Short term evolution in trees

Adaptation under heterogeneous selection

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Sopron, University of West Hungary, 13th May 2009

Scope of the conference

How marginal populations deals with climatic shift at the receding edge ?

Global context :

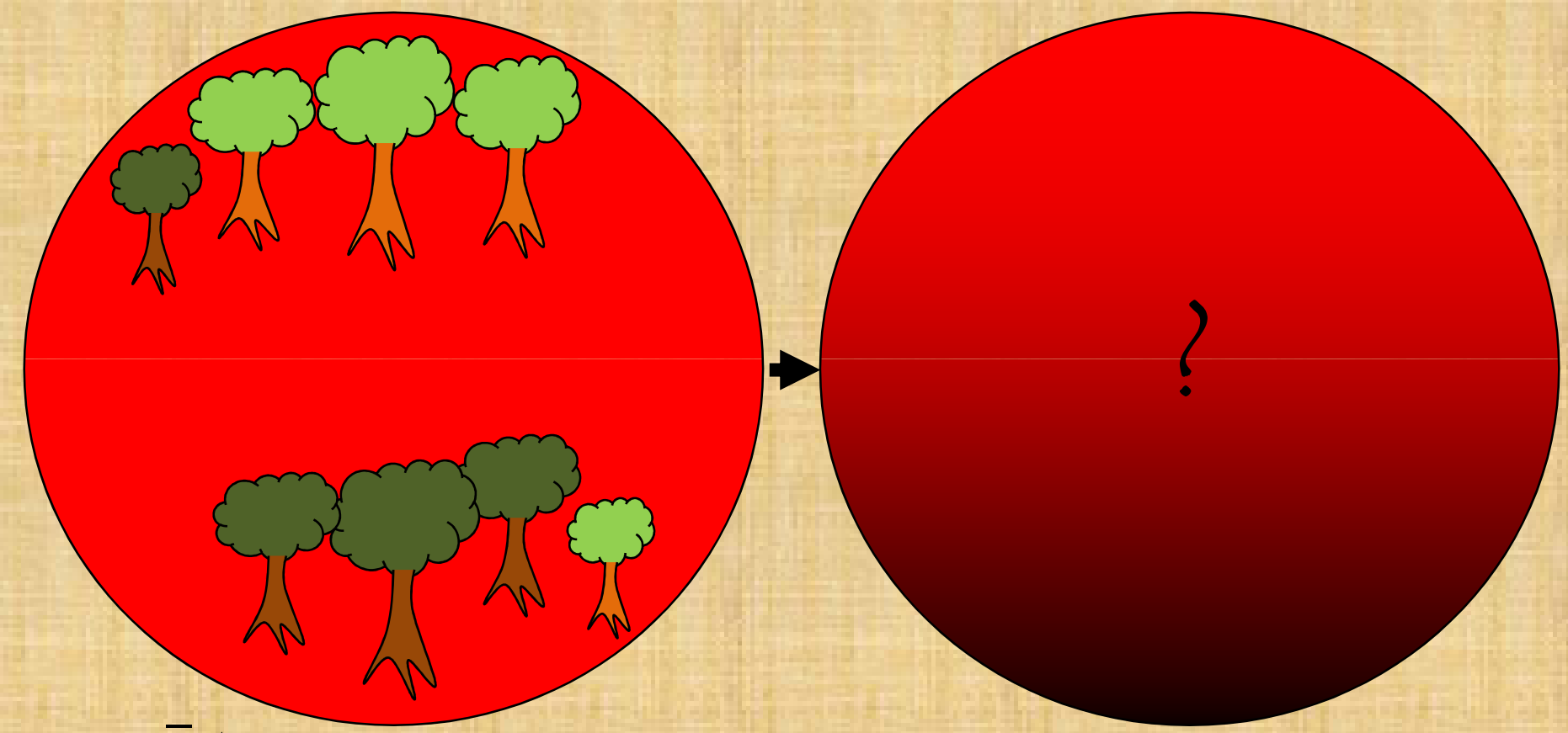
Conservation of biodiversity and genetic variability

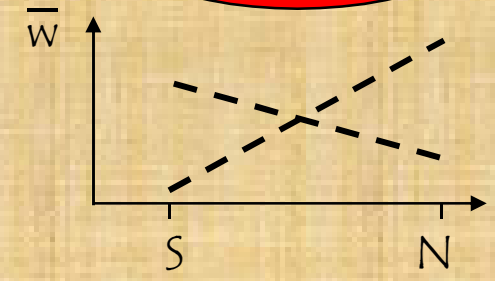
- What kind of populations to focus on ? Size, age, position, viability?

