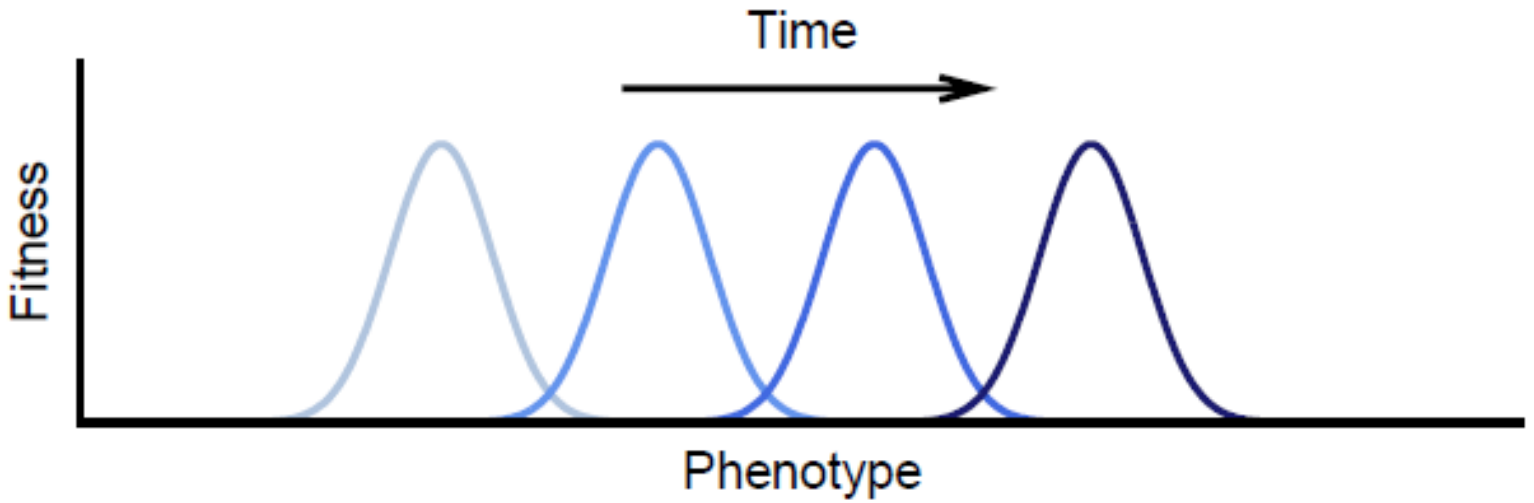
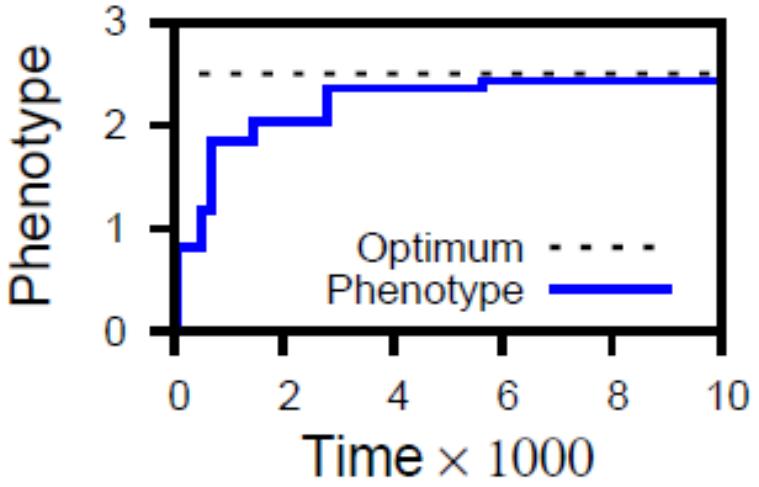
The moving optimum model



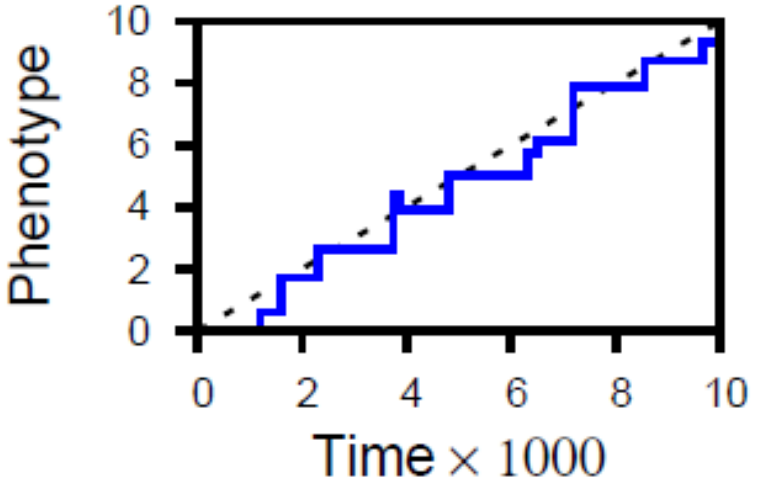
- Single trait under stabilizing selection
- Optimal phenotype moves at speed *v*
- Explicit genetics: population adapts by fixation of beneficial mutations
- **Environmental *and* genetic timescales**

Constant selection



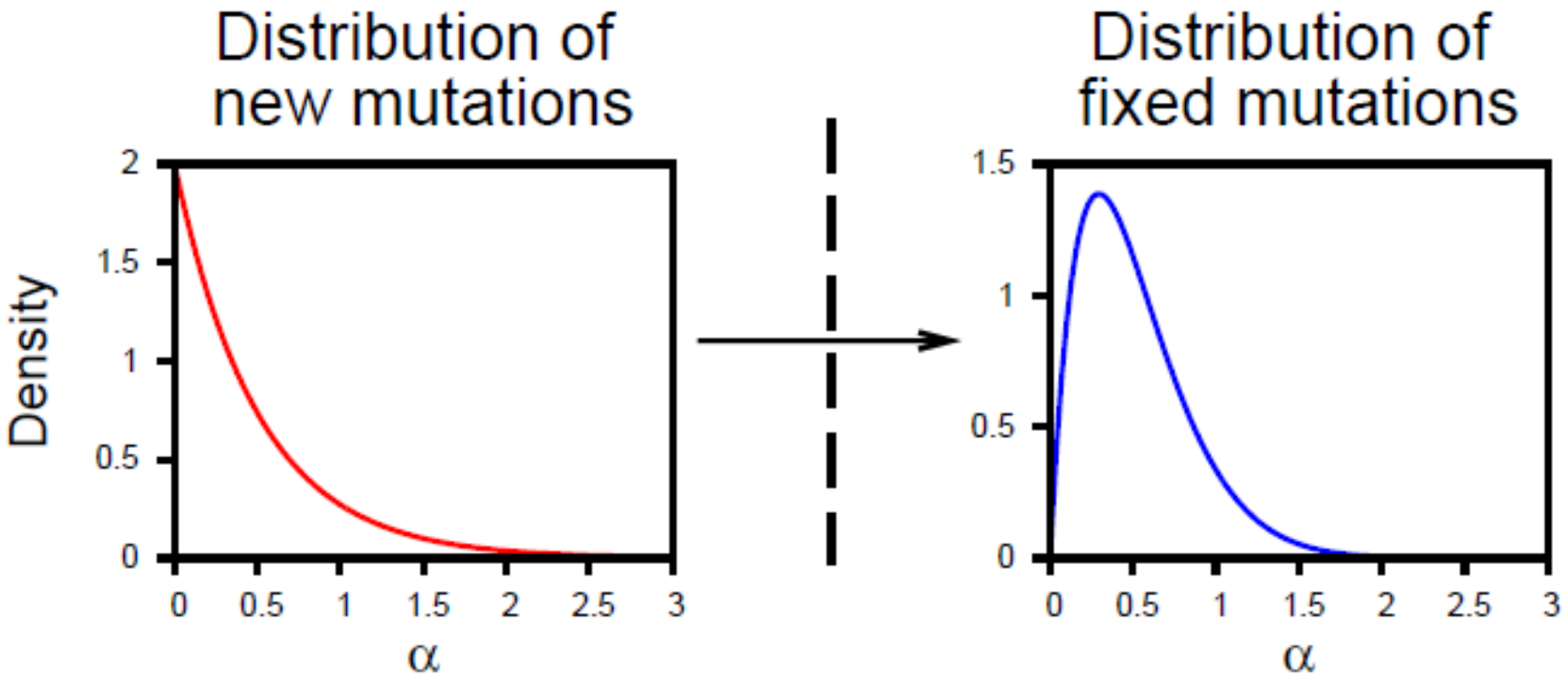
Population approaches the optimum with diminishing returns.

