This game was designed to illustrate the process of selection. It is a four player game, with each player picking from the roles of No Selection, Adaptive Variant, Maladaptive Mutation, and Domestication.

Game pieces include four distinguishable sets of tokens (illustrated by colored notecards in these instructions). Another option for tokens would be candies of different colors, or anything with at least four clear variations. These 4 colors (Red (R), Orange (O), Yellow (Y) , Pink (P)) represent different **phenotypes** or **traits**, while the letters written on the tokens (RR, YY, RY, P) are the **alleles** creating the tokens' **genotypes** underlying the different colors. Game play also requires a random number generator or four sided die.

The first step is to set up the initial population and record the distribution of traits. Shuffle the tokens, without including the Pinks, and have each player draw 12, except the Maladaptive Mutation and Domestication players who should build this population specifically: 3R, 5O, 3Y, 1P. Record the number of individuals with each trait (color) in your population.

Because of the natural life cycle, the individuals in your population will change over time through birth and death. How this changes the distribution of traits is dependent on the influence of selection.

On each players turn, they will perform an elimination step and a regeneration step to remove and add new individuals to their population. The details of each step are particular to each player's selection role, and are outlined below.

Basic Game (no selection)

12 pieces each, (3R, 6O, 3Y)

1. <u>Elimination Step:</u> Shuffle your population and remove 3 tokens
2. <u>Regeneration Step:</u> Shuffle again and pick 2
    a. Add 1 token representing the offspring of the 2 tokens you selected. Choose the correct token based on the chart below. If your chosen tokens yield multiple options for offspring, use the random number generator or die to roll for which token to draw.
        - R+R ⇒ R (100%)
        - R+Y ⇒ O (100%)

        - R+O ⇒ R(50%), O(50%) [Random number 1-4, odd=R, even=O]
        - Y+Y ⇒ Y (100%)
        - Y+O ⇒ Y(50%), O(50%) [Random number 1-4, odd=Y, even=O]
        - O+O ⇒ R(25%), O(50%), Y(25%) [Random number 1-4, 1=Y, 3=R, even=O]
3. Repeat the regeneration step until the population is back to 12 (total 3 times)
4. This completes 1 turn

Selection for an adaptive variant

Start and play like basic game <u>except during the elimination round</u>

    - If you pick R, give it a 50% of being eliminated [Random number 1-4, odd=survive, even=die]
    - If not eliminated, put back into the population and shuffle
    - If you pick R again, it is eliminated

This setup makes tokens with the Red trait more likely to survive.

Selection against a mutation

Start with 12 pieces (3R, 5O, 3Y, 1P)

- Play as in basic game except:
    - If P is drawn during elimination, 1 other P from the population (if it exists) is also eliminated
    - If P is drawn during regeneration, the offspring are always P

This setup makes P unlikely to survive in the population, as if it were a maladaptive trait.

Domestication of P

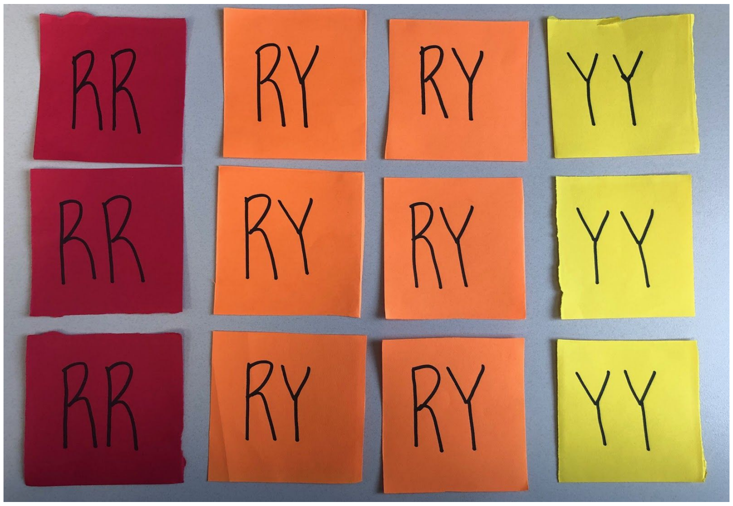
Start as with Selection against a mutation

- Play as in basic game except:
    - If P is selected during regeneration phase, add 2 P to the population until 12 is reached

This setup makes P likely to survive in the population because we are selectively breeding for it in the regeneration round like during the domestication process.

