Cochineal
The Crimson Bug

Wayne P. Armstrong

Cochineal, which refers to both the insect, and the red dye which comes from the female bug, is ubiquitous. In addition to clothing, cochineal red dye is still used in many foods and drinks, including candies, ketchup and soft drinks. To be certain, you must check the list of ingredients on packaging or online. Cochineal is also used in cosmetics, such as lipstick and face powders. It has also been used for the pink coloration of lunchmeats and hotdogs. The pharmaceutical industry uses cochineal to color pills and ointments. Some health-conscious connoisseurs think cochineal is a better alternative to artificial red dye #40 derived from petroleum; however, the latter dye is considered safe by the FDA. Natural Red Dye 4 is different from #40. The active ingredient, carminic acid, is derived from cochineal insects and is used in bacteriological and histological stains. It can be found under multiple names, including carmine, cochineal, cochineal extract, natural red 4, crimson lake, carmine lake, and E120. Red lake pigments are organic dyes made from plants and insects that are mixed with mordants, such as white chalk or alum. They were commonly used in Renaissance and Baroque art.

Cochineal insects *(Dactylopius coccus)* are related to aphids, scale insects and mealy bugs, formerly in the insect order Homoptera. According to evidence from DNA sequencing, they are now placed in the large order Hemiptera with true bugs. They live on species of prickly-pear cactus *(Opuntia)*, especially the mission prickly-pear *(Opuntia ficus-indica)*, a large, thicket-forming cactus native to the New World (probably Mexico). There are numerous cultivated varieties, including some with spines and some without spines. Spineless cultivars were highly-prized for their fleshy, sweet fruits since prehistoric times, and were traded by native American people in Mexico and tropical America. The cactus pads (stem segments) are sliced, cubed and cooked (boiled) like string beans. Called *nopales* or *nopalitos* in Mexico, they are sold in supermarkets as a delicious vegetable, especially when cooked with eggs, meat, chilies, and onions.

The fresh, many-seeded fruit, called cactus apple or *tuna*, is eaten raw or made into drinks. One must be very careful when preparing the fruits because of minute, hair-like spines called glochids that readily penetrate fingers. The painful glochids can be removed from the fruits by scraping or singeing them with a flame, boiling them, or by washing them thoroughly in a tub with a high pressure nozzle.

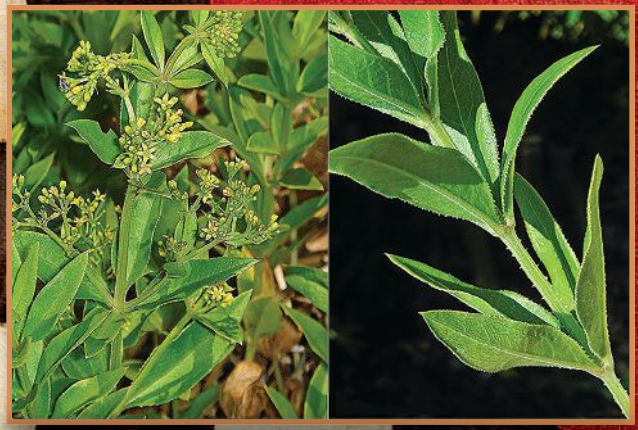
The literal translation of its specific epithet *(ficus-indica)*, is Indian fig; however, it is not a fig *(Ficus)* and not from India. I suppose the fleshy, many-seeded interior of the fruit might superficially resemble a fig, but the painful glochids are not present on any fig fruit. What most people call a fig "fruit" is technically a fleshy, hollow flower inflorescence called a syconium that is unique to figs. Some references credit Columbus for discovering this cactus in India; however, he landed in the New World. One must question his navigation skills in 1492.

During the 1700s and 1800s in California, mission prickly-pear was planted near the Spanish missions and on the large Spanish ranchos. In addition to the cooked stems and sweet fruits, the cactus pads were used as a source of mucilaginous binding material for adobe bricks for the mission buildings. Over the centuries, this species has spread and cross-pollinated with many native species of prickly-pears, resulting in numerous intermediate forms (called hybrid swarms) throughout its range. In fact, some of the massive, thicket-forming, hybrid clones can even survive chaparral and grass fires

ORLANDO DUGI (Diné), evening gown (from the Red Collection) of hand-dyed silk duchesse satin, silk organza, and silk thread; cut glass and sterling silver beads, French coil, Swarovski crystals, vintage beads and crystals; lining of duchesse satin and tulle, 160.0 x 132.1 centimeters, 2014. *Collection of the artist. Photograph by Blair Clark.*

FRUIT-BEARING *Opuntia ficus-indica* in coastal sage scrub near Palomar College.

