**Koi Evolution**

1. The three genotypes are RR, Rr, and rr. The RR genotype corresponds to solid, deep orange scales. Rr corresponds to a mottled pattern of orange and white. And rr corresponds to solid white scales. The alleles express a codominant relationship.
2. At the end of simulation one, the population size was 194, the R allele had a frequency of 0.73 and the r allele had a frequency of 0.27. The rr, Rr, and RR genotypes had frequencies of 0.06, 0.41, and 0.53 respectively.
3. Based on the observed allele frequencies of 0.73 and 0.27, we square the R frequency to get the expected frequency of the RR genotype to be 0.533. By the same process, the expected frequency of the rr genotype is 0.073. Using the equation 2pq, the expected frequency of the Rr genotype is 0.394. These are reasonably close to the observed values of 0.53, 0.06, and 0.41.
4. The observed genotypes are reasonably close to the predicted values, as shown in the previous step. However, the simulation meets only four of the five requirements of HWE. There is no selection occurring, as the relative fitness of all genotypes is set to 1. Both migration and mutation are set to 0. The strength of assortment setting is set to 0, ensuring random mating. The missing requirement is a large population size. Demonstrating that this simulation is not in HWE, the proportion of the R allele steadily rose as the generation progressed.
5. Yes. The proportion of the R allele steadily rose as the generation progressed. This is due to genetic drift that occurred as a result of the low initial population.
6. RR Genotype Relative Fitness was changed from 1 to 0.9. At the end of the simulation, the population size was 194, the R allele had a frequency of 0.25 and the r allele had a frequency of 0.75. The rr, Rr, and RR genotypes had frequencies of 0.56, 0.39, and 0.06 respectively.
7. Based on the observed allele frequencies of 0.25 and 0.75, we square the R frequency to get the expected frequency of the RR genotype to be 0.063. By the same process, the expected frequency of the rr genotype is 0.563. Using the equation 2pq, the expected frequency of the Rr genotype is 0.375. These are reasonably close to the observed values of 0.06, 0.56, and 0.39.
8. No. By definition, as the parameter that was changed resulted in different genotypes having different fitness levels, the population is not in HWE.
9. Yes, the r allele was lost after roughly 125 generations.
10. No allele was lost in this simulation.
11. Small populations are more susceptible to genetic drift as the inherent randomness of mating and evolution have a proportionally larger effect when the population size is small.
12. Setting the relative fitness of the rr genotype to 0.2 resulted in the individuals with the rr phenotype being far less likely to survive and reproduce, which limits their ability to pass their genes onto the next generation. In comparison, individuals which had the R allele in either the heterozygous or homozygous genotypes were much fitter, and therefore more likely to survive and pass their genes on to later generations.
13. Neither allele disappeared during the simulation. At the end of the simulation, the population size was 499, the R allele had a frequency of 0.9 and the r allele had a frequency of 0.1. The rr, Rr, and RR genotypes had frequencies of 0.0, 0.19, and 0.81 respectively. Note: the proportion of the R and r alleles stabilized at its final numbers after around 130-140 generations.
14. Setting the relative fitness of the RR and Rr genotypes to 0.2 resulted in the individuals with the R allele being far less likely to survive and reproduce, which limited their ability to pass their genes onto the next generation. In comparison, individuals which had the rr genotype were much fitter, and therefore more likely to survive and pass their genes on to later generations.
15. The R allele disappeared from the population after roughly 100 generations. At the end of the simulation, the population size was 504, the R allele had a frequency of 0 and the r allele had a frequency of 1. The rr, Rr, and RR genotypes had frequencies of 1, 0, and 0 respectively.
16. Recessive genes, and by extension, recessive genetic disorders can persist in the population when the presence of the recessive allele is not detrimental to the heterozygous genotype. In this situation, the recessive allele can persist through generations, and homozygous recessive disorders can still arise when two heterozygous parents have offspring.

