The Southwestern Pipevine (Aristolochia watsonii) in Relation to Snakeroot Oil, Swallowtail Butterflies, and Ceratopogonid Flies

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At first glance there is little to differentiate our native Southwestern Pipevine *(Aristolochia watsonii)* from common weeds of the desert. Being a dull-colored plant which grows close to the ground, it is difficult to notice even when growing at a person's feet. In reality this obscure plant is a maverick with an unusual chemistry, the producer of a once famous but now maligned drug, the obligate food plant of a beautiful and well-known butterfly, and the possessor of a fantasy-like pollination mechanism involving a treacherous group of insects with tendencies variously described as "vampire-like" or even "ghoul-like" in the literature. The intention of this article is to demonstrate a few very specific relationships involving this lowly plant. Other such "nondescript" plants have interesting things to teach us as well. By studying the life cycle of *Aristolochia* and insects with which it is associated, we become impressed that nature is much less haphazard than at first glance might appear.

In much of North America *Papilio philenor*, a species of Swallowtail Butterfly, is rare or entirely absent. It represents the tropical subgenus *Battus* of *Papilio* which feeds primarily on the tropical-subtropical genus *Aristolochia*. This plant genus is the namesake for the entire Birthwort Family, the Aristolochiaceae. The name *Aristolochia* derives from the Greek *aristos* = best and *locheia* = parturition (childbirth). Thus did the ancients see the plant as the aristocrat of medicines given at childbirth.

Aristolochia was the source of the active ingredient in "snakeroot oil" sold by itinerant snakeroot doctors who staged medicine shows in the western United States in the Nineteenth Century. They claimed that their medicine would cure anything from feminine complaints to snakebite if the proper dosage were taken, and when applied externally would kill lice and cure scabies as well as healing wounds! More on this will be presented below.

Aside from being called Snakeroot, *Aristolochia* is also commonly known as Pipevine or Dutchman's Pipe, names inspired by the peculiarly twisted brown flowers shaped like curved smoking pipes. Although *Aristolochia* is basically a tropical and subtropical genus, it does extend somewhat into Europe and the eastern United States. The Southwestern Pipevine *(Aristolochia watsonii)* grows in scattered locations from western Texas to southern Arizona in the Upper Sonoran Life Zone and in the upper reaches of the Lower Sonoran Life Zone. Rarely at a given location is *Aristolochia watsonii* a common plant. An exception is found at the Boyce Thompson Southwestern Arboretum where the vine grows wild in the Cactus Garden and in some adjacent areas having soil derived from rhyolite.

Perhaps the most common name for *Aristolochia* in English is "Birthwort" and in Spanish "Guaco." In Arizona, New Mexico and Texas the names "Indian Root" and the Spanish equivalent "Raiz del Indio" are commonly applied to *Aristolochia watsonii* as well as to the medicine derived from it. The "*watsonii*" in the scientific designation of the Southwestern Pipevine is for Sereno Watson, the plant scientist who succeeded the famed Asa Gray at Harvard University. It seems singularly appropriate that Watson be remembered in the name of this fascinating plant of humble appearance. Watson began his plant science career barefoot and in the fifth decade of his life when he quite unexpectedly wandered into the camp of a government exploring expedition and asked for a job. Little did the leader of the expedition know that by hiring this eccentric, gangling, barefoot and middle-aged fellow to make herbarium specimens, he was starting him on a career which would lead to one of the most distinguished curatorships in the nation, the Asa Gray chair at Harvard!

Although famous as an aid in childbirth for centuries, *Aristolochia* contains some very powerful chemicals including the bitter poisonous *aristolochin* as well as a strong volatile oil and an alkaloid. The *Materia Medica* of Pedianos Dioscorides, written in the First Century A.D., stated that the powdered root of *Aristolochia* mixed with wine "brings away both birth and afterbirth and whatsoever a careless midwife hath left behind."