Moving optimum



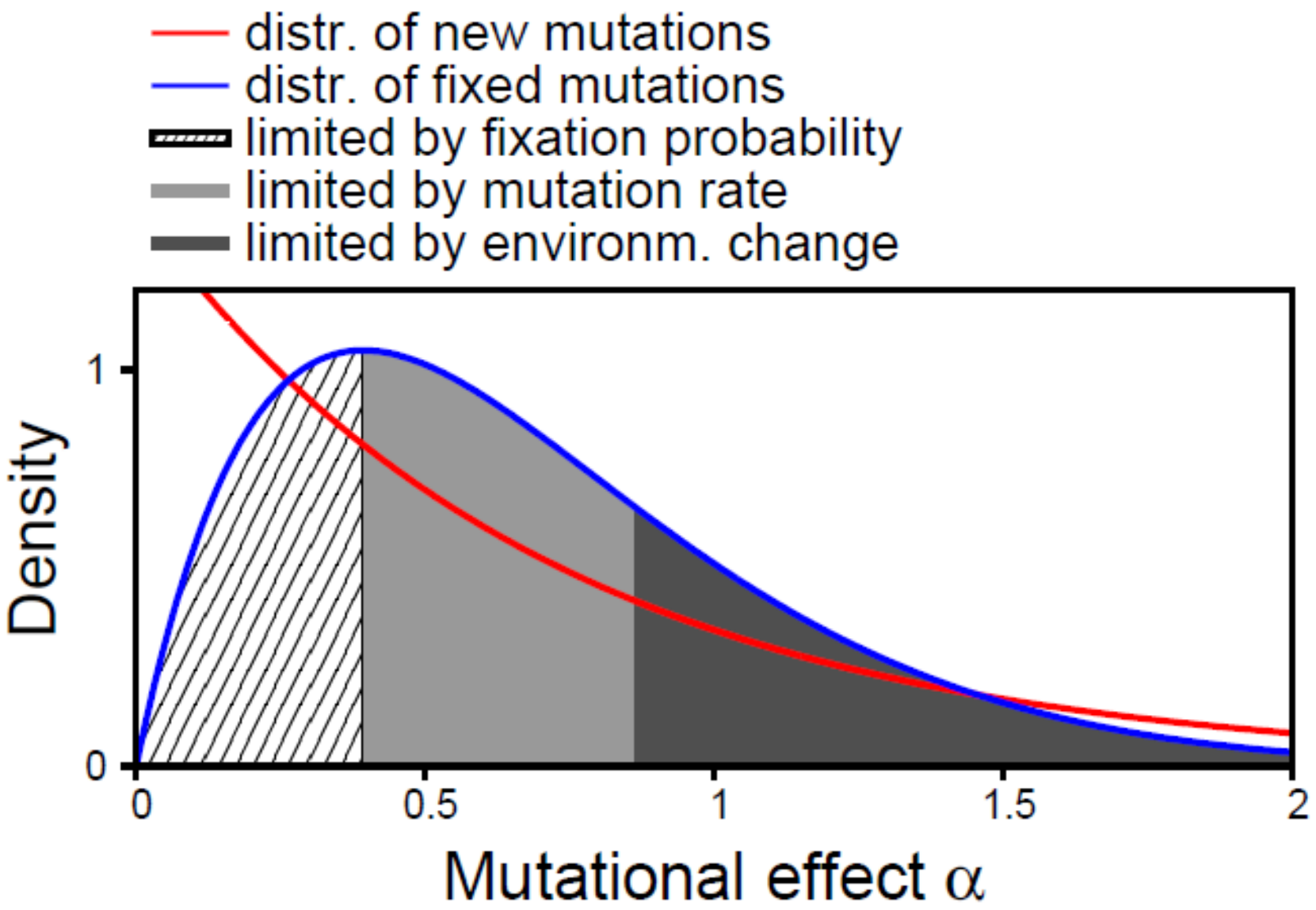
Population follows the optimum in a quasi-steady state.

The environment as a “sieve”



A given **distribution of new mutations** . . .

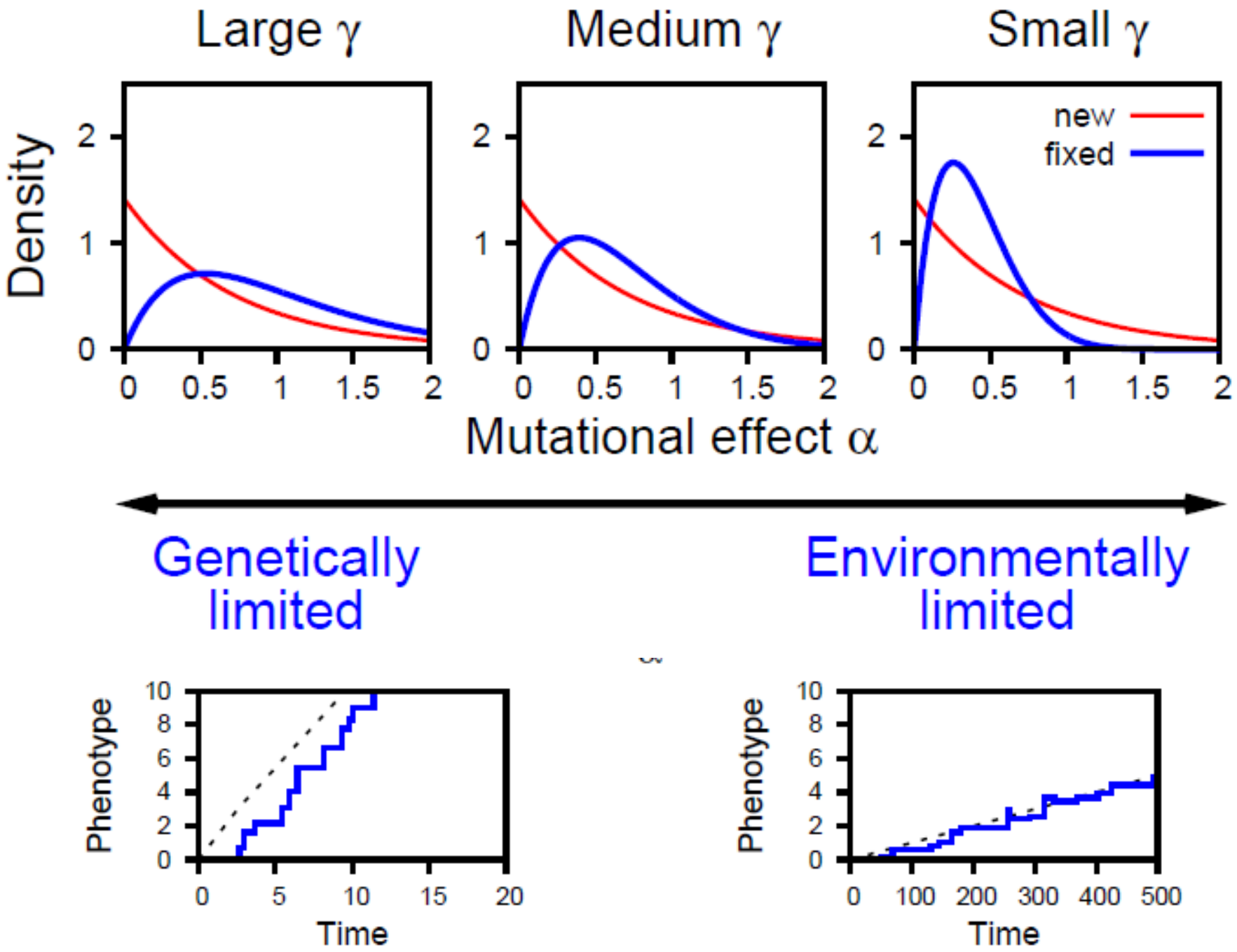
. . . is transformed into a **distribution of fixed mutations**.


distr. of new mutations
distr. of fixed mutations
limited by fixation probability
limited by mutation rate
limited by environm. change
Density
1
0
0
0.5
1
1.5
2
Mutational effect α

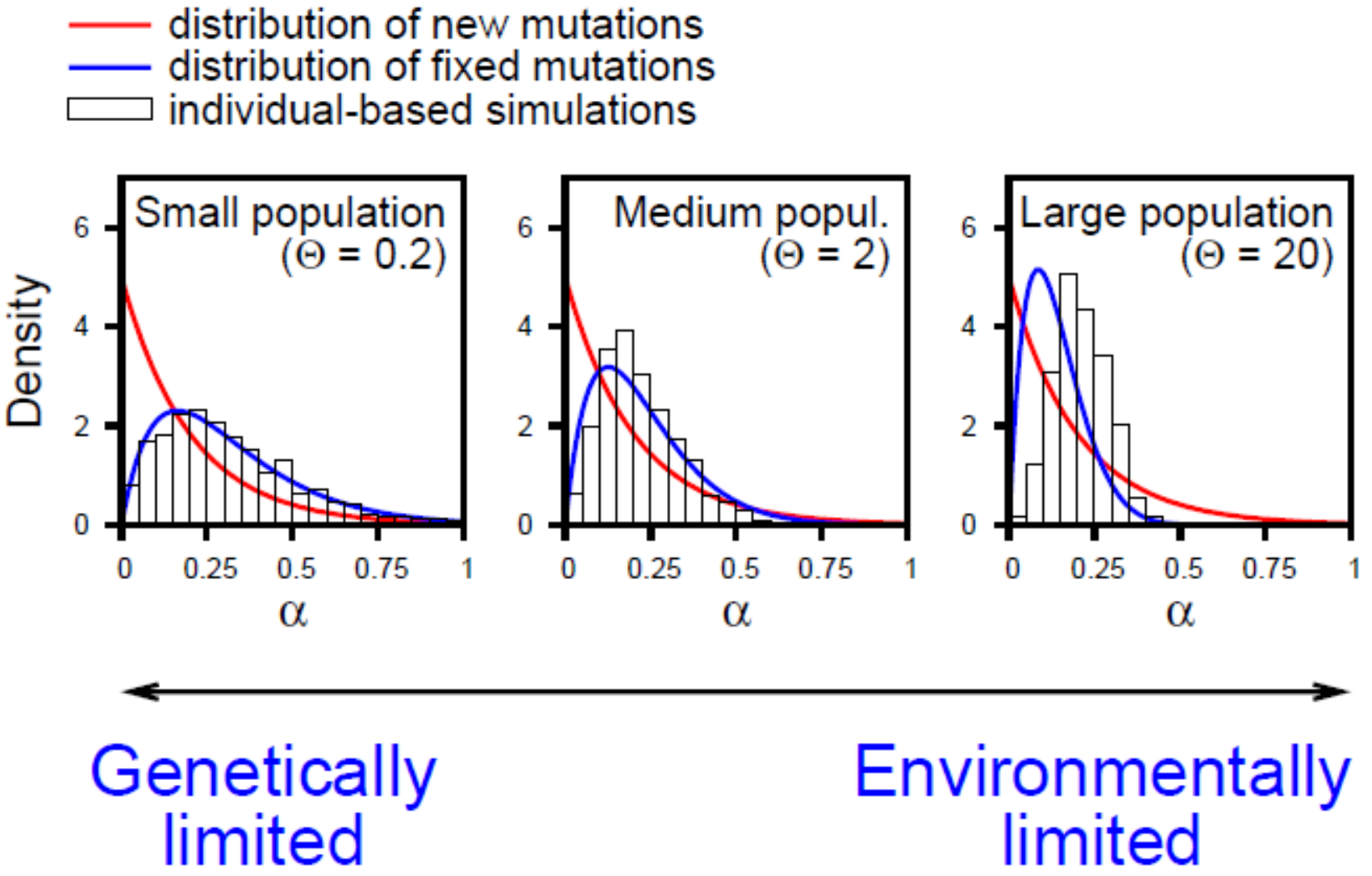
The environmental "sieve" is determined by . . .

$$\gamma = \frac{v}{\Theta\omega^3\sigma} = \frac{\text{speed of optimum}}{\text{"adaptive potential"}}$$