Game play is illustrated below...

Set up for the basic game

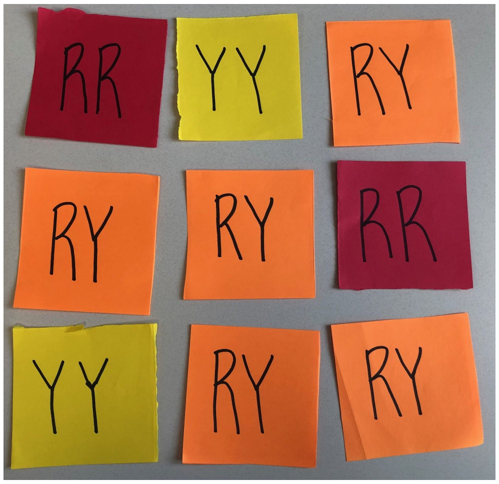


Elimination Step:

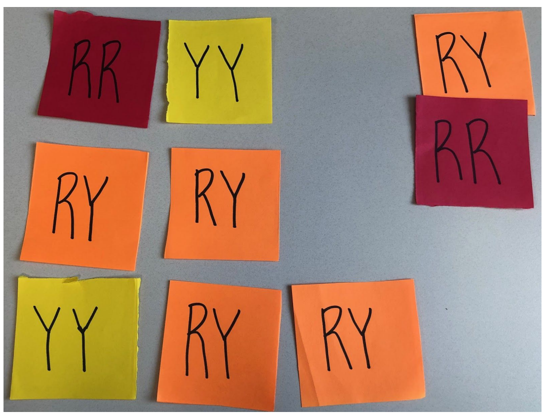
Shuffle the tokens

Take 3 tokens at random and discard them

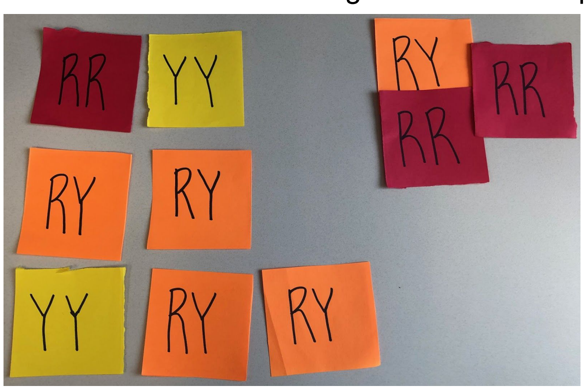
Regeneration Step:



Make sure there are only 9 tokens in your population



Choose 2 at random and figure out what offspring they would produce



In this example the offspring is Red (RR)

Before adding in the offspring, do this regeneration step until your population + offspring == 12 tokens

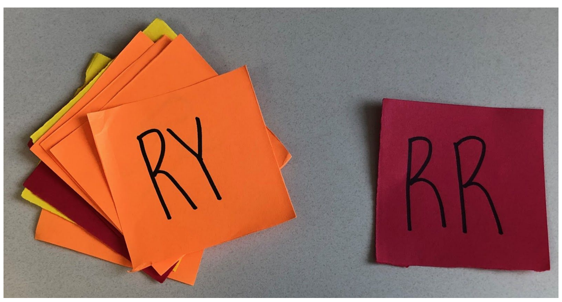
Make sure you have 12 tokens and this ends 1 cycle. Repeat until you finish all cycles. We recommend at least 3-5 cycles

At the end of all cycles compare your final population to your starting population. How has the population changed? Are there more individuals of 1 group than another? How different/similar is it to the starting population?

