

# The genetic basis of variation in plant traits

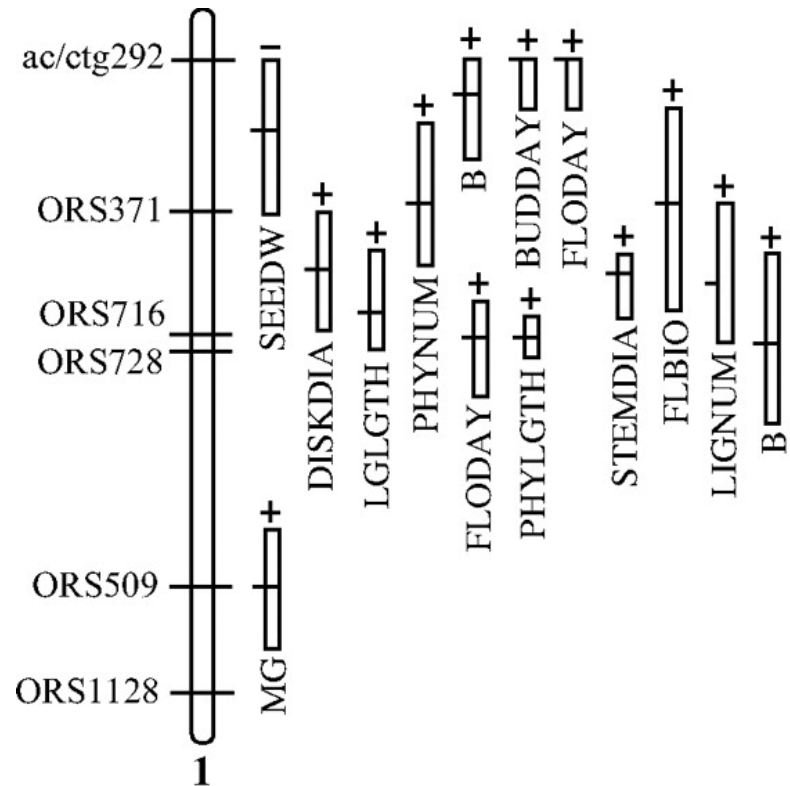
Rose Andrew

University of British Columbia



# Quantitative genetics

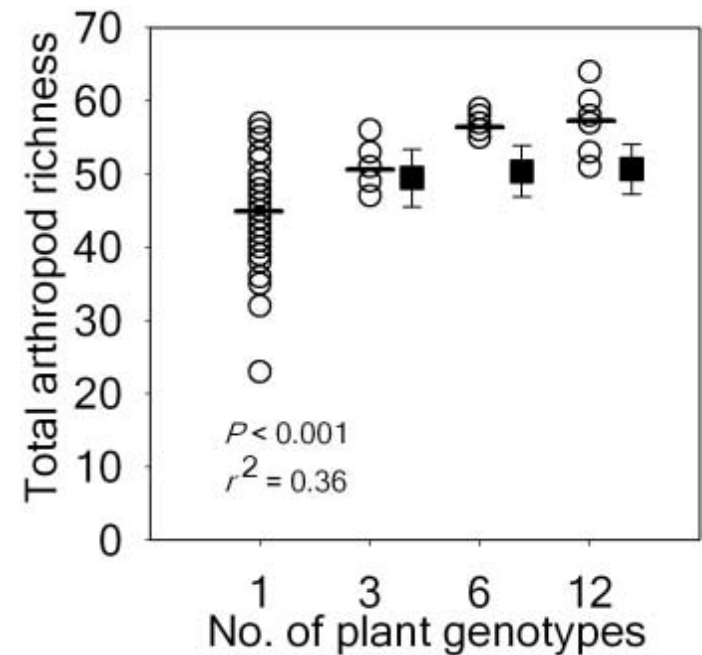
- Molecular approaches (QTL mapping)
- Persistent question: are most traits controlled by a few genes with large effects or many genes with small effects?



# Individual variation in plant traits

Why should ecologists care about variation below the level of species?

1. Reality (e.g. climate change)
2. Emergent effects of individual variation
3. Niche breadth
4. Macroevolution results from microevolutionary processes



Arthropod communities on Solidago  
Crutsinger et al 2006 Science.

