Genetic Drift, Mutation, Gene Flow (Migration)
Genetic Drift

- Undirected change in allele frequencies
  - Leads to loss of alleles --> basically, due to sampling error
  - Is genetic variation lost?
- In infinite, or very large populations, sampling error plays a small role; in small populations, it matters a lot!
Drift in small pops

- Allele frequencies in P generation
- Colonizers of Pitcairn island:
  - Effective Population size (number of breeders) = $N_e$
  - $N_e = 12$
  - Randomly create six couples that produce 2 children each

<table>
<thead>
<tr>
<th>Couple</th>
<th>Father</th>
<th>Mother</th>
<th>Child 1</th>
<th>Child 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Couple 1</td>
<td>$A_3A_3$</td>
<td>$A_2A_3$</td>
<td>$A_3A_3$</td>
<td>$A_3A_3$</td>
</tr>
<tr>
<td>Couple 2</td>
<td>$A_2A_3$</td>
<td>$A_2A_3$</td>
<td>$A_2A_3$</td>
<td>$A_3A_2$</td>
</tr>
<tr>
<td>Couple 3</td>
<td>$A_1A_2$</td>
<td>$A_2A_3$</td>
<td>$A_2A_3$</td>
<td>$A_1A_2$</td>
</tr>
<tr>
<td>Couple 4</td>
<td>$A_1A_1$</td>
<td>$A_1A_2$</td>
<td>$A_1A_2$</td>
<td>$A_1A_1$</td>
</tr>
<tr>
<td>Couple 5</td>
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<td>$A_3A_3$</td>
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<td>$A_1A_3$</td>
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<tr>
<td>Couple 6</td>
<td>$A_1A_2$</td>
<td>$A_1A_3$</td>
<td>$A_2A_3$</td>
<td>$A_2A_1$</td>
</tr>
</tbody>
</table>

Table 24-3  Biological Science, 2/e
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Drift in small pops

<table>
<thead>
<tr>
<th>Couple</th>
<th>Father</th>
<th>Mother</th>
<th>Child 1</th>
<th>Child 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A₃ A₃</td>
<td>A₂ A₃</td>
<td>A₃ A₃</td>
<td>A₃ A₃</td>
</tr>
<tr>
<td>2</td>
<td>A₂ A₃</td>
<td>A₂ A₃</td>
<td>A₂ A₃</td>
<td>A₃ A₂</td>
</tr>
<tr>
<td>3</td>
<td>A₁ A₂</td>
<td>A₂ A₃</td>
<td>A₂ A₃</td>
<td>A₁ A₂</td>
</tr>
<tr>
<td>4</td>
<td>A₁ A₁</td>
<td>A₁ A₂</td>
<td>A₁ A₂</td>
<td>A₁ A₁</td>
</tr>
<tr>
<td>5</td>
<td>A₁ A₂</td>
<td>A₃ A₃</td>
<td>A₁ A₃</td>
<td>A₁ A₃</td>
</tr>
<tr>
<td>6</td>
<td>A₁ A₂</td>
<td>A₁ A₃</td>
<td>A₂ A₃</td>
<td>A₂ A₁</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>F₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>A₁</td>
<td>7/24</td>
<td>29.2%</td>
</tr>
<tr>
<td>A₂</td>
<td>8/24</td>
<td>33.3%</td>
</tr>
<tr>
<td>A₃</td>
<td>9/24</td>
<td>37.5%</td>
</tr>
</tbody>
</table>
Consequences of Drift

- No allele is more fit than any other (no natural selection)
  - *drift is random with respect to fitness*
- BUT, some alleles clearly “won” the reproduction lottery
  - *They randomly increased their frequency in the population*
- In finite populations equally fit alleles are at risk of disappearing = *loss*
  - *Over time drift can produce random loss or fixation of alleles*
Drift in Allele $A_1$

- $N_e = 20$; @ each generation, individuals breed and die...maintains population size @ 20
- Alleles = $A_1$ & $A_2$
- Freq $A_1 = 0.49$
- What will happen to $A_1$?
  1. It will be lost
  2. It will fix
  3. It will remain forever
  4. It depends
Depends on what?

