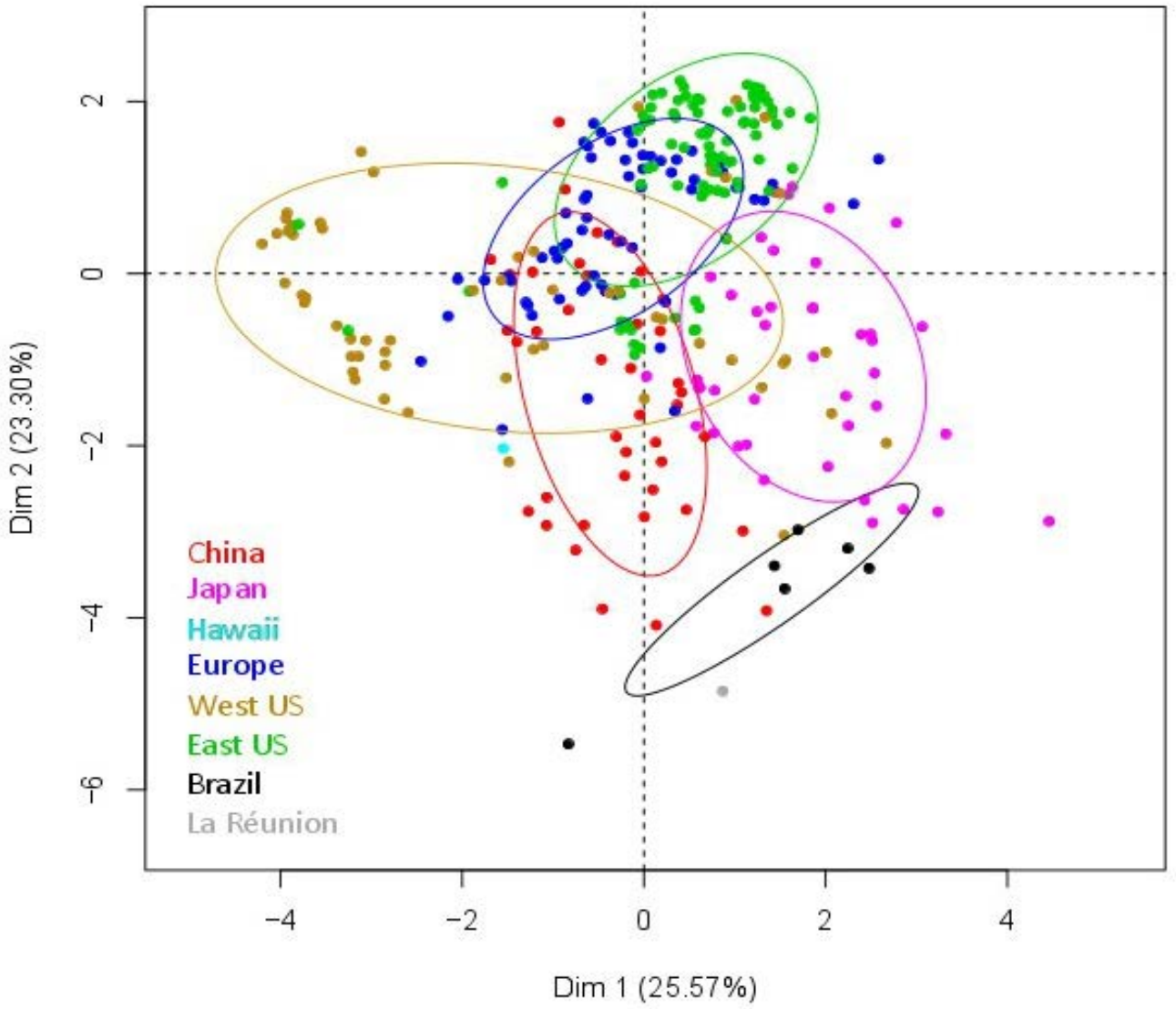
Precipitation of the driest month

Precipitation of the wettest month



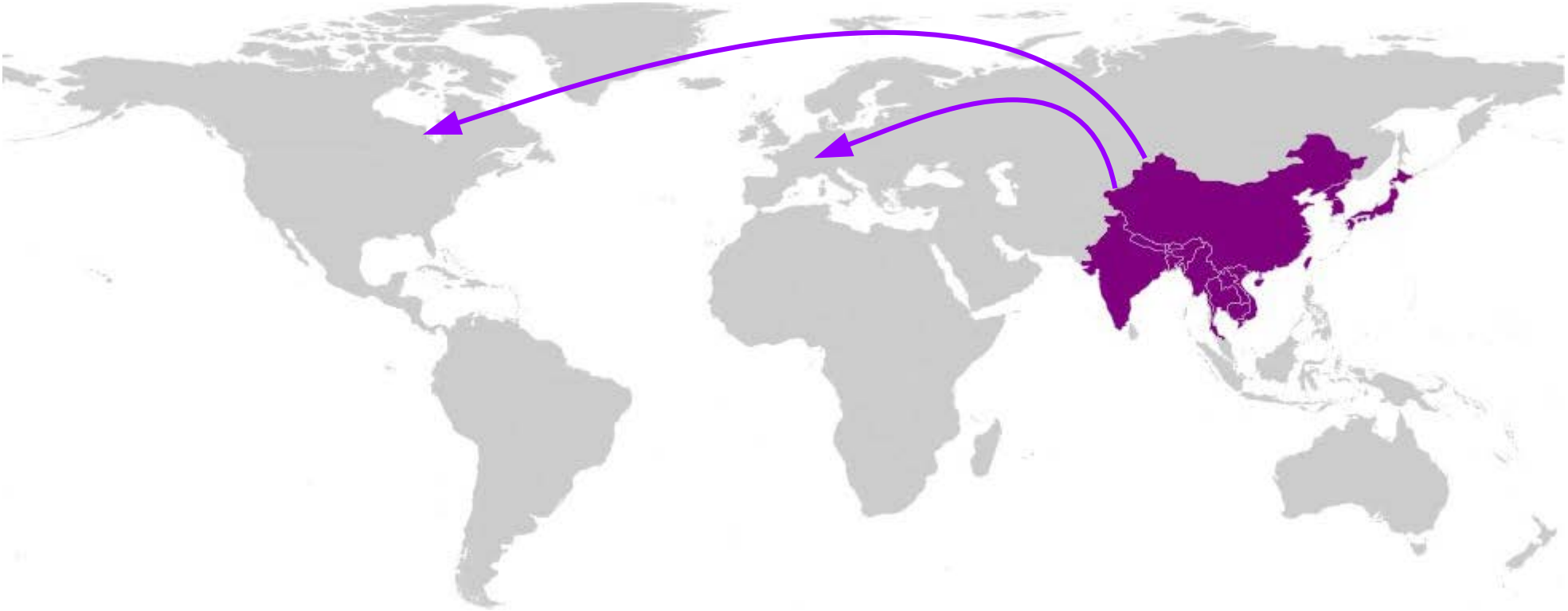
Estimation of the climatic niche of *D. suzukii* from presence data