Climate change

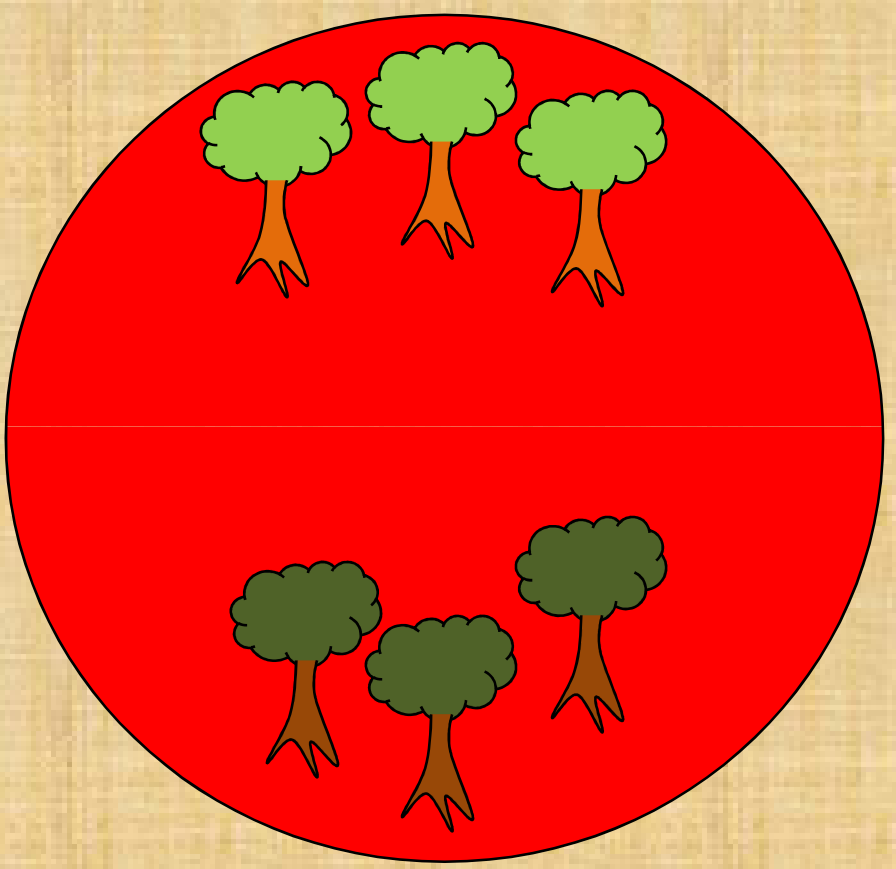
- What heterogeneity (present, future) ? What effects on living organisms ?

Local adaptation : new focus





Local adaptation : mechanisms



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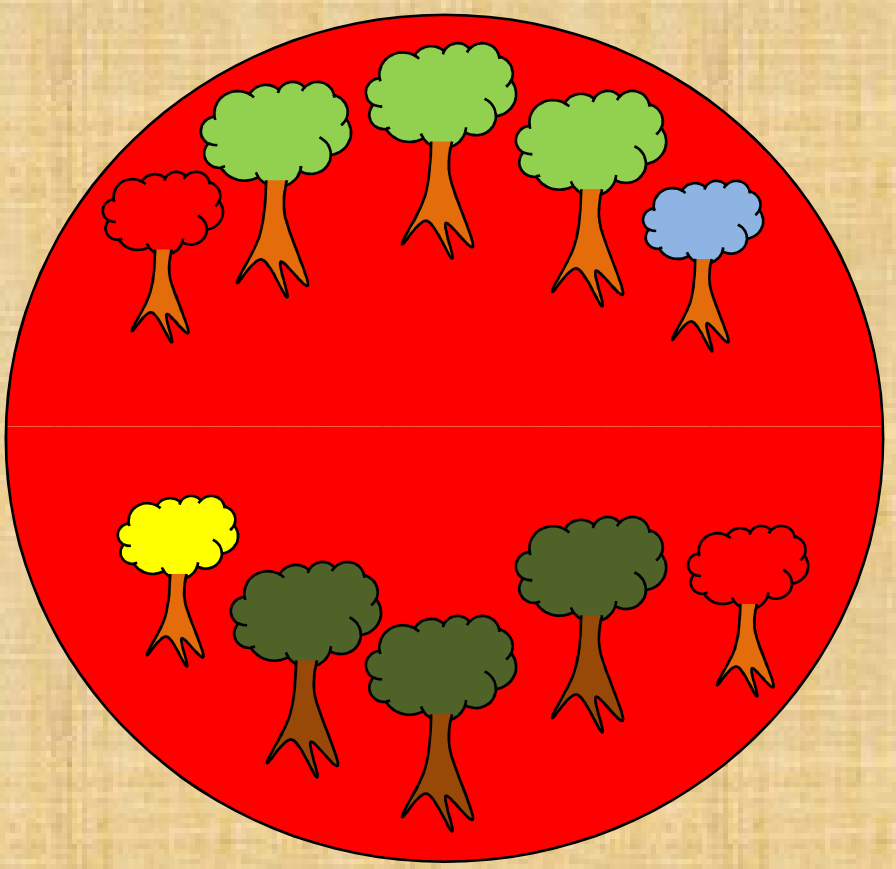
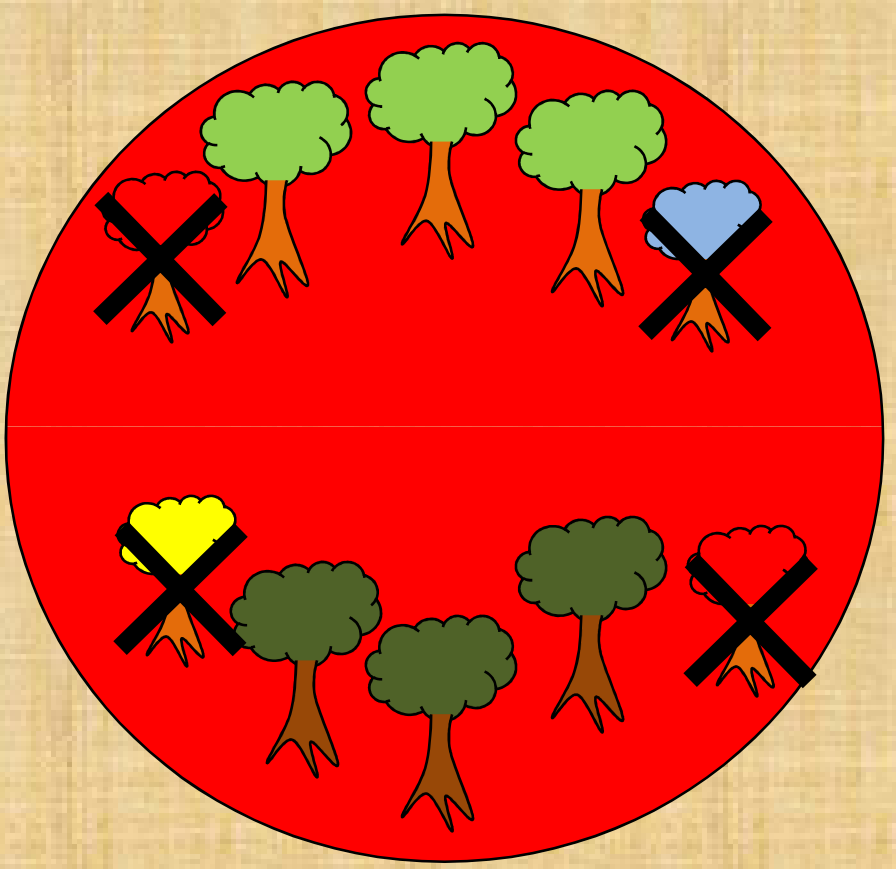