# Key concepts in quantitative genetics

**Genetic variance** = trait variation due to genetic differences among individuals

- total, additive, dominance, epistasis, inbreeding
- Measured using covariance among relatives

$$V_P = V_G + V_E + V_{G \times E}$$

$$V_P = V_A + V_D + V_I + V_E + \dots$$

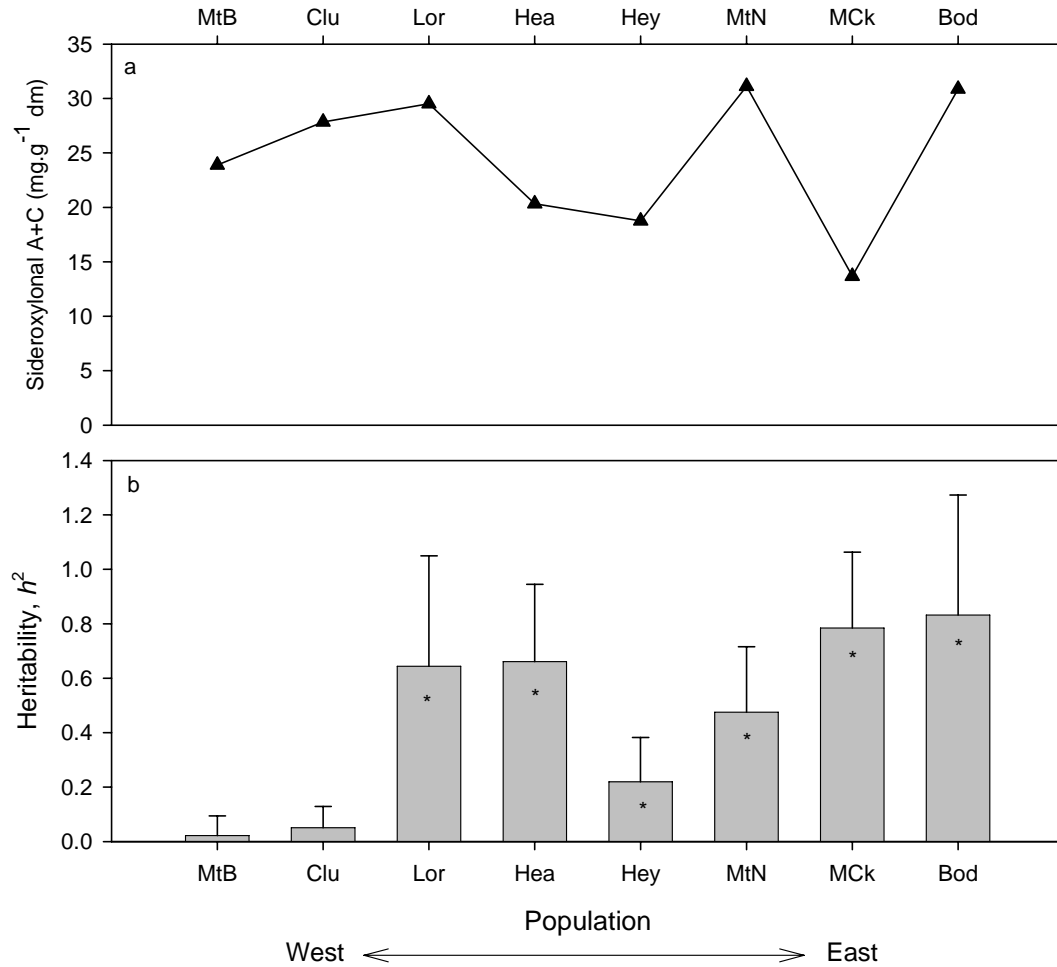
**Heritability** = the proportion of phenotypic variation caused by genetic effects

