Exploring the Effects of Mutation Rate on Individuals

Left: Pale grass blue butterfly (*Z. maha*) with normal fore and hind wings.
Right: Mutated butterfly with stunted wings.

Background

On March 11, 2011 the largest earthquake ever to hit Japan, and one of the five largest in recorded history, occurred 40 miles (70 km) off the coast of Tōhoku. The quake triggered a tsunami that produced waves with heights up to 133 feet (40.5 m) that traveled as much as 6 miles (10 km) inland, causing extensive damage to property and significant loss of human life. Among the infrastructure casualties was the Fukushima Daiichi Nuclear Power Plant complex. Three reactors sustained heavy damage, resulting in the worst nuclear accident since Chernobyl in 1986. The area within a 20-mile (~30 km) radius of the Fukushima plant was determined to have dangerously high levels of radiation, with the highest levels up to 2 miles (3 km) from the plant. The Japanese government prohibited access to this area and ordered the evacuation of anyone living between 2 and 12 miles (3 and 20 km) of the plant. People living between 12 and 20 miles (20 and 30 km) away were put on high alert and also encouraged to evacuate.

The disaster at Fukushima has provided scientists with an opportunity to investigate the biological impact of radiation on organisms. One species in particular, the pale grass blue butterfly (*Zizeeria maha*), is helping researchers pursue questions about the immediate and long-term effects of radiation at various doses (Hiyama et al., *Scientific Reports* **2** Article 570, 2012). Butterflies collected closer to the power plant experienced larger doses of radiation than those farther away, and the scientists found that larger doses were associated with increased infertility, mortality, and incidence of physiological abnormalities. Many of these abnormalities were inherited and amplified in offspring of butterflies that had been exposed to the radiation initially as overwintering larvae. The researchers concluded that “[I]t is most likely that the abnormal phenotypes observed are produced by random mutations caused by the exposure to radiation” (p. 8).

Using digital organisms as a model, your goal in this exercise is to test the scientists’ claim: assuming that higher doses of radiation are associated with increased mutation rates, can exposure to radiation account for the adverse biological effects reported in the study?

Assignment Tasks

Predict: What will happen to an individual Avidian's genome as it replicates at different mutation rates (low, medium and high)?

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

1.) Download the "All Functions" organism ("@allfunctions") from the Avida-ED website. Import this organism into the program.
2.) In the Organism viewer, drag the ancestor organism ("@allfunctions") into the viewing pane. Under the Settings, set the per site mutation rate to 1%.
3.) Click on the Run button and allow the ancestor to replicate.
4.) On your data sheet, record the number of mutations in the offspring (circled in green).
5.) Drag the offspring to the freezer. Name it in a way that will allow you to match it to your data (e.g., "1%no01"). *Note: You may have to create a new workspace before freezing your first organism. Name it something recognizable and save it to the Desktop.*
6.) Repeat steps 2 – 5 ten times, completely filling out the first "Mutations (n)" column of your data sheet.
7.) Drag your first saved offspring from the freezer into the Organism viewing pane. Click Run and record the number of functions (9 metabolic functions and the ability to replicate) it has **lost**. Repeat this for all remaining offspring until you have completely filled out the first "Abnormalities (n)" column of your data sheet.
8.) Repeat steps 2 – 7 at 5%, 10%, and 15% mutation rates, recording data in the appropriate spaces on your data table.
9.) Use your data to calculate the average number of mutations and percentage of abnormalities for each of the four mutation rates.

Results: Were your predictions confirmed or disconfirmed by the data you collected?

Discussion: What do your tests reveal about the relationships between mutation rate, frequency of mutations, and physiological abnormalities?

Does the evidence from your study support the researchers' claim that "it is most likely that the abnormal phenotypes observed are produced by random mutations caused by the exposure to radiation"? How?

Data Table. Keep track of your experimental observations in the table provided.

	Mutation Rate							
	1%		5%		10%		15%	
Offspring	Mutations (n)	Abnormalities (n)	Mutations (n)	Abnormalities (n)	Mutations (n)	Abnormalities (n)	Mutations (n)	Abnormalities (n)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
	Average number of mutations	Abnormality rate	Average number of mutations	Abnormality rate	Average number of mutations	Abnormality rate	Average number of mutations	Abnormality rate

Data Chart. Plot your data to reveal patterns.