

Unit 8.1

“Bugs in the Beds!?”:

Adaptation and Natural Selection

Unit Overview

Unit Summary

In this unit, students discover how a species can survive a change in the environment through the processes of natural selection and adaptation. Students use models and mathematical representations to support their explanation for how the traits of a population of organisms can change over time in order to adapt to a change in their environment. The Unit Challenge uses bed bug resistance to insecticide as the context to explore these processes in action in a real-life scenario.

To begin the unit, students first learn that traits in a population can have different effects on organisms depending on the environmental conditions present, and those traits can affect some individuals’ probability of surviving and reproducing (MS-LS4-4). Then students examine how different traits can occur in a population, first building on prior knowledge from Unit 7.6 about sexual reproduction and then examining another cause - genetic mutations - and their effect on the structure and function of an organism’s proteins (MS-LS3-1). Students apply these concepts over large timescales to explain how natural selection can affect the distribution of traits in a population over time, causing the population or species to adapt to the change in the environment (MS-LS4-6).

NOTE: We strongly recommend that students complete Unit 7.6, or Lessons 3-5 of Unit 7.6 prior to completing Unit 8.1. These lessons support students to be able to model the structure and function of proteins, and how genetic code determines protein shape. This prior knowledge will support students to engage in Unit 8.1.

Unit Challenge Question

- How can a species survive a change in the environment?

Connection to 21st Century Issues

Natural selection and adaptation have been occurring in species since the dawn of time. Up until recently, however, the changes a species experienced was solely caused by natural environmental factors. Today, organisms are subjected to a plethora of human-made or -enhanced compounds, like herbicides, insecticides, and antibiotics, because humans have deemed many plants, insects, and bacteria unwanted or harmful to our existence. These treatments have been used to greatly improve human health and well-being across the planet - preventing farm crops from competing with nutrient-stealing weeds, eliminating unwanted pests from farms and cities alike, and reducing disease-causing bacteria from our bodies to keep us healthy.

Initially, these treatments were extremely effective at controlling the unwanted critters, there were many options available for any single pest, and the economic benefits were huge. Unfortunately, what has become evident over just a few decades of use is that these pests are adapting, developing new ways to survive our countermeasures. We have been forced to find new and creative ways to defeat these pests, which sometimes ends up causing immunity to everything we've got, such as MRSA (Methicillin-resistant *Staphylococcus aureus*) or deleterious effects to other organisms, like the poisoning effect of certain insecticides (neonicotinoids) on pollinators.

Being aware of the choices we make and their effects (e.g., not taking a full course of antibiotics leads to antibiotic-resistant bacteria) is paramount to keeping this issue from becoming exponentially worse. Extensive research is underway to better understand the effects of our farming, home, and medical practices on the organisms we share the planet with and emerging technologies and opportunities are being developed to circumvent these issues. Understanding the underlying mechanisms that cause these issues, natural selection and adaptation, are the first step to being a part of the solution!

Unit Challenge

Unit Challenge Summary

Students are presented with a problem at a local hotel - an infestation of bed bugs! Students are tasked with explaining why the hotel's bed bugs aren't being killed by the insecticide treatment that used to work for the hotel owner's Dad and Grandma, who were the hotel's previous owners. They review past diary entries and bed bug information to determine that the bed bugs were able to survive this change in their environment - but how? Students examine how the traits of the bed bug population give some individuals a better chance at surviving and reproducing in the insecticide-laden environment, and how this trait becomes more common in the population over time due to the process of natural selection and adaptation. They determine that the survival trait was caused by a mutation in the genetic code of the bed bugs, and when enough of the individuals in the population carry this mutation, the population is resistant to the insecticide treatment. Students use this information to explain to the hotel owner why the insecticide no longer works, using models and mathematical representations as supporting evidence. An optional extension lesson is also provided, where students explore what can limit a population's ability to adapt to a change in the environment by looking at two other treatment options, excessive heat, to which the population cannot adapt, and another insecticide that will likely result in additional resistance.

