Problems of small populations

A crash course in evolutionary principles

Conservation Biology EEB 115/515

Nathalie Sommer

Key Concepts

- Traits vary among individuals
- Traits are heritable
- There is variation in reproductive success across individuals
- Not all offspring survive to reproduce

- Genotype = genes
- Phenotype = what you see
- Fitness = differential reproductive success
  - "Ability to make successful grand-kids"
  - Reproduction & Survival

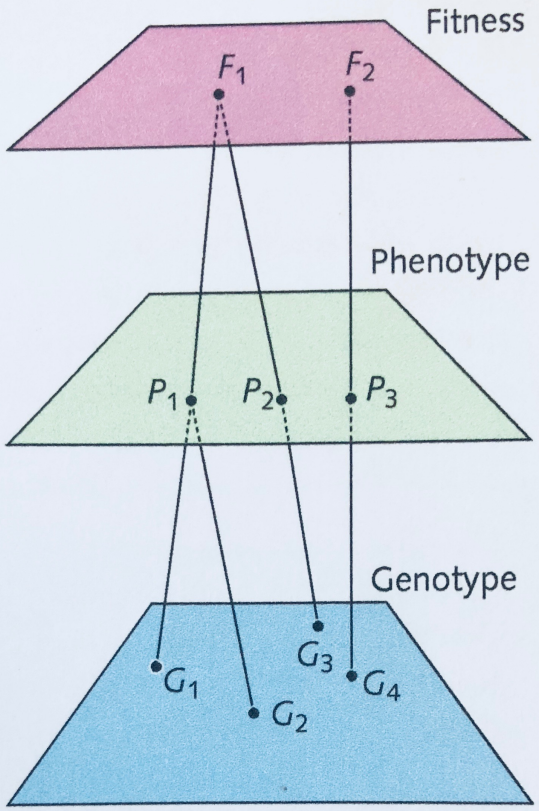


Figure 3.1 Schematic relations between variation at the levels of the genotype, the phenotype, and fitness. G_i, where $i = 1–4$, denotes different genotypes; P_i, $i = 1–3$, denotes different phenotypes; and F_i, $i = 1, 2$, denotes different fitnesses. The variation between the genotypes G_1, G_2, and G_3 is neutral with respect to fitness.

Stearns & Hoekstra

Evolutionary Principles

- Evolution = change in allele frequency over time in populations
  - A population is a group of interbreeding individuals of the same species
- Gene pool = sum total of all alleles within a population
- Gene frequency = $\frac{\text{\# of specific allele}}{\text{total \#of alleles}}$

Four Forces of Evolution
(remember: change in allele frequency in a pop over time)

- Selection
  - Environment acts on the phenotype
  - Some phenotypes have lower fitness
  - Over time, those phenotypes (& their genotypes) are lost in the population
- Mutation
  - Random change, at the level of the gene
  - Occurs during mitosis or meiosis
- Flow
  - Movement of genes between populations
  - Requires BOTH immigration & mating
- Drift
  - Change in allele frequency due to **random chance**
  - Always occurs, but its effects are seen at a greater magnitude in small pops

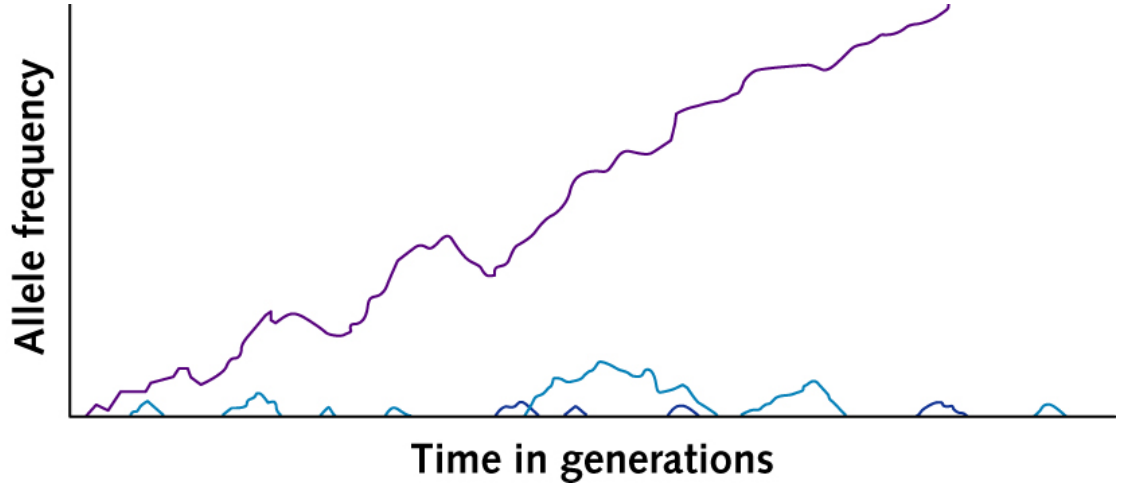
Origins of Genetic Variation

1. Sexual recombination (≠ evolution)
2. Mutation
3. Flow

- But how is variation maintained in the face of evolutionary forces that will erode variation?
- When are evolutionary forces balanced to maintain variation?