Principal component analysis



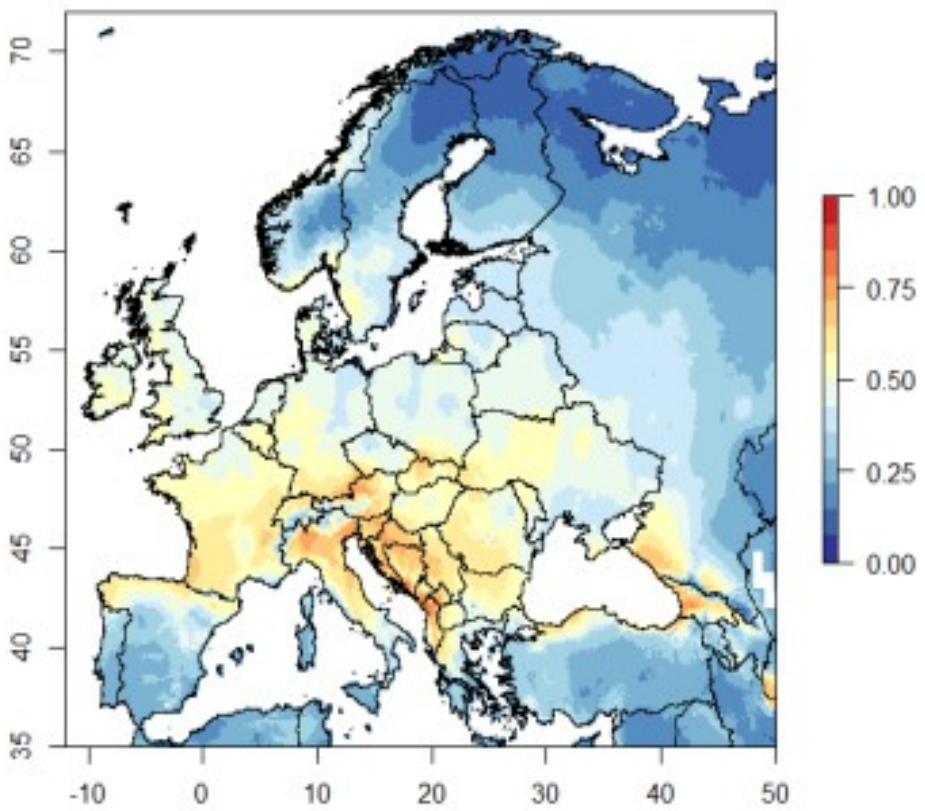
Quantifying the ancestral niche through species niche modeling (SDM)

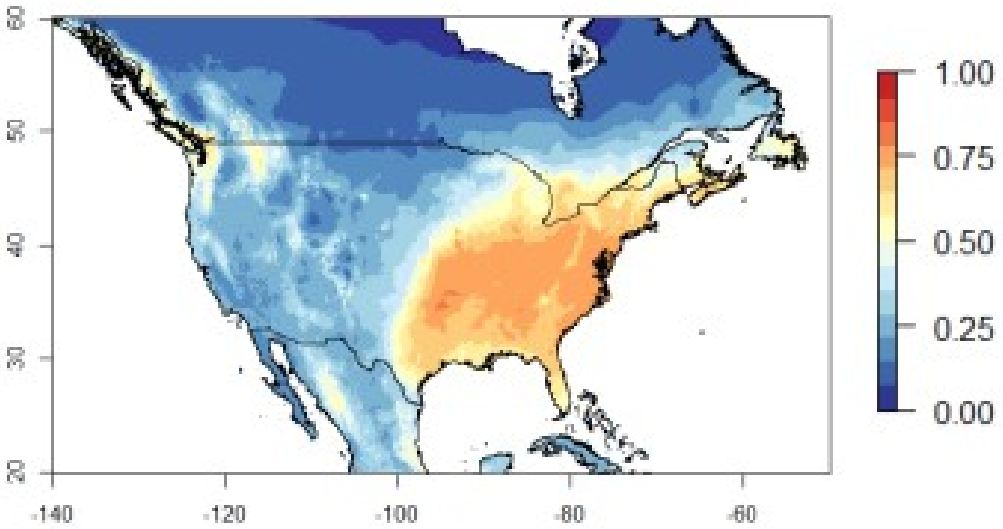
Projection of the ancestral niche in invaded ranges