Selection for a standing variant

<u>Change to Elimination Step:</u>

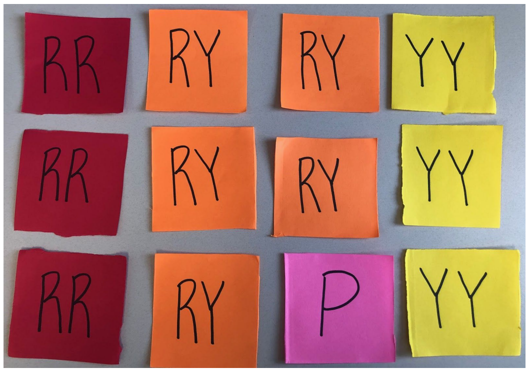
If you pull a Red (RR) token during the elimination step, it has a 50% chance of actually being eliminated.



If you pick an even number (random generator 1-4), then eliminate the token.

If you pick an odd number (random generator 1-4), then put it back in the population and draw another token at random for elimination. If Red (RR) is picked again, it is eliminated.

Selection against a mutation

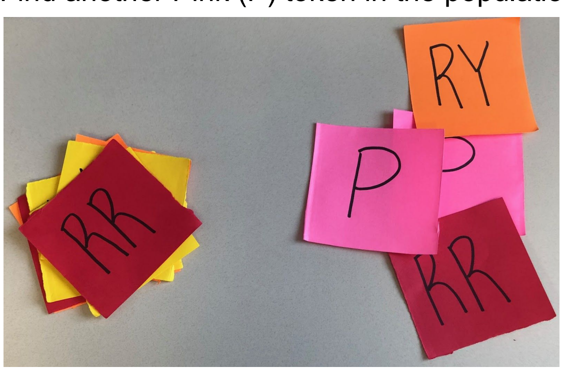


Starting Population

<u>Elimination Step:</u>

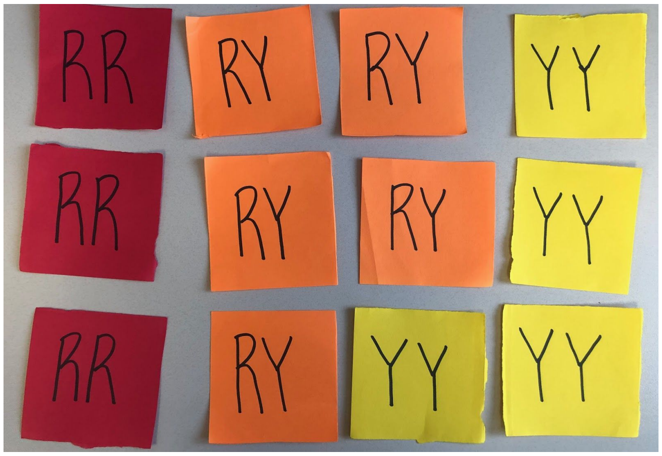
If Pink (P) is picked during elimination step

Find another Pink (P) token in the population



Eliminate both Pink (P) tokens from the population

During the Regeneration Step, complete it until the Population + Offspring tokens == 12
Every 3rd cycle, replace one of the population tokens with a Pink (P) token if there are no Pink (P) tokens left in the population.

