

Monarch Butterfly, *Danaus plexippus* Linnaeus (Lepidoptera: Nymphalidae: Danainae)¹

Andrei Sourakov²

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Introduction

The monarchs, *Danaus plexippus* Linnaeus, are among the best known of the world's butterflies due to their remarkable ability to migrate, wide distribution, and charismatic appearance. The last Pleistocene glaciations in North America instigated migration to Mexico in the east and to the Californian coast and deserts in the west. In the western U.S., the overwintering colonies are smaller and more numerous, while in Mexico, they are few but more spectacular, with billions of butterflies concentrating in one spot.



Figure 1. Adult monarchs, *Danaus plexippus* Linnaeus, from Gainesville, Florida.

Credits: Andrei Sourakov, Florida Museum of Natural History

1. This document is EENY-442, one of a series of the Entomology and Nematology Department, UF/IFAS Extension. Original publication date October 2008. Revised December 2014 and March 2021. Visit the EDIS website at <https://edis.ifas.ufl.edu> for the currently supported version of this publication. This document is also available on the Featured Creatures website at <http://entnemdept.ifas.ufl.edu/creatures/>.
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Figure 2. Adult monarchs, *Danaus plexippus* Linnaeus, migrating at their Mexican overwintering site in Sierra Madre, Michoacán.
Credits: Andrei Sourakov, Florida Museum of Natural History

Distribution

Danaus plexippus is found throughout the Americas and Australia, with individuals reported in New Guinea and Western Europe. Sedentary populations that are found in Mexico, and Central and South America (including the Caribbean islands) are somewhat different from migratory populations of *D. p. plexippus* found in North America. Several subspecies, such as *M. p. megalippe* (Mexico, southern U.S.) and *M. p. menippe* (South America) have been described. Monarchs fly from sea level up to 2,500 meters.



Figure 3. Adult monarch, *Danaus plexippus* Linnaeus, emerging on Christmas day in the resident population in North Florida, Gainesville.
Credits: Andrei Sourakov, Florida Museum of Natural History

Some of the *D. p. plexippus* reach Cuba instead of Mexico, where they mix with the resident population of *D. p. megalippe*, from which they noticeably differ in behavior and wing length and shape (Dockx 2007).



Figure 4. Adult migrating monarch, *Danaus plexippus* Linnaeus, in Mexico.
Credits: Andrei Sourakov, Florida Museum of Natural History

Description

Orange-and-black warning coloration of monarchs is noticeable, and its memorable pattern is directed at repelling insectivorous birds. Experiments conducted with captive blue jays showed that monarchs indeed are toxic (Brower et al. 1968). Being distasteful due to ingestion by larvae and sequestration by adults of cardenolides that are toxic to birds, monarch serves as a model for several mimetic species and is frequently confused with the viceroy (*Limenitis archippus* (Cramer, 1776)) and queen (*Danaus gilippus* (Cramer, 1775)) butterflies. That mimicry is considered to be Müllerian, with all species involved being distasteful to some degree and contributing to each others' defense (Ritland and Brower 1991).



Figure 5. Viceroy butterfly, *Limnitis archippus* (Cramer, 1776), upperside, Gainesville, Florida; a mimic of the monarch, *Danaus plexippus* Linnaeus.
Credits: Andrei Sourakov, Florida Museum of Natural History



Figure 6. Viceroy butterfly, *Limenitis archippus* (Cramer, 1776), underside, Gainesville, Florida; a mimic of the monarch, *Danaus plexippus* Linnaeus.

Credits: Andrei Sourakov, Florida Museum of Natural History

Other than its mimics, the monarch can be confused with very few other butterflies. However, on the islands of Hispaniola and Jamaica, a smaller Jamaican monarch, *Danaus cleophile* (Godart, 1819), can be found flying together with the *D. plexippus*.



Figure 7. Jamaican monarch, *Danaus cleophile* (Godart, 1819), ovipositing on *Asclepias nivea* in Cordillera Central, Dominican Republic.

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Biology and Life Cycle

Monarchs lay their eggs singly on the underside of leaves and sometimes on the flowers of different milkweeds (Asclepidaceae: *Asclepias*). Recent analysis of genomes of migratory and non-migratory monarchs shows that monarchs originated in North America from a migratory ancestor.



Figure 8. Egg of the monarch butterfly, *Danaus plexippus* Linnaeus, on the underside of the leaf of scarlet milkweed, *Asclepias curassavica*, Gainesville, Florida.