Projection of the ancestral niche in invaded ranges

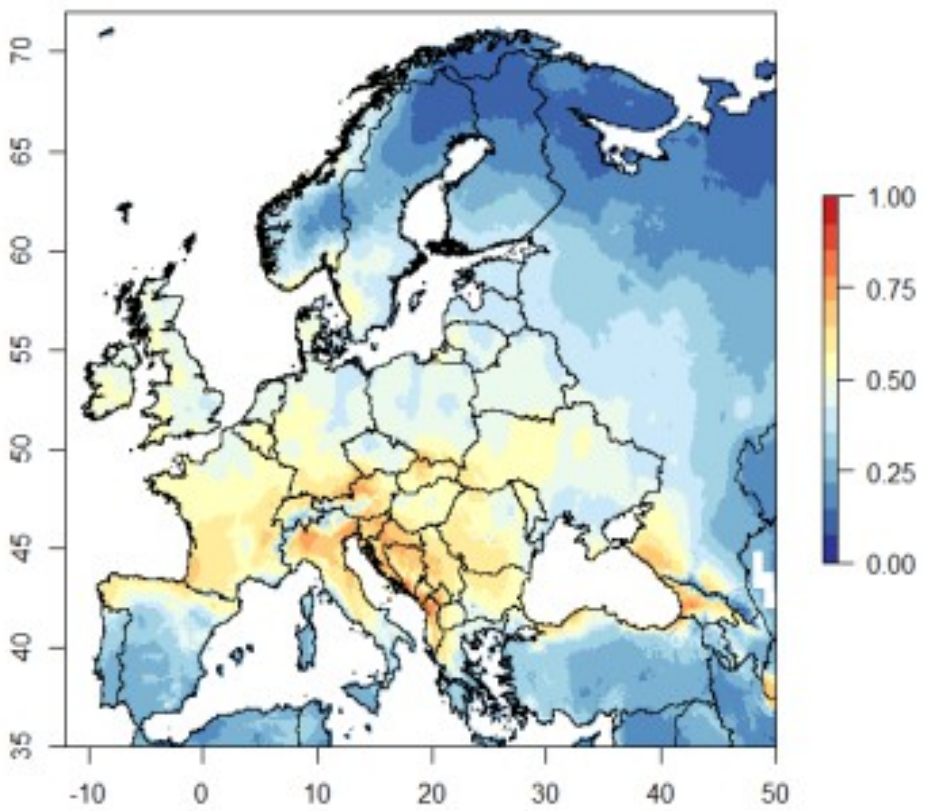
From Asia to Europe and USA

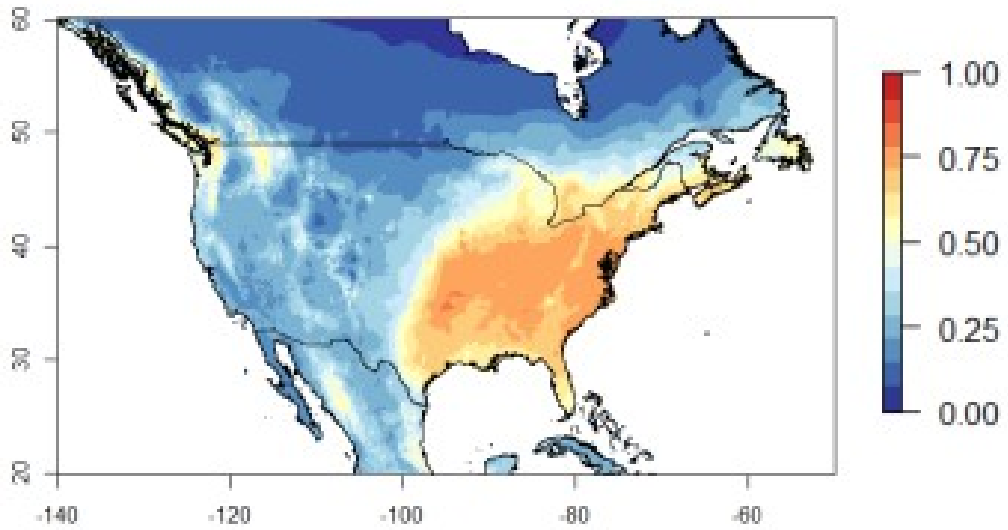




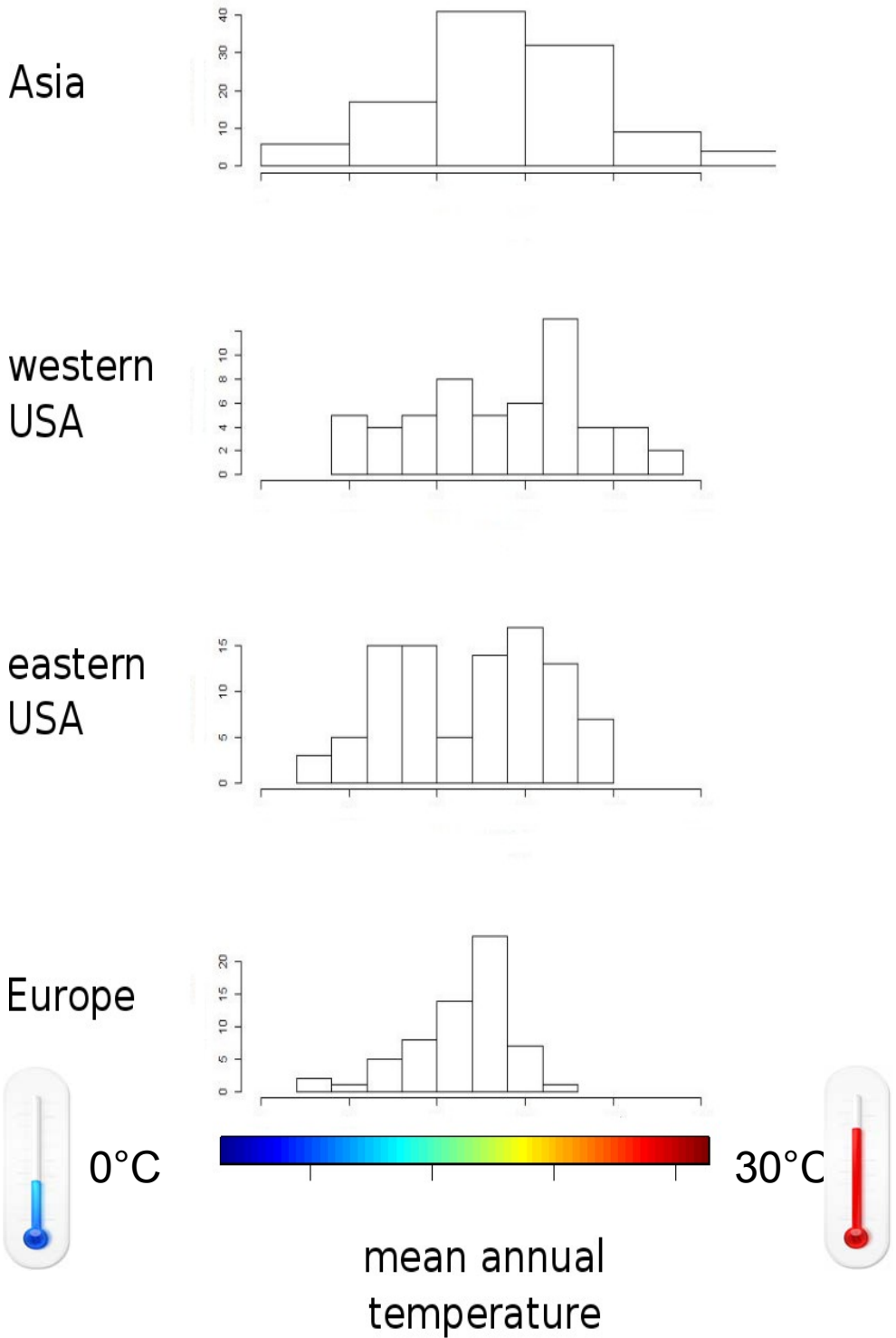
Projection of the ancestral niche in invaded ranges

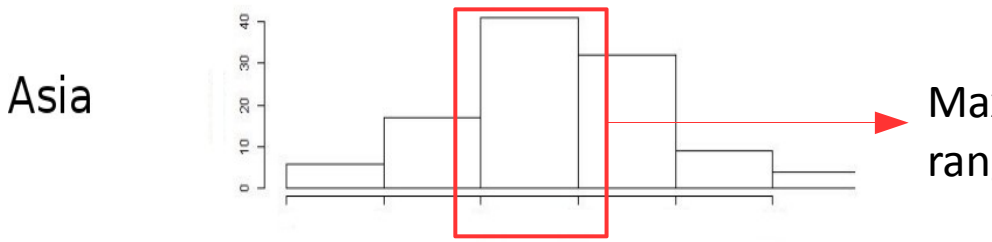
From Asia to Europe and USA





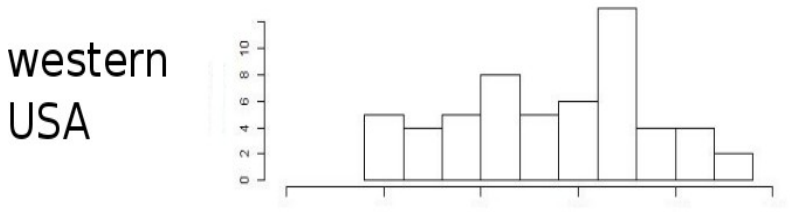
Very low probability of presence in western USA