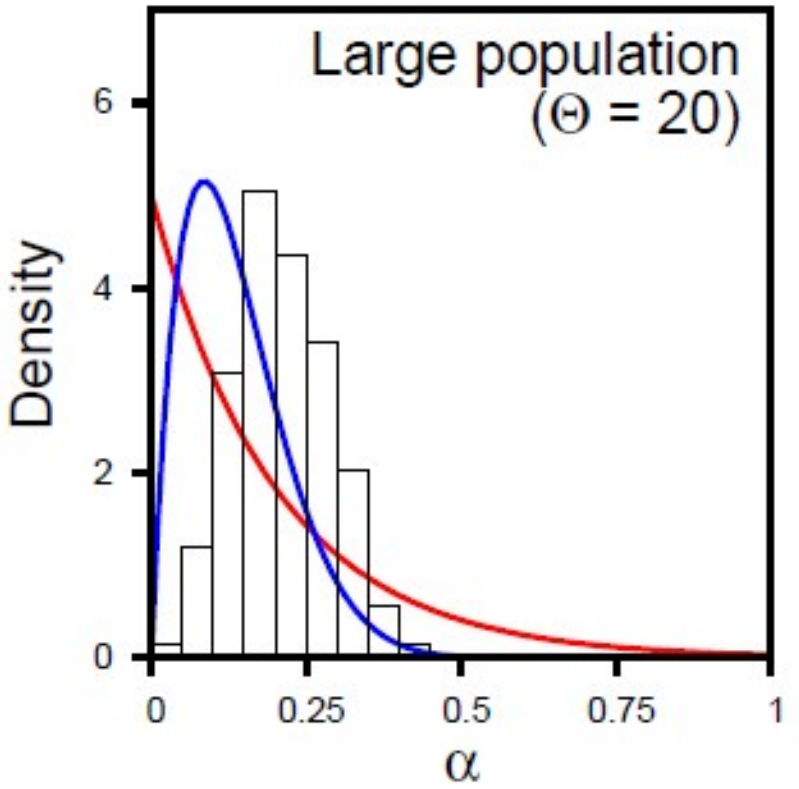
- $v =$ speed of optimum
- $\Theta =$ population-wide mutation rate
- $\omega =$ standard deviation of new mutations
- $\sigma =$ strength of stabilizing selection

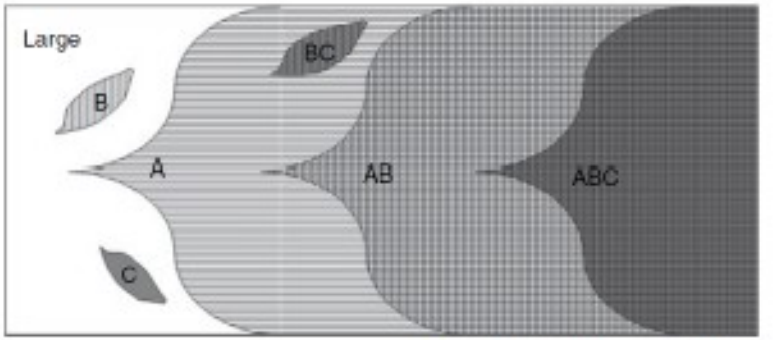

Large γ
Medium γ
Small γ
Density
new
fixed
Mutational effect α
Genetically limited
Environmentally limited
Phenotype
Time
Phenotype
Time