Use of medicine from Snakeroot was not at all limited to childbirth. Millspaugh (1892) recorded claims for use of *Aristolochia* as an alexeteric (snakebite cure), alexipharmic (countering bacterial toxins), antiparalytic, antiperiodic (countering malaria or recurrent fevers), antiarthritic, aphrodisiac (increasing sexual desire), antihelmintic (killing internal parasites), antipsoric (curing scabies or relieving itch), emmenagogue (correcting menstruation), but first and foremost as an "energetic sudorific" = diaphoretic (promoting copious perspiration). He noted use of it "in bilious, typhoid, and typhus fevers, small-pox, erysipelas, pneumonia and amenorrhoea," and as an antiseptic poultice "for open, indolent wounds, ulcers, etc."

The potency of Snakeroot medicine and the violence with which it can act is shown by a quotation from the experiments of Jorg published in 1825 in his *Materialien zu einer Kunftigen Heilmittellehre:* administration of *Aristolochia* to a patient was documented as causing " . . . copious salivation; eructations; great nausea, and vomiting; a sense of weight in the stomach; distention of the abdomen, with colic and borborygm, frequent expulsion of flatulence, tenesmus and solid stools, with itching . . . , a sensation of heat, and weight in the head followed by cephalagia . . . " The eructations referred to would involve the belching of gas and/or the bringing up of acid fluids from the stomach. Borborygm would involve rumblings and gurglings in the lower alimentary tract audible at a distance. Tenesmus can best be described as a painful spasm with an urgent and involuntary (but ineffective) straining to evacuate the bowel. Cephalagia is headache.

Fancy names for Snakeroot potions generally made use of the Latin word *serpentaria* for snake, as did the name for the species growing in the eastern United States, *Aristolochia serpentaria* L. Some Snakeroot preparations actually found their way into official listings in the U.S. Pharmacopaea as *"Extractum Serpentariae Fluidum"* and *"Tinctura Serpentariae."* Pammell (1911) considered *Aristolochia* poisonous and treated it in his *Manual of Poisonous Plants.*

It is intriguing indeed that a plant with such potent chemistry could serve as the food plant for the delicate caterpillar of a butterfly. Nevertheless there is such a strong relationship between *Aristolochia* and *Papilio philenor* that we may refer to the butterfly as the "Pipevine Swallowtail." The dependence of *Papilio philenor* on *Aristolochia* is perhaps best demonstrated by the fact that where the *Aristolochia* is absent, the butterfly is unknown or known only as a casual immigrant. An example of this phenomenon is shown by a short quotation from Fisher (1981) in *Butterflies of the Rocky Mountain States:* " . . . *[Papilio philenor]* enters our area as a rare stray. Temporary breeding colonies occur periodically; one of the best known existed at Fountain Valley School near Colorado Springs, Colorado, during the 1930s. It survived for several years until a very cold winter killed the food plant that supported the colony."

The butterfly species is a rather common sight at the Arboretum. Female butterflies lay eggs directly on the food plant, *Aristolochia watsonii.* Caterpillars feed on leaves, flowers and fruits, shedding their outer skin several times as they grow. The caterpillars present an arresting appearance. The reddish-purple body color is strikingly set off by dorsal pairs of reddish-orange tentacle-like tubercles, set on each body segment. The pair nearest the head point forward, giving the impression of antennae. When disturbed, a bright yellow, y-shaped scent gland or osmaterium is everted from a pouch just behind the head capsule. It glistens as the bitter smell it contains is released into the air.

When on the food plant, the caterpillar's purplish body color blends in somewhat with the purplish-colored heart-shaped leaves. As they become larger and defoliate the vines or as the mature caterpillars leave the plant to search for a pupation site, they are more likely to be noticed and to resort to defensive use of the osmaterium. The caterpillar usually climbs vertically—onto a branch, tree, wall, stem, pipe or the like—to shed its skin for the last time and become a chrysalis instead of a caterpillar. Before molting, it slings a silken belt about its body to support the quiescent pupal stage. When pupation is complete, the chrysalis splits dorsally, the adult butterfly emerges, expands and hardens its wings, and flies in search of nectar. There are several generations a year during long desert spring and summer. Adult butterflies overwinter in protected areas.