1. Mutation-Drift Balance

- When would drift be in balance with mutation?
  - Drift erodes variation (fixation = allele substitution)
  - Mutation introduces new variation



- Drift would be in balance with mutation when:
  allele substitution rate = mutation rate

2. Mutation-Selection Balance

- When would erosion of genetic variation due to selection be balanced by the introduction of new variation by mutation?

$$\text{Frequency of new mutant alleles} = \frac{\text{Mutation rate per locus}}{\text{Selection against mutant alleles}}$$

3. Opposing-Selection Balance

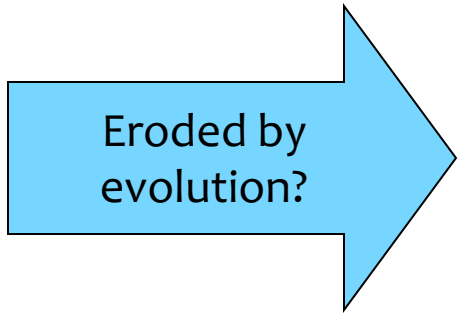
- When mutations are adaptive (or maladaptive), new alleles are driven to fixation (or loss)

- However, if selection is acting in opposing directions simultaneously, adaptive/maladaptive mutations can also occur at intermediate frequencies (e.g. heterosis in sickle-cell anemia)

