

THE MONARCH EFFECT



SURVIVING
POISON,
PREDATORS,
AND PEOPLE

DANA L.
CHURCH

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CHAPTER ONE

BABY MONARCHS AND BARFING BLUE JAYS

A little egg, barely the size of a pinhead, sits on the underside of a milkweed leaf. After four to five days, if you were to look at the egg through a magnifying glass, you would see that the top of the egg has turned black. That's the head of the baby monarch caterpillar that's inside, and it's ready to come out.

Once the tiny, pale green caterpillar with its shiny black head breaks through the eggshell, it eats the shell. The eggshell, known as the **chorion**, is mostly protein, and this makes for a nutritious first meal for the caterpillar. And the pale green caterpillar must eat in order

to grow, because it is barely as big as the writing on a dime.

After the tiny caterpillar has eaten all of its eggshell, it's ready to eat even more. Luckily, the milkweed leaf it's on provides a feast. However, the caterpillar can't dig in just yet. The surface of the leaf is covered in hairs called **trichomes**.

When you're as small as a newly hatched monarch caterpillar, those hairs are like big spikes. The caterpillar sets to work, cutting the trichomes with its mouth. It

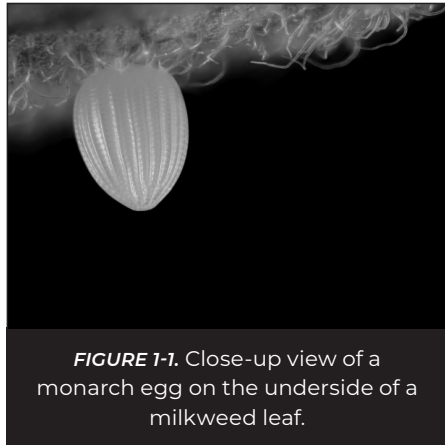


FIGURE 1-1. Close-up view of a monarch egg on the underside of a milkweed leaf.

doesn't eat the trichomes, but instead acts sort of like a mini lawn mower.

Once the caterpillar has cleared a spot, it still can't chomp down on the leaf. It must bite with care, because under the surface of the milkweed leaf are special cells that contain a white, oozing liquid called **latex**. When the caterpillar bites down and punctures these cells, the latex immediately spurts out and is extremely sticky. It also dries fast like glue, so the caterpillar risks getting

its mouth stuck shut or even its body stuck on the leaf, unable to move. On top of that, the latex is filled with deadly poisons. Scientist Dr. Anurag Agrawal described the monarch caterpillar's situation like this: "Visualize a toddler trying to eat a salad, with lettuce leaves covered in cactus spikes and with a dressing made of thick and toxic glue." What a challenge for the poor hungry caterpillar!

But let's look at things from the milkweed's point of view. Monarch caterpillars eat these plants. The plants need to defend themselves, so they developed trichomes and latex. As we will see, milkweed also developed special poisons. Sometimes that poison can kill monarch caterpillars; other times the caterpillars are able to use it to their advantage. If that wasn't enough, milkweed plants also give off smells that attract predators, such as wasps, flies, spiders, and stinkbugs, that would gladly make a monarch caterpillar their next meal. How does a newly hatched caterpillar deal with all this? When it comes to predators that hunt them down, the caterpillar unfortunately has no defenses yet and they often end up dying.

But if a caterpillar is not found by another hungry critter, it has to deal with the gush of latex from the milkweed leaf it will encounter when it bites the leaf.



FIGURE 1-2. Some types of milkweed are woollier than others.

Top: Monarch caterpillars of different ages on less-woolly milkweed leaves. Bottom: A monarch caterpillar on a milkweed leaf with lots of trichomes.

Do caterpillars have a strategy to deal with the sticky goo? Here is what scientists know about what caterpillars typically do on common milkweed (*Asclepias syriaca*). First, the caterpillar takes a bite out of the leaf. Then it backs away, wiping any latex that got onto its head or legs onto the leaf. It eventually returns to where it bit the leaf and bites again. It slowly chews a moat around itself, creating a little island where it can feed.



FIGURE 1-3. A monarch caterpillar, only a few hours old, chews a circle trench in a milkweed leaf. Blobs of latex form after the caterpillar bites the leaf.

Dr. Agrawal calls this a “circle trench.” Sometimes the caterpillars will dig the circle trench at the same time as they shave off the trichomes, while other times they shave off the trichomes in a circle first.