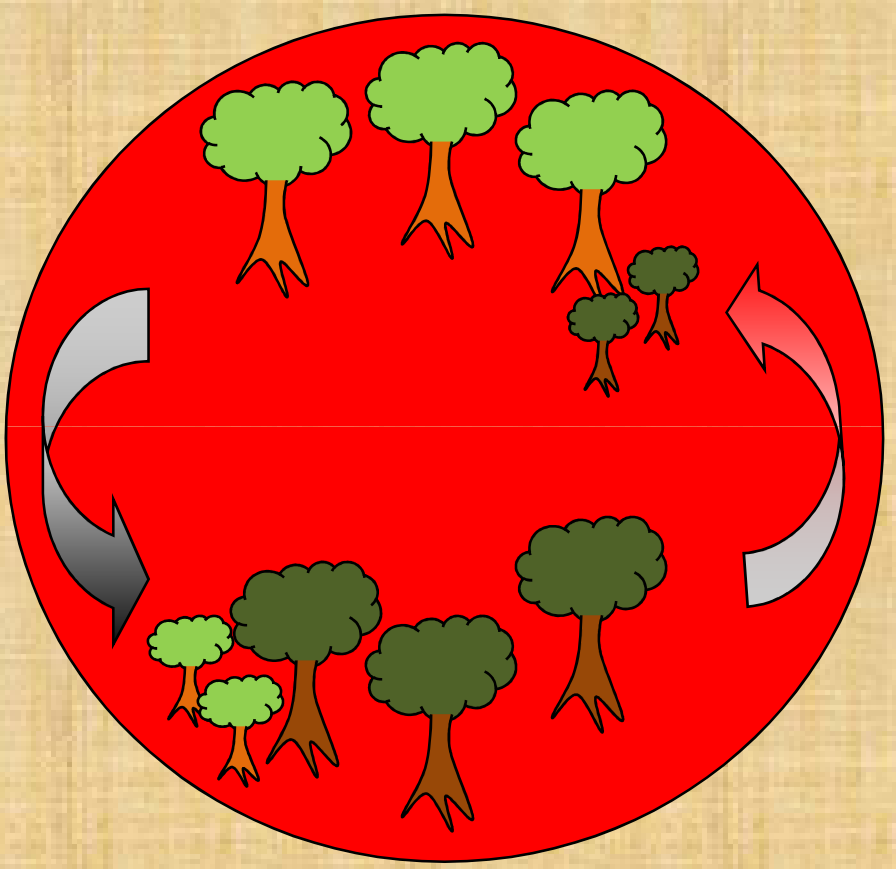
Mutation

Local adaptation : mechanisms



Selection

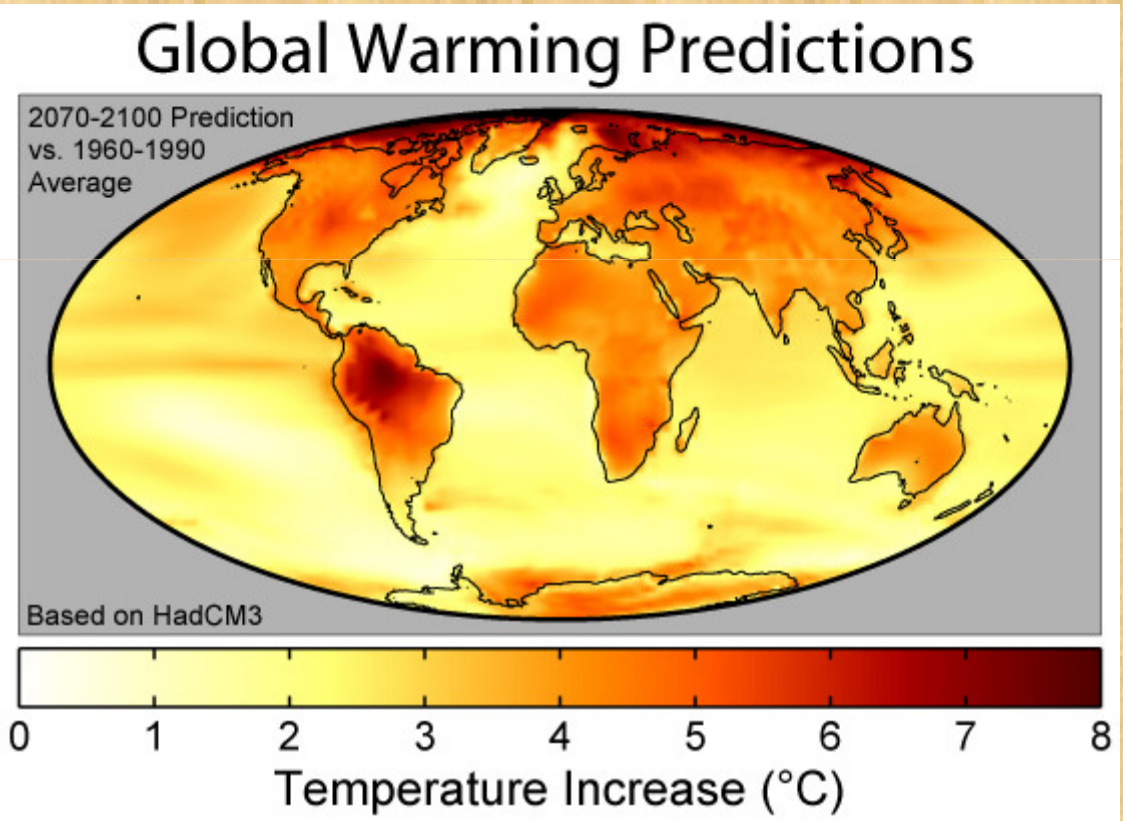
Local adaptation : mechanisms



Gene flow

Local adaptation and climate change

New environmental gradients and/or
new selection intensity



Evolution T° = means + seasonality + extreme values

What evolution during climate change?

What about the data ?

Evidence of past migrations by pollen records (trees)

Few evidence of rapid evolution (not trees)

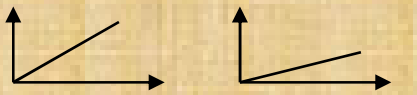
Wyeomyia smithii (pitcher plant mosquito)

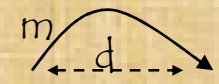
Significant evolution of genetically determined diapause entrance in 5 years in response to warmer climate

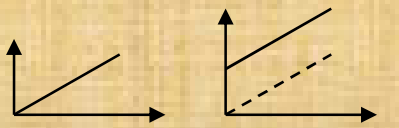
What evolution during climate change?