Credits: Andrei Sourakov, Florida Museum of Natural History

Link to video of egg hatching - <http://www.youtube.com/watch?v=1Vw4-FnAtgw>

The first instar larva is white with a black head. The larva develops a more conspicuous striated yellow-and-black coloration in the second instar. This coloration varies depending on subspecies in mature larvae. Larvae also develop two thoracic and two abdominal dorsal filaments.



Figure 9. First instar larva of the monarch butterfly, *Danaus plexippus* Linnaeus, hatches from the egg, which it immediately consumes. Gainesville, Florida.

Credits: Andrei Sourakov, Florida Museum of Natural History

The pupa (chrysalis) is formed by the larva hanging on a substrate, such as underside of leaves and twigs, usually away from the host plant. When formed, it is green with gold markings.



Figure 10. Fourth instar larva of the monarch butterfly, *Danaus plexippus* Linnaeus, Gainesville, Florida.
Credits: Andrei Sourakov, Florida Museum of Natural History



Figure 11. Fifth instar larva of the monarch butterfly, *Danaus plexippus* Linnaeus, feeding on scarlet milkweed, *Asclepias curassavica*.
Credits: Andrei Sourakov, Florida Museum of Natural History

Link to video of caterpillar forming chrysalis - <http://www.youtube.com/watch?v=DKjG1vm5F84>

Link to video of adult emerging - <http://www.youtube.com/watch?v=TTa-HMMi7yc>

Development from egg to adult takes less than a month.
In North America, the monarchs go through at least four generations a year before they start migrating south in the fall.



Figure 13. Pupa of the monarch butterfly, *Danaus plexippus* Linnaeus.
Credits: Andrei Sourakov, Florida Museum of Natural History

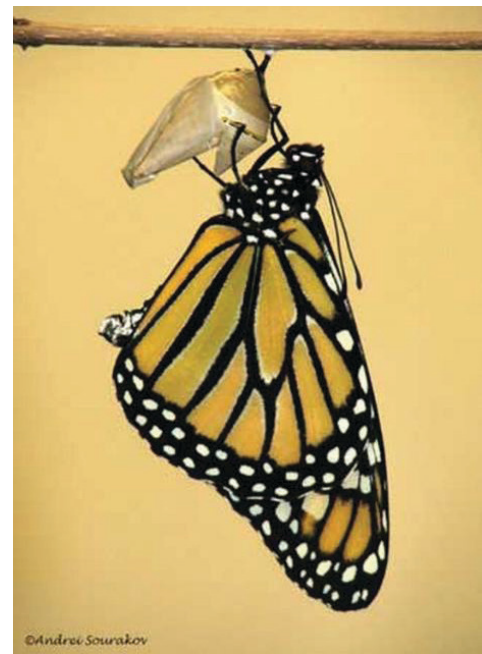


Figure 14. Adult monarch butterfly, *Danaus plexippus* Linnaeus, emerging from the pupal case.
Credits: Andrei Sourakov, Florida Museum of Natural History

Adults are strong fliers and can fly for 11 hours straight. In the fall, enough fat is stored in the adults to allow a continuous 1000 km flight without feeding. Some make a journey of a total of 4000 km to reach overwintering sites in the Sierra Madre de Oriente, where they settle inside the coniferous forest of the state of Michoacán. Monarchs also fly across the Gulf of Mexico with overwater flights of 600 km.



Figure 15. Adult monarch butterflies, *Danaus plexippus* Linnaeus, covering fir trees in the overwintering colony at El Rosario, in Sierra Madre, Michoacán, Mexico.
Credits: Andrei Sourakov, Florida Museum of Natural History

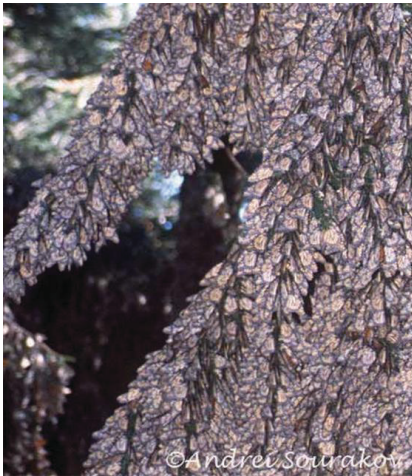


Figure 16. Close-up of adult monarch butterflies, *Danaus plexippus* Linnaeus, covering fir trees in the overwintering colony at El Rosario, in Sierra Madre, Michoacán, Mexico.
Credits: Andrei Sourakov, Florida Museum of Natural History



Figure 17. Adult monarch butterflies, *Danaus plexippus* Linnaeus, migrating at their Mexican overwintering site in Sierra Madre, Michoacán, Mexico.
Credits: Andrei Sourakov, Florida Museum of Natural History



Figure 18. Close-up of an adult monarch butterfly, *Danaus plexippus* Linnaeus, migrating at its Mexican overwintering site in Sierra Madre, Michoacán, Mexico.
Credits: Andrei Sourakov, Florida Museum of Natural History

A tagging program was initiated by F. A. Urquhart of the Royal Ontario Museum in the 1950s and is continued to this day. It allowed scientists to determine the migration path of monarchs.