Adults of the Pipevine Swallowtail are conspicuous for their large size and elegant coloration. Wings open, they display velvety black forewings and flashing metallic blue hindwings. Viewed from the side when the wings are closed, hindwings have an even deeper blue irridescence, and are splotched with red and yellow dots. The blue color is due to refracted rather than reflected light, and the color changes according to the angle of refraction. This gives a peculiarly rich and fascinating play of blues and blue-silver. Pipevine Swallowtails frequent flowers with abundant nectar supplies. At the Arboretum they can be seen on the clustered flowers of *Verbena, Lantana, Buddleia, Perezia, Callistemon* and *Melaleuca.* Singly borne flowers of *Anisacanthus thurberi, Salvia greggii* and *Cordia boissieri* also attract them.

Clark (1927) has noted that males of *Papilio philenor* have a "sweet flowery odor" but that the females have a "strong and disagreeable scent, pungent and penetrating, with a suggestion of acetic acid." Although scientists studying butterflies have recorded a considerable amount of variation in fragrance from one species to another, the odor dimorphism between the sexes of *Papilio philenor* seems to fit a model which is not at all uncommon in the Lepidoptera. It has been suggested that when male butterflies have a flower-like odor, it is almost universally to attract females. Clark (1927) has gone so far as to suggest that the male odor is more than a mere attractant, being in reality a stimulant to actually cause females to mate.

Female butterflies generally live longer than males so that a degree of flexibility is achieved in the time span and climatic conditions under which the fertile eggs are deposited. The disagreeable odor of the female is thought to be a protective adaptation to decrease predation, thereby extending female life-span. Without the disagreeable odor, the female Pipevine Swallowtail would be particularly susceptible to predation because she spends considerable time near the ground searching for plants of *Aristolochia* and laying eggs on them. The extent to which compounds from *Aristolochia* might be used by the insect in creating offensive odors and tastes needs further research.

As adults, butterflies live on nectar from flowers of a wide variety of plants, as has been shown. It is not at this stage that *Papilio philenor* is restricted to *Aristolochia.* Indeed, the unusual curved brownish flowers of *Aristolochia* have a musty odor which attracts small flies for pollination rather than butterflies. Rather, it is in the larval (caterpillar) stage that the Pipevine Swallowtail depends on *Aristolochia* for

The brown coloration of Southwestrn Pipevine (Aristolochia watsonii) *makes the plant blend unobtrusively with the ground in front of the green blades of a grass in the cactus garden of the Boyce Thompson Southwestern Arboretum. Note that the pipe-like flower in the center of the photograph has rich reddish-brown veins which resemble somewhat the blood veins in the ears of rodents or lagomorphs. See text for explanation.*

Photographs by Carol D. Crosswhite

A Pipevine Swallowtail (Papilio philenor) *visiting flowers of* Leucophyllum *in the Arboretum.*

Red markings on the larva of the Pipevine Swallowtail contrast markedly with the dark body.

food. Although the range of *Papilio philenor* is clearly governed by the distribution of *Aristolochia* as the larval food plant, occasional perplexing records are found in the literature of this *Papilio* feeding on other kinds of plants. Occasionally such records are used to discredit the concept of a strong relationship between the butterfly and *Aristolochia.* Such records probably can be accounted for in two ways: 1) An observer witnesses an adult Pipevine Swallowtail feeding from a plant other than *Aristolochia* and routinely records the fact on a specimen label or in a list of insects visiting specific plants or flowers. The record of itself may not specifically state whether the *Papilio philenor* was a caterpillar or adult. When compiling records from specimen labels and/or the literature, an author making up a list of food plants for publication may assume that a given record refers to the larval stage merely because most other records being summarized do. 2) Although there is an exceedingly strong likelihood that *Aristolochia* is necessary for completion of the life cycle of *Papilio philenor,* there is no need to assume that 100% of the diet must be of *Aristolochia* for the larvae to thrive. Research needs to be conducted to determine the degree to which the larvae thrive on diets of varying percentages of *Aristolochia.* The occasional finding of larvae on leaves of other plants does not disprove an obligate relationship between the insect and *Aristolochia* as a larval food plant.