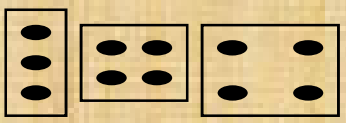
What about the theoretical tools ?

Models	Environment	Selection	Population(s)	Genetics
Analytical	Continuous	Strong/weak	Densities	1 locus/ multilocus
Simulations	Subdivided	+/- heterogeneous	Migration	$0< h^2 <1$
		Space/time	Number	Additive/non add.
			Position	Drift
				Mutations









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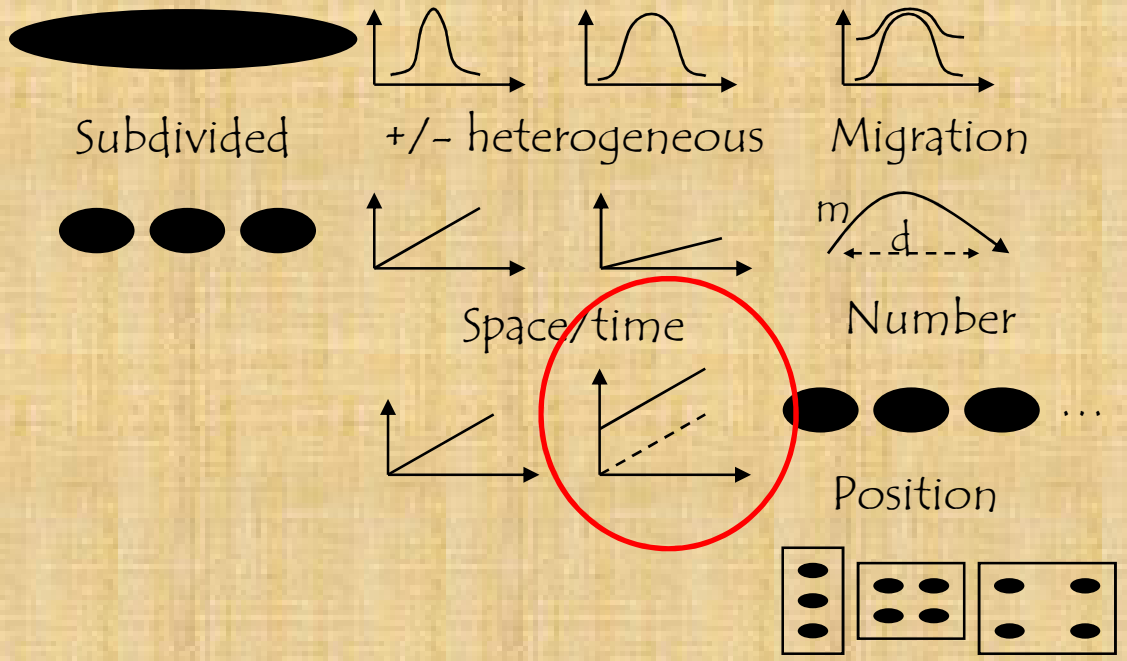


What about trees ?

Local adaptation and evolution in TREES

Several puzzling observations :

Forests can show new marked adaptation in few generations

Strong adaptive divergence between populations but large adaptive diversity within populations

Observed latitudinal and altitudinal clines for adaptive traits but neutral homogeneity

How does Natural Selection act on Trees ?

