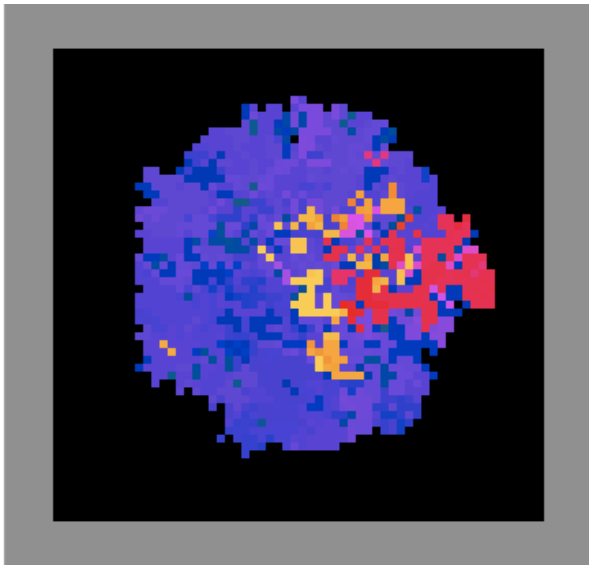
Exploring the Effect of Mutation Rate on Populations



A population of digital organisms growing in a virtual Petri dish

Background

Genetic variation is introduced into a population by random mutations that occur as individual organisms replicate. The rates at which these random mutations occur affect both the number of mutations and viability of the individual's offspring. But how do mutation rates affect populations?

Two important characteristics that we can use to describe a population are the average fitness[1] of the individuals that make up that population and the population size. In this exercise you will determine whether these characteristics are affected by mutation rate and, if so, in what ways.

The exercise has two parts. In the first part, each student research team will develop a hypothesis about the relationship of mutation rate to the overall fitness and size of an Avidian population. Every team in the class will then run a series of experiments in Avida- ED under the same set of specified conditions. This will allow us to explore as a class the results of several independent experiments, and see if changes in mutation rate lead to predictable and repeatable outcomes in an Avidian population.

[1] A note on fitness: In biological organisms, "fitness" usually refers to a measure of (potential or actual) reproductive success. Organisms possessing traits that afford some sort of reproductive advantage will tend to have more offspring, and are therefore more fit, than organisms lacking such traits. In Avida, fitness is a function of an organism's metabolic rate divided by its gestation time. As an individual's fitness increases, the rate at which it is able to replicate increases; therefore, it will produce more offspring than organisms with lower fitness in a given amount of time.

In the second part of the exercise, each student team will test its own ideas about the relationships between mutations, mutation rate, and fitness. Using the class results as a starting point, student teams will devise a new hypothesis, and then devise and carry out their own experiments to test their hypothesis.

Assignment Tasks

Part 1.1 Generating class data

Hypothesize: As a team, discuss and formulate hypotheses (and the corresponding null hypotheses) regarding the relationships between the average fitness of individuals in your population of Avidians and population size as a function of the mutation rate. Be sure to include in your hypotheses a statement about why you think this is so.

Test: Follow the instructions carefully. Use the sheet provided to record your data.

1.) In the Population viewer, flip to Settings and set the following parameters:
- World size: 60x60
- Per site mutation rate: 1%
- Place offspring: Near parent
- Resources: All (checked)
- Repeatability mode: Experimental
- Pause run: At update 2000

2.) Drag the @ancestor organism into the dish and click Run. The experiment should pause automatically at 2000 updates.

3.) In your data sheet, record:
   a. Population size and average fitness for your population.
   b. Sketch (or export and copy/paste) the graph showing fitness as a function of update.
   c. Describe what your Petri dish looks like (i.e., are there a lot of different colors? Are the different colors grouped together, etc.?).

4.) Repeat steps 1 – 3 at 5%, 10%, and 15% mutation rates.

Results and discussion: As a team, discuss whether or not *your team's data* support your team's hypothesis.

Contribute the fitness and population size data from each of your four experiments to the class database. (Your instructor will inform you as to how the data should be submitted to make up the class data.) The instructor(s) will process the class data and prepare graphs that will be explored as a group in class during Part 1.2.

Part 1.2 Exploring class data

1.) Incorporate into your team's data sheet the graphs of the class data for both Avg. Fitness and Population Size (at Update 2000) at all four mutation rates.

2.) As a team comment on the relationship of your team's data to the data collected by the class as a whole.

3.) As a team, discuss whether or not the *class data as a whole* support your team's hypothesis.

4.) Given your team's results, and the results of the class as a whole, would your team modify its original hypothesis in any way, or keep it the same? Explain your answer.

Discussion questions:

1.) Did all of the student teams in the class get the same results for their three trials with respect to average fitness and population size? Why or why not? How can you explain these results?
2.) If mutations are random, why do the results of our investigation not appear random?
3.) How is it that in some instances average fitness increased at a mutation rate of 15%, while in other instances average fitness decreased?

Part 2. Further exploration

In the space below, work as a team to develop an idea to test using Avida-ED pertaining to mutations, mutation rate, and fitness.

Team Data Sheet

Team Name: _____

Team Members: _____

Hypothesis:

Individual Team Data

1. Mutation Rate = 1%

a. Avg. Fitness at Update 2000: _____

b. Pop. Size at Update 2000: _____

c. Graph of Avg. Fitness as a function of Update

d. Picture of your plate

e. Description of the plate (50 words)

2. Mutation Rate = 5%

a. Avg. Fitness at Update 2000: _____

b. Pop. Size at Update 2000: _____

c. Graph of Avg. Fitness as a function of Update

d. Picture of your plate

e. Description of the plate (50 words)

3. Mutation Rate = 10%

a. Avg. Fitness at Update 2000: _____

b. Pop. Size at Update 2000: _____

c. Graph of Avg. Fitness as a function of Update

d. Picture of your plate

e. Description of the plate (50 words)

4. Mutation Rate = 15%

a. Avg. Fitness at Update 2000: _____

b. Pop. Size at Update 2000: _____

c. Graph of Avg. Fitness as a function of Update

d. Picture of your plate

e. Description of the plate (50 words)