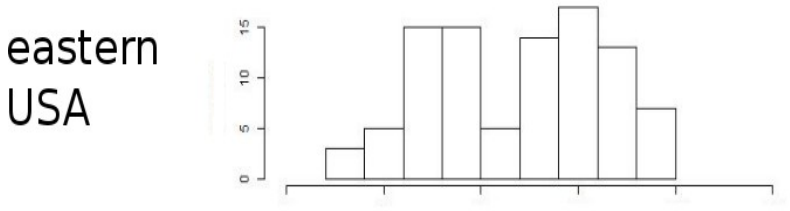

Asia
western USA
eastern USA
Europe
0°C
30°C
mean annual temperature

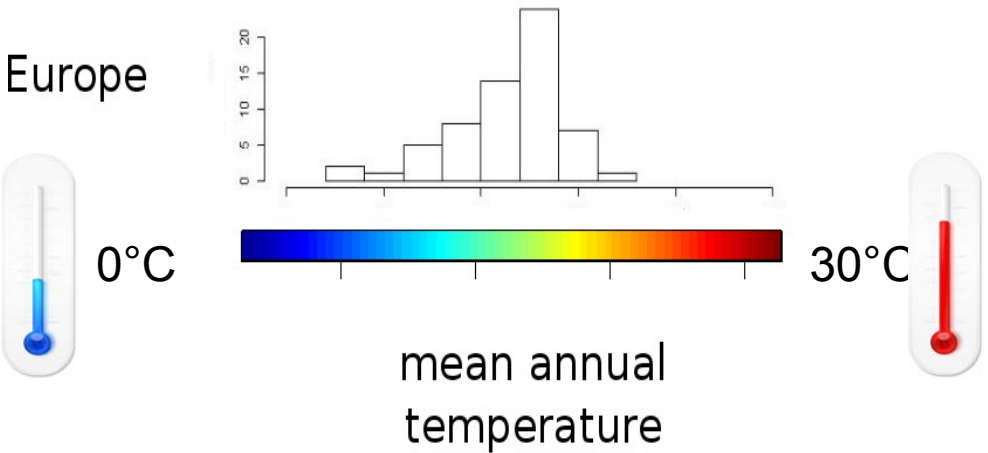


Maximum occurence in the native range between 10-15°C

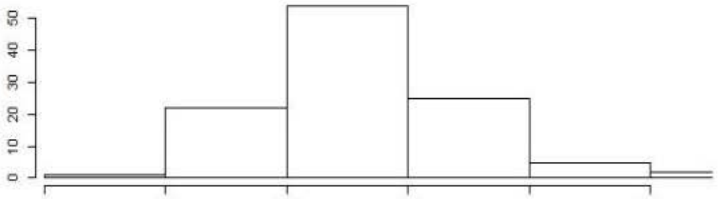
Historical temperature optimum could indeed be ~16°C



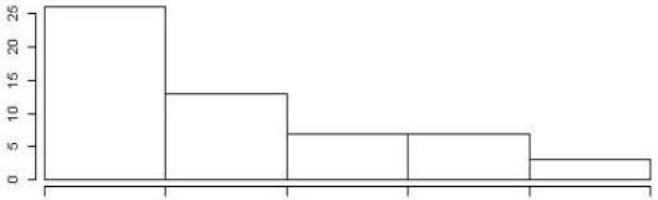




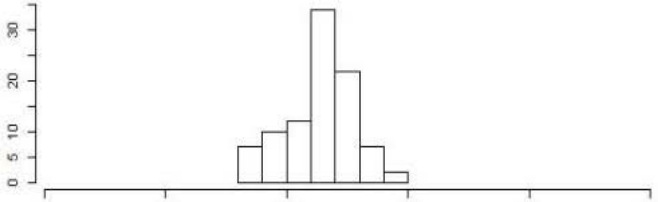
Asia



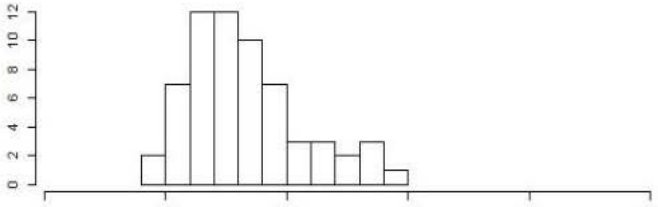
western USA



eastern USA

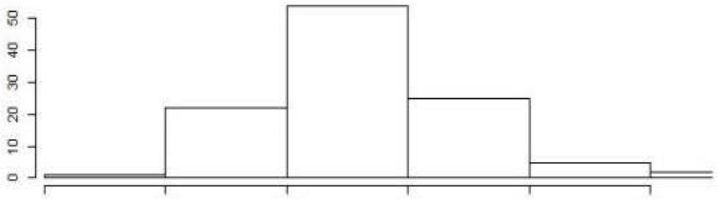


Europe

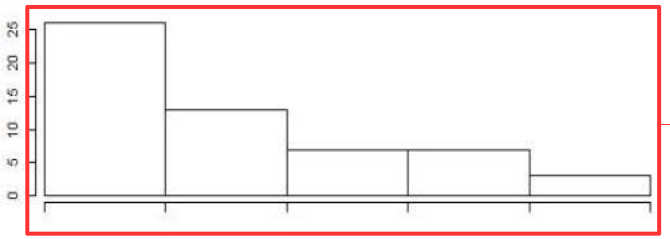


mean annual precipitation

Asia

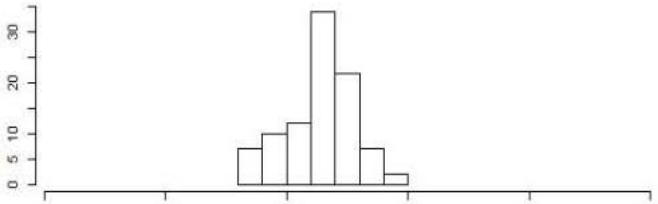


western USA

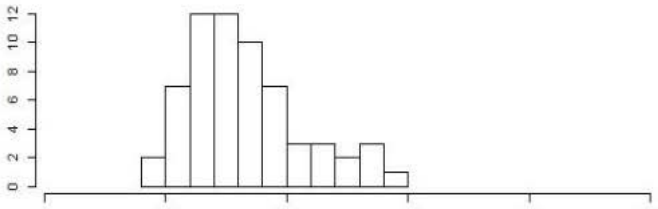


→ Shift to dry climate

eastern USA



Europe



mean annual precipitation

Conclusions on Chapter 4

Climatic niche

Climate diversity worldwide

Conclusions on Chapter 4

Climatic niche

Climate diversity worldwide

Wide ancestral niche emcompasses invasive climates (eastern USA and Europe)

Conclusions on Chapter 4

Climatic niche

- Climate diversity worldwide
- Wide ancestral niche emcompasses invasive climates (eastern USA and Europe)
- Optimal climate seems temperate (16°C and not dry)