Long and complex life cycle

What about trees ?

Most theoretical models for annuals !

But trees are big, long living, strong fertility

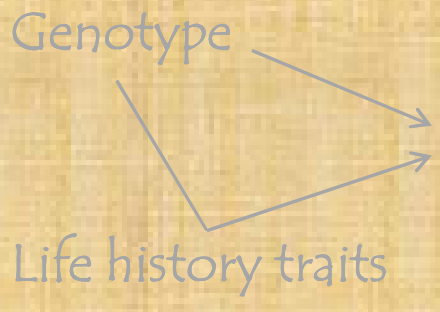
How modeling trees ?

Before dealing within several populations under climatic shift …

We need to understand evolution in a single population under heterogeneous selection

The model

Classical local adaptation model

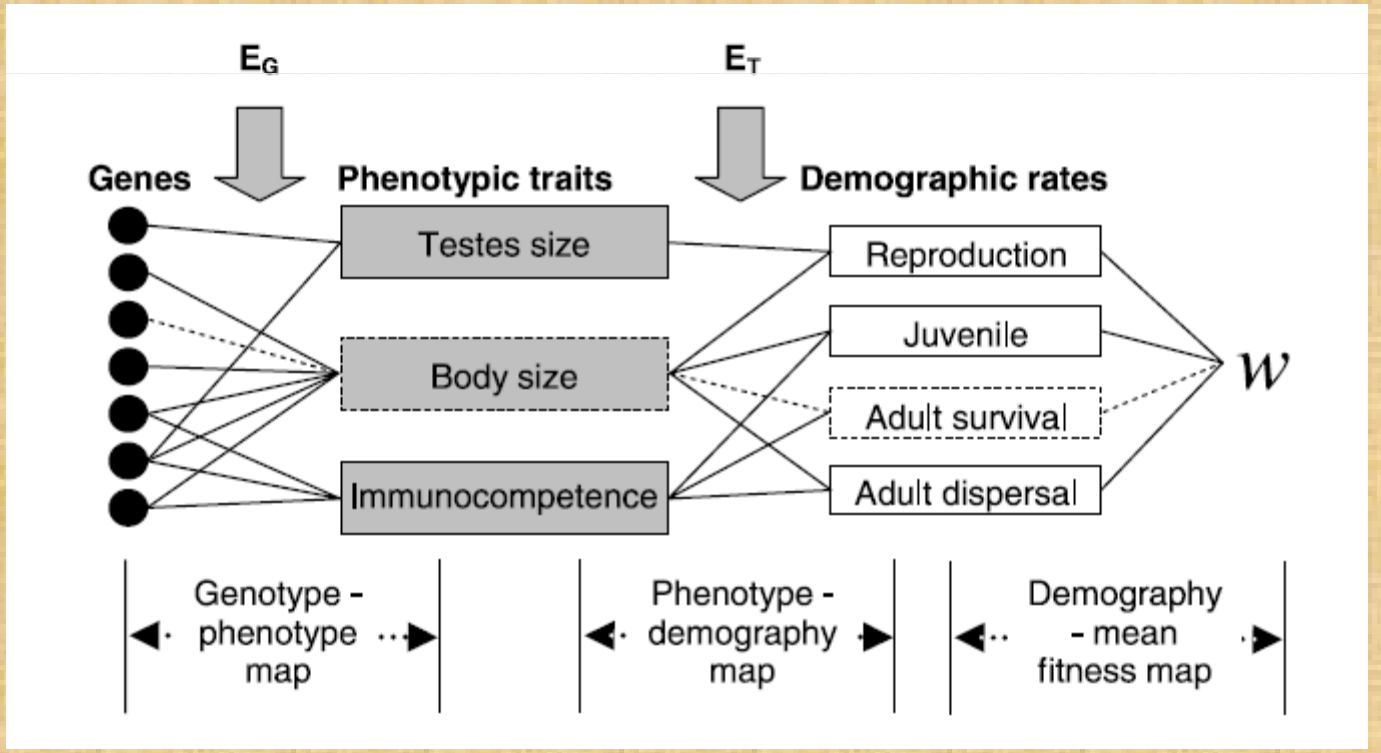


But how to account for complex interactions between genes or traits under selection ?

Specially for unstable demography or variable environment …?

The model

Coulson *et al.* (2006) suggested to partition evolutionary drivers into genotype-phenotype-demography map



The model : Luberon

Simulation platform : Capsis

Innovation : understanding local adaptation of trees with an individual based, spatially explicit model including demography

Demo-genetic model :

