**Lab Objectives:**

* Be able to determine the allelic frequency for a population.
* Understand the effects of selection on the genetics (allelic frequency) of a population
* Know that evolution occurs to populations (not individuals or whole species)
* Understand how the bottleneck effect occurs and result this has on a population in terms of genetic diversity.

**Introduction:**

The smallest unit that can **evolve**, or change through time, is a **population**. A population is defined as a localized group of individuals of the same species that are capable of breeding and producing fertile offspring. All of the genes available in a population at a given time comprise the population’s **gene pool**. The gene pool consists of all **alleles** at all gene loci in all individuals of the population. (Alleles are different versions of genes). Diploid individuals can be **homozygous** or **heterozygous** for a given allele if there are two or more alleles for that locus in the population. Homozygous individuals have two copies of the same allele, e.g. AA or aa, and heterozygous individuals have two different alleles in the pair, e.g. Aa.

Each allele has a **frequency** (proportion) in the population. The frequency of an allele is represented as a decimal, e.g. 0.2 which stands for 20%, and all of the allele frequencies have to add up to 1, or 100%. Over time, **mutations** (changes in nucleotide sequences) can lead to the formation of new alleles, increasing the genetic variability in a population. Natural populations may have more than two alleles, but the total number of frequencies must still add up to 1.

**Question 1:** Why do allele frequencies for a particular gene need to add up to 1?

the sum of the parts of a population will always add up to the total population

Imagine a population of 100 cats with two alleles (CB and Cw) at a locus that code for fur color. The relationship among the alleles is *not* one of complete dominance; one color doesn’t completely mask the other. Cats that are homozygous, CBCB, have black fur; cats homozygous, CWCW, have white fur; heterozygous, CBCW, have gray fur. In this hypothetical cat population, there are 16 white cats, 64 black cats, and 20 gray cats.

Because cats are diploid, there are actually 200 total CB and CW alleles. The CB allele accounts for 148 of the alleles [(64 x 2) + (20 x 1)]. The CW alleles make up the remaining 52 alleles [(16 x 2) + (20 x 1)]. To calculate the frequency for each allele, you divide the number of each allele (CB or CW) by the total number of alleles; for CB and 52/200 for CW.

**Question 2:** What are the frequencies of CB and CW?

cb: 0.74, cw: 0.26

**Effects of Selection**

Charles Darwin proposed the mechanism of **natural selection** as the driving force behind evolution. He inferred natural selection by connecting two features he observed in natural populations: 1) individual variation, and 2) overproduction and competition among individuals in populations. These two observations led to two inferences: 1) there is unequal reproductive success in populations, and 2) that unequal reproductive success lead to evolutionary adaptation of a population to a particular environment. In a nutshell, Darwin was proposing that certain individuals have traits that make them better at attracting mates, and those individuals tend to leave more offspring. Over time, the population will be comprised of a higher proportion of individuals with the desirable traits.

**Question 3:** What are the two major **observations** that led to Darwin’s proposal of natural selection?

the two major observations are individual variation and overproduction/competition

The make-believe blue-throated brushbird depends upon blue throat feathers to attract the ladies, i.e. female blue-throated brushbirds; chosen females must also have blue throat feathers. The allele that codes for blue throat feathers (B) is dominant to the allele that codes for brown feathers (b). If either sex lacks blue throat feathers, they cannot attract a mate, and do not get to pass on their genes to future generations. The homozygous recessive genotype, bb, is lethal.

In this exercise, you will be simulating the effects of selection on a brushbird population. Blue marbles represent the dominant allele, and clear marbles represent the recessive allele. You will be performing matings by selecting marbles from a plastic container that represents the mating arena and then determining the genotype of the resultant offspring. If you select homozygous recessive genotypes, you will remove the alleles from the population to represent the lethal effects of that genotype.

**Question 4:** Which marble color represents the **dominant** allele?

The black alleles are dominant

**Question 5**: Which phenotype is lethal? What is the genotype that determines this phenotype?

a homozygous recessive genotype is lethal. The phenotype expressed by this is brown throat feathers

**Procedure:**

1. Using 100 marbles and a plastic container, place the marbles in the container, and mix them well.
2. Select two alleles from the container at a time *without looking*, and record the offspring’s genotype in the space below.
3. Sort the dominant and recessive alleles resulting from BB and Bb genotypes into dishes #1 for B and #2 for b. **All** marbles from the homozygous recessive individuals (bb) need to be placed in dish #3, the death pile.
4. Repeat until you have selected all of the marble pairs.
5. Count the marbles in dishes 1 and 2, and record the number of remaining alleles in Table 10.1. Once the marbles have been placed in dish #3, those alleles are no longer passed on, and aren’t a part of the gene pool of successive generations.
6. Place the alleles of the survivors (they’ve grown up and survived to reproduce) back into the plastic container, mix well, and mate the individuals to produce the F2 generation.
7. Repeat steps #3-7 to obtain generations 2-10 (F2-F10). Record all data in Table 10.1.
8. Determine the allele frequency of B and b in each generation, and record the data in Table 10.1.
9. Plot the frequencies of B and b on Graph 10.1 in the Review Questions section using a solid line for B and a dotted line for b.

**Question 6:** What were the initial frequencies for the B and b alleles in the brushbird population? (the marbles/alleles you began with)

The initial frequencies are 0.5 and 0.5, since they represent the two halves of the initial population.