Interference in large populations



Interference in large populations

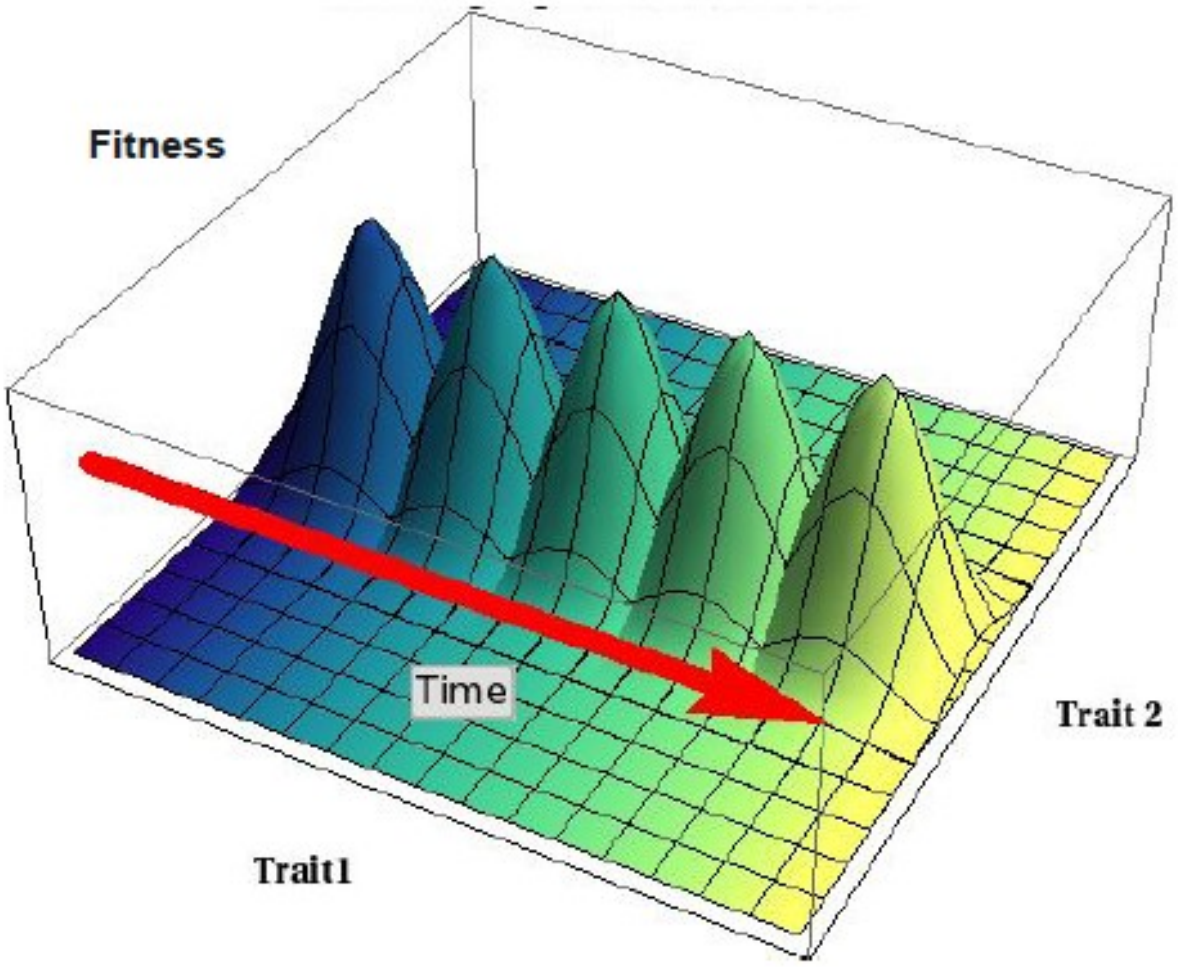


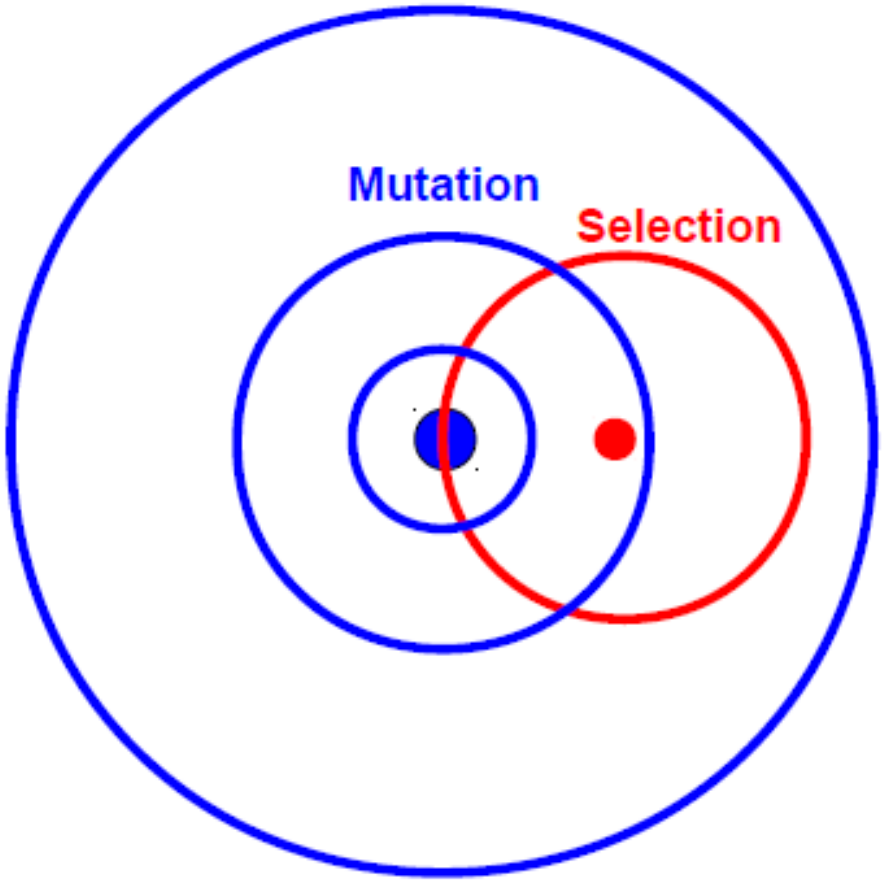


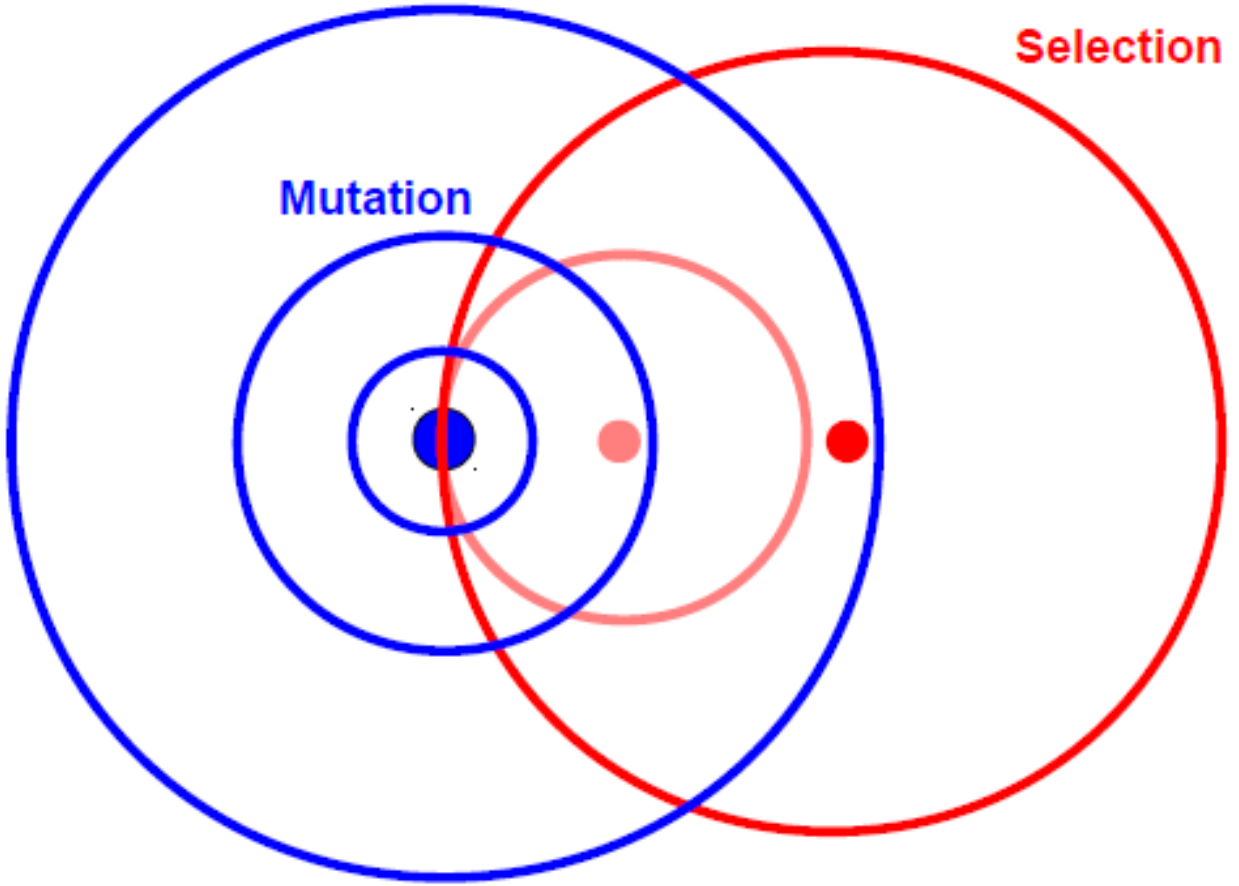
From de Visser & Rozen (2005)

Shift towards larger steps in large populations.