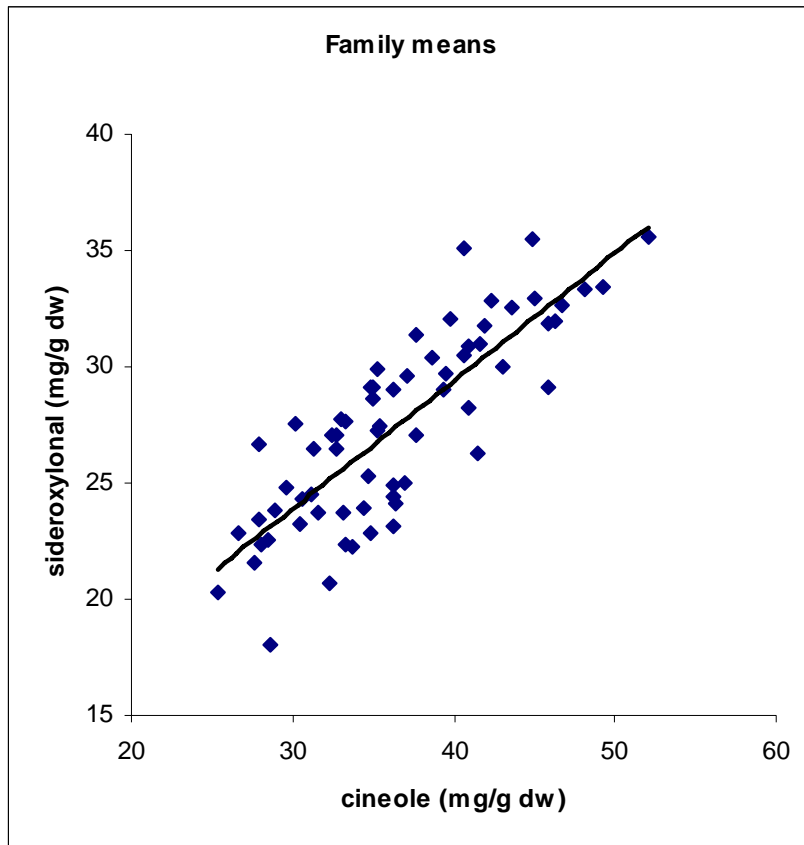
- Broad-sense or narrow-sense
- Predict evolutionary response
- Mating system
- Population-specific

$$H = V_G / V_P$$

$$h^2 = V_A / V_P$$

# *Eucalyptus tricarpa* chemical defence



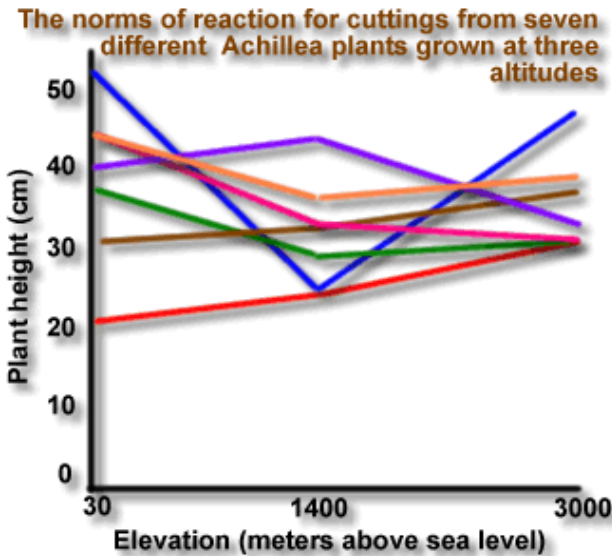


**Genetic covariance** = the covariance of genetic effects between traits

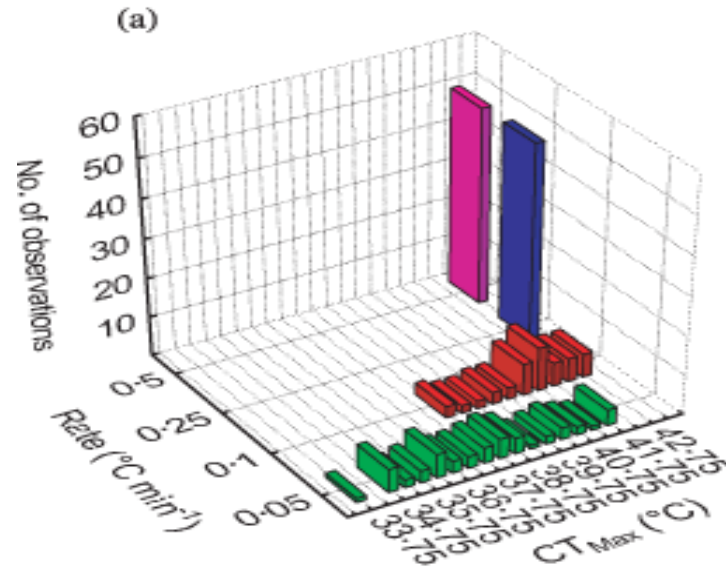
- May differ in direction from phenotypic covariance
- **Genetic correlation:** scaled by genetic variance
- Linkage or pleiotropy
- Multivariate quantitative genetics: G matrix