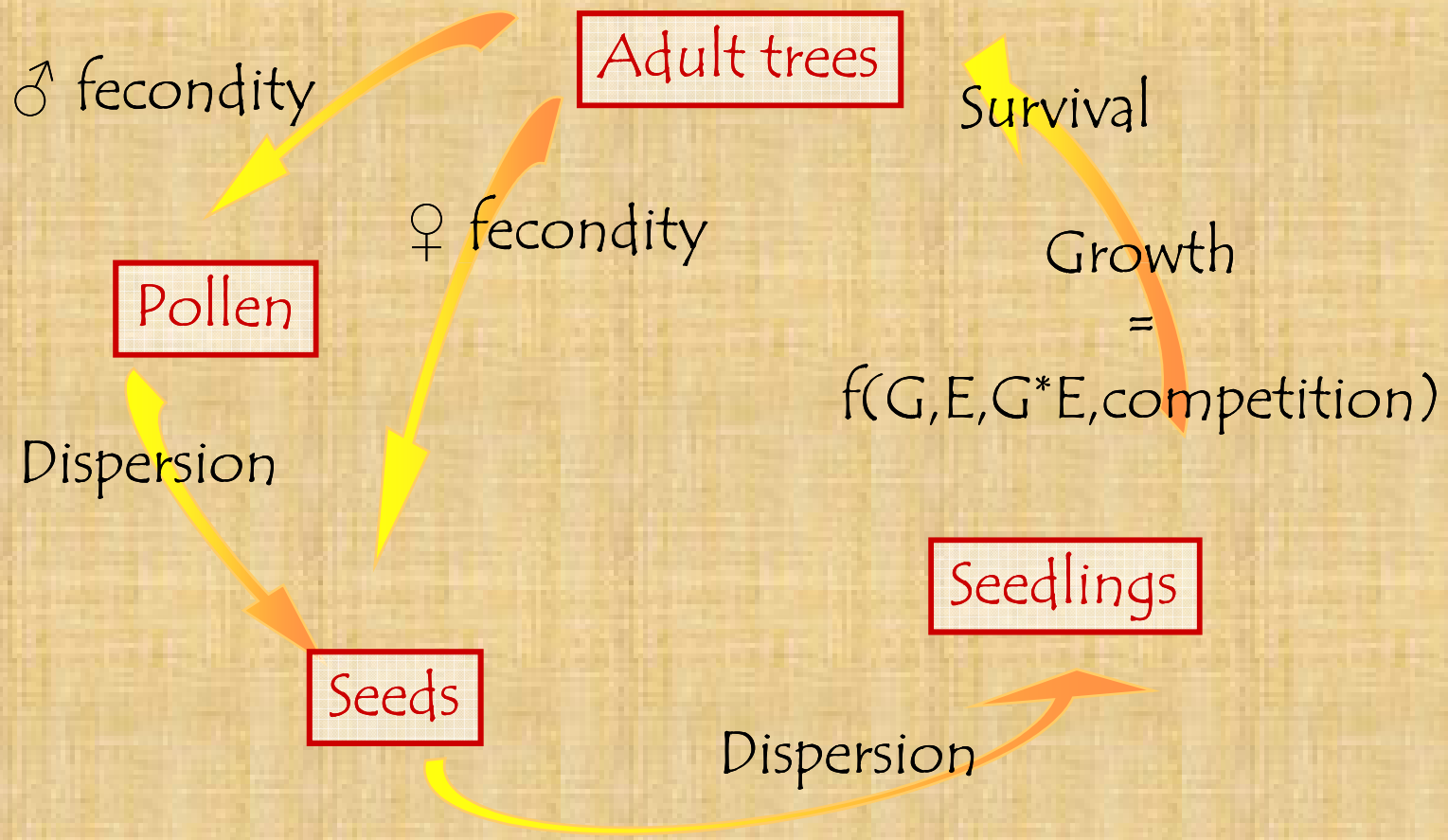
Genotype » Phenotype » Demography » (Fitness)

(10 loci/2 alleles) ↑ (Diam. Increment) ↑ (Survival)

Env. Env.

Individual fitness dynamically results from the demographic processes and environment quality that can vary in time and space

Life cycle


Adult trees
♂ fecondity
♀ fecondity
Pollen
Dispersion
Seeds
Survival
Growth
=
f(G,E,G*E,competition)
Seedlings
Dispersion

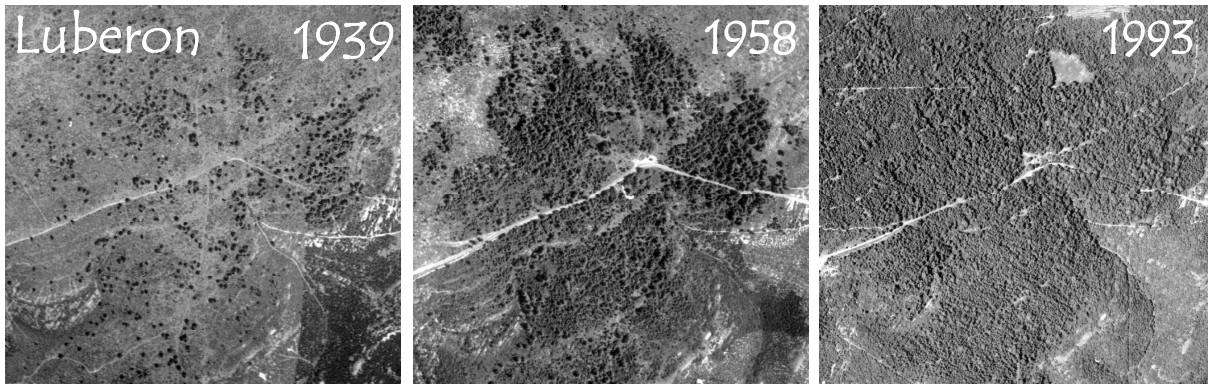
The tree

Cedrus atlantica

Introduction in South East of France mid XIXs.

Colonisation of an open place through natural regeneration.

Today : 3 generations forming a closed forest.



The main question

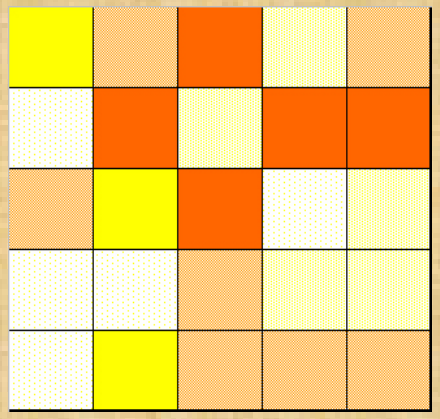
What are the impacts of interaction between seeds and pollen dispersal on the evolutionary trajectory under different environmental heterogeneity ?