Less than half of all monarch caterpillars survive the milkweed’s latex. That’s an incredible number of caterpillars that die, considering one female monarch butterfly lays several hundred eggs in her lifetime. This means latex is quite an effective way for the milkweed to defend itself from being eaten alive. If the amount of latex a caterpillar ends up accidentally eating doesn’t kill them, they can recover in five to ten minutes. Otherwise, they end up in a nonresponsive, coma-like state and die.

Newly hatched caterpillars face various challenges, depending on the type of milkweed plant their mother laid their egg on. If a caterpillar was lucky enough to be laid on butterfly weed (*Asclepias tuberosa*), which can be found across North America, and is a type of milkweed that produces little if any latex, the baby caterpillar can dive right in without having to make a circle trench. On the other hand, if a baby caterpillar finds itself on sandhill milkweed (*Asclepias humistrata*), which is quite

common in Florida, it has to deal with a very waxy, slippery surface. Caterpillars can easily fall off to their death (another way that the milkweed plant defends itself from being eaten). Sandhill milkweed also produces lots of latex. Caterpillars born on this type of milkweed have their work cut out for them. To deal with the slipperiness and all the latex, monarch caterpillars on sandhill milkweed spin a thick mat of silk that acts as a platform where they can rest and not fall off the leaf. It also helps stop the flow of latex once the caterpillar starts chewing the leaf. A pretty clever strategy, if you ask me.

It is amazing that a creature so small has different survival strategies, depending on the type of milkweed plant it finds itself on. To test this even further, scientists took monarch butterfly eggs from common milkweed in New York and placed them on sandhill milkweed in Florida. They also did the reverse: They took monarch eggs laid on sandhill milkweed in Florida and placed them on common milkweed leaves in New York. The result? The New Yorker caterpillars started spinning silk mats in Florida, and the Floridian caterpillars started digging circle trenches in New York. The

caterpillars adjusted their behavior depending on the circumstances they found themselves in. Amazing!

If a monarch caterpillar survives past its first few days of life, its next job is to eat, eat, and eat some more. Caterpillars are basically eating, growing, and pooping machines. It takes about a week for a monarch caterpillar to grow from being barely the size of the writing on a dime to about the size of a sunflower seed. Although that is still quite small, it is a big difference in size. The caterpillar keeps growing until it reaches between one to one and a half inches, a little bit smaller than the length of your thumb. Dr. Agrawal put the caterpillar's growth spurts in perspective: "If an eight-pound human baby were to grow at this rate, by the end of one year, she would weigh as much as thirty-five of the largest adult elephants, about half a million pounds."

One funny thing about all this growing is that a caterpillar's skin doesn't grow with it. Imagine not being able to change into larger clothes as you grow bigger. You would eventually burst out of your clothes! This is essentially what happens to monarch caterpillars: They burst out of their skin. There is a soft, new skin underneath that quickly hardens. This bursting, or shedding

of skin, is called **molting**. Monarch caterpillars molt five times before forming a **chrysalis** (a protective covering). The space of time between each molt is called an **instar**. So, monarch caterpillars go through five instars before turning into an adult butterfly. Often the caterpillar will eat its old, discarded skin. Yuck! I can't imagine eating my old, discarded clothes, let alone my own skin!

Milkweed leaves don't contain much nutrition, so monarch caterpillars have to eat a lot of leaves to get the energy and nutrients they need to grow. This is pretty much the case for all **herbivores**, or animals that eat plants. This is the opposite of **carnivores**, or animals that eat meat. Meat is very dense in nutrients and so the animal doesn't have to eat nearly as much or as often to get similar benefits. For example, a panda bear needs to eat up to eighty-four pounds of bamboo leaves each day to stay healthy, whereas a lion eats about an average of seventeen to twenty pounds of meat per day. Monarch caterpillars eat so much that if you were to look inside their body, it would be entirely filled with ground-up milkweed leaves. And most of the leaf material can't be digested, so monarch caterpillars poop . . . a lot (see Figure 1-4).