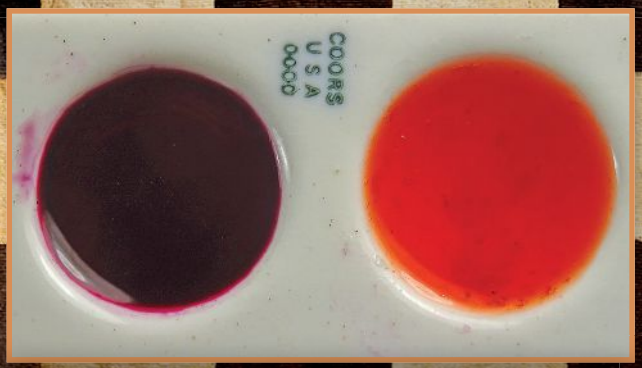
EXCEPTIONALLY SPINY FRUITS on this *Opuntia ficus-indica* at Palomar College.



EUROPEAN DYE PLANT CALLED MADDER *(Rubia tinctorium)*, a Mediterranean perennial with square stems and whorls of four to five prickly leaves at the nodes. Retrorse barbs along the stem make it cling to your clothing, like species of bedstraw *(Galium)* in southern California. The flowers are small, greenish-yellow and inconspicuous. It also is used as a red dye.

CLOSEUP PHOTOGRAPH OF COCHINEAL ON CACTUS PAD AFTER SOAKING RAIN: Male nymphs develop into winged adults in the small cylindrical structures.

Photographs by Wayne Armstrong except where noted.



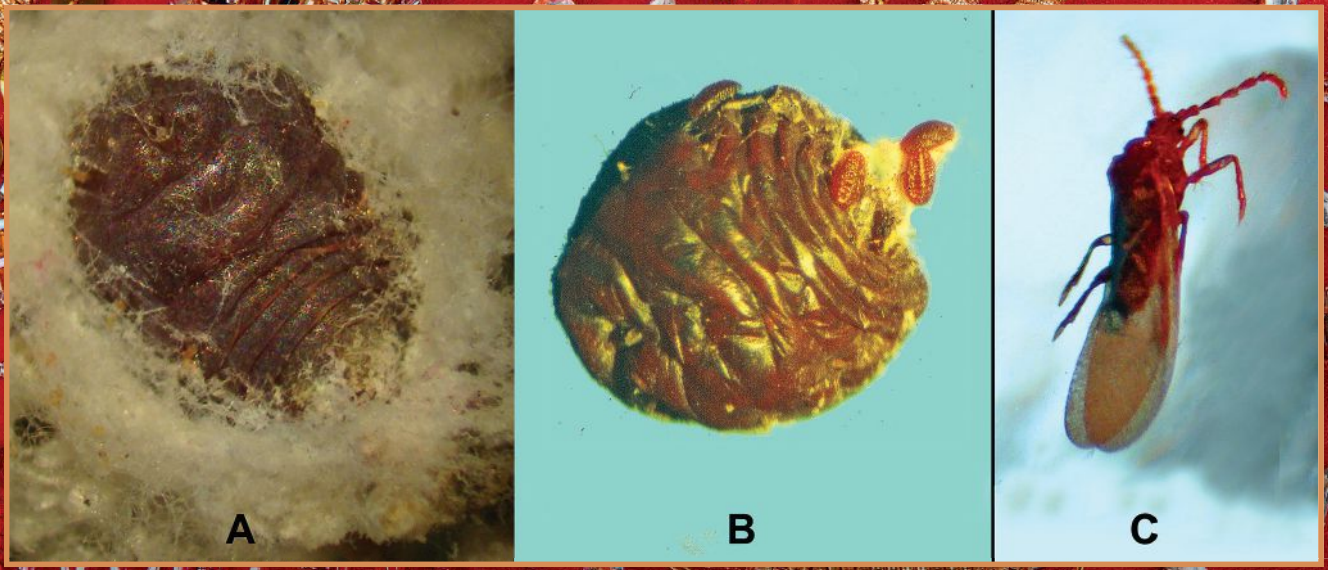
DIFFERENT COLORS OF COCHINEAL BY CHANGING THE PH: by lowering the pH of cochineal dye bath, color changes from dark, blood red to orange.