Unit Challenge Scenario

The family that owns the Spring Square Hotel has been offering a good night's rest to visitors for almost 50 years. Their business is quite steady throughout the year. The only little problem is that the hotel has always had some bed bugs.

Bed bugs are small insects that feed on blood and leave red, itchy bumps on your skin. The manager's grandmother who founded the hotel in 1972 had a difficult time with the bed bugs. When the manager's father took over from his mother, he started using a chemical insecticide called "Invade." He had an exterminator come every few months to spray "Invade." Below are entries from the manager's family diaries.

Grandma's Diary, March 3, 1975

The bed bugs at the hotel give us the worst trouble. The guests complain constantly about finding itchy, red bumps on their bodies during their stay at the hotel. We aired out all of the mattresses, and it still didn't help. We have done everything we could think of to get rid of them!

Dad's Diary, April 17, 1995

The guests had been complaining again. The exterminator recently told me about a new chemical insecticide called "Invade." It works so well! We spray every few months, and the guests don't complain any more. I am a happy manager! The guests are happy too! I'm inviting the exterminator back every few months. I remember when I was a kid and Ma put all the mattresses outside because of the bed bugs. No more bed bugs for us!

The hotel manager continued her father's tradition, and the "Invade" seemed to work well, because guests had not complained in years. She kept a close eye on the beds, and she saw very little evidence of bed bugs. Recently, though, guests have begun complaining again about itchy bumps on their bodies, and after a thorough search around the hotel, she found evidence that a concerning number of bed bugs were still living in the hotel.

The manager thought more "Invade" might help. She called the hotel exterminator. They sealed off all the rooms in the hotel and sprayed the bed bugs with a double dose of "Invade," and waited a week. The manager was shocked to find almost all of the bed bugs were still alive a week later!

Manager's Diary, March 22, 2021

I'm so disappointed and confused. I was certain that "Invade" was going to kill the bed bugs. It used to work for my father. Within a few days I was getting complaints again from guests about red itchy bumps on their skin. It turns out that almost all of the bed bugs survived the Invade insecticide treatment. Only a few of them died. I don't understand! That chemical was the real deal. I could even smell it. I need to know what happened!

The manager of the Spring Square Hotel needs your help. Please construct an explanation for the manager of the Spring Square Hotel to help her understand how the bed bugs were able to survive this change in their environment.

Lesson Sequencing Table			
Lesson #	Lesson Questions	What students do...	# days
1 (opener)	How can a species survive a change in the environment?	Students engage with examples of organisms being affected by a change in their environment through pesticide, antibiotics, and climate-related changes. Finally, students are introduced to the Unit Challenge Scenario and begin gathering information on bed bugs.	2
2	What affects whether organisms survive?	Students observe that traits in a population can have different effects on organisms depending on the environmental conditions present. Students apply what they learn to determine that bed bugs have a trait that has made them more likely to survive insecticide treatment.	5-6
3	Why do different traits occur in a species?	Students model how genetic mutations can result in new traits in a population. Students apply this to the Unit Challenge by developing models of the proteins in bed bugs that can and cannot survive insecticide and explain how these traits are related to a past genetic mutation within the bed bug population.	3
4	How can a rare mutation become common in a population?	Students use mathematical representations to identify how over time, traits can change within a population of organisms as an adaptation to environmental changes. They use this understanding to explain why the bed bug's insecticide survival trait became so common.	3-4
5 (closer)	How can a species survive a change in the environment?	Students develop and present a final presentation regarding the Unit Challenge Scenario. Finally, the class comes to consensus regarding why bed bugs are able to survive insecticide.	2-3
6 (optional extension)	What can limit a population's ability to adapt to a changing environment?	Students analyze data to address whether or not there are limits to adaptation by a population. Students use what they learn to evaluate the long term efficacy to two alternative bed bug treatment options.	2-3

Unit Advance Preparation:

- Consult the Unit Materials List