# Fishbowl Simulations Worksheet

| **Simulation 1: No Selection, Mutation, or Migration** | | |
| --- | --- | --- |
| **Settings** | **Results** | |
| Leave all of the parameters at the default settings.  Min. Generations = 100 | Generations | 100 |
| Population Size | 194 |
| Proportion R allele | 0.73 |
| Proportion r allele | 0.27 |
| Proportion rr genoype | 0.06 |
| Proportion Rr genotype | 0.41 |
| Proportion RR genotype | 0.53 |
| A picture containing text, screenshot, line, plot  Description automatically generatedAllele frequency vs. time | |

| **Simulation 2: One Added Evolutionary Force** | | |
| --- | --- | --- |
| **Settings** | **Results** | |
| Change **one** of the evolutionary parameters (Migration Rate, one of the Mutation Rates, or one of the Genotype Relative Fitnesses).  *Which one did you change, and to what?*  RR Genotype Relative Fitness changed to 0.9  Leave all of the other parameters at the default settings.  Min. Generations = 100 | Generations | 100 |
| Population Size | 194 |
| Proportion R allele | 0.25 |
| Proportion r allele | 0.75 |
| Proportion rr genotype | 0.56 |
| Proportion Rr genotype | 0.39 |
| Proportion RR genotype | 0.06 |
| A graph with red line  Description automatically generated with low confidenceAllele frequency vs. time | |

| **Simulation 3: Small Population** | | |
| --- | --- | --- |
| **Settings** | **Results** | |
| Change the Initial Size and the Carrying Capacity both to 25, and the Mortality Rate to 5.  Leave all of the other parameters at the default settings. (Change back whatever you changed in Sim. 2.)  Min. Generations = 200 | Generations | 200 |
| Population Size | 25 |
| Proportion R allele | 1.02 |
| Proportion r allele | 0 |
| Proportion rr genotype | 0.04 |
| Proportion Rr genotype | 0.03 |
| Proportion RR genotype | 1 |
| A picture containing text, screenshot, number, line  Description automatically generatedAllele frequency vs. time | |

| **Simulation 4: Large Population** | | |
| --- | --- | --- |
| **Settings** | **Results** | |
| Change the Initial Size and the Carrying Capacity both to 500, and the Mortality Rate to 5.  Leave all of the other parameters at the default settings.  Min. Generations = 200 | Generations | 200 |
| Population Size | 503 |
| Proportion R allele | 0.75 |
| Proportion r allele | 0.25 |
| Proportion rr genotype | 0.06 |
| Proportion Rr genotype | 0.39 |
| Proportion RR genotype | 0.56 |
| A picture containing text, screenshot, line, number  Description automatically generatedAllele frequency vs. time | |

| **Simulation 5: Selection against recessive** | | |
| --- | --- | --- |
| **Settings** | **Results** | |
| Change the Initial Size and the Carrying Capacity both to 500, and the Mortality Rate to 5. (Same as Sim. 4)  Set the fitness for rr = 0.2.  Leave all of the other parameters at the default settings.  Min. Generations = 200 | Generations | 200 |
| Population Size | 499 |
| Proportion R allele | 0.9 |
| Proportion r allele | 0.1 |
| Proportion rr genotype | 0 |
| Proportion Rr genotype | 0.19 |
| Proportion RR genotype | 0.81 |
| A graph with a red line  Description automatically generated with low confidenceAllele frequency vs. time | |

| **Simulation 6: Selection against dominant** | | |
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| **Settings** | **Results** | |
| Change the Initial Size and the Carrying Capacity both to 500, and the Mortality Rate to 5. (Same as Sim. 4)  Set the fitness for rr = 1, Rr = 0.2, and RR = 0.2.  Leave all of the other parameters at the default settings.  Min. Generations = 200 | Generations | 200 |
| Population Size | 504 |
| Proportion R allele | 0 |
| Proportion r allele | 1 |
| Proportion rr genotype | 1 |
| Proportion Rr genotype | 0 |
| Proportion RR genotype | 0 |
| A graph with a red line  Description automatically generated with low confidenceAllele frequency vs. time | |