Summary of genetic variation

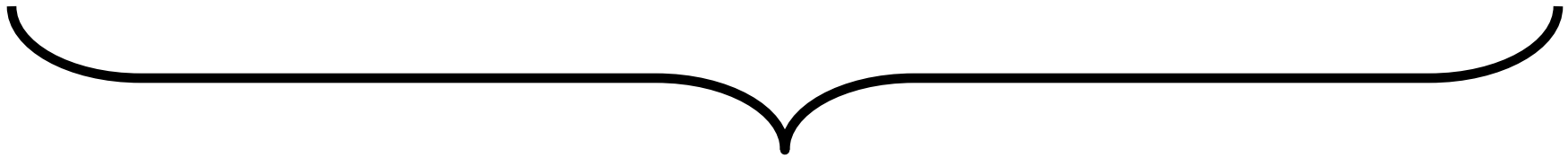
Origins of genetic variation

1. Recombination
2. Mutation
3. Migration



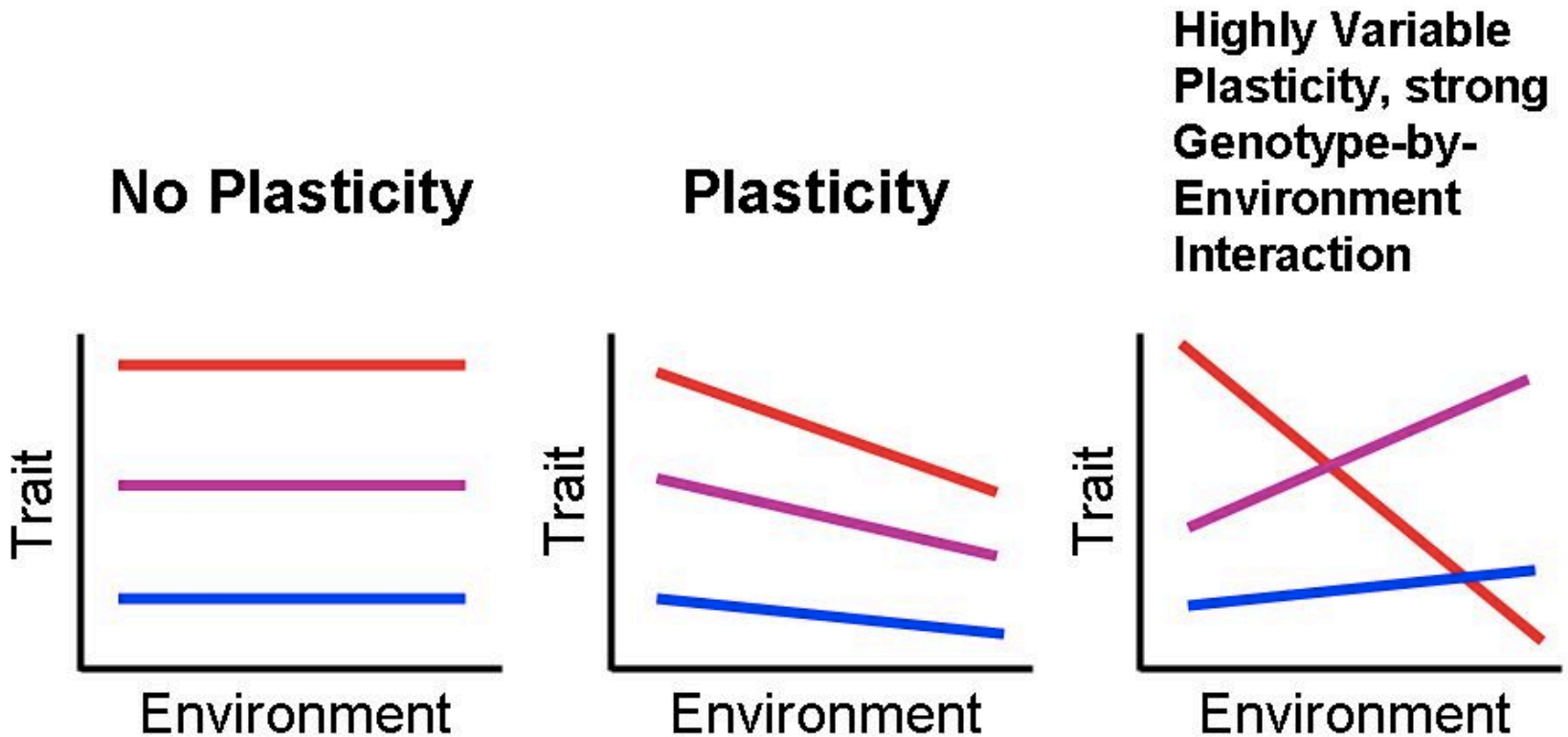
Maintenance of variation

1. Mutation-drift balance
2. Mutation-selection balance
3. Opposing selection



Maintain the fuel for evolution

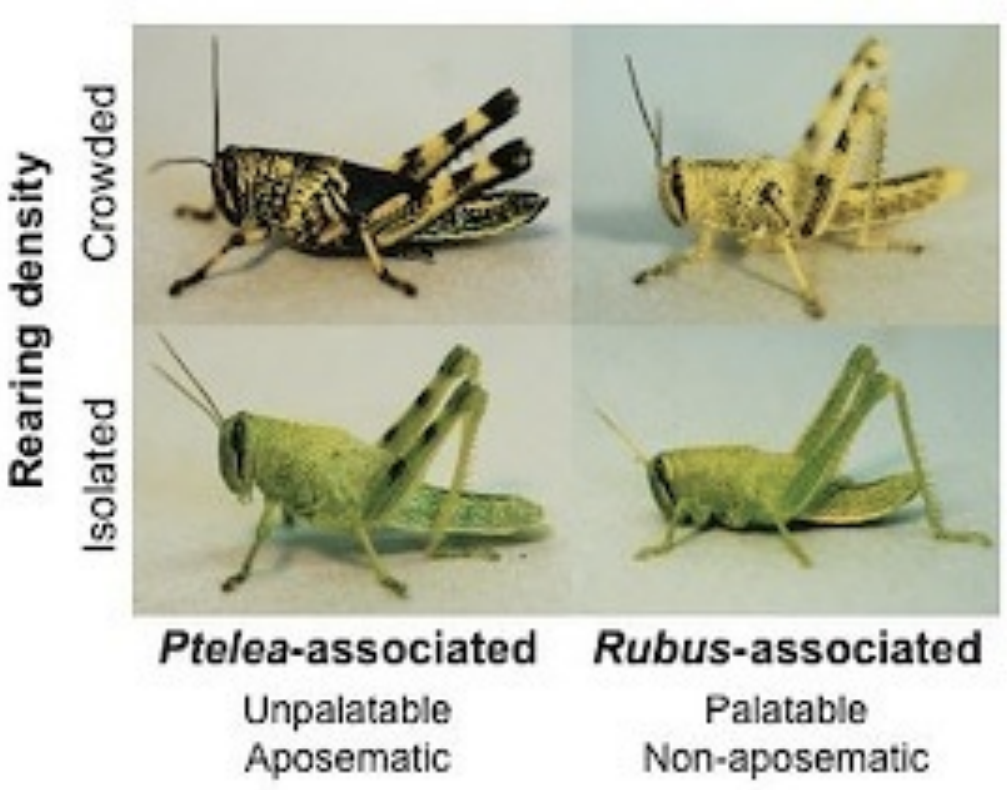
The ability of one genotype to produce more than one phenotype when exposed to different environments.