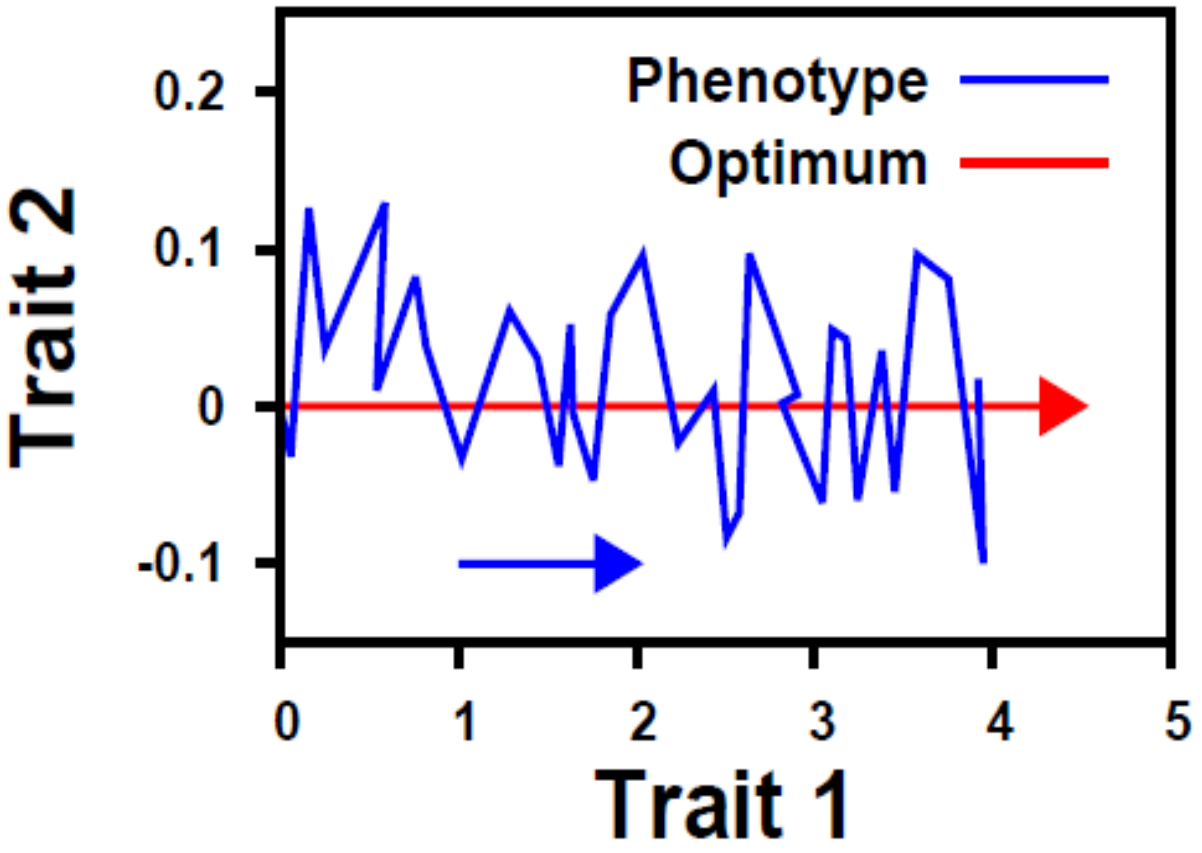
Fisher's model with a moving optimum



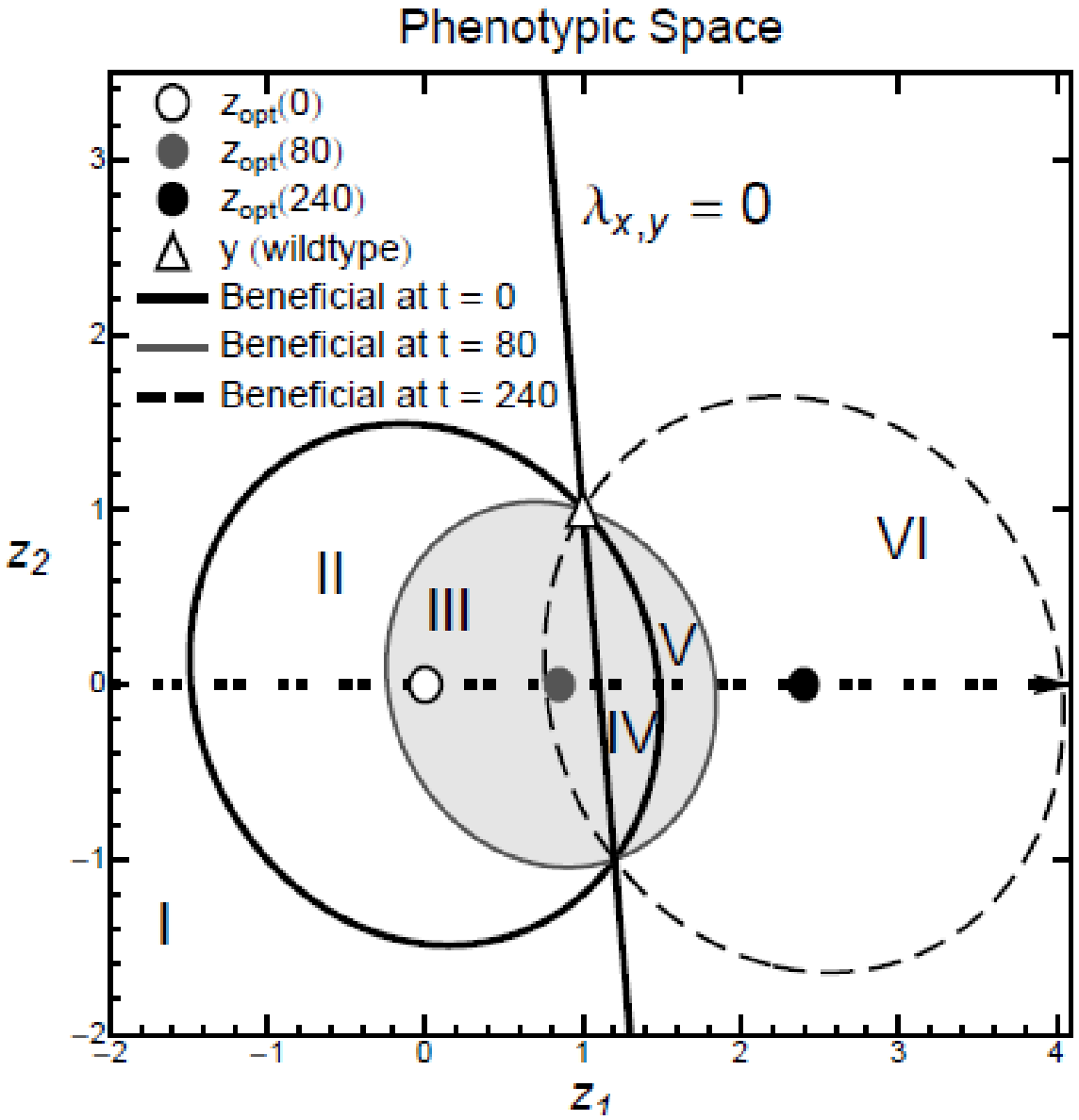

Mutation
Selection


Selection
Mutation

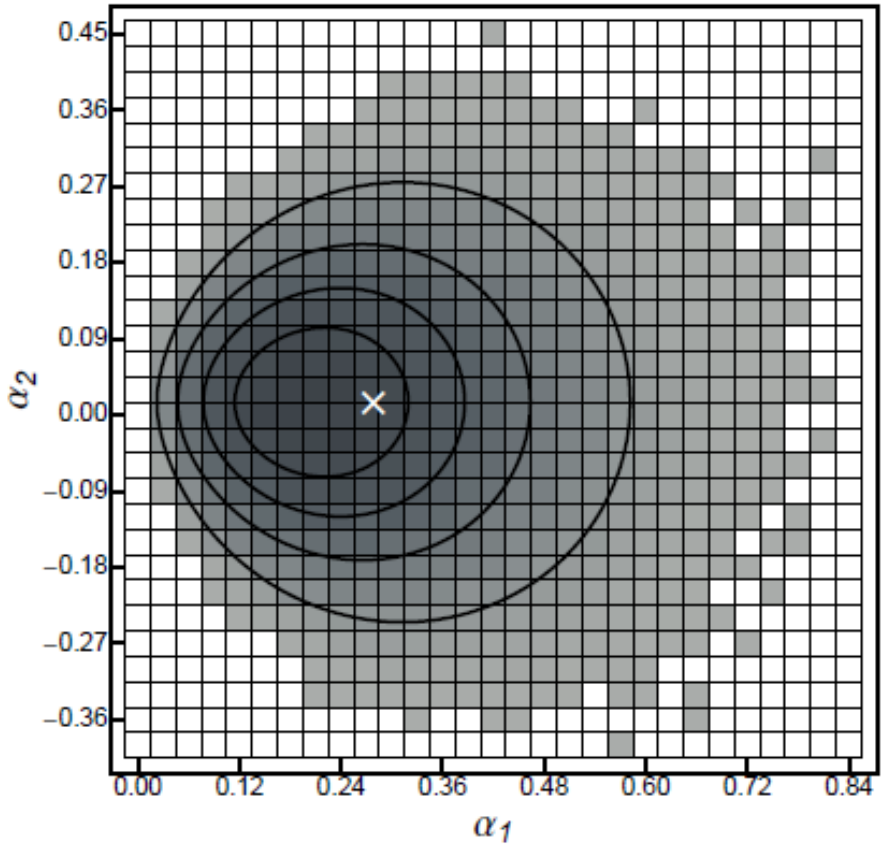
Adaptive walks



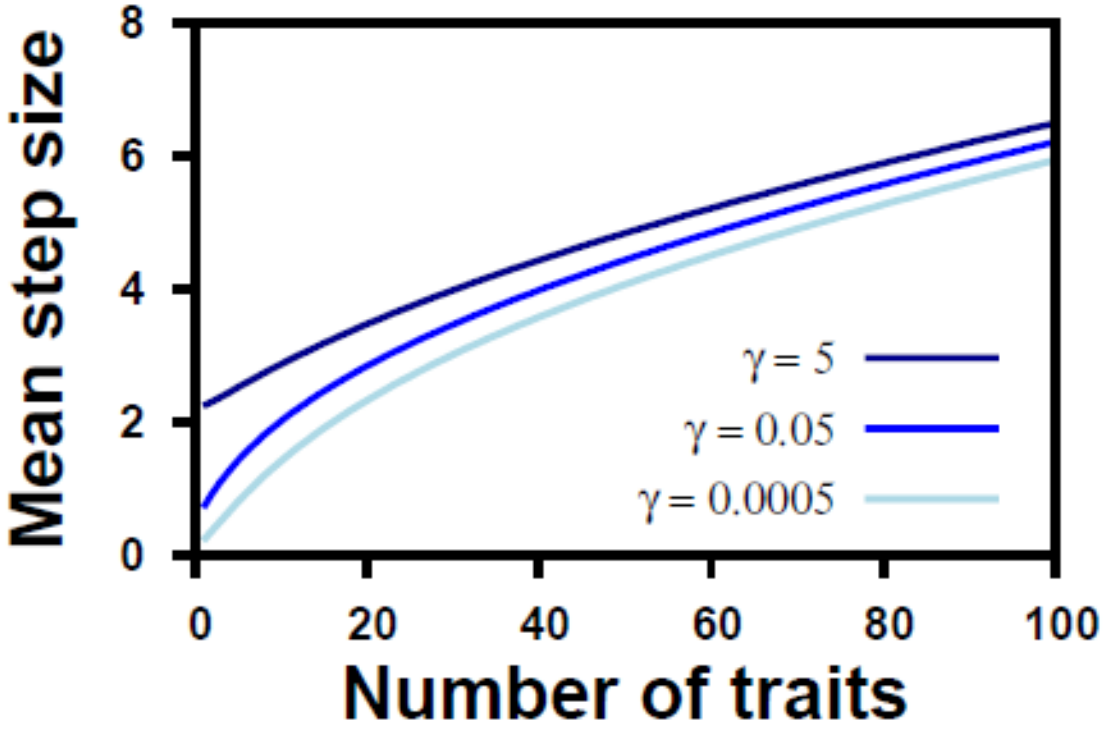
Dynamics of selection coefficients



Distribution of first step in 2 dimensions

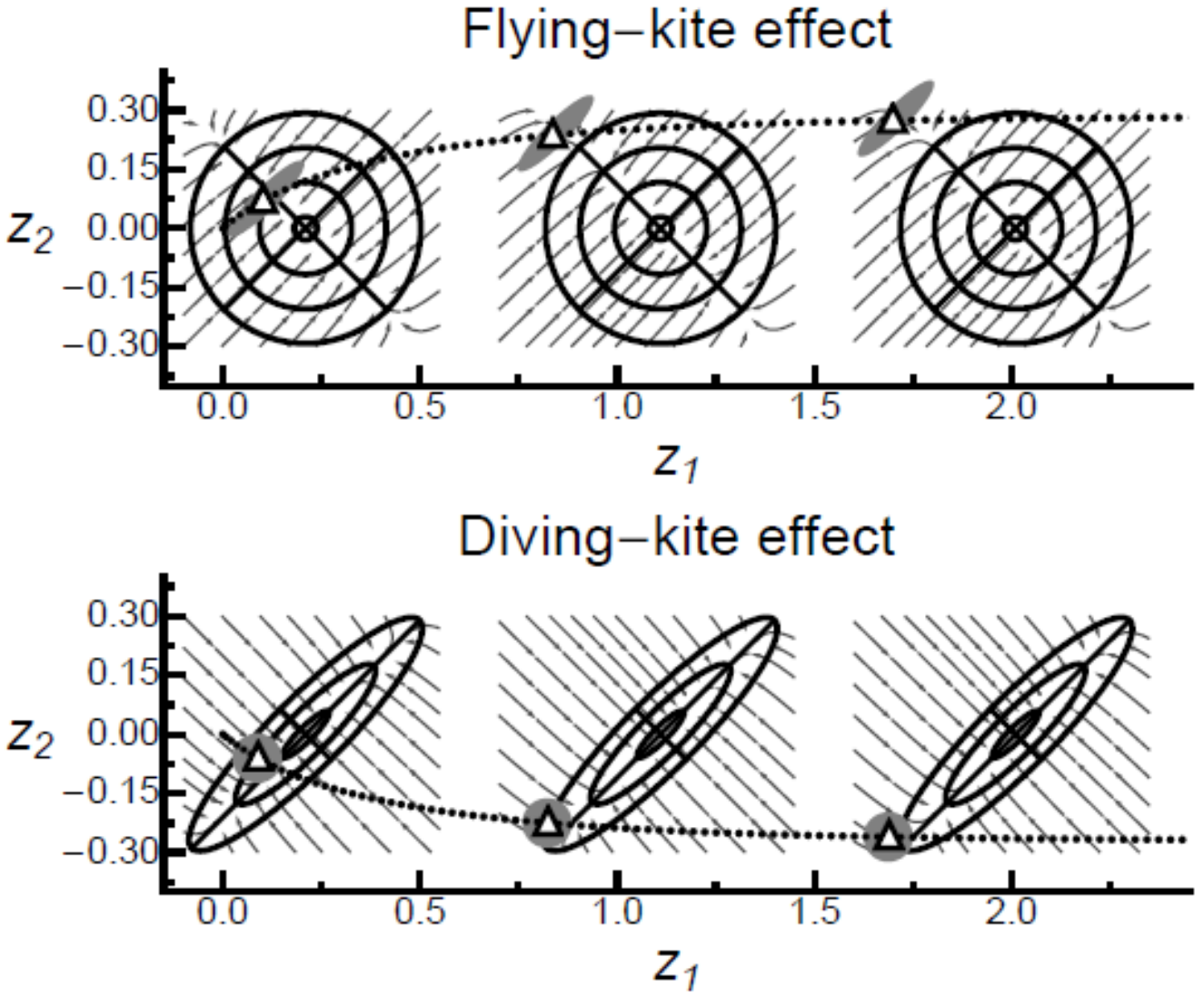


The mean step size increases with the number of traits

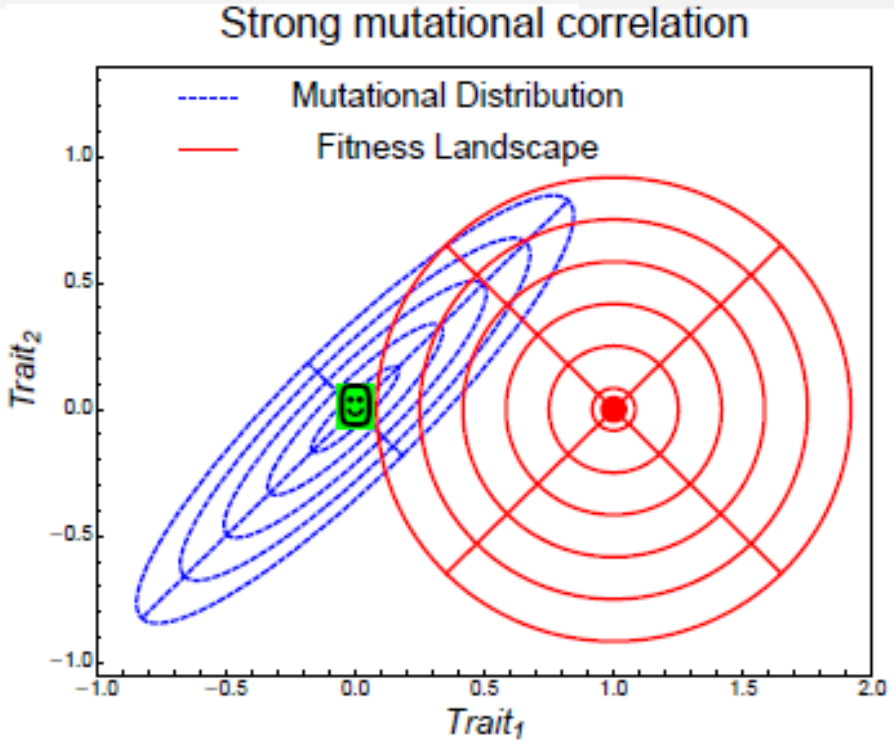


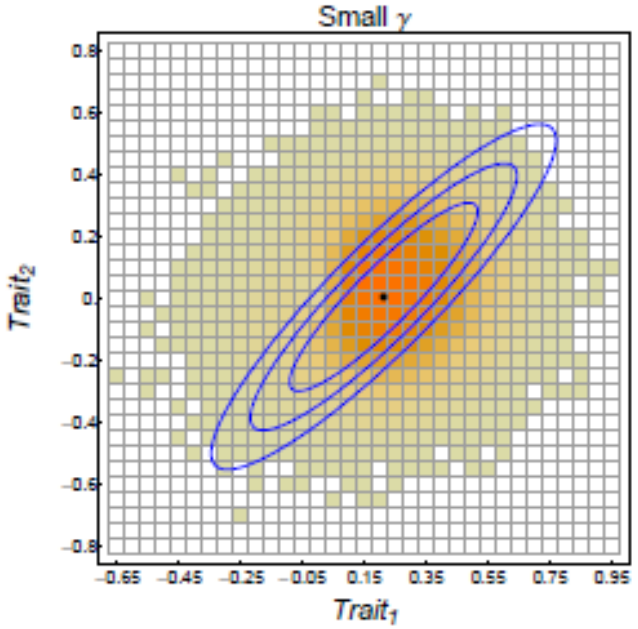