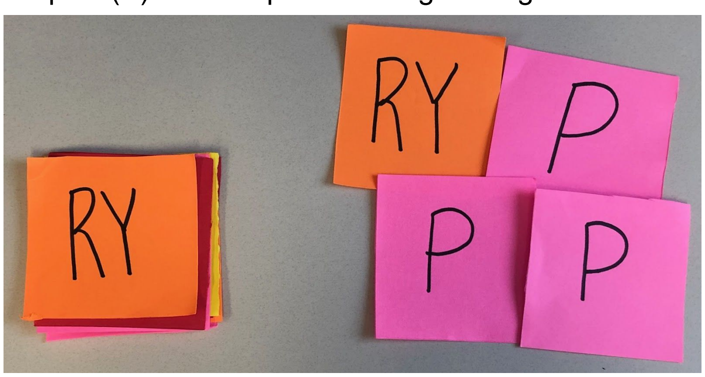


Example final population after 5 rounds. How did the Pink (P) group do? How is this similar or different from previous rounds of the game?

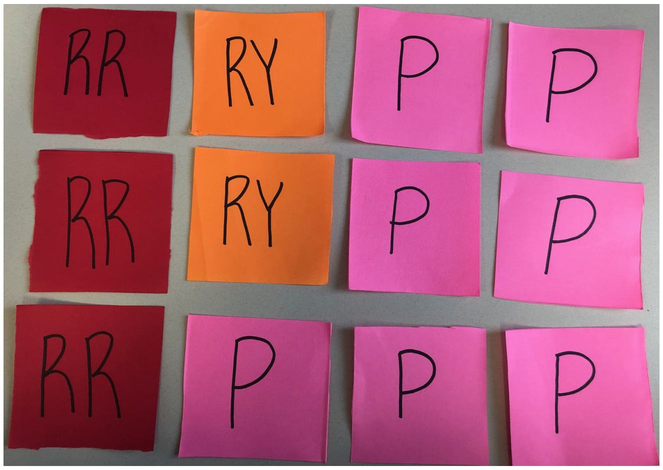
Domestication of P

Regeneration Step:

If a pink (P) token is pulled during the regeneration step



Then it produces 2 Pink (P) offspring (until the population + offspring == 12. Only add P offspring until 12 is reached)



Example of a final population after 5 rounds. How did the Pink group do in this setting? How is it similar or different from other versions of the game? How is this similar to what happens in domesticated species versus their wild counterparts?

Teacher’s Note
Below are our reasons for setting up the different scenarios, what you might expect under each, and how they relate to what geneticists do in their experiments. This is broken down each scenario.

Basic Game (no selection)
<u>Why this set-up:</u>
In this scenario, tokens die and create offspring with equal probability. This means that no one allele or trait is more beneficial than any other within the population. Therefore, there is no selection acting on the population.

<u>Expectations:</u>
We expect that the allele frequencies won’t change drastically from the starting cycle to the end cycle, i.e. the proportion of R’s and Y’s within the population will remain constant. However, this might not always be the case. By random chance, the allele frequencies may change over time. This is called *genetic drift,* where the allele frequencies change over time but due to random chance and not selection. Smaller populations are more sensitive to genetic drift because a single random event can have a larger impact. If a student is curious about this, you can recommend trying this scenario again, but change the population size.

<u>How it relates to experiments:</u>
Geneticists are usually interested in detecting selection. However, genetic drift can look like selection and it can be difficult to tease the two apart. Running a simulation like this scenario where there is no selection, researchers can create a null hypothesis about how much variation in allele frequency they can expect from a population if selection is not acting. Then they can compare their observed allele frequency changes to this expectation. If allele frequencies differ beyond that expected variation, they can feel more confident that selection rather than drift is causing these allele frequency changes.

Selection for a standing variant (positive selection on survival)
<u>Why this set-up:</u>
This scenario demonstrates positive selection for a particular trait (red color). Survival and reproductive success are the two halves of *fitness* or how well an organism is adapted to their environment. In this case selection is acting on survival. By giving the red tokens a 50/50 chance to “escape” elimination, this simulates a trait giving an organism a better chance of avoiding predators. To keep the math simple we chose 50/50, but selection could act with different strengths which could be portrayed as different survival odds. If a student is interested in how the strength of selection affects the outcome, they could try doing this scenario using different odds of red “escaping” elimination or assign other odds to the other tokens (for example, red always escapes, orange escapes 50% of the time, and yellow never escapes or red and yellow always escape, but orange escapes only 50% of the time; the possibilities are endless!).