# Genotype x environment interaction effect (GxE)

- Norms of reaction
- Genetic variation in **plasticity**
- Instability of genetic effects



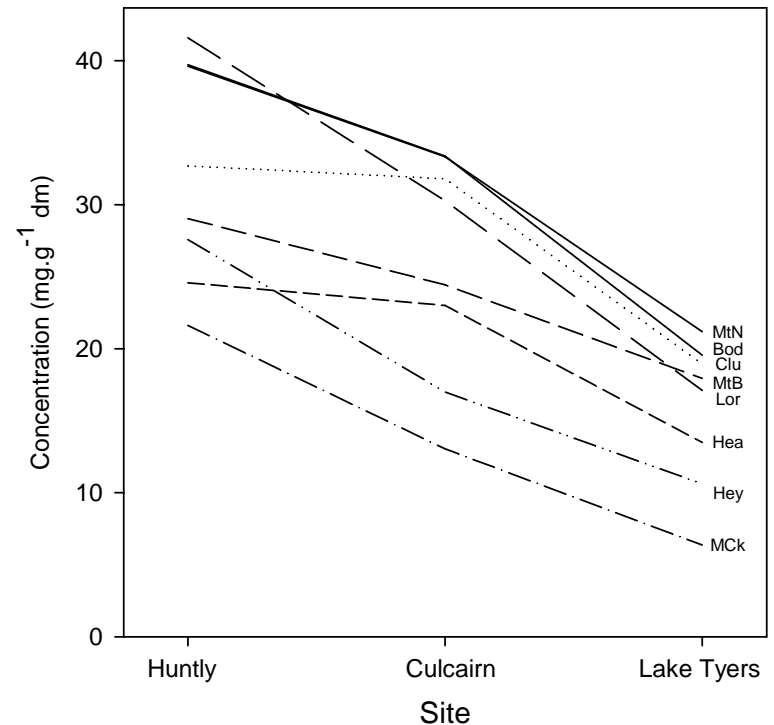
Clausen et al. 1958 in Suzuki et al, 1981



*Drosophila* thermal tolerance  
(Chown et al 2009 *Funct. Ecol.*)

# Population differentiation

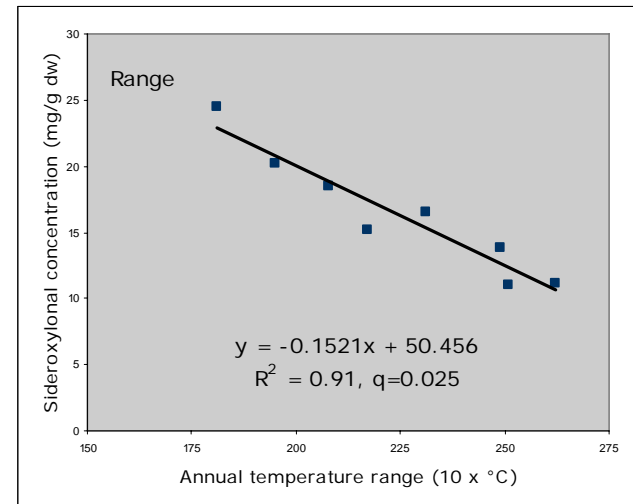
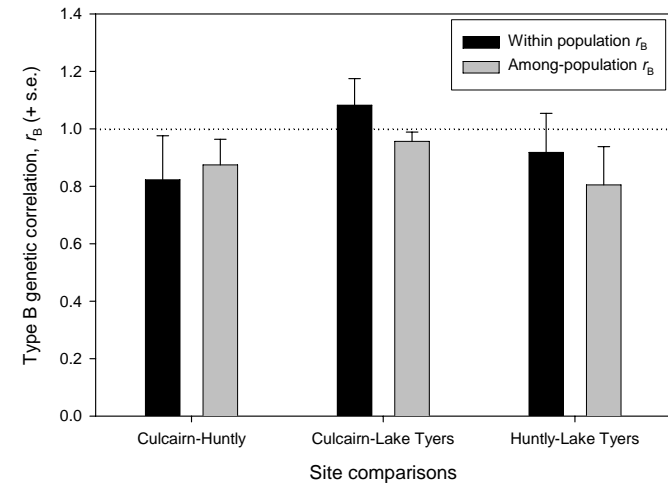
- Along environmental gradients or in different communities
- Genetic and environmental effects
- Adaptation or drift?
- Population-level GxE