Although *Aristolochia* controls the distribution of *Papilio philenor,* the butterfly does not seem in any way to control the distribution of the plant. There is good evidence, however, that the plant is limited in distribution to sites having an abundance of small flies of the family Ceratopogonidae. These specific flies function in the life cycle of *Aristolochia* in an unusual syndrome of pollination which can be called sapromyophily.

Plants having sapromyophily are somewhat deceitful. In normal plants, flowers openly reward pollinators with pollen and nectar as food. Presumably the pollinators know that they are visiting flowers. *Aristolochia,* however, has flowers which are specialized to trap Ceratopogonid flies and hold them captive. The flies are enticed into the flower by means of deception. Ceratopogonids include the "punkies" or "no-see-ums" which have the reputation of being among the most bloodthirsty and pestiferous, to humans and animals, of all the gnats.

The larvae of Ceratopogonidae are aquatic or semi-aquatic, finding good niches in the vicinity of the Arboretum at Ayer Lake, along Queen Creek, and in Arnett Canyon. Adults of the flies make themselves known to humans through biting and bloodsucking. They may suddenly appear in an ear with a very high-pitched buzz.

An *Aristolochia* flower resembles the ear of a small mammal. The odor is somewhat musty. That Ceratopogonids are otherwise attracted to small mammal ears is shown by the observations of Cole (1969) that one species is commonly collected from the ears of Jackrabbits. Such rabbit ears are highly engorged with blood veins and capillaries as part of the thermoregulation mechanism of the animal. The flowers of *Aristolochia watsonii* are rich in pinks and browns reminiscent of haemoglobin. If they were truly mammal ears they probably couldn't appear much more engorged with blood. When a Ceratopogonid lands on the inner surface of the flower it is greatly surprised. Rather than finding an animal epidermis which can be held on to firmly, a smooth and slippery specialized surface is encountered. Landing on this surface causes the fly to slip and fall down into the "pipe" of the flower. In passing down the flower tube, the fly brushes against downwardly pointing hairs which are no impediment to reaching the chamber at the base of the flower but which do prevent the insect from escaping until it is in the plant's advantage for it to do so. The genus *Aristolochia* exhibits protogyny—the stigmas mature two or three days before the anthers, making the flower first functionally female and then functionally male. It is during the female stage that the flower acts as a trap. Small flies falling into the basal chamber at this stage attempt to suck nutrients by using their sharp piercing mouthparts. They probably still think that the flower is an ear or other choice part of a warm-blooded animal. Tissues of the basal chamber are rather well engorged with fluid of a nectar-like nature which the captive flies feed on.

A question yet to be researched is whether a fly which has fed on this secretion must also obtain a blood meal from a human or animal to be able to lay viable eggs. Can males survive on the flower secretions alone? Feeding habits within the Ceratopogonidae are variable and quite fascinating although often somewhat ghoul-like in the terminology of some authors. Cole (1969) deplored the bloodsucking activity of Ceratopogonids, characterizing them not only as pests of man because of their savage bites, but noting that they also " . . . attach themselves to big insects, such as mantids, or descend in a diabolic manner upon small and weak forms, such as other midges, and like miniature vampires proceed to drain them."

Edwards (1920) documented several observations of female Ceratopogonids playing the role of vampire with regard to males. McCafferty (1981) described Ceratopogonids which fly into a swarm of midges, mosquitoes, mayflies, or even their own species, " . . . hovering or hunting within the swarm, capturing an individual (usually a male), and devouring its bodily fluids." Further, according to McCafferty, females of some Ceratopogonids " . . . normally feed on the male of their own species while mating." Cole (1969) describes how a female Ceratopogonid when alighting on the back of a mayfly, " . . . jabs its beak in the victim's eye and settles down to absorb nourishment." Thus we see that Ceratopogonid adults suck a variety of nutritious fluids other than those of *Aristolochia.* Our research has not yet revealed the extent to which specific species of Ceratopogonids may depend on *Aristolochia* and conversely what effect *Aristolochia* may have on the life cycles of specific Ceratopogonids.