Conclusions on Chapter 4

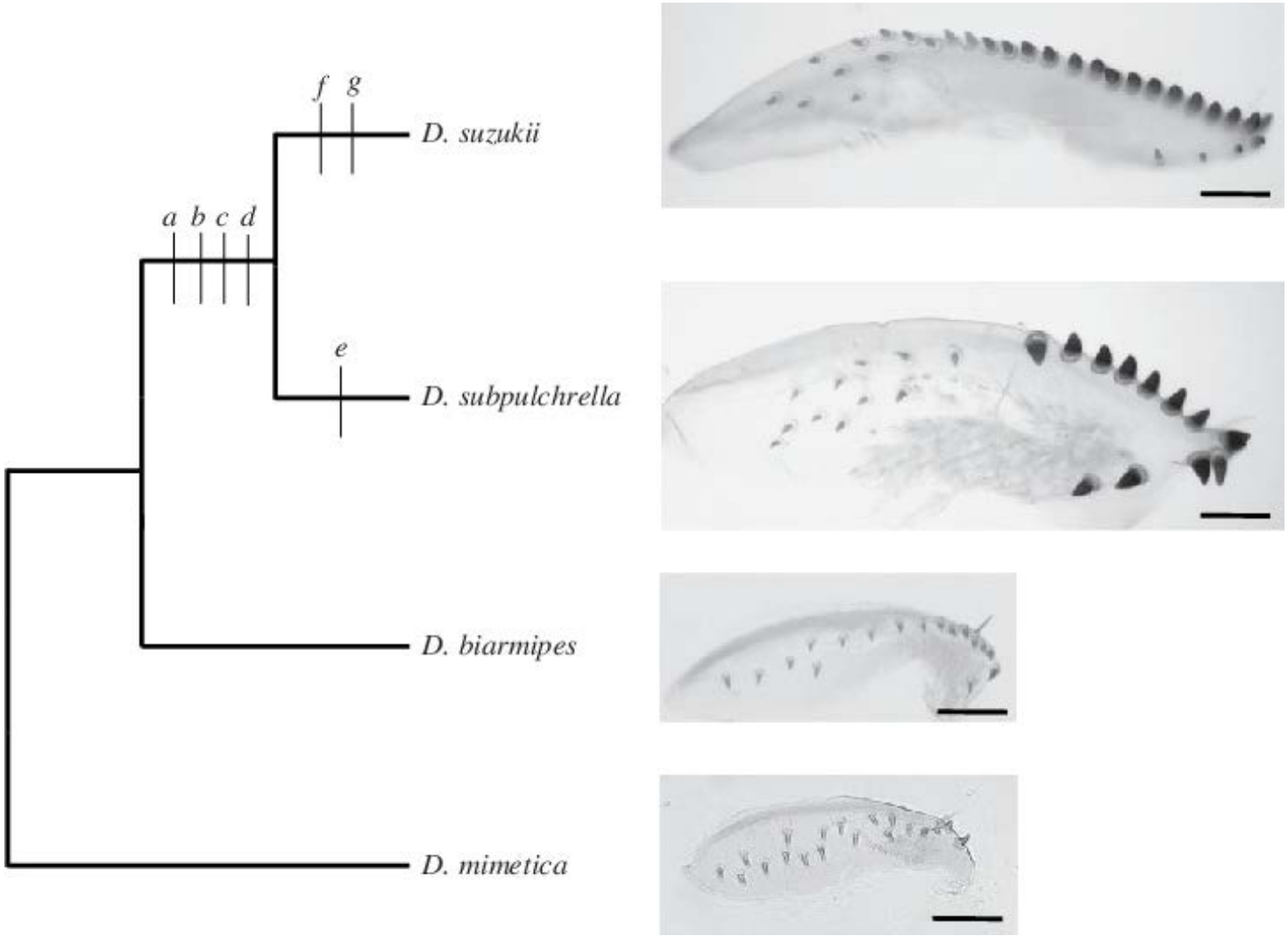
Climatic niche

- Climate diversity worldwide
- Wide ancestral niche emcompasses invasive climates (eastern USA and Europe)
- Optimal climate seems temperate (16°C and not dry)
- However niche shift to very dry climate in southern USA

Post-doc CBGP

D. suzukii's ovipositor morphometrics

D. suzukii's ovipositor



Atallah *et al.* 2014, *Proc. B.*

How variable is the ovipositor?

Genetic variation?

How variable is the ovipositor?

- Genetic variation?
- Between different populations?

How variable is the ovipositor?

- Genetic variation?
- Between different populations?

- Environmental variation (plasticity)?

How variable is the ovipositor?

Genetic variation?

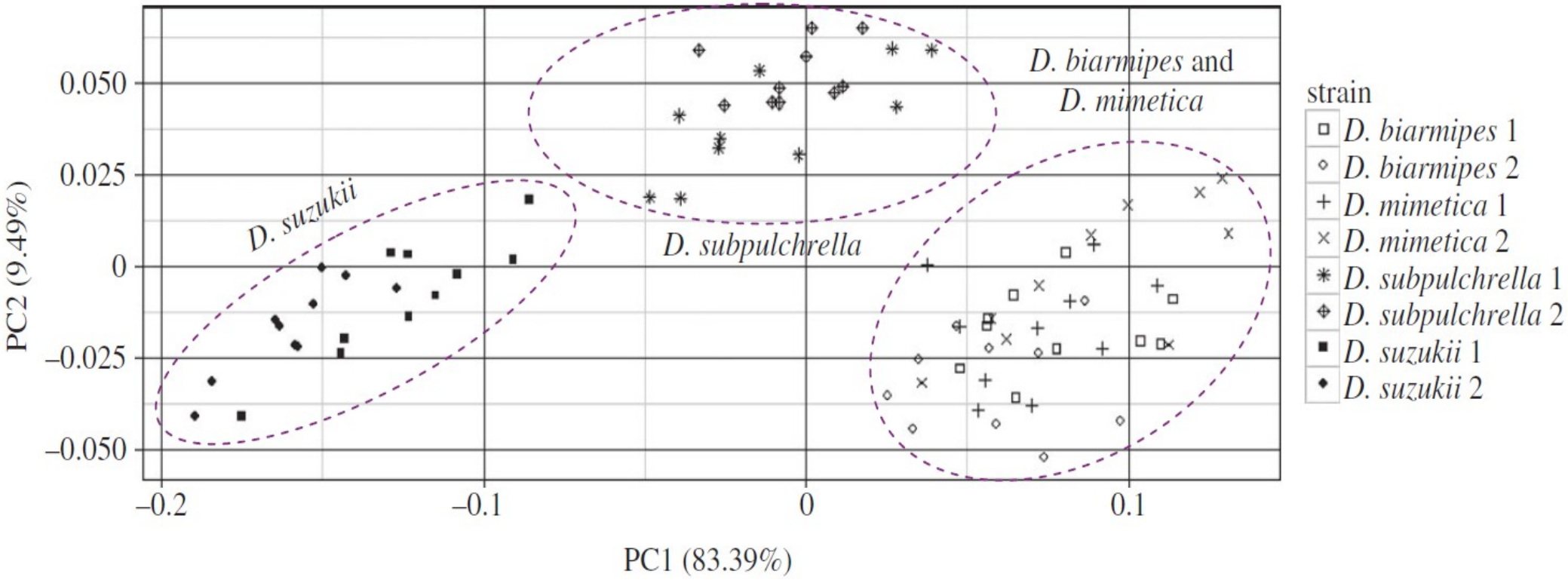
Between different populations?

Environmental variation (plasticity)?

Between different temperatures, substrate etc.