Each of the colored lines is a "Reaction Norm"

Plasticity

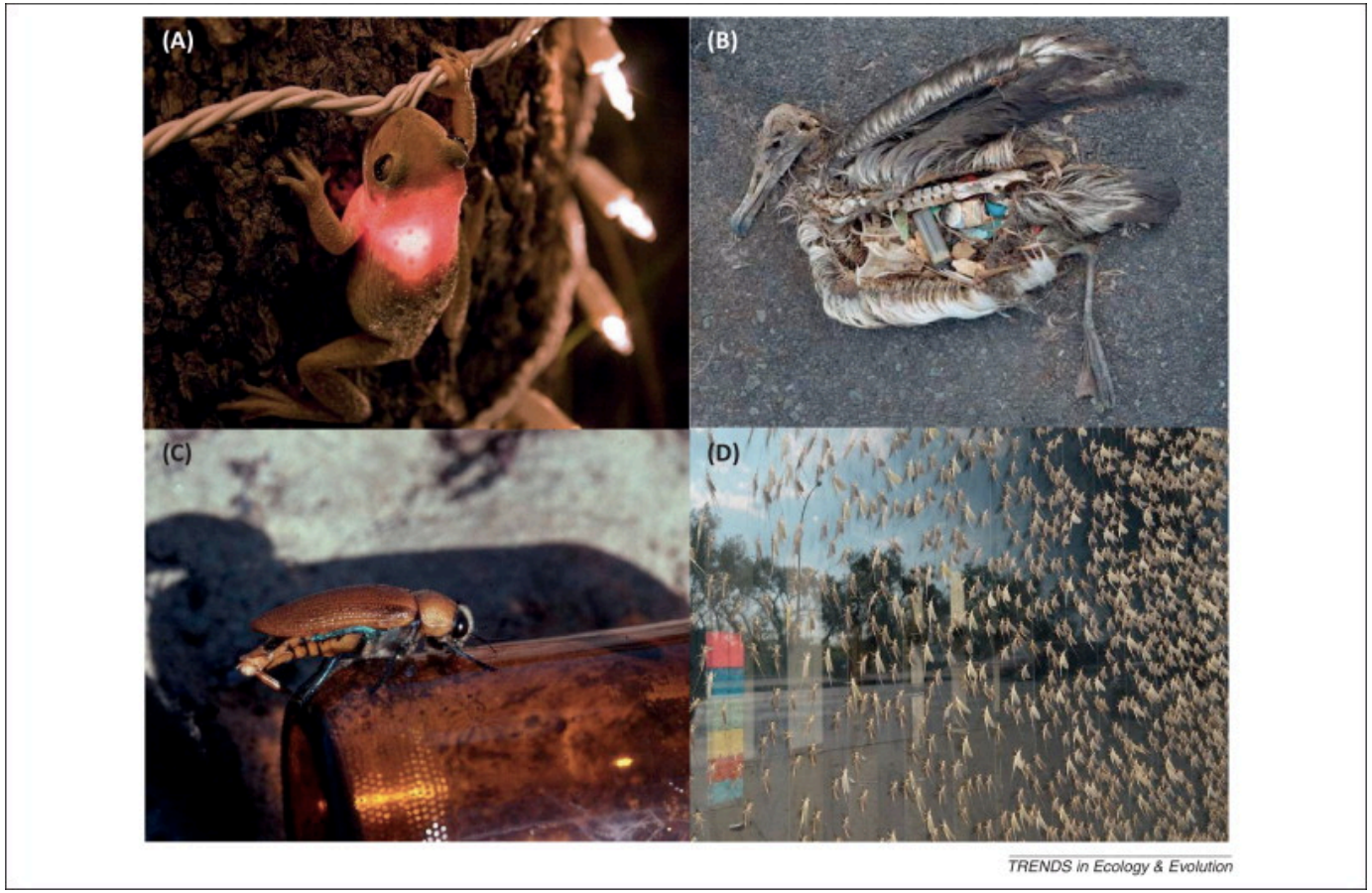
- Same genotypes, different environment
- Best examples of plasticity are driven by different environmental conditions *during development*