**Question 7:** Why weren’t you supposed to look at the marbles when selecting them from the plastic container?

In this simulation, randomness was important, as it simulates randomness in finding mates.

Record the genotypes of your F1 generation (the offspring from step 2) below:

**Table 10.1** Population genetics of a hypothetical blue-throated brush bird population.

| **Generation** | **Number of individuals** | **Number of each allele (B and b)** | **Total number of alleles** | **Allele Frequencies** |
| --- | --- | --- | --- | --- |
| F1 | 37 | B:50  b:24 | 2 | B:0.675  b:0.325 |
| F2 | 34 | B:50  b:18 | 2 | B:0.735  b:0.265 |
| F3 | 31 | B:50  b:12 | 2 | B:0.805  b:0.195 |
| F4 | 30 | B:50  b:10 | 2 | B:0.83333  b:0.166666 |
| F5 | 30 | B:50  b:10 | 2 | B:0.83333  b:0.16666 |
| F6 | 29 | B:50  b:8 | 2 | B:0.862  b:0.138 |
| F7 | 29 | B:50  b:8 | 2 | B:0.862  b:0.138 |
| F8 | 28 | B:50  b:6 | 2 | B:0.893  b:0.107 |
| F9 | 26 | B:50  b:2 | 2 | B:0.962  b:0.038 |
| F10 | 26 | B:50  b:2 | 2 | B:0.962  b:0.038 |

**Question 8:** Would you expect the same results in another brushbird population where brown-throated brushbirds were able to reproduce? Why or why not?

No, there would be many more total birds, and although there would be less brown throated birds, they would still exist

**Question 9**: What results would you expect if having blue feathers stopped you from reproducing? If these two populations met would they be able to reproduce with each other?

If blue feathered birds stopped reproducing, the population would decrease dramatically, and all of the birds would die, because none of them could reproduce

**Effects of Genetic Drift**

**Genetic drift** is the change in allele frequencies from generation to generation as a result of chance events, e.g. hurricanes, disease, or over-hunting. Over time, genetic drift tends to reduce genetic variation in populations through losses of alleles from the gene pool. Two situations that can increase the likelihood of genetic drift are the **bottleneck effect** and the **founder effect**.

A disaster caused by a sudden change in the environment may drastically reduce the size of a population. In effect, the few survivors have passed through a restrictive “bottleneck”, and their gene pool may not be representative of the original population’s gene pool. The founder effect occurs when a few individuals become isolated from a larger population, and they establish a new population. Again, their gene pool may not be representative of the original population’s gene pool. Today, you will be examining the bottleneck effect.

**Question 10**: Name two events that can lead to a bottleneck effect in natural populations.

Wars and natural disasters can lead to bottlenecks in natural populations.

Cheetahs are unusual among the felids (family Felidae; the cats) in exhibiting near genetic uniformity at a variety of loci screened to measure the population’s genetic diversity. It has been hypothesized that the genetic uniformity is a result of a bottleneck event in the cheetah’s evolutionary history.

In this scenario, you will evaluate the effects of a bottleneck event on the allele frequencies in a cheetah population. There are three alleles for the gene X; XB,XC, and XR.

**Procedure:**

1. At the front of the room you will find several bottles consisting of 100 X allele marbles. In each bottle there are 50 XB alleles (blue marbles), 36 XC alleles (clear marbles), and 14 XR alleles (red marbles).
2. Obtain a bottle, and pour out 10 marbles. Count the number of each allele, and fill in Table 10.2

**Question 11:** What were the initial allele frequencies for XB, XC, and XR?

xB = 0.5 ; xC = 0.36 ; xR = 0.14

**Table 10.2** Population genetics of a cheetah population after a bottleneck event.

| **Allele** | **Number of alleles** | **Allele frequency** |
| --- | --- | --- |
| XB | 6 | 6/11 = 0.5454 |
| XC | 3 | 3/11 = 0.2727 |
| XR | 2 | 2/11 = 0.1818 |

**Review Questions**

1. Define **evolution**. Did you see evidence of evolution in any of the simulations you performed today? If so, which one(s)?

Evolution is the process of change over time that results in the diversity of life on Earth. More specifically, it refers to the process by which populations of organisms change over generations, through mechanisms such as natural selection, genetic drift, mutation, and gene flow. Evolution explains how all living organisms on Earth have adapted to their environments over time, leading to the diversity of life we see today.

1. A. In the **selection** exercise, what happened to the dominant and recessive alleles over time?

The dominant alleles stayed the same, but the recessive alleles decreased exponentially over time

b. Did the recessive allele disappear from the population? If not, why, when homozygous recessive genotypes are lethal?

The two heterozygous individuals never bred to produce a homozygous recessive individual. Until this breeding happens, there will still be recessive alleles in the population.

1. In the **bottleneck exercise**, was the gene pool of the new population reflective of the original population? Support your answer with data from Table 10.2.

yes it was. all of the alleles are within 4% of where they initially were before the bottleneck event.

1. Propose a scenario where the results of the **bottleneck exercise** have a **negative** effect on the cheetah population.

If some of the cheetah population suffered from a genetic disease that affected individuals with the heterozygous and homozygous recessive genotype, a bottleneck event that killed a higher proportion of the healthy individuals, compared to unhealthy individuals, would decrease the health of the overall population.

1. Graph your data from **table 10.1** in Graph 10.1