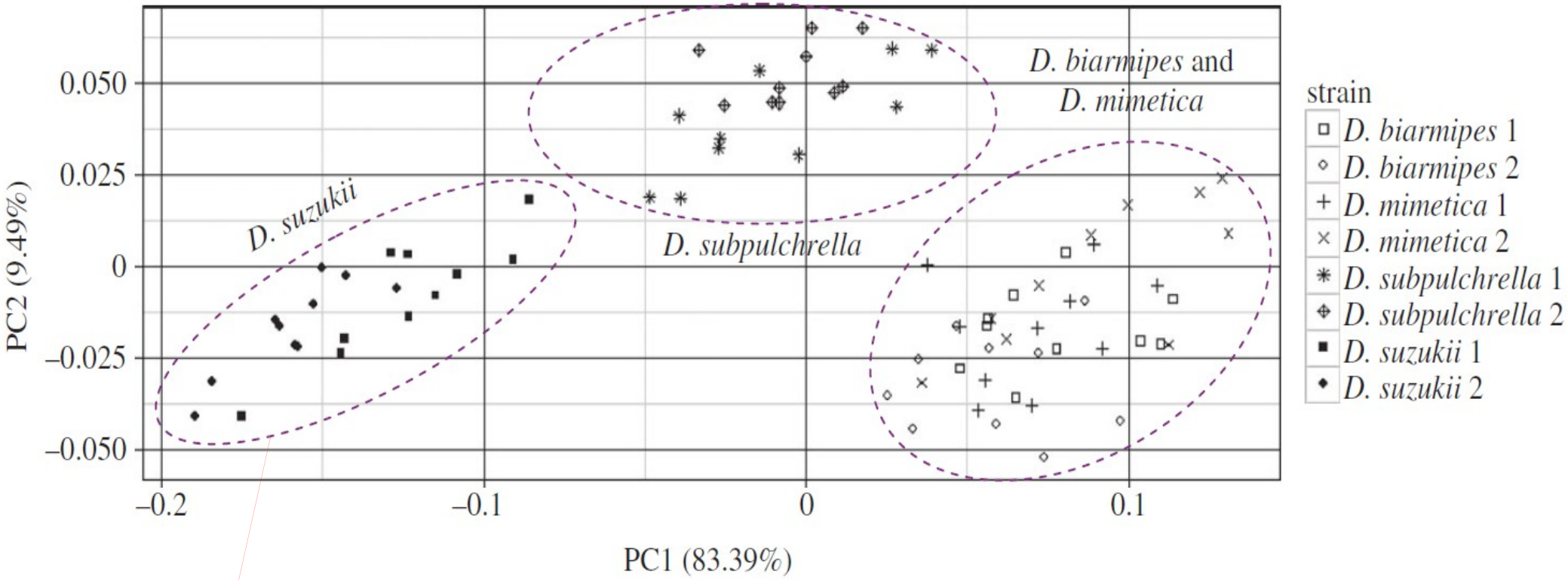
How variable is the ovipositor?

Few information so far



Atallah *et al.* 2014, *Proc. B.*

How variable is the ovipositor?



Only two lab-reared lines used here

Atallah *et al.* 2014, *Proc. B.*

Characterization of ovipositor's morphology

Using multiple lab-reared lines

Sokol

U.S.A

- 16°C *n=10*
- 22°C *n=9*
- 28°C *n=9*

Paris

France

- 16°C *n=6*
- 22°C *n=13*
- 28°C *n=9*

Sapporo

Japon

- 16°C *n=10*
- 22°C *n=12*
- 28°C *n=10*

Total = 88

Within treatment between populations = genetic variation
Within population between treatment = plastic variation