More traits ⇒ Fewer beneficial mutations ⇒ Longer waiting time between steps ⇒ Optimum moves farther away ⇒ Selection for larger mutations.

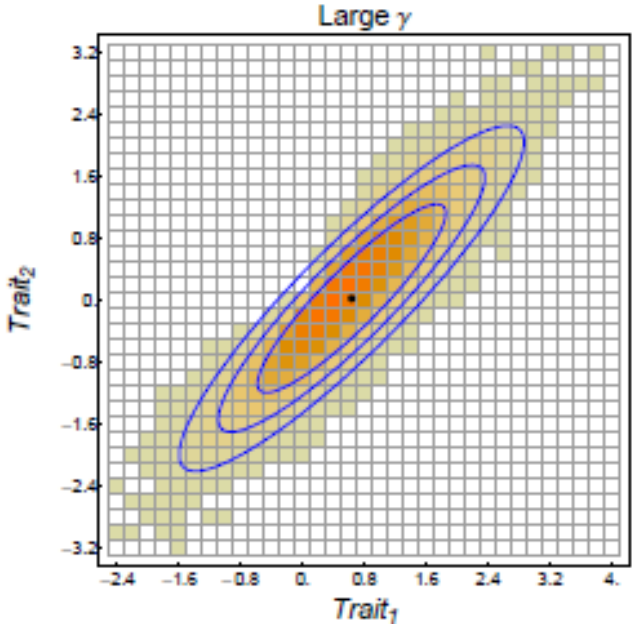
Effects of mutational and selective correlations on the trajectory of the mean phenotype



The shape of the mutational distribution

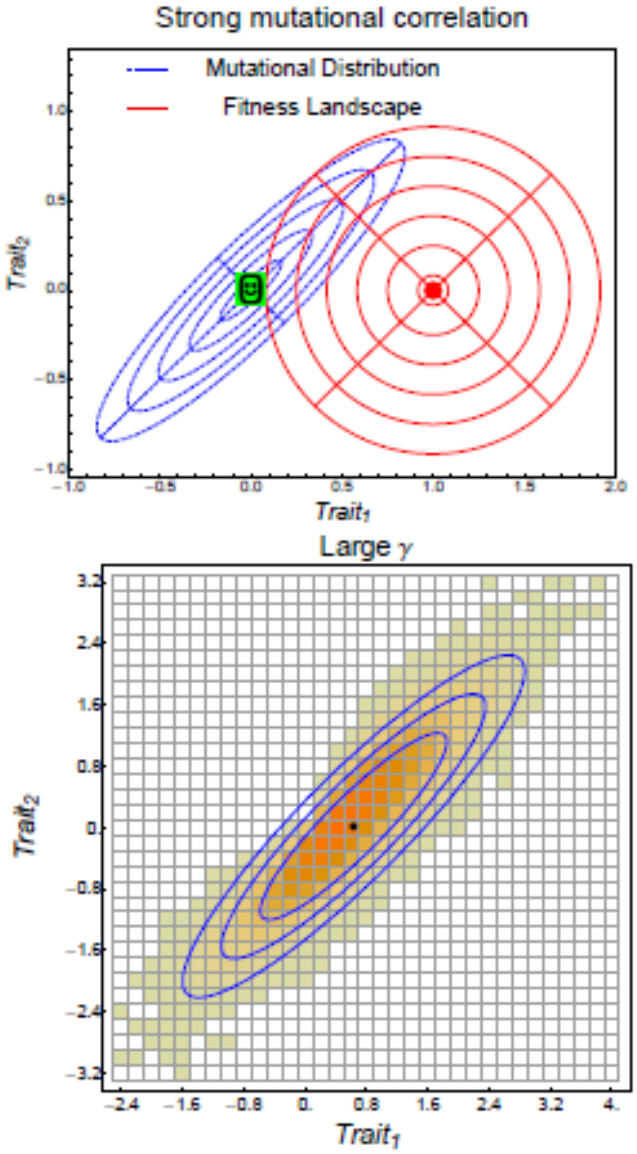


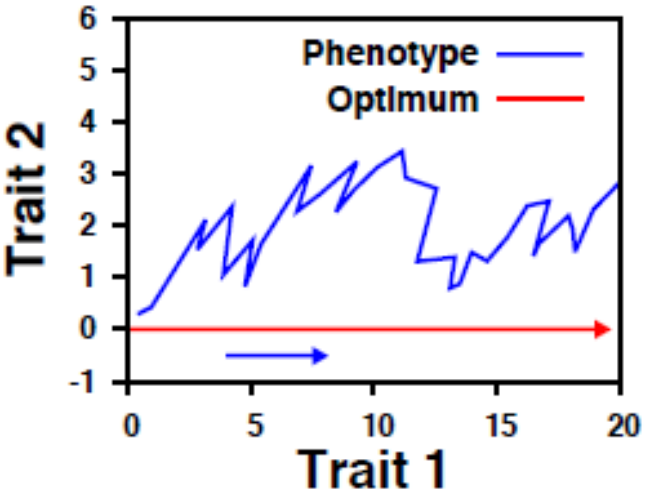


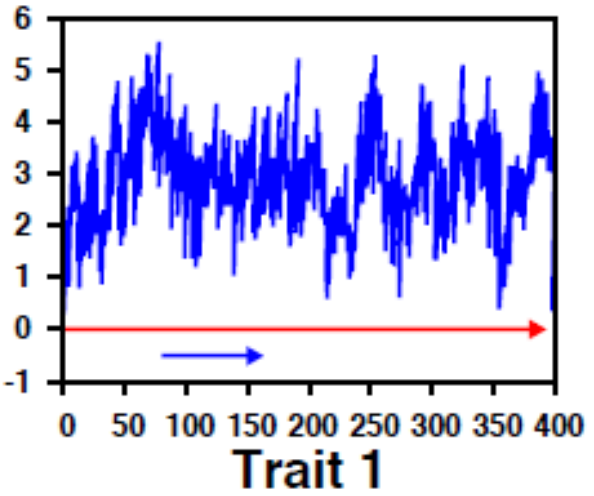


- If the environment changes fast the distribution of adaptive substitutions resembles the shape of the mutational distribution
- This effect reduces as the scaled rate of environmental change decreases