# Population differences

- What is a trait?
  - Measured on any plant?  
Wild or in a common garden
  - Measured in a specific environment?
  - Reaction norms?
  - Plasticity?

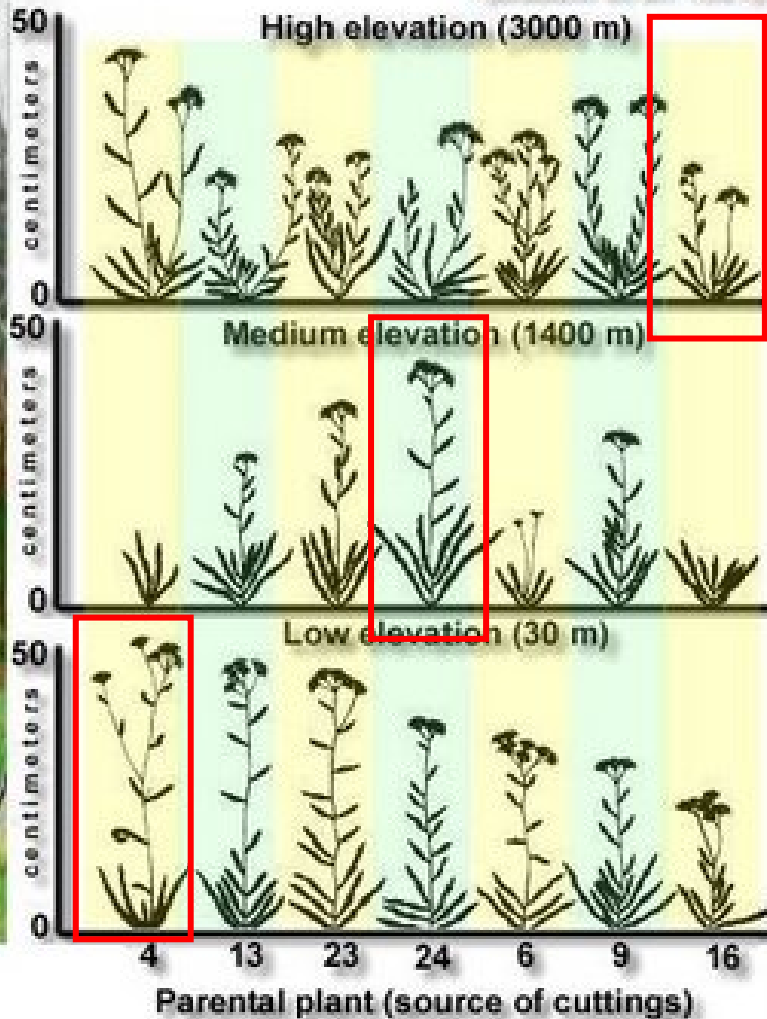
Genetic correlations among sites



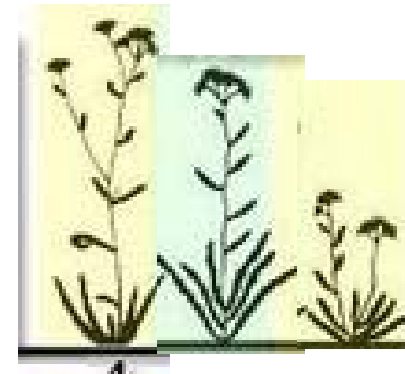
Source population climate and phenotypic plasticity