Expectations:
We expect that selection will raise the proportion of red tokens. It is most likely that the final population will have more red tokens than the starting population. There is an element of randomness to the game, so this may not always be the case. You could compare multiple outcomes of this scenario with multiple outcomes of the no selection scenario to convince yourself/your students that this scenario is more likely to end with more red tokens than the starting population.

How it relates to experiments:
Often times a population's adaptation comes from a standing variant within that population (in this case the RR genotype). This could be due to a change in the environment that now applies selection for a trait that was previously not under selection. For example, the populations of English moths that were mostly white before the Industrial Revolution and mostly black after is the result of a changing environment (soot darkening the trees where they live, making the whites easier for predators to see and eat). Black moths did occur within those populations, but they were only selected for after the environment changed.
https://www.smithsonianmag.com/smart-news/new-evidence-peppered-moths-changed-color-sync-industrial-revolution-180959282/

Selection against a mutation (negative selection on survival)
Why this set-up:
The pink mutation represents a new mutation within the population. Because mutations first arise in a single individual, that is why only a single pink token is added at the start. New mutations are always occurring, usually at a consistent rate (though that rate varies across species). The continuous addition of new mutants is represented by swapping in a pink token if none exist every 3rd cycle. Here the mutant is dominant to keep the math and game play simple. However all new mutations are initially heterozygous (in this case it would be RP or YP) and most often recessive. We also chose to have the mutation negatively affect survival. By taking out another pink token from the population, the pink tokens have a lower fitness than the other tokens and thus will be kept at low frequency (*negative selection*).

If a student would like to try a more realistic scenario, they would need to make a set of new markers (PP, RP, and YP) and choose either 1 RP or YP token to start the population. Selection will only be against PP tokens (so take the place of P in the scenario rules) because the negative effects are recessive. The student could also simulate with or without continued mutations (keep it simple by only have the P mutation, though in reality it would most likely be a completely different mutation).

Expectations:
The P alleles and pink tokens will likely go extinct (none in the final population) or occur at low frequency. It is unlikely that these tokens will accumulate in the final population.

How it relates to experiments:

Often times new mutations are *deleterious* or cause a reduction in fitness. Researchers can be interested in how deleterious a new mutation might be or how much the fitness is reduced by the mutation. One of the ways is to see how rare a variant/mutant is within the larger population. More rare variants are more likely to be more deleterious because they're kept at low frequency.

Domestication (positive selection on reproduction)

<u>Why this set-up:</u>

Here selection is now acting on the reproductive phase. We thought this might be more similar to domestication since early farmers and plant breeders were actively assisting the reproduction of early domesticates by collecting their seeds and planting them the next season. Here we represent that with more offspring from individuals with the desired trait (pink) making it to the next generation. There could also be negative selection against another trait at the same time, which a student could model with changing the probability of a particular token color producing offspring (like if a farmer avoided picking or planting seeds from those kinds of plants).

<u>Expectations:</u>

Like the positive selection acting on the survival of red tokens, we would expect that pink tokens will not only rise in frequency but become the major color of the final population. This is because of the strong selection for pink tokens to pass on their offspring to the next generation.

<u>How it relates to experiments:</u>

Often times we compare the genetics of domesticated and wild varieties of the same species. This helps researchers identify potential genes responsible for traits important for domestication (fruit size, toxicity, ease of harvest, etc.). Many of these domestication traits are unfavorable in wild conditions but extremely favorable in agricultural environments. Researchers can compare the frequency of an allele within both populations. If an allele occurs at high frequency in the domesticated population and a low frequency in the wild population, that allele likely played a role during domestication. If the frequency is in the opposite pattern, that allele is likely the antithesis of a domestication loci (good for surviving the wild, but not for cultivation).