

## **The Science Behind the Ladybug Game**

In this game the ladybug tries to capture the aphids. When one aphid is caught, a different, randomly selected, aphid reproduces. The ladybug is more likely to see and chase aphids that don't blend into the background. So, the aphid population tends to evolve to blend into the background to avoid being captured.

Evolution requires three features: inheritance, variation, and selection.

Inheritance is simply the tendency of offspring to look like their parents (because they inherit their parents' genes).

Variation occurs because individuals don't inherit perfect copies of their parents' genes, instead they get a mixture of genes and/or slightly mutated genes.

Selection occurs because environmental factors, like a hungry ladybug, make some individuals less likely to survive and reproduce.

In this program the aphids have three genes that control their color. When an aphid reproduces its offspring inherits those genes, but with slight variations due to mutation. E.g. an aphid might be a little more or a little less green than its parent. This creates inheritance and variation.

The ladybug tries to capture the aphids, but is less likely to see aphids that are closer to the background color. This creates selection.

Thus, in a population with aphids of different colors the ones least like the background are more likely to be caught and the ones most like the background are more likely to survive long enough to reproduce. Their offspring are also more similar to the background, but due to variation might be a little more similar or a little less similar to the background. Again the less similar ones are more likely to be caught and the more similar ones (the ones that blend in) are less likely to be caught. So, over time the surviving aphids evolve to be more similar to the background - they blend in better.

A few things to note:

- Individuals don't change color or evolve - it's a population that evolves.
- Variation is random, not guided, so a mutation may make an aphid more or less well adapted - but the less adapted ones are captured and don't reproduce.
- Without variation the whole population eventually ends up looking identical and can't re-adapt to a new environment.
- Without inheritance each new aphid is random - well adapted aphids don't pass on traits to their offspring.
- Selection isn't perfect - sometimes the ladybug spots a well-adapted aphid, but on average the better adapted aphids are more likely to survive to reproduce.
- Without selection there's nothing to "push" the aphids towards a particular color - the population will randomly drift towards some color that is probably not similar to the background.

## **5 Lessons to Try**

**Lesson 1:** The user controls the ladybug. The user may target aphids of a particular color, mimicking selective breeding. Alternatively, the user may simply capture aphids as fast as possible, resulting in less predictable evolutionary outcomes.

**Lesson 2:** Compare the outcome of evolution in the two different environments. Typically, the aphids evolve to match their respective backgrounds, but in some cases their behaviors may evolve more strongly than their colors. Once the aphids have similar colors try changing the backgrounds (using the color wheel). Note that it may take some time for a strongly converged population to evolve dramatically different colors.

**Lesson 3:** Aphids in the left-hand environment don't mutate - they are identical to their parents. Initial variation in the left-hand population may lead to aphids similar to the background color, but changes in the background won't result in changes in the aphids' color once the population has converged on a color.

**Lesson 4:** Aphids in the left-hand environment do not inherit traits from their parent - each offspring is completely random. Although well-fit aphids do emerge they do not pass their traits onto their offspring, so the population as a whole does not adapt.

**Lesson 5:** The ladybug in the left-hand environment is effectively colorblind. Aphid color doesn't affect the probability of capture. As a result there is no selection based on color and the aphids will generally not converge on the background color. Note that the aphids' color may eventually converge on some color due to chance.