# Population differences

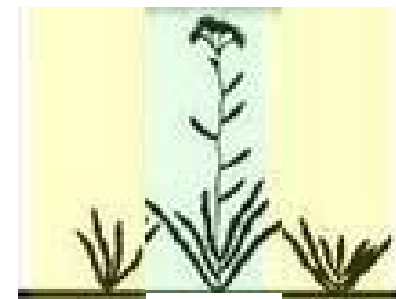
Norms of reaction to elevation for seven different *Achillea* plants. A cutting from each plant was grown at low, medium and high elevations. (Suzuki et al. 1981).



Home environments

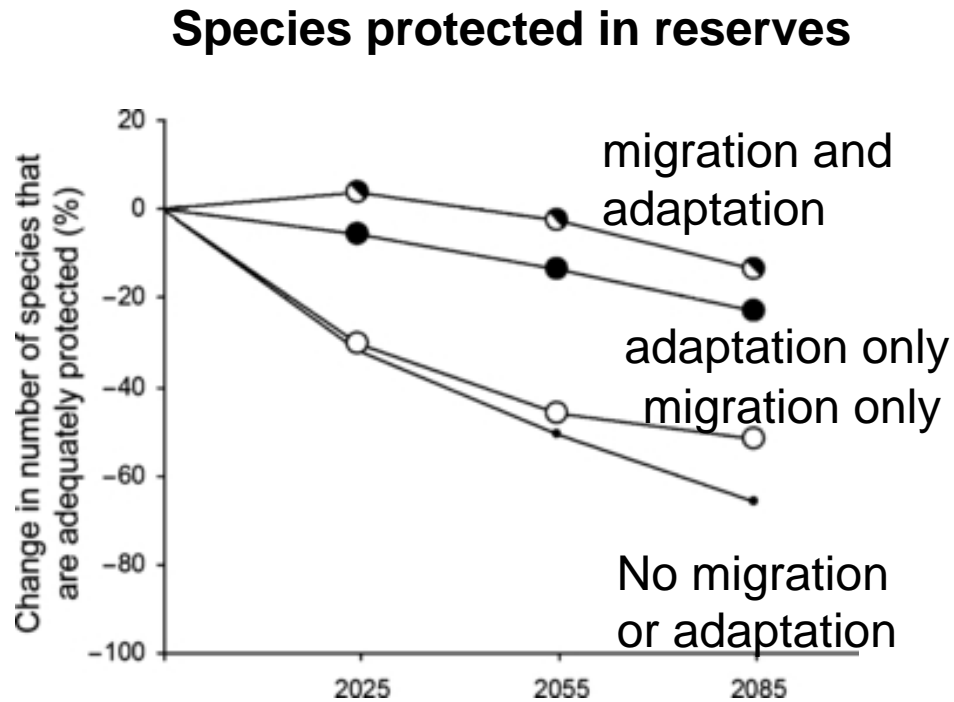


Average environment



# Plant responses to environmental change

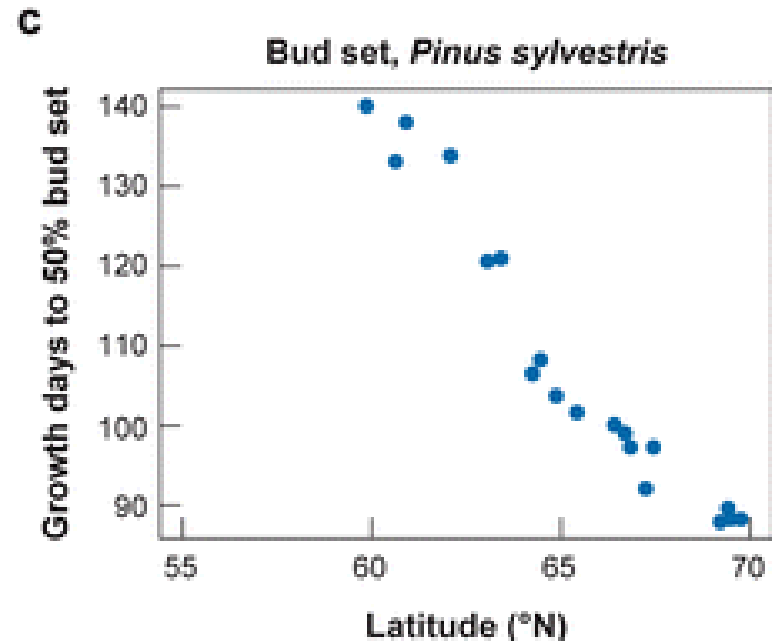
- Migrate? Die out? Evolve?
- Is there enough genetic variation to adapt?
  - If the rate of change is slow (Lynch and Lande, 1993)
- Will populations migrate to track optimal conditions?