WHOLE, DRIED COCHINEAL FEMALE BODIES ordered on the Internet. They can also be shipped as ground up powder: Just add water to make the dye!

in Southern California. They regenerate from live stems in the center of the thickets where the fire is unable to penetrate. This complex species and its various cultivars and hybrids now grow throughout temperate and tropical regions of the world.

Cochineal insects on cactus pads are covered by a protective cottony mass which they secrete. Entomologist extraordinaire Thomas Eisner describes them as "cloaked in a fluffy investiture of waxy powder and silken threads, which gives them a woolly appearance." The "wool" is absent from newly hatched nymphs. I prefer the adjective "cottony." The cottony masses containing female cochineal are brushed from the cactus pads, dried, and the bright red pigments are extracted from the dried bodies of females. One pound of dye represents about 70,000 insect bodies. From the region of Oaxaca alone, for the period 1758 to 1780, the production of cochineal amounted on average to about 1 million pounds per year. Peru is the primary producer, making 85% of this dye, with the Canary Islands next in productivity (Clark 2015).

INCA MILITARY TUNIC dyed by cochineal. *www.worldhistory.org/cochineal.*



FEMALE COCHINEAL INSECT with and without cottony secretion (A, B) and male with folded wings (C). This comparison shows the vast differences in body structures.

The bright red dye and the biological stain carmine are made from the crushed bodies of these unusual insects. Cochineal-laden cacti were introduced into Australia for this valuable dye with disastrous consequences. By 1925, sixty million acres of valuable range land was covered by prickly-pear cactus, which had become a major invasive species.

To control the spread of mission prickly-pear cactus in Australia, the cactus moth (*Cactoblastis cactorum*) was introduced, and by 1930, thanks to the voracious larvae, vast areas of cactus scrub had been denuded; however, this method of biological control raised havoc in other areas of the world due to "nontarget effects." The moth attacked other species of cacti, some of which are rare and endangered.

The plump female cochineal insect resembles a minute wrinkled ball with vestigial, nonfunctional legs. She feeds on cactus juices with piercing-sucking mouthparts. As I stated above, adults are concealed by a protective, cottony mass that is secreted around their red bodies. They are not readily seen unless the insect's body is crushed, when the red body fluids seep out. The bright red fluids are the source of cochineal dye. Mesoamericans realized thousands of years ago that pinching these insects produced blood-red stains on their fingers. Much like we raise bees for honey today, they began farming the cochineal insects for dye. According to Amy Butler Greenfield (2005), in Mexico's southern highlands (the area now known as Oaxaca), the Zapotec and Mixtec people bred the insects for the color, potency and amount of dye they produced.

The male and female cochineal insects are a remarkable example of sexual dimorphism where the sexes have no phenotypic resemblance to each other. The mature female is reduced to a solitary, sessile (immobile), reddish ball about 5-6 millimeters in diameter. The males are only about 2 millimeters or less (including wings) and resemble a minute, flying ant. Male nymphs secrete a protective, cylindrical cottony sheath from which the winged adult emerges. Their distinctive pair of elongate, hair-like tail filaments often protrude from the cottony sheaths. Some references state they are rarely seen, but once I discovered what to look for, I found numerous males. It is hard to believe they are the same species as the females! Photographing them is

MARY SLY paints her clothing with undiluted natural textile dyes. Her **KIMONO TULIP JACKET** is drawn freehand with gutta, and then handpainted on charmeuse silk. This dye is likely either madder or cochineal. *Model: Linda Kuo. Photograph by John F. Cooper.*

a real challenge, especially when they are embedded in the dense cottony masses on cactus pads. Ideally, they need to be carefully removed from the tangled fibers and placed under a dissecting microscope.

I have not witnessed the copulatory behavior of cochineal insects out of my respect for their privacy, but it starts with the male mounting the female who resembles an immobile ball. He finds her by the chemical scent of pheromones. The details described in peer-reviewed entomology journals are beyond the scope of this article. Females of some species can reproduce asexually by parthenogenesis, in which eggs develop without fertilization. Eggs are laid in a waxy meshwork during their incubation period, and tiny red offspring (nymphs) are released from under her body into the cottony mass surrounding her. Numerous tiny red nymphs are scattered throughout the cottony masses on cactus pads. Male nymphs feed on cactus juices until they reach sexual maturity. They live only long enough to find a female and fertilize her eggs. For this reason they are not commonly seen by the casual observer.