Figure 19. Tagged adult monarch, *Danaus plexippus* Linnaeus, Gainesville, Florida, released during the Butterfly Festival, October 2007.
Credits: Andrei Sourakov, Florida Museum of Natural History

Monarchs feed extensively on the way, accumulating body fat sufficient to last them through the winter. At the overwintering sites in Mexico, the monarchs spend over four months in a reproductive diapause. They feed and drink as the weather warms up, but return to their resting sites.



Figure 20. Adult monarchs, *Danaus plexippus* Linnaeus, drinking at the creek in El Rosario Colony, Michoacán, Mexico.

Credits: Andrei Sourakov, Florida Museum of Natural History



Figure 21. Adult monarchs, *Danaus plexippus* Linnaeus, sunning themselves before going to feed, El Rosario overwintering colony, Michoacán, Mexico.

Credits: Andrei Sourakov, Florida Museum of Natural History

Courtship behavior of monarchs has been described in detail and consists of a mating ritual, where a male grasps the female in the air and brings her down to the ground, where mating occurs. Mating occurs several times, both during the summer and at the overwintering sites. Mating attempts frequently fail because of resisting by females (e.g., Frey, 1997).

Monarchs begin to fly north in March, reproducing along the way. Migration north continues, with the second and third generations recolonizing the continent.

The ability to navigate to the overwintering sites is genetic and is linked to time-compensated sun compass

orientation. This ability requires constant recalibration of genetic program by changing surrounding. It is linked to the activity of the central complex is a midline structure consisting of protocerebral bridge and central body in Monarch's brain.

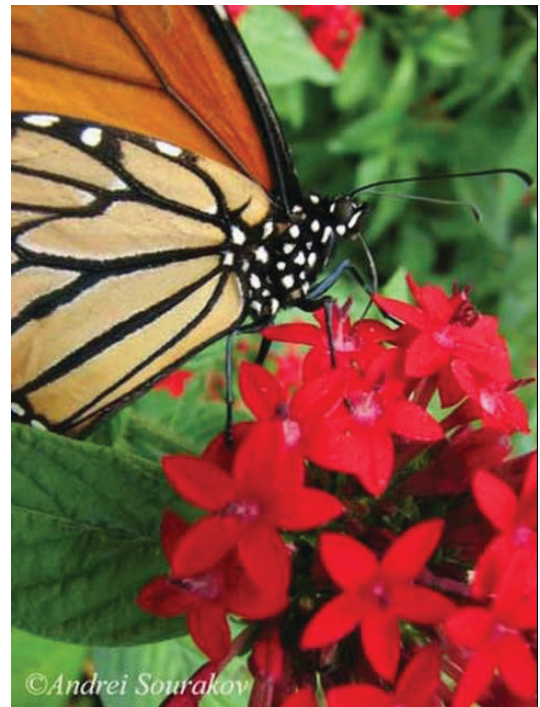


Figure 22. Adult monarch, *Danaus plexippus* Linnaeus, feeding.

Credits: Andrei Sourakov, Florida Museum of Natural History

Geomagnetic forces are probably used as monarchs get closer to their overwintering sites since the migratory monarchs' bodies contain higher quantities of magnetic material than non-migrating butterflies. The vicinity of overwintering sites in the Mexican Transvolcanic Range contains high level of magnetic anomalies, which probably help monarchs find them. Social behavior and pheromones probably also play large role in choosing the overwintering site.

To understand migration, the gene expression patterns that define the migrating monarchs are being investigated. Specific genes are regulated by juvenile hormone, which is responsible for interruption of reproductive behavior and initiation of migration. Micro RNAs regulate gene expression, and each miRNA can regulate several proteins. In other systems, miRNAs are involved in epigenetic developmental events. They may be involved in initiating/mediating the migratory state in monarch butterflies. The effort to assess genome of monarchs, which proves to be smaller than in other butterflies, and more similar in size to that of mosquitoes is being made (Zhu et al. 2008).