Characterization of ovipositor's morphology

Using multiple lab-reared lines + natural populations from different sources

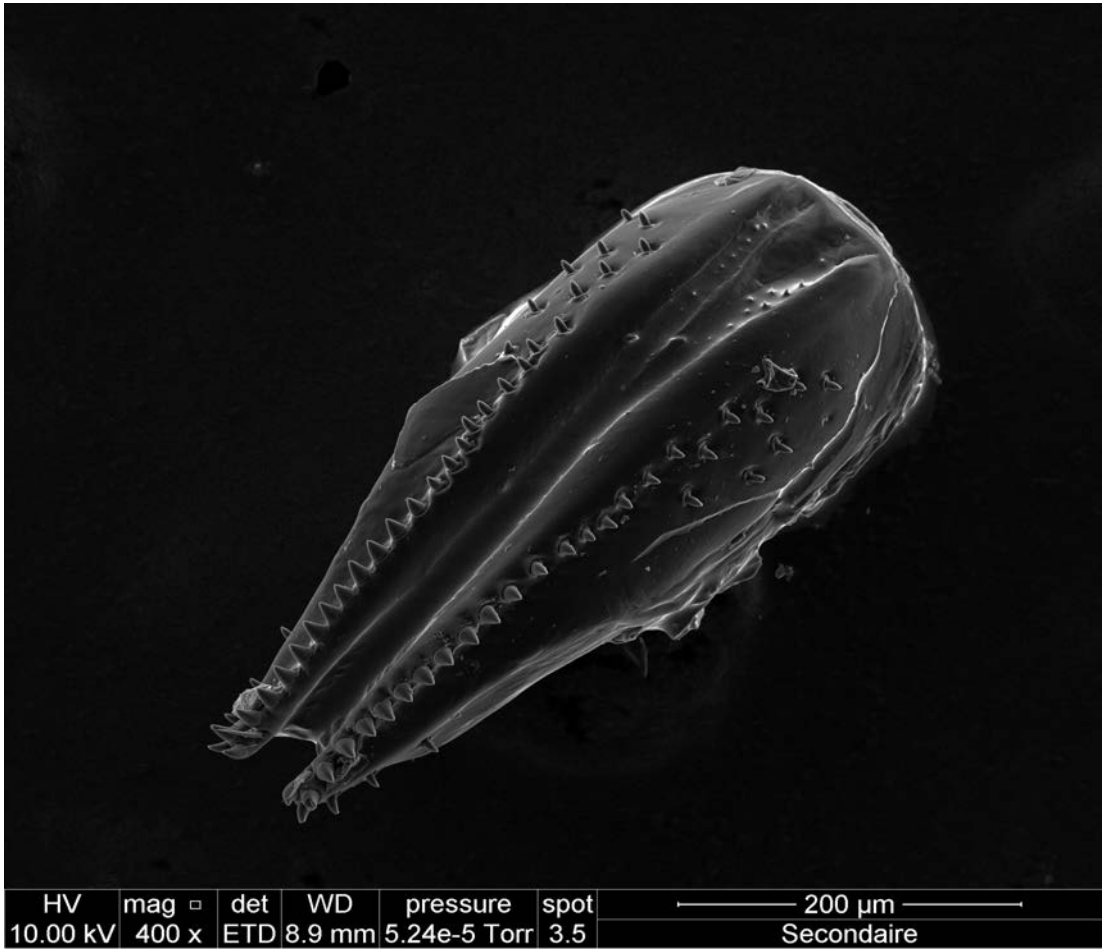
Emergence from strawberries

Emergence from blackberries

„Winter population“

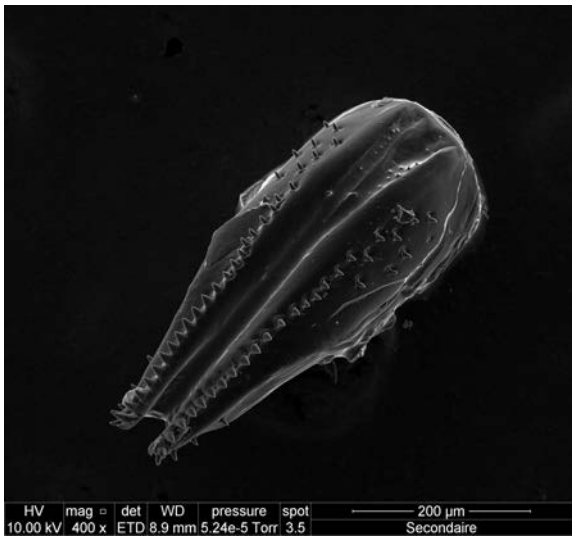
How to quantify the ovipositor?

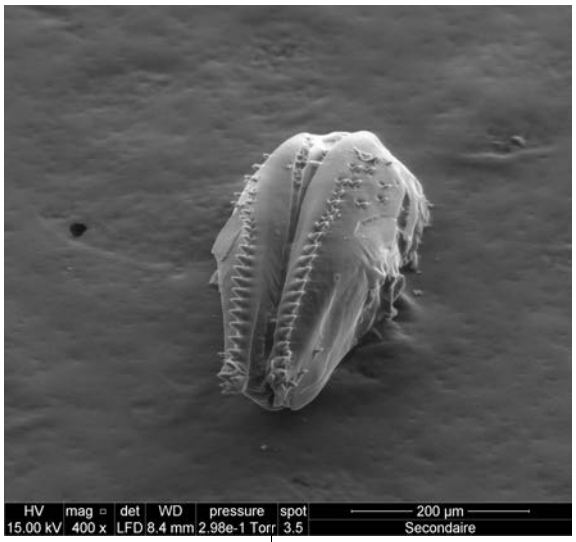
3D geometric morphometrics from SEM images

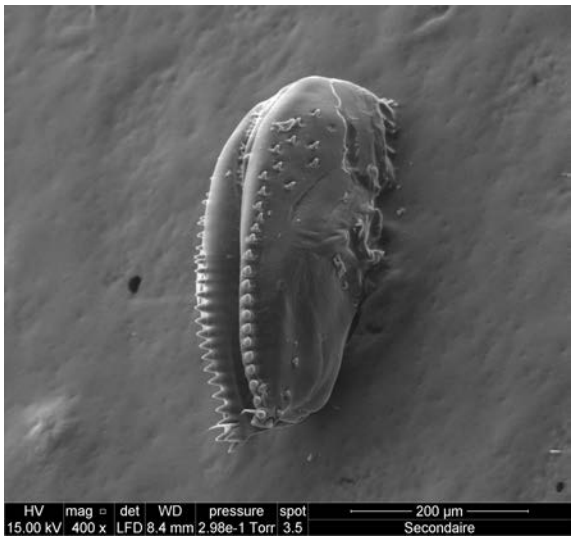


How to quantify the ovipositor?

3D geometric morphometrics from SEM images







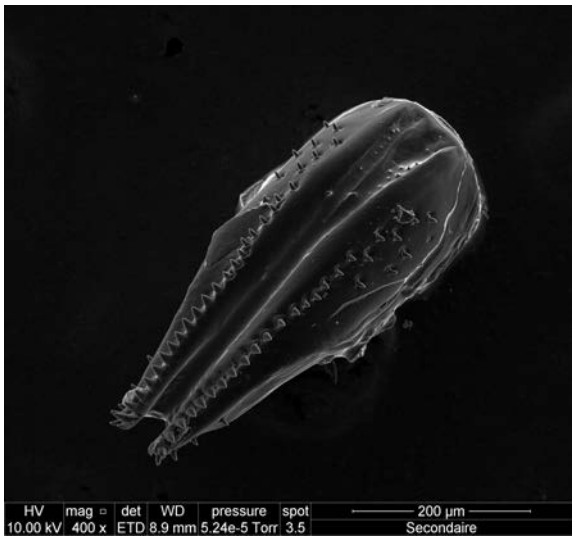
3D model of the ovipositor

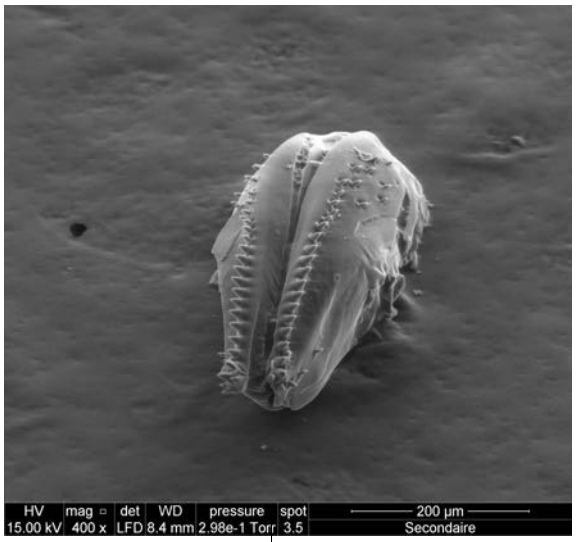
Quantification of shape differences

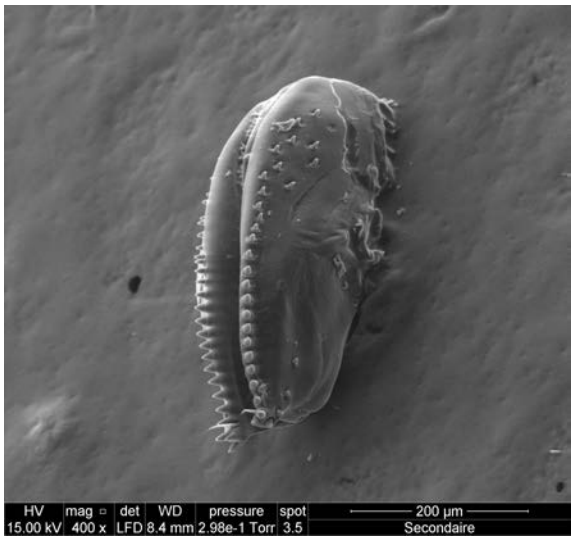
Method from Raphael Cornette (MNHN)

How to quantify the ovipositor?