Aitken 2008 Evol. Appl.

# Plant responses to environmental change

- Will geographic variation be important?
- Adaptation or drift
  - $F_{ST}$  (neutral markers) vs.  $Q_{ST}$  (quantitative trait)

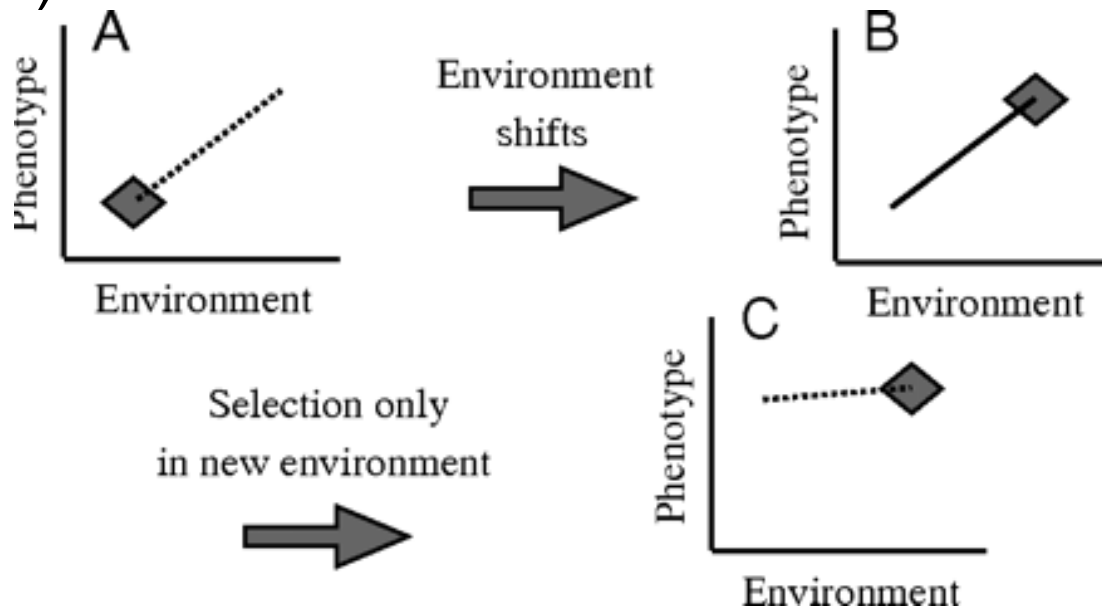


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 Savolainen O, et al. 2007.  
Annu. Rev. Ecol. Evol. Syst. 38:595–619

# Plant responses to environmental change

- What role will plasticity and genetic assimilation play?
- Does phenotypic plasticity precede adaptation?
  - West-Eberhard (2003), Pigliucci et al (2006), de Jong (2005)



# Methodological issues

## Maternal effects

- Genetic and environmental
- Grow for a generation in greenhouse?
  - Domestication
  - Disruption of relationship structure



## Common gardens

- Compare apples and apples
- No covariance of genotype and environment
- GxE and population structure may cause differences between common garden and natural populations

## **Interesting questions**

- Which traits are responsible for the emergent properties of genetic variation?
- How do genetic and environmental effects contribute to alpha and beta traits?

## **Other issues**

- QTLs: identification and interpretation
- Gene expression as a trait
- Quantitative genetics in the wild