Genetic Drift Lecture outline

1. Founder effect
2. Genetic drift consequences
3. Population bottlenecks
4. Effective Population size
Odd populations

Deer at Seneca Army Depot

Cheetah
Silvereyes (Zosterops lateralis)

(example of sampling error)

Clegg et al
Founder Effect
What happens when a small number of individuals start a new populations?

Predict a decay in allelic diversity

Can result in:
Change in allelic composition (loss of diversity)

Allelic diversity
Average number of alleles found per locus

Allelic diversity
Sampling Error and Evolution

Founder effect
• Reduced diversity
• Change in allele frequencies
A review of Hardy-Weinberg assumptions

- No selection (random fitness)
- No mutation
- No immigration or emmigration
- Random mating
- Large population size
Large Population Size?

Question:
What happens if the population has a small size?

Answer:
Genetic Drift
The role of Random Chance

**Genetic Drift**: change in frequencies of alleles in a population resulting from sampling error

Does not lead to adaptation!
A toy (mouse) example

- Population size
  - 10 mice
- Initial allele frequencies
- Generate gametes based on these frequencies

Next generate 10 new individuals
New population of 10 mice

Number of adults

$A_1A_1$ $A_1A_2$ $A_2A_2$

Genotype

6

2

2
Calculate new Allele Frequencies

**Genotype Frequencies**
- $A_1A_1 = \frac{6}{10} = 0.6$
- $A_1A_2 = \frac{2}{10} = 0.2$
- $A_2A_2 = \frac{2}{10} = 0.2$

**New Allele frequencies**
- $\text{Freq}(A_1) = 1 \times \text{Freq}(A_1A_1) + \frac{1}{2} \times \text{Freq}(A_1A_2)$
  - $\text{Freq}(A_1) = 1 \times 0.6 + \frac{1}{2} \times 0.2 = 0.7$
- $\text{Freq}(A_2) = 1 \times \text{Freq}(A_2A_2) + \frac{1}{2} \times \text{Freq}(A_1A_2)$
  - $\text{Freq}(A_2) = 1 \times 0.2 + \frac{1}{2} \times 0.2 = 0.3$
Result of Drift

Random change in allele frequencies
What are the HW equilibrium values?
Imagine 1000 replicate populations

what’s the distribution of new allele frequencies?

Overall probability that new frequency is greater than 0.6 is approximately 41.5%

Overall probability that new frequency is less than 0.6 is approximately 40.5%

Probability that new frequency is exactly 0.6 is approximately 18%
What happens in the future?

- We’ve just measured the change across one generation.
- How does the allele frequency change through time?
- Can it be predicted?
Random fixation of alleles

**But…**

Given enough time
what’s the **probability** that an allele goes to fixation?

Each **copy** of an allele has an equal chance of becoming fixed.
Each copy of A1 has this chance.
Suppose there **x copies** in the population.

\[
x \times \frac{1}{2N} = \frac{x}{2N} = freq(x) = p
\]

- **Number of copies of allele**
- **Chance of each copy becoming fixed**
Heterozygosity

Frequency of heterozygotes in the population \((H = 2pq)\)
Heterozygosity

(e) Population size = 40

Blue = actual H
Black = predicted H
Loss of heterozygosity

\[ H_{g+1} = H_g \left[ 1 - \frac{1}{2N} \right] \]

Heterozygosity in next generation
Heterozygosity in current generation

Reduced by this much
Consequences of Genetic Drift

Over time:

1. Random fixation of alleles
   - Allelic diversity within populations decreases

2. Loss of heterozygosity

3. Variance among populations increases
   - Proportion of shared alleles between populations decreases
Genetic Drift and Population Size

How does the effect of genetic drift change with the population size?

Recall distribution of allele frequencies for population of size 10
Genetic Drift and Population Size

\[ N = 10 \quad N = 100 \quad N = 1000 \]

\[
\text{Var}(p) \quad \text{describes the range of expected allele frequencies.}
\]

\[
\text{var}(p) = \frac{p(1-p)}{2N}
\]

What happens to \text{var}(p) value as \( N \) increases?
Genetic Drift and Population Size

• Fixation of alleles and Loss of heterozygosity
  – Rapid in small populations
  – Slow in large populations
Results of Genetic Drift

1. Allele frequencies fluctuate randomly from one generation to the next
2. Eventually one of the starting alleles is fixed and others are lost
3. Expected heterozygosity declines over time
4. Rate of drift is directly related to population size
Change in population size over time

We need a measure of $N$ that accounts for this change over time

$N_e$ : Effective population size
Size of a theoretical population that would lose heterozygosity at the same rate as the actual population
Population bottlenecks

Harmonic mean of N

\[ N_e = \frac{t}{\sum_{i=1}^{t} \frac{1}{N_i}} \]

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\[
N_e = \frac{5}{\frac{1}{1000} + \frac{1}{1000} + \frac{1}{1000} + \frac{1}{1000} + \frac{1}{1000}} = \frac{5}{0.005} = 1000
\]

\[
N_e = \frac{5}{\frac{1}{1000} + \frac{1}{250} + \frac{1}{1000} + \frac{1}{1000} + \frac{1}{1000}} = \frac{5}{0.008} = 625
\]

\[
N_e = \frac{5}{\frac{1}{1000} + \frac{1}{250} + \frac{1}{250} + \frac{1}{250} + \frac{1}{1000}} = \frac{5}{0.014} = 357
\]
Effect on $N_e$ depends:
1. Magnitude of bottleneck
2. Duration of bottleneck