Heterogeneous selection

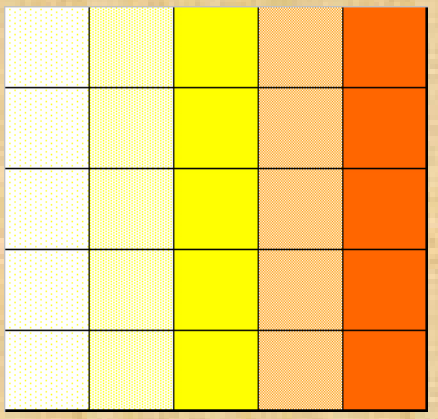
5 levels of environment fertility

5*5 cells of 250*250 m.

Stochastic

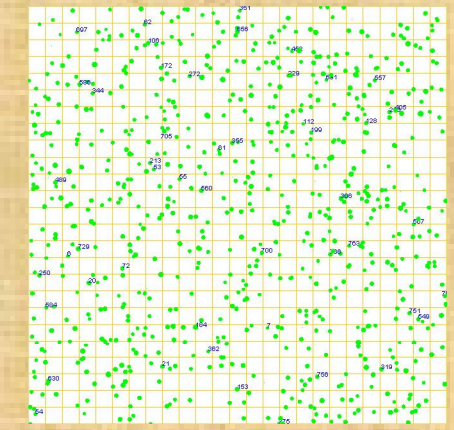


East-West gradient



Simulations

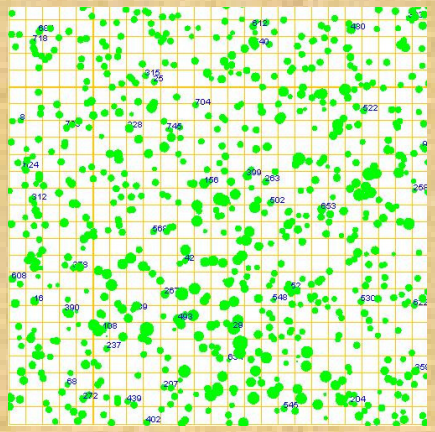
1860



800 seedlings

>>>

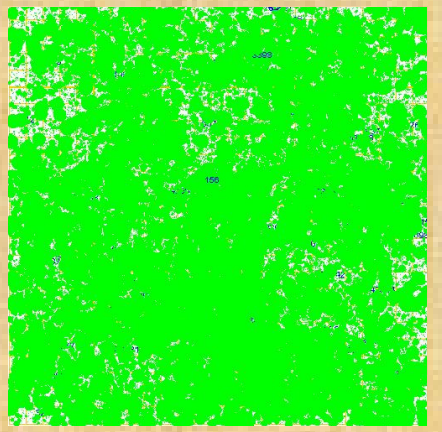
1910



800 trees

>>>...>>>

2010



Population
3 generations

Environment
Random
Gradient

X

Seed dispersal
50m.
100m.