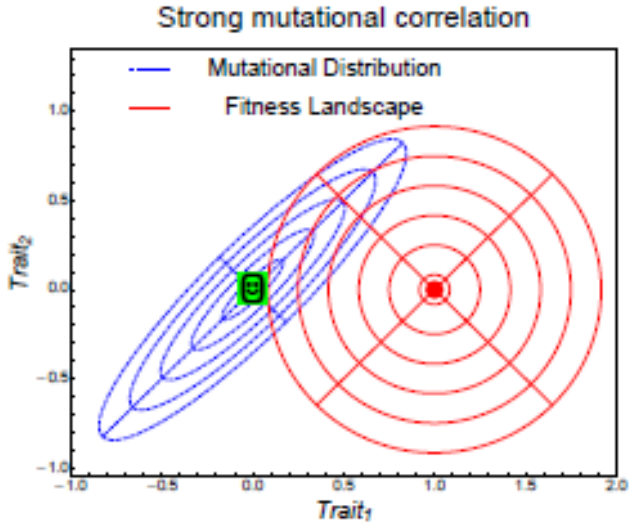
The trajectory of adaptive evolution

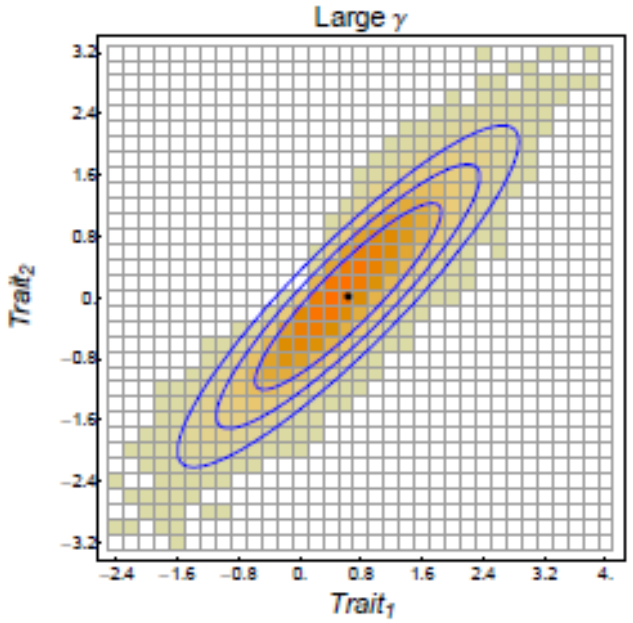


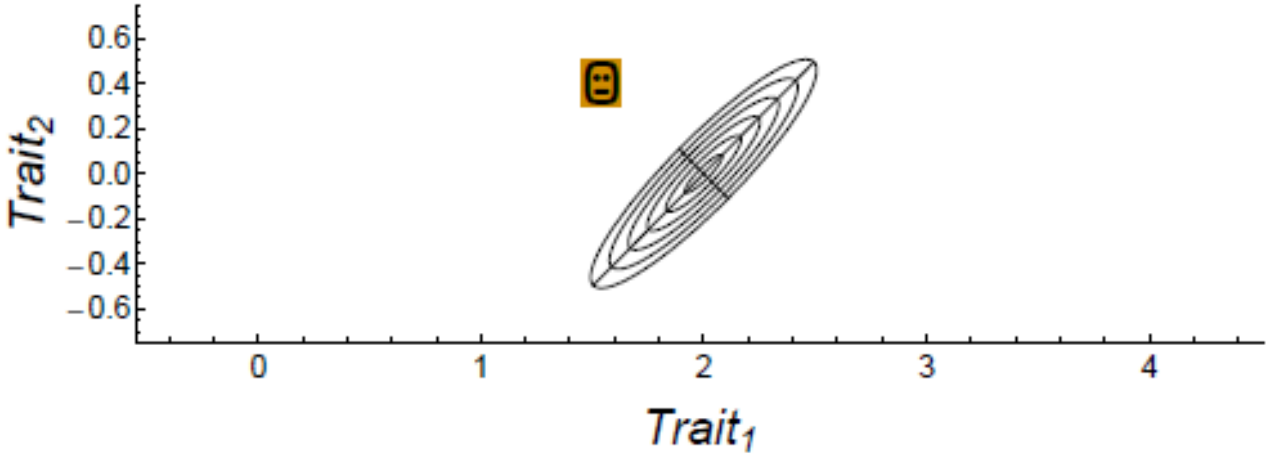




The trajectory of adaptive evolution





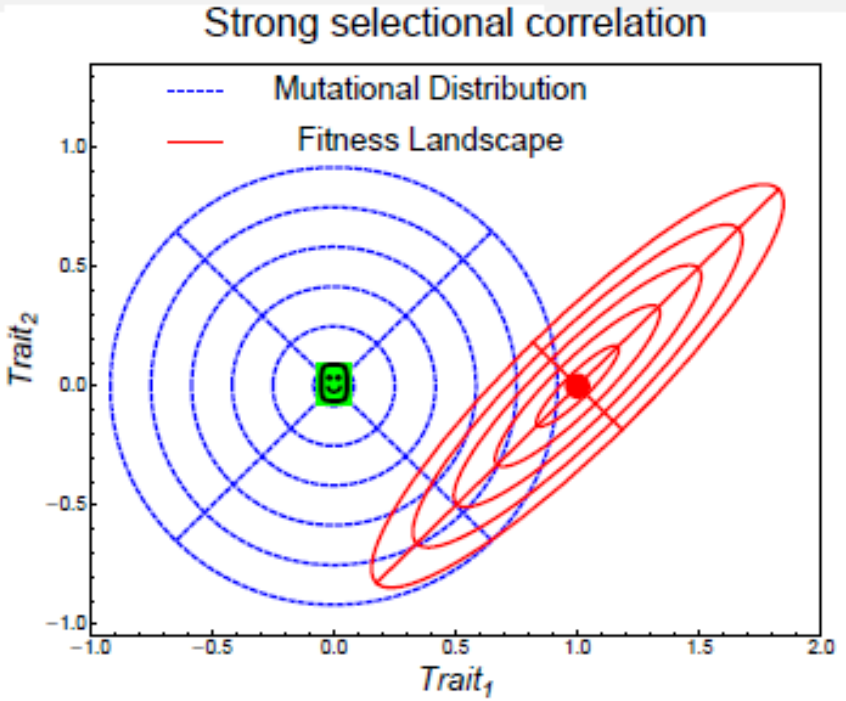


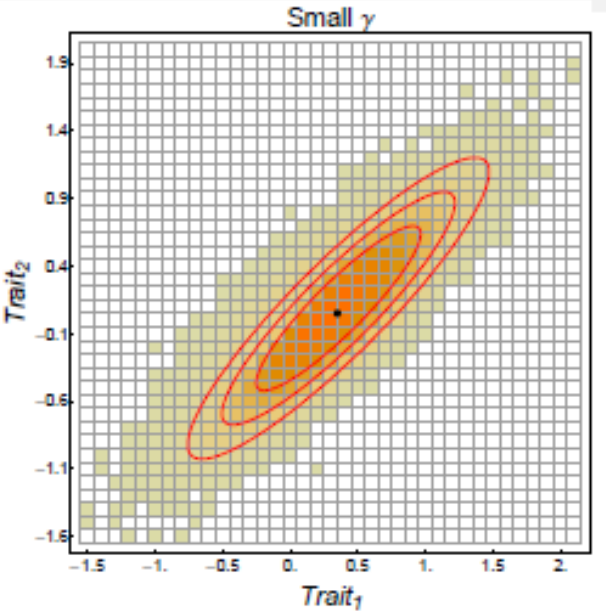
Strong (positive) mutational correlation causes the phenotypic mean to consistently trail behind and above the optimum

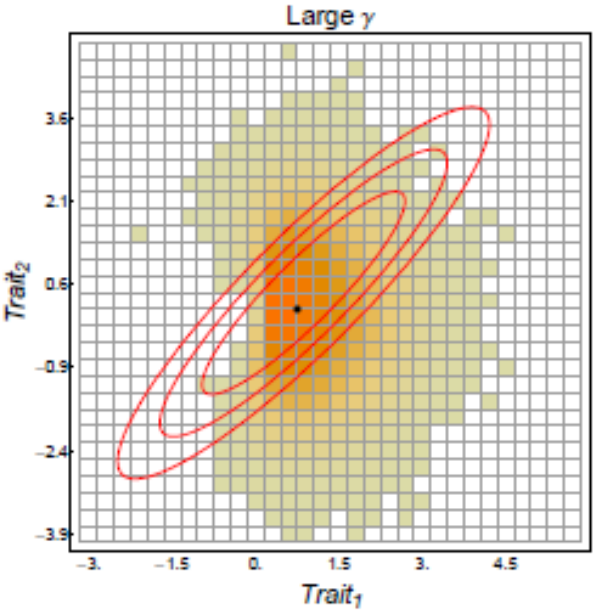
→ "Flying kite effect"

Jones et al. (2004)

The shape of the fitness landscape

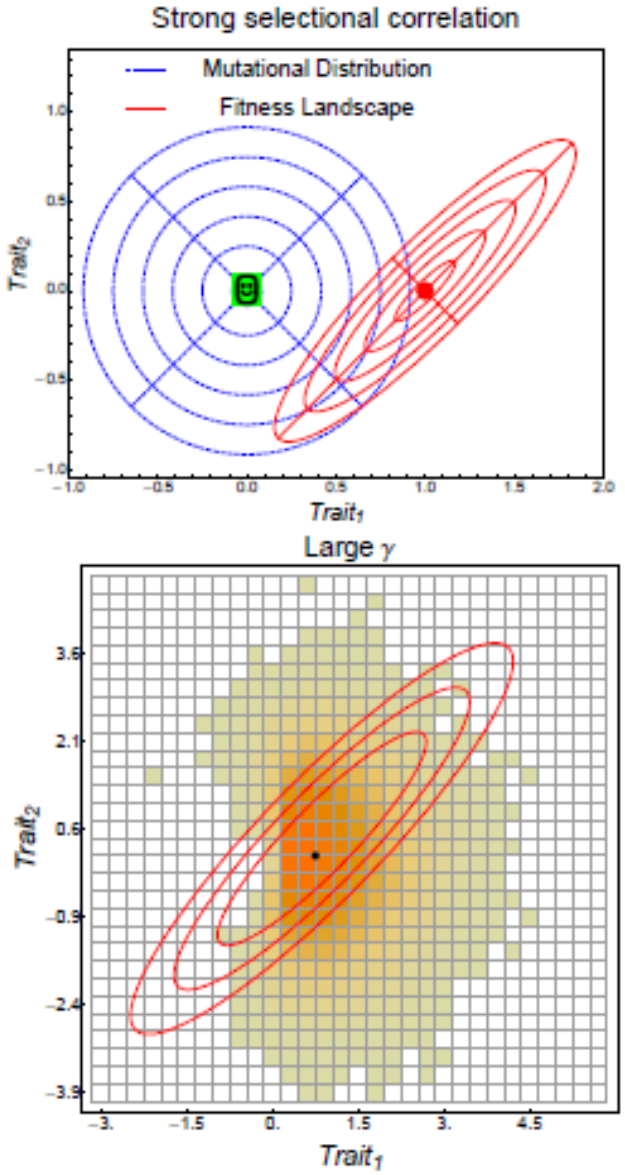


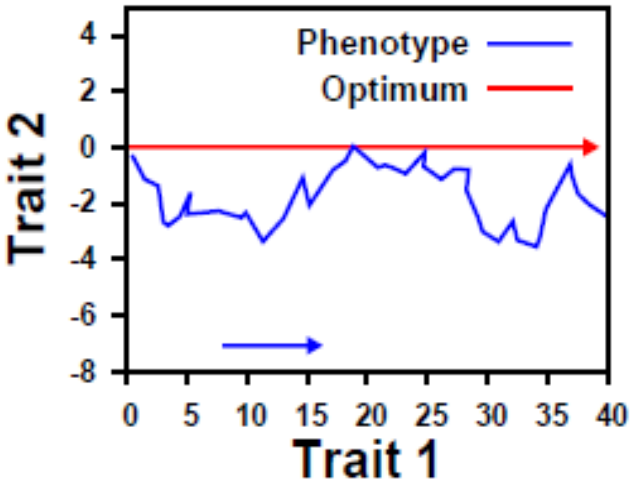


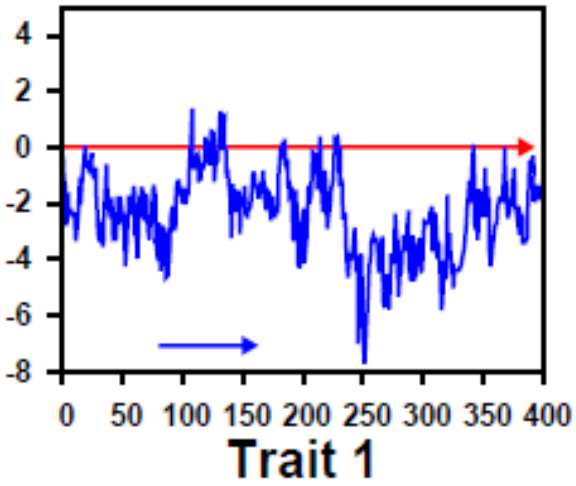


- If the environment changes slowly the distribution of adaptive substitutions resembles the shape of the adaptive landscape
- This effect reduces as the scaled rate of environmental change increases