NAVAJO SARAPE with small poncho neck slit of red raveled wool weft yarn (one-two S-spun strands) dyed with one hundred percent cochineal, 183.0 x 122.0 centimeters, Navajo Nation, Arizona or New Mexico, mid-Classic period, ca. 1865. *Photograph by Blair Clark. Courtesy of The Owings Gallery, Santa Fe, New Mexico.*

Carminic acid, the dye from cochineal insects, is an anthraquinone. Quinones are common in biological systems and a lecture topic in organic chemistry courses. Quinones occur in blackened apples and potatoes, and the brown pigment cells of duckweeds. Urushiol, the insidious allergen of poison oak, is a phenolic compound that is oxidized into a quinone after it has penetrated the epidermis of skin. A special quinone called ubiquinone (the oxidized form of coenzyme Q) is found in the membranes of bacteria and cellular organelles (mitochondria and chloroplasts) where electron transport and ATP production occurs. It is a vital molecule essential for life.

Carminic acid is also classified as a weak organic acid with carboxyl groups (C=O/OH). Familiar organic acids are acetic acid in vinegar, and lactic acid in milk products; however, in the case of carminic acid, its structural formula is quite complex and was not elucidated until 1959. Typically it comprises 17-24% of the dried insects' total weight. It is mixed with aluminum or calcium salts to make carmine dye, also known as cochineal. What intrigues me the most about this molecule is how a significant dye that enhanced civilizations for millennia, and one of the most widely used natural products of all times, just happened to evolve in these tiny insects. Is there any adaptive advantage that would explain its origin in accordance with Darwin's scientific "Theory of Natural Selection"?

According to Thomas Eisner, *et al.* (Science 30 May 1980), carminic acid is a potent feeding deterrent to ants.

CACTUS PAD, RED DYE WITH MORTAR & PESTLE. WHOLE, DRIED COCHINEAL female bodies ordered on the Internet.

PRE-COLUMBIAN TEXTILES FROM PERU, colored by cochineal, circa 800-1300 A.D.
Rowanwindwhistler, CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0), via Wikimedia Commons.

This may have evolved as a chemical weapon against predation. The Argentine ant supercolony at my home thrives on honeydew secretions of aphids, and they commonly distribute these minute parasites on my cultivated plants. It will be interesting to see how these very aggressive ants react to the masses of cochineal insects on prickly-pear cactus I have planted in my yard. Eisner offered ants sugar solutions with and without carminic acid. Even in darkness the ants avoided the carminic acid, proving their rejection was not based on the red color. The carnivorous caterpillar of a pyralid moth (*Laetilia coccidivora*) is undeterred by the dye and feeds on cochineal insects. In fact, this moth has the remarkable habit of utilizing the ingested carminic acid for its own defensive purposes.

Dyemaking is a labor intensive process. In order to make natural dyes colorfast they must be used with various mordants, such as alum, acetic acid (vinegar) and cream of tartar. Without the proper mordants the dyes will wash out and fade rapidly. As I discovered without mordants, other clothes in a washing machine will no longer be white if mixed with clothes where the dye has not been set. The action of mordants is very complex, but essentially they serve to chemically bind the dye molecules with the fabric polymer. Different colors are produced depending on the type of mordant and duration of the dye bath, including bright reds and beautiful shades of blue, from light lavender to a deep blue-black. Different colors (hues) can also be obtained by lowering the pH of dye bath, from dark, blood red to orange. The recommended mordant for cochineal is alum (aluminum potassium sulfate), a common mordant found in the baking powder and spice sections of most supermarkets or on Amazon. It is sold for pickling and canning to help maintain the firmness and crispness of fruits and vegetables in preserved foods.

There is substantial evidence that dyeing and painting with cochineal were a long-standing practice with

IKAT ROBE, 138.4 x 213.7 centimeters, Uzbekistan, late 19th or early 20th century. Central Asian ikat began using artificial dyes during the second half of the nineteenth century. However, many examples were found to use both artificial and cochineal dyes separately for the warp and weft. *Courtesy of The Textile Museum.*

What intrigues me the most about this molecule is how a significant dye that enhanced civilizations for millennia, and one of the most widely used natural products of all times, just happened to evolve in these tiny insects.