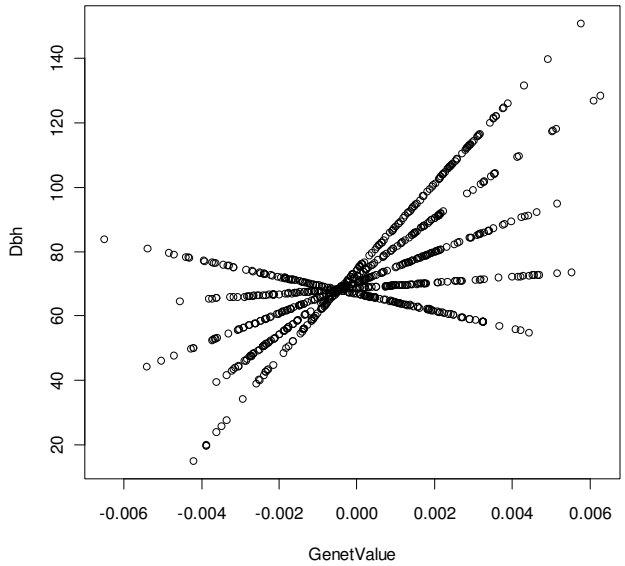
X

Pollen dispersal
Local
Panmixia

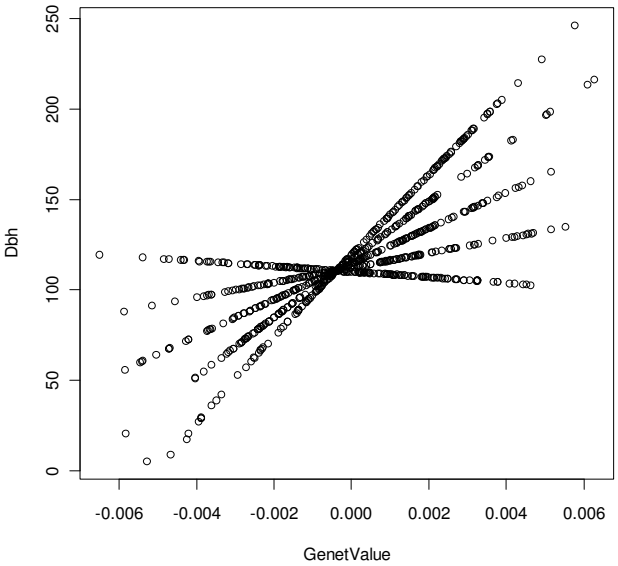
Results

Interaction genotype * environnement

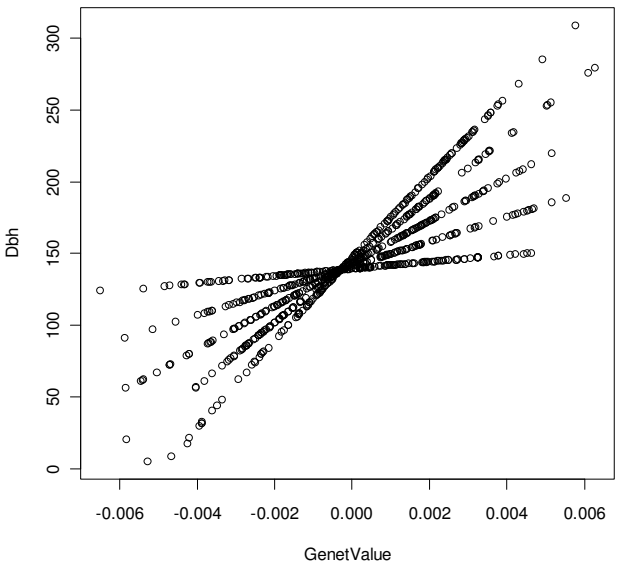
Evolution for the founders : diameter



G0 en 1910



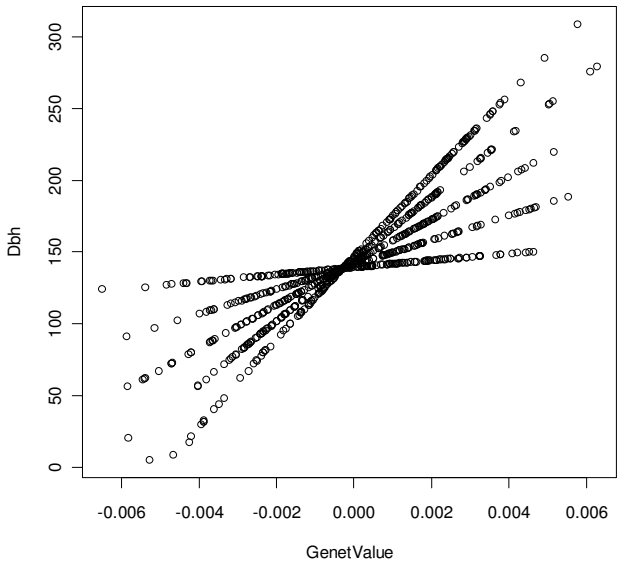
G0 en 1960



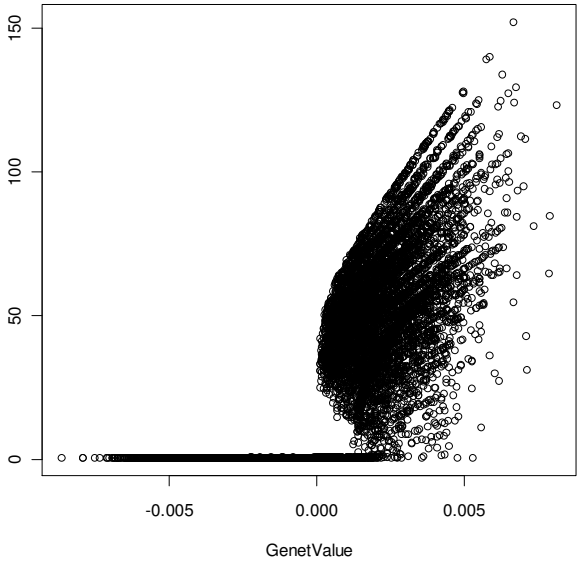
G0 en 2010

Results

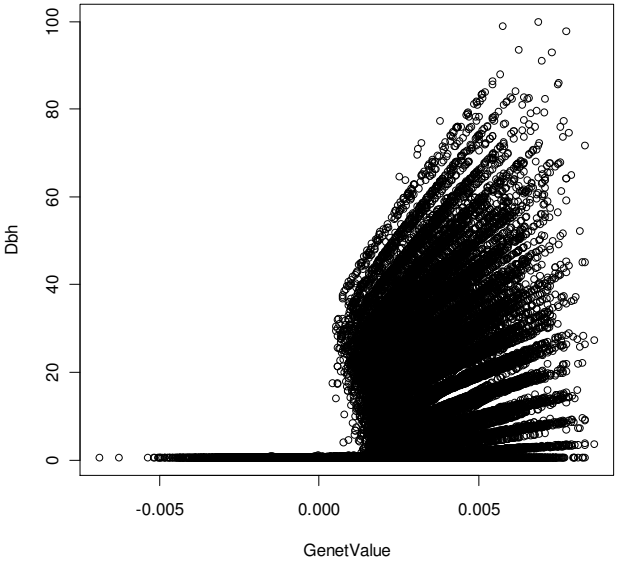
Evolution genotype/phenotype across generations



G0 en 2010



G1 en 2010



G2 en 2010

Results

↑ dispersal distance ↓ differentiation for genes under selection

Moderate dispersal ⟶ impact of heterogeneity pattern

Gradient ↑ local adaptation (spatial autocorrelation)

Medium seed dispersal ↑ local adaptation (genetic rescue)

Gradient > random

Conclusion

Local adaptation depends on the movement of genes relatively to the scale/pattern of spatial environment heterogeneity

Spatial autocorrelation of selection may change during climate shift … so how to model it ? What impact ?

The nicest thing is to compare simulation results to long term observation data of the Cedar forest in Luberon

and to data obtained from seedlings common garden experiment

Thank you for your attention !