3D geometric morphometrics from SEM images







3D model of the ovipositor

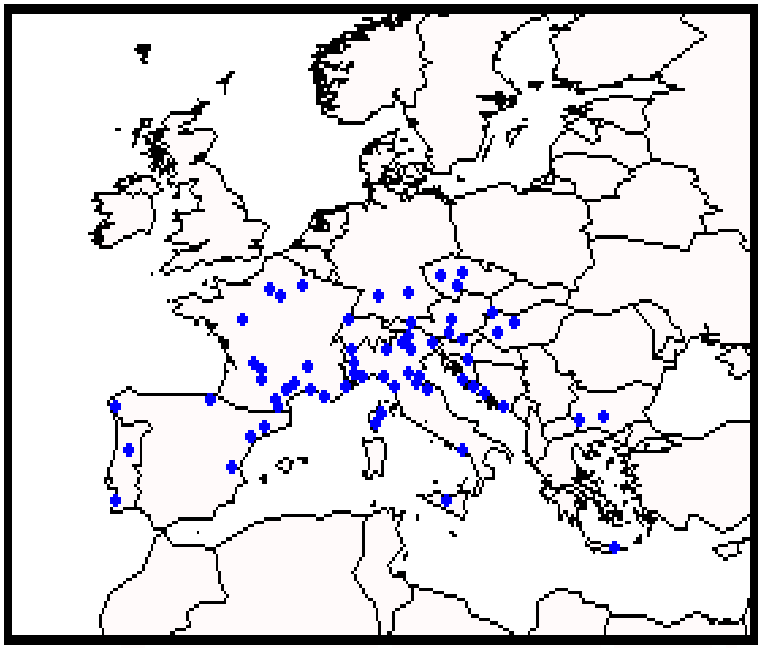
What contribution to ovipositor's variation from genetic and/or environmental components?

To be continued...

Merci !

Reciprocal projections in the invaded ranges

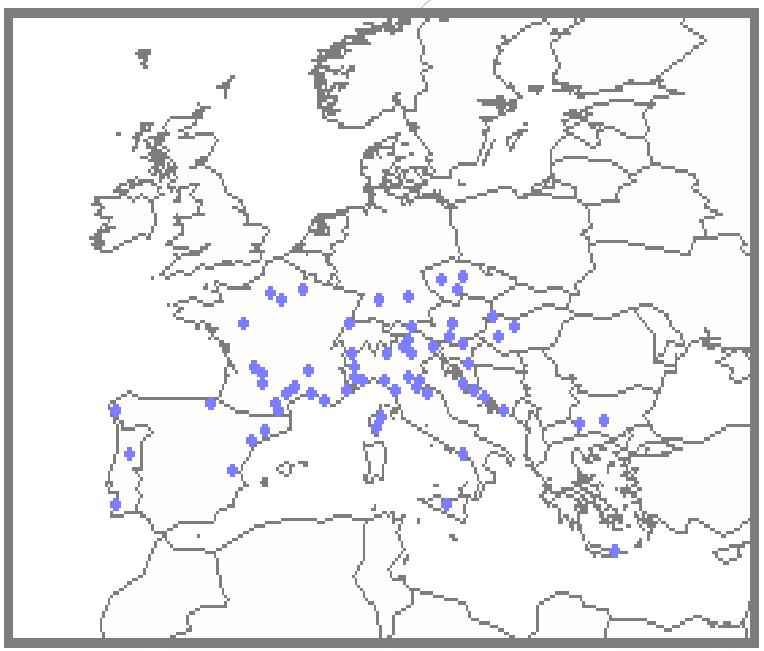
From Europe and USA

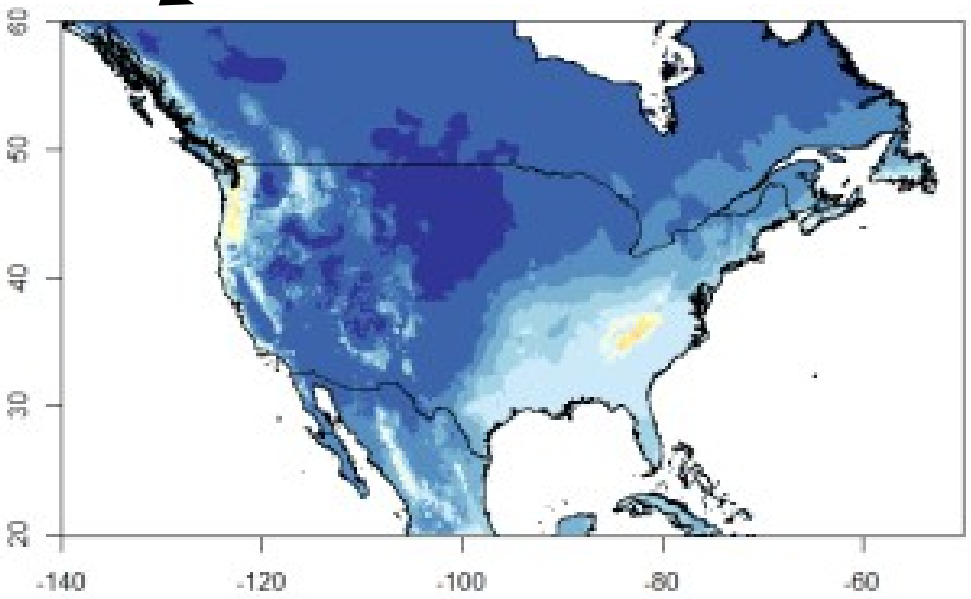


Estimating European niche

Reciprocal projections in the invaded ranges

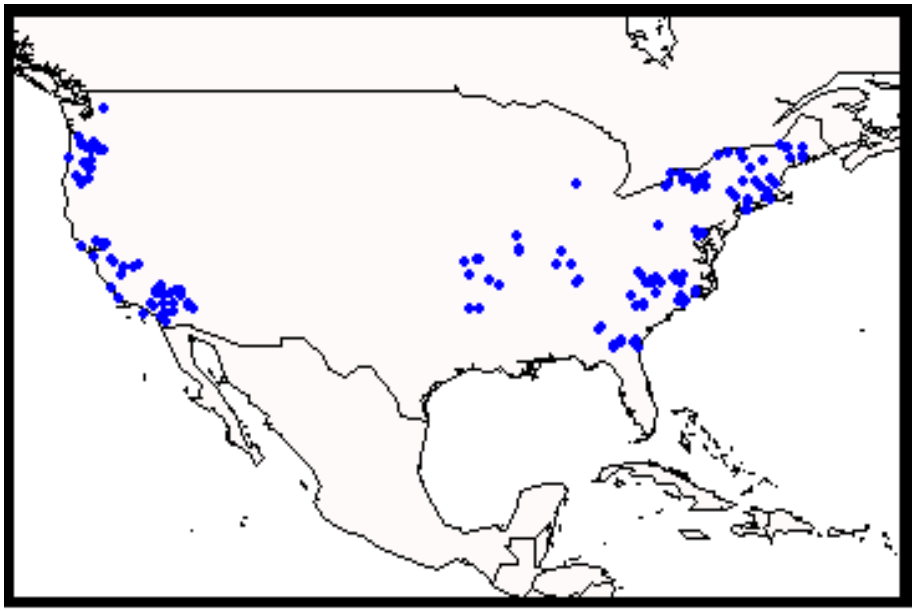
Model calibrated on European climate poorly predicts presence in USA





Reciprocal projections in the invaded ranges

From USA to Europe



Estimating north American niche

Reciprocal projections in the invaded ranges

Model calibrated on north American climate predicts well presence in Europe !