33RD REGIMENT OF FOOT (WELLINGTON'S REDCOATS) who fought in the Napoleonic Wars between 1812 and 1816, here showing the standard line 8th Company and the red dyed coat. WyrdLight.com, CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0), via Wikimedia Commons.

SLEEVE PATCH for a Shidong Miao festival jacket known as an *outou* or "the bright dress". This example is roughly fifty years old. *Photograph by Robert K. Liu.*

indigenous people of Mexico and Peru. This red dye was highly valued and traded. It was carried on long journeys covering thousands of miles, from Mexico to South America. Native people revered it in rituals and prayers, thanking their gods for the cochineal harvest. According to LaVerne Dutton (1992), cochineal was so important to the Zapotec culture that they had a deity for agriculture and sustenance called "Coqueelaa", god of the cochineal harvest. The reference to this god also appears on www.godchecker.com; however, there is online disagreement on some of these "facts" about natural dyes. Pieces of the hardened resin copal were used as offerings during worship rituals. Copal is obtained from several tropical tree species, including West Indian locust (*Hymenaea courbaril*). Hardened globs of terpene resin become buried in the soil around massive trunks of dead trees. It is often sold as faux amber.

The demand for cochineal fell sharply by the mid-1800s because of the advent of synthetic aniline dyes. It was the age of organic chemistry and pigments of diverse hues could be made in laboratories. The effect on the cochineal industry was disastrous. It would take a multi-volume book to cover all the details of the biology and history of cochineal; how it was discovered, cultivated, marketed and used. It is prominent in our own American history, including British redcoats that confronted Americans in the Revolutionary War. Several references have implied that cochineal may have been used for red stripes on the very first American flag. It was undoubtedly a natural red, possibly cochineal or madder, a plant derived dye.

Although it is still used by people of Mexico and South America, it is doubtful that cochineal will ever achieve the world importance that it held during the past two centuries. Kings and clergymen no longer wear robes dyed with cochineal; however, carmine will probably always be around on the shelves of microbiology laboratories. It will also be an important food coloring ingredient, especially for health-conscious people who prefer natural over synthetic dyes made from petroleum. It may even be in your bottle of ketchup!

The days of rugged buccaneers have long since passed and their marvelous masted sailing ships no longer ride the ocean currents and trade winds back to England. But the memories of those times are forever commemorated in the fabulous paintings and museum art pieces when the perfect red was as valuable as gold and silver.

REFERENCES/BIBLIOGRAPHY

Campana, M. G., N.M. Robles Garcia and N. Tuross 2015 America's red gold: multiple lineages of cultivated cochineal in Mexico. *Ecology and Evolution* 5 (3): 607-617.

Clark, L. 2015 International Arts. Cochineal. The Red that colored the World. *Ornament* 38 (4): 28-29.

Donkin, R. A. 1977. "Spanish Red: An Ethnogeographical Study of Cochineal and the Opuntia Cactus." *Transactions Of The American Philosophical Society* 67 (Part 5): 1-84.

Dutton, LaVerne M. 1992. "Cochineal: A Bright Red Animal Dye." MS Thesis in Environmental Archeology. Baylor University, Waco, Texas. Excellent reference available online at: https://www.cochineal.info Copyright 2025.

Eisner, Thomas. 2023. For Love of Insects. Harvard Univ. Press, Cambridge, Massachusetts, and London, England. 448 p.

—1980. "Red Cochineel Dye (Carminic Acid): Its Role in Nature." *Science*: 208: 1039-1042.

Greenfield, Amy Butler. 2005. A Perfect Red: Empire, Espionage, and the Quest for the Color of Desire. HarperCollins Publishers, New York. 338 p.

—2019. "The Bug That Had the World Seeing Red," in Smarthistory, September 15, 2019. https://smarthistory.org/cochineal/. Accessed March 14, 2025.

Harvard Museums of Science & Culture. "Cochineal: How Mexico Made the World See Red." https://hmsc.harvard.edu/online-exhibits/cochineal/ Accessed March 14, 202

Scully, Simone. 2021. "The Bug the World Fought Over." Mental Floss: https://www.mentalfloss.com/article/648050/cochineal-insect-red-dye. Accessed March 17, 2025.

Tamburini, Diego, Zeina Klink-Hoppe and Blythe McCarthy. "New insights into the dyes of Central Asian ikat textiles." https://www.sciencedirect.com/science/article/abs/pii/S1296207423002509.