• Population size! ($N_e$)
• Probability that an allele will become fixed in the population = frequency of that allele in the population
  - @ each generation, probability of fixation changes!
• Average time to fixation = $2N_e$
A_1 experiment

- \( N_e = 20 \)
- \( A_1 = 0.50 \)
- \# replicate populations = 20
- In Gen 1, what is the probability that \( A_1 \) will fix? \( \frac{1}{2} \)
- On average, how many times will \( A_1 \) fix in our 10 populations?
  1. 10
  2. 5
  3. 2
  4. 0
Kerr & Wright

- **Sewell Wright**: Genetic drift & modern synthesis
- Drosophila exp. (1950's); examined drift as an evolutionary force
- # replicate populations = 96
- $N_e = 8$ (4 males, 4 females)
- Trait = bristle
  - Forked OR straight
  - No fitness component, no migration, effectively no mutations...Why are these important?
Kerr & Wright

- # replicate populations = 96
- \( N_e = 8 \) (4 males, 4 females)
- Trait = bristle
  - Forked OR straight

- At each generation randomly “chose”, from each population, 8 offspring to breed and create next gen.
- Examined results after 16 gen.

<table>
<thead>
<tr>
<th></th>
<th>Forked</th>
<th>straight</th>
<th>neither</th>
</tr>
</thead>
<tbody>
<tr>
<td># Fixed</td>
<td>29</td>
<td>41</td>
<td>26</td>
</tr>
</tbody>
</table>

** In 73% of populations (70 of 96), genetic drift had reduced allelic diversity to 0!
Importance in natural populations?

- **Small**: zoos, endangered species
- **Large**: *pseudogenes* & *silent* mutations have no effect on fitness (invisible, *for now*, to selection), but are an important source of raw material for future selection events; *Drift can eliminate these from populations.*
- *Reduces genetic diversity*
Founder effects

• A specific type of **sampling error** (drift)
• Loss of genetic diversity due to colonization of new habitat by **few** individuals with a **random & reduced** sample of alleles from the source population
  - Consider the extreme: **two** humans colonize a new planet. Is the genetic diversity of this new human population **>, <, or =** to that of human pop on Earth?
• Islands and island-like habitats
  - Caves, ponds, mountain-top forests, alpine meadows
Population bottlenecks

- **Bottleneck** = rapid, large reduction in population size (often due to random catastrophe)
  - Leads to **genetic bottlenecks** = reduction in genetic diversity
  - *EvoDots* Ex: imagine dot speed is determined by alleles at a single gene locus
  - What happens if population size stays low for multiple generations?
Gene Flow

• Movement of alleles from one population to another (immigration or emigration)
• Equilibrates allele frequencies between populations
• Maintains genetic diversity of populations
  - What happens to genetic diversity if population only receives immigrants?
  - If gene flow is bi- or multi-directional?
Gene Flow among populations

- Size = population size
- Arrows = direction of gene flow
  - Source population
  - Sink
Clicker Q

• What happens when individuals ONLY leave a population?
  1. Genetic diversity is reduced
  2. Genetic diversity is increased
  3. Genetic diversity remains the same
Allele $A_1 Q$

• Is gene flow important for maintaining genetic diversity in very large populations? Is there any tendency for alleles to be lost?*

• How will immigration affect the genetic diversity of small sink populations?
  1. Increase diversity
  2. Decrease diversity
  3. Maintain diversity
Effect on average fitness

• It depends
  - Genetic drift *reduces* allelic diversity, so the arrival of new alleles *might* increase fitness
  - BUT, If populations are well adapted to environment, then new (non-adaptive) alleles might reduce average fitness*
Mutation

1. The **only** creator of novelty (new alleles)
2. Always *restores* genetic diversity
3. Fitness of mutations is random
   1. **Most** mutations are *deleterious* (negative effect on fitness)
   2. Sometimes they're beneficial, and may spread through the population
Are mutations likely to spread?

- No...unless...??*
- highest mutation rates per gene = 1/10,000; average ~ 1/40,000
- Humans have ~ 30,000 genes = 60,000 alleles
- Average person has 1.6 novel mutations
  - If they are selected for...
  - If they are silent...
Why is inbreeding a bummer?

• Like mates with like
• Increases homozygosity!
• Have allele frequencies changed?
• Has the probability of generating homozygotes increased?
Inbreeding depression

- Reduction in fitness (viability, fertility) due to increasing homozygosity caused by inbreeding