

One protein, four times over

Grades 9 to 12, ages 14 to 18. Two 50-minute sessions.

Resistance to cardenolides evolved independently in monarchs, milkweed bugs, milkweed beetles and several other insects, through changes at the same handful of amino acid positions. Students work from the molecule to the population and meet convergent evolution with a real dataset behind it.



R. A. Nonenmacher. CC BY-SA 4.0. Wikimedia Commons.

What students will be able to do

- Explain how a point mutation changes protein structure and therefore function.
- Define convergent evolution and give a molecular example.
- Evaluate the cost side of an adaptation, not just the benefit.

Materials

- A diagram of the sodium-potassium pump
- Amino acid sequence alignments for resistant and non-resistant insects
- The milkweed and monarchs guide

How it runs

1. Establish the baseline: what the sodium-potassium pump does in every animal cell, and why stopping it is fatal.
2. Show where cardenolides bind, on the outward-facing part of the protein.
3. Introduce the substitutions that confer resistance, and have students predict from the structure why a change at that position would reduce binding.
4. Reveal that this has happened independently in several insect lineages, at overlapping positions. Ask what that repetition tells us about how many solutions exist.
5. Discuss the cost. A modified pump is usually a slightly worse pump. Ask what would have to be true for the trade to be worth it.
6. Finish on sequestration, which is a second adaptation on top of the first, and on aposematic coloring, which is a third.

Discussion questions

- Why is the same solution arrived at repeatedly rather than many different ones?
- Resistance and sequestration must have evolved in some order. Which came first, and how would you test it?
- Gene editing has reproduced monarch resistance in fruit flies. What does that experiment establish that comparison alone cannot?

Taking it further

Compare with warfarin resistance in rats or insecticide resistance in mosquitoes. Same logic, much shorter timescale, and a live public health problem.

Safety

None.

NGSS alignment

Code	Performance expectation
HS-LS4-4	Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
HS-LS4-2	Construct an explanation based on evidence that the process of evolution primarily results from four factors.
HS-LS1-1	Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins.

<https://milkweedusa.com/learn/natural-selection-sodium-pump/>