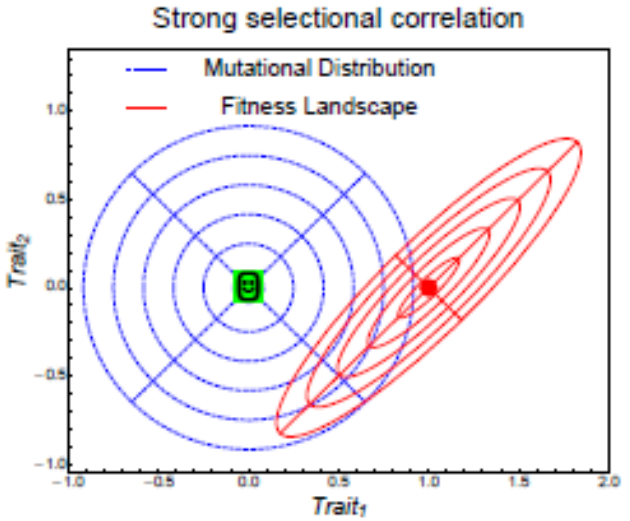
The trajectory of adaptive evolution

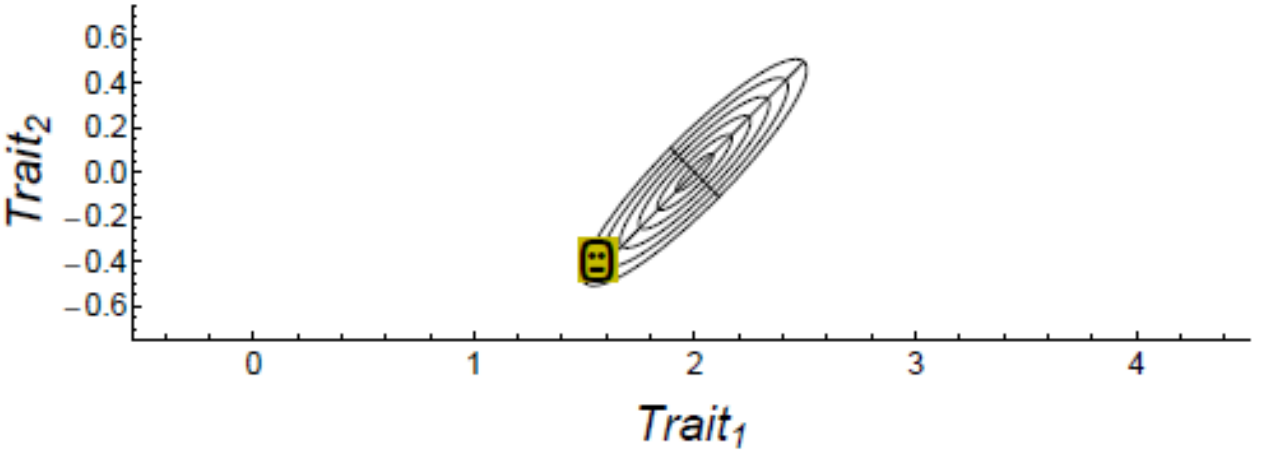


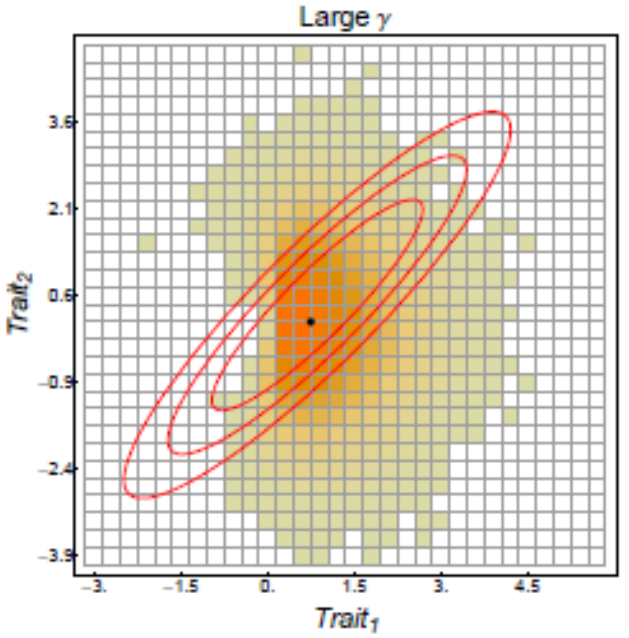




The trajectory of adaptive evolution



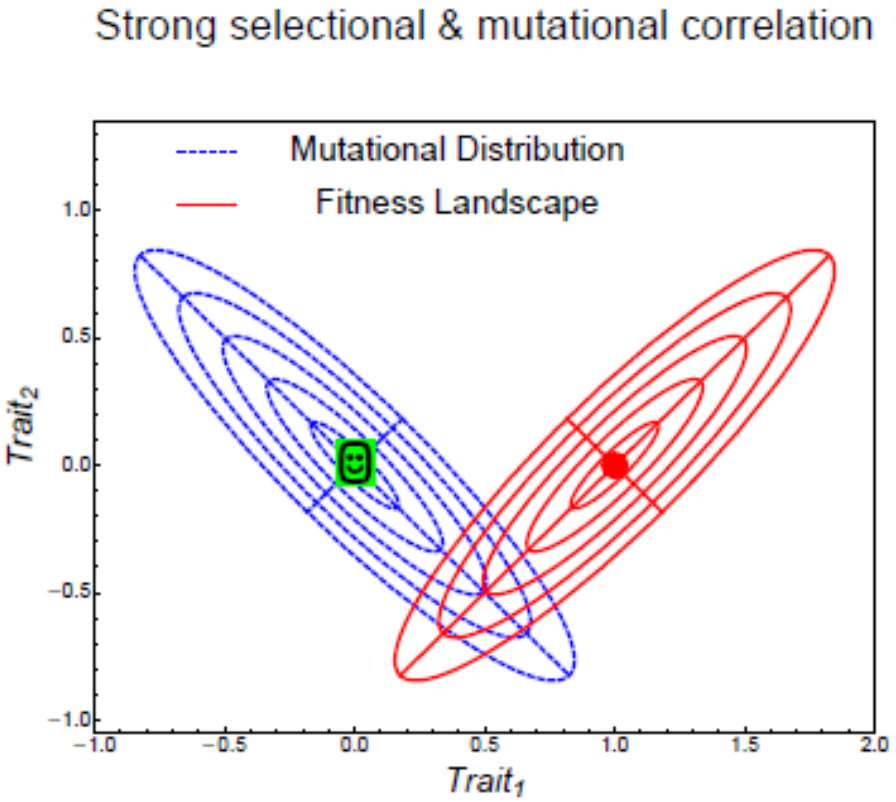


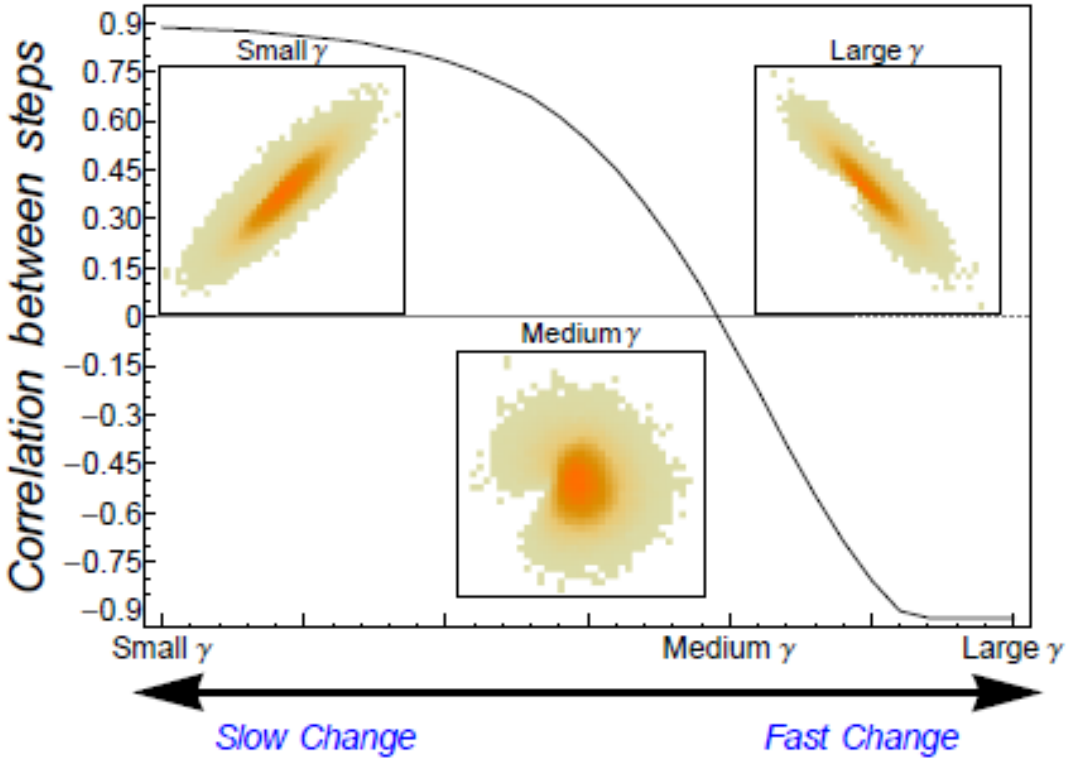


Strong (positive) selectional correlation causes the phenotypic mean to consistently trail behind and below the optimum

→ "Diving kite effect"

Strong selectional & mutational correlations





Slow environmental change → distribution of adaptive substitutions resembles the adaptive landscape

Fast environmental change → distribution of adaptive substitutions resembles the mutational distribution

Step size distribution and G-matrix