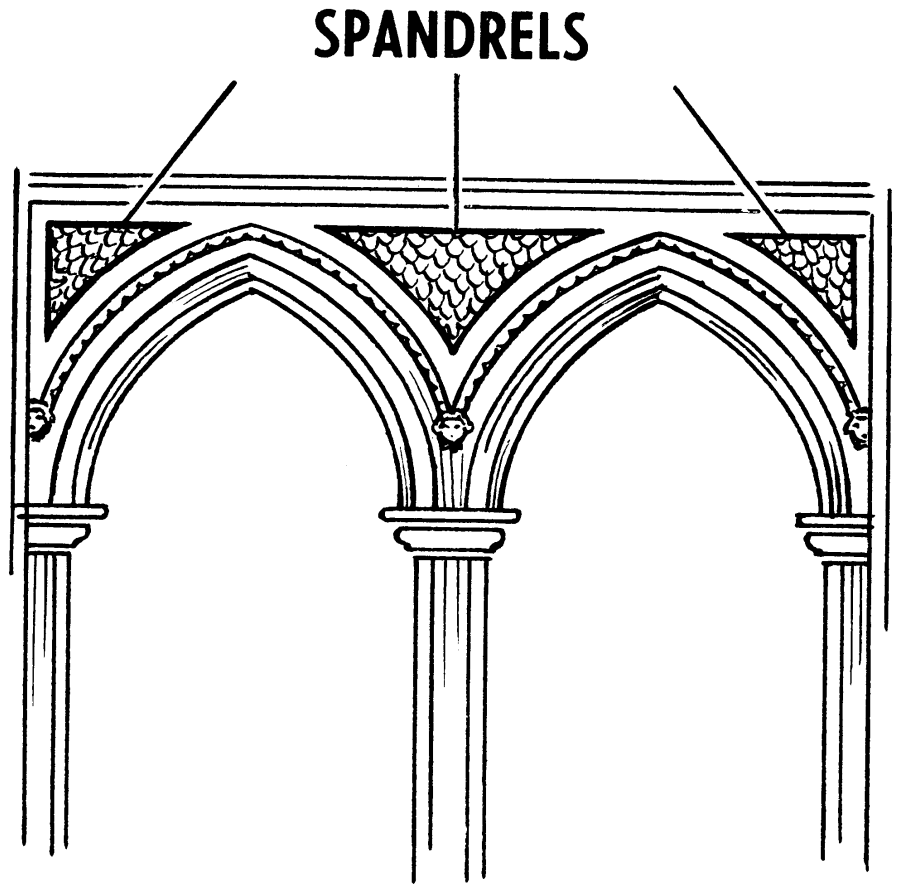


Acclimation

- Same genotypes, different environment
- Change is *short term adjustment*

An “evolved” population ≠ an “adapted” population





Take-aways

- Evolution does not have intent or direction
- Individuals do not evolve
  - Acclimation vs Adaptation
- Adaptive evolution vs Neutral evolution
- Genetic variation = evolutionary flexibility

- Selection and drift erode genetic variation
- Flow and mutation promote genetic variation
  - Flow and mutation can result in maladaptation

Activity: Integrating concepts

Exploring evolutionary problems of small populations

https://www.radford.edu/~rsheehy/Gen_flash/popgen/

Discussion: Wolves of Isle Royale

Peterson et al. 1998

Restoring Wolves at Isle Royale

Through years-long advocacy efforts by National Parks Conservation Association, the National Park Service will bring more wolves to Isle Royale National Park, an island in Lake Superior. More wolves will keep the island's rapidly growing moose population in check and improve the overall health of the park landscape.

1. The Plan

20-30 wolves over three years, targeting 6-8 wolves per year, to address the population imbalance between predator and prey.

The Numbers

20-30
Wolves to be moved

over a period of

3 years

2. The Capture

Will take place optimally between late fall and early winter each year from areas near the park. Researchers use strict guidelines for selecting wolves.

Challenging Weather

Lake Superior's sometimes severe weather can impact the ability to travel safely to and from the island.

3. Transporting

Can be a challenge for an island national park and requires many modes of transportation.

4. The Release

Will occur in multiple locations throughout the park.

Potential Drop Off Points

5. Monitoring

The National Park Service will track the wolves and monitor progress to ensure a successful recovery at the park.

NATIONAL PARKS CONSERVATION ASSOCIATION

To learn more and follow along, visit:
www.npca.org/wolves | #wolfwatch