Although monarch caterpillars are little eating machines, they do have one other important job: to not be eaten! How do they defend themselves against the flies and wasps that try to make them their meal? Interestingly, monarch caterpillars react to sounds, and they react to the buzzing of a predator's wings as it approaches. The

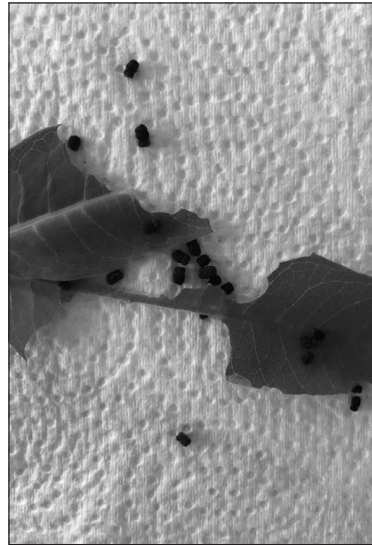


FIGURE 1-4. A pile of monarch caterpillar poop next to a snacked-on leaf for scale.

caterpillar freezes, ducks, or twitches its head up and down, waves the two antennae-like filaments on its head (called **tentacles**), or even drops off the plant. Freezing is thought to be helpful because some insect predators can zero in on their prey only if it is moving. Ducking, twitching, or waving their head shoos the predator away, and dropping off the plant is a quick escape. Scientists have seen these responses by monarch caterpillars when the scientists play recordings of buzzing insect wings and when bumble bees (who don't eat caterpillars) fly nearby. Monarch caterpillars also respond to human voices and

even to jets. This was a surprise finding by two scientists, Dame Miriam Rothschild and Dr. Gunnar Bergström, who wrote:

Once or twice weekly, these machines [Harrier aircrafts] sweep across the greenhouse, the pilots from the local base thus exhibiting their skill in low flying exercises. The loud aerial disturbance frightens the human bystanders if unaccustomed to the sudden rushing noise; and the vibration not infrequently cracks panes of glass in the roof of the greenhouse. The caterpillars, in unison, are then thrown into violent paroxysms of head jerking and tentacle waving, which subsides equally suddenly as the jets vanish. The effect is striking, occasionally on-lookers burst out laughing as the food plant appears momentarily to have come alive!

If monarch caterpillars can hear all these sounds, do they have ears? Not exactly. Scientists found very tiny hairs near the caterpillar's head that are connected to nerve

cells. When these hairs were removed, the caterpillars stopped reacting to sounds. What might the experience of sound be like for a caterpillar? That remains a secret.

NATURE'S FASHION STATEMENT

One other peculiar thing about monarch caterpillars is how brightly colored they are, with their white, black, and yellow stripes. Scientists aren't sure whether **invertebrate** predators (animals without a backbone) can see the bright advertisement of a monarch caterpillar's presence. However, **vertebrates** (animals with a backbone), such as birds, certainly can. And birds are another predator that monarch caterpillars have to watch out for. Does the monarch caterpillar's brightly colored body attract birds, and as a result, are they eaten more often than other types of caterpillars that blend in with their surroundings?

Dr. Colleen Hitchcock did a clever experiment that helps us answer this question. She made life-size clay models of caterpillars: Some were green that blended in with leaves, some were the same shade of brown as branches, and the rest were white with painted yellow-and-black stripes, just like monarch caterpillars. Dr. Hitchcock then placed these clay caterpillars on branches and leaves all over the fields and forests of Moose Hill Wildlife

Sanctuary and Assabet River National Wildlife Refuge in eastern Massachusetts. To prevent birds from flying off with the clay models, she tied the models to the branches or leaves with clear nylon thread. Before placing all her clay caterpillars out in the field, though, she made sure that caterpillars and birds already naturally existed in the areas. She found hundreds of green caterpillars, brown caterpillars, and monarch caterpillars, as well as over sixty species of birds. The most common birds she encountered were blue jays, American crows, tree swallows, black-capped chickadees, American robins, gray catbirds, northern mockingbirds, eastern towhees, northern cardinals, and American goldfinches. Would these birds be fooled by her clay models?

Altogether, Dr. Hitchcock made and used over 3,000 clay caterpillars. She put them in the field for twenty-one days and checked on each one every three days. She was looking for beak marks left by birds when they pecked at them. Dr. Hitchcock was clever and used a type of clay that didn't harden. Beak marks were V-shaped patterns in the clay or pairs of angled marks. She counted how many clay caterpillars had these attack marks on them and noted the color of these attacked clay caterpillars.