# The puzzle of monarchs
## and their association with plants containing pyrrolizidine alkaloids

A counterintuitive sight: a monarch butterfly (*Danaus p. plexippus*) not gathering nectar from a flower but pyrrolizidine alkaloids (PAs) from a *withered* leaf of boneset (*Eupatorium serotinum*) in Maryland


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Monarch butterflies (*Danaus plexippus*) are unusual in having two special relationships with plants: one to milkweeds on which the caterpillars develop and from which they obtain cardiac glycosides (CGs; cardenolides), the second to various unrelated plants which can provide them with pyrrolizidine alkaloids (PAs) – another large and diverse group of 'toxic' chemicals. PAs are only gathered by the adult butterflies, mainly from *dry* plant matter and most often quite separately from feeding behavior. Adults also visit a very wide variety of flowers for nectar. Much research has focused on the relationship between monarchs and the plants they use for larval growth, adult nectar sources, and CG-derived defense. But the relationship between monarchs and PAs has been largely neglected (1).

### Pyrrolizidine alkaloids (PAs)

Pyrrolizidine alkaloids play an important role in the lives of many organisms (2). Like CGs, PAs are natural chemicals (secondary plant metabolites) that are produced by plants belonging to several unrelated families and used to deter parasites (3). For humans and livestock, PAs pose serious health risks (2). In contrast, various insects store PAs for their own defense. Many male glasswing and milkweed butterflies (Ithomiini and Danaini but not *D. plexippus*) and tiger and wasp moths (Arctiini) also use odors (pheromones) derived from PAs in their often elaborate courtship behavior.

PAs occur inside plant cells, often only in particular parts of the plant and in varying amounts, concealed within the cell walls and inaccessible to butterflies until a plant is dry or injured.

PAs are not nutritional. Butterflies do not 'feed' on PA-plants in a literal sense but instead 'take up' PAs. Loosely speaking, for adult milkweed butterflies PA-plants provide 'pharmacies' but not 'grocery shops'. This implies that gathering PAs is not a lifelong activity but a temporary one. It is costly not only because sources of PAs need to be located but also because the PAs in dry plant matter have to be dissolved – by regurgitating saliva which is then sucked up again – a time-consuming process. The amount of alkaloid gathered varies individually. A monarch can live without PAs, but its success in obtaining these chemicals might extend its life and/or increase its fertility.

### Lack of field records

In the garden of one of the authors, in Sykesville, Maryland, both male and female monarchs have been repeatedly observed during recent summers uncoiling their proboscides on dry or damaged parts of boneset (*Eupatorium serotinum*, Asteraceae; see Figure), a plant that contains PAs. Surprisingly, only a few such field records on monarchs and PA-plants are available in the literature, although as long ago as 1955 the celebrated American naturalist William Beebe found *D. plexippus* at withered *Heliotropium indicum*. PA-pharmacophagy is without doubt a basic character of monarch butterflies but it has been largely ignored. Although they might seem less eager to obtain PAs than most other milkweed butterflies, gathering PAs could nonetheless play an important role in monarch biology.

### Major goals for necessary studies

- Which plants serve as natural sources of PAs for monarchs?

Keep eyes open for monarchs with uncoiled proboscides at dry or injured plant leaves, stems or exposed roots.

- Do male and female monarchs gather PAs equally or is there a sex-bias?

Determine sex of monarchs at presumed PA-sources.

- Are certain flowers visited (almost) exclusively by monarchs?

Flowers of blue mistflower (*Conoclinium coelestinum*) and some others (including species of *Eupatorium*) are considered 'monarch magnets'—monarchs might be particularly attracted to them not because of their nectar but because of PAs they contain; PAs probably deter other insects. Which flowers are mainly visited by monarchs? Which other insects visit them? What is the sex-ratio of monarchs at preferred flowers?

- Do monarchs engage in PA-pharmacophagy only occasionally?

If in monarchs PA-gathering is a plastic behavior, in which circumstances does it occur? Numerous independent scientific natural history observations might help put the puzzle pieces in place.

- Are monarchs visiting PA-sources infected by the protozoan parasite *Ophryocystis elektroscirrha* (Oe)?

Perhaps monarchs carrying Oe perform 'self-medication'? (PAs might harm Oe.) Check monarchs found at PA-sources for spores of Oe (see 4).

### What should be done?

Answers to the questions raised above could be obtained by field observations. An additional approach is to conduct monitoring with PA-baiting: take a home-made or commercial butterfly trap (e.g., 5) and use dry PA-plants as bait whenever monarchs are around. Baiting with PA-plants is useful for checking if butterflies are looking for PAs, particularly in areas or at times when natural PA-sources are unavailable. Recorded specimens can be marked and continue to be observed.

Note that PA-baits become weaker over time, that PA-content within a given plant may vary and in some cases is highest in roots, and that release of attracting 'PA-odor' requires humidity (for practical tips see 3).

### Potential sources of PAs for monarchs

The lack of sufficient field observations means that we currently do not know the range of plants from which monarchs gather PAs; unfortunately chemical knowledge is limited (see 3). Studies of other insects (including other species of milkweed butterflies) have revealed that they do not have relationships with particular plants but with the alkaloids as such. Thus, we can plausibly assume that many Echiteae (Apocynaceae), Senecioneae, Eupatorieae (Asteraceae, "Compositae"), Heliotropiaceae, Boraginaceae (Boraginales) and Crotalarieae (Fabaceae) including species of *Artemisia, Amsinckia, Crotalaria, Eupatorium, Hackelia, Heliotropium*, and *Senecio*, are potential sources of PAs.

A peculiar PA-containing plant is Senegal tea plant (*Gymnocoronis spilanthoides*), an invasive introduction to the U.S. (6). Not only its flowers but also uprooted dry plants are very attractive to monarchs (7). This plant is commercially available for use in aquaria, it can be cultivated and propagated easily, and can be used as bait for monitoring monarchs and PAs. This plant should however be handled with great care to avoid release into the natural environment.

### What needs to be recorded?

To reach a more complete understanding of monarchs and PAs, we request that observers put as much information as possible on record, including place, date, and time of day; general environmental conditions; estimated abundance of monarchs; which plant species and which parts of the plant were visited; condition of the plants (dry/wounded); numbers and sex of butterflies at PA-source; and whether or not the monarchs were infected with Oe.

### Reporting

Please report your observations and findings our citizen science project "**Monarch Rx**" (citsci.org/projects/monarch-rx), ideally with photographs, or contact nancy@humanegardener.com. Comments and questions are welcome. We will compile and analyze the data from citizen scientists for a future report that will acknowledge all contributors.

### References


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