Monarchs are great model organisms for researching many general questions about animals in general. For

instance, recent studies conducted on monarchs allowed for understanding the evolution and function of cryptochrome proteins in animals (Zhu et al. 2008). Cryptochromes are critical for circadian timing in butterfly's clock mechanism. In monarchs, one of the cryptochromes functions as a likely circadian photoreceptor, while another appears to function as the major transcriptional repressor of the clockwork transcriptional feedback loop.

Hosts and Monarch Toxicity

Monarch toxicity has been linked to the toxicity of the plants upon which they feed. Monarchs oviposit on milkweeds of the genus *Asclepias* from which the caterpillars collect the cardiac glycosides toxic to birds. These substances are passed on to the adult butterflies, which are also toxic. The idea of automimicry (that some monarchs are more toxic than others, but that the birds, unable to distinguish between the traits, avoid all of them) has been investigated (Brower et al. 1970). Apparently, there are costs and benefits to the ingestion of glycosides, since it was shown that monarch females prefer plants with intermediate cardenolide level, rejecting higher and lower level-containing plants (Oyeyele and Zalucki 2008).



Figure 23. Adult monarch butterfly, *Danaus plexippus* Linnaeus, feeding on flower of scarlet milkweed, *Asclepias curassavica*.
Credits: Andrei Sourakov, Florida Museum of Natural History



Figure 24. Pinewoods milkweed, *Asclepias humistrata* Walter (Apocynaceae), a host of the monarch butterfly, *Danaus plexippus* Linnaeus.
Credits: Jerry Butler, University of Florida



Figure 25. White swamp milkweed, *Asclepias perennis* Walter (Apocynaceae), a host of the monarch butterfly, *Danaus plexippus* Linnaeus.

Credits: Donald Hall, University of Florida



Figure 26. Butterfly milkweed, *Asclepias tuberosa* L. (Apocynaceae), a host of the monarch butterfly, *Danaus plexippus* Linnaeus.
Credits: Donald Hall, University of Florida



Figure 27. Pink swamp milkweed, *Asclepias incarnata* L. (Apocynaceae), a host of the monarch butterfly, *Danaus plexippus* Linnaeus.
Credits: Donald Hall, University of Florida



Figure 28. Scarlet milkweed, *Asclepias curassavica* L. (Apocynaceae), a host of the monarch butterfly, *Danaus plexippus* Linnaeus. Credits: Donald Hall, University of Florida



Figure 29. Common milkweed, *Asclepias syriaca* L. (Apocynaceae), a host of the monarch butterfly, *Danaus plexippus* Linnaeus. Credits: Donald Hall, University of Florida

Conservation Status

Monarchs are not endangered as a species due to many sedentary populations in the south of its range. However, the deforestation around their overwintering sites in Mexico puts the northeastern population of monarch and

the remarkable phenomenon of migration in danger. For instance, in 2002 severe winter weather killed off an estimated 80 percent of monarchs in overwintering colonies in Sierra Chincua and Sierra Campanario, with some colonies reduced in size by 90 percent (Brower et al. 2004).

A few years ago, the controversy over the influence of *Bt* corn on monarch mortality arose. However, though mortality due to ingestion of corn pollen does occur, it has been shown that its effect on monarch population might not be as dramatic as was initially thought (Auman-Bauer 2001).

In late August 2014, the Xerces Society, Center for Food Safety, Center for Biological Diversity, and Dr. Lincoln Brower submitted a petition to the Secretary of the Interior requesting the Monarch butterfly be listed as “threatened” under the Endangered Species Act.

Natural Enemies

Birds such as black-beaked orioles and black-headed grosbeaks attack monarchs at their overwintering sites. Apparently the toxins deteriorate during the migration, hence the birds can eat them. Orioles slit open the monarchs’ abdomens avoiding most of the toxins in the cuticle. Grosbeaks eat the entire abdomen and can tolerate higher levels of cardenolides. These two birds account for over 60 percent of the total monarch mortality. Among other vertebrates, rats have been observed feeding on monarchs at overwintering sites.

Invertebrate predators such as ants, spiders, and wasps attack monarch larvae on milkweed plants. Tachinid flies and braconid wasps are known to parasitize larvae. Several entomopathogenic organisms can infect monarchs, including a nuclear polyhedrosis virus and *Pseudomonas* bacteria, protozoan parasites such as *Ophryocystis elektroscirrha*, and a microsporidian *Nosema* species (McLaughlin and Myers 2007).

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