Relationships between *Aristolochia* and Ceratopogonids are complex. Meeuse and Morris (1984), in describing pollination of *Aristolochia clematitis,* describe pinpoint-size pores in the basal chamber of the flower which " . . . allow water vapour to diffuse into the chamber from the turgid cell walls of the chamber, keeping the gnats at the correct humidity." We have yet to determine whether such pores are merely stomata-like or are created or enlarged by the piercing mouthparts of the Ceratopogonids. Detailed study shows that many species of *Aristolochia* have "window-like" structures which let light into the basal chamber or "dungeon" to attract the flies to the stigmas and stamens. Such "windows" are patches of tissue deficient in the reddish-brown or other dark pigments and therefore more translucent. In a flower's female stage the Ceratopogonids repeatedly crawl over the stigmas during their captivity. After two or three days the anthers dehisce and the flower becomes functionally male. After the gnats are covered with fine-grained pollen, the downwardly pointing hairs on the inner surface of the flower tube wilt with a dramatic change in the water potential of the tissue, allowing the flies to escape.

The Ceratopogonids seem not to learn how to avoid being trapped in other *Aristolochia* pipes. Indeed, for pollination to occur, the same gnat must fall into two different flowers! The protogynous mechanism is an adaptation to avoid self-pollination and to promote out-crossing. The stamens of a particular flower do not become functional until after the stigmas have been fully receptive for some time and the pollen tubes normally would have already grown toward the ovules.

Concluding Remarks. The absence of the Southwestern Pipevine *(Aristolochia watsonii)* in the driest parts of the Sonoran Desert can probably be attributed to a corresponding absence of Ceratopogonid flies whose larvae need aquatic or semi-aquatic conditions. Ceratopogonids are part of a fantasy-like pollination mechanism in *Aristolochia*. Ceratopogonids find suitable habitats at Ayer Lake, along Queen Creek, and in Arnett Canyon at the Boyce Thompson Southwestern Arboretum. *Aristolochia* is native to the Arboretum and not uncommon, probably because of the abundance of the Ceratopogonids. Due to the presence of *Aristolochia* as a larval food plant, the beautiful Pipevine Swallowtail *(Papilio philenor)* is seen throughout the Arboretum sucking nectar from flowers of various herbs, shrubs and trees.

Aristolochia, under such names as Indian Root, Raíz del Indio, Snakeroot, Guaco, and Birthwort, has been considered a powerful medicine by numerous quite unrelated ethnic groups. The violence of its action in certain dosages is underscored by the awfulness of terms such as "eructation, borborygm and tenesmus" which have been used to describe the medicated condition. Authors have commented on the fact that quite unrelated ethnic groups in far-flung parts of the world have seemingly independently come to use the plant as a cure for snakebite. Two explanations seem logical: 1) If the plant was indeed effective among primitive ethnic groups in curing snakebite, for example, then it is perhaps the most misunderstood and wrongly maligned of all plants today in the civilized world. If so, its alexeteric properties may relate to an ability to cleanse tissues of toxins, incidentally producing the horrible side-effects of "eructation, borborygm and tenesmus." 2) If the plant is indeed worthless medicinally, as implied by the current acceptance of "snakeroot oil" as a symbol of quackery in the Nineteenth and early Twentieth Centuries, then perhaps the violent effects of "eructation, borborygm and tenesmus" merely inspired awe in ignorant patients! During the awful effects of the *Aristolochia*, the patient's mind was taken from his original affliction. As effects of the *Aristolochia* would have dissipated, the patient probably gained a positive attitude and knew that he had survived the affliction and would become well.

Although it is easy to assume that the second explanation is correct, we should remember that snakeroot medicine was discredited at a time when we did not have access to current biochemical techniques. Medicine became enchanted with the use of aspirin, sulfa drugs and finally antibiotics. Now we are beginning to look back at medicines used by primitive ethnic groups with a more believing eye. In discrediting snakeroot medicine, have we merely ruled out the efficacy of some of the most obvious constituents of *Aristolochia* which cause "eructation, borborygm and tenesmus" and missed some delicate and complex molecules which are indeed alexeteric or otherwise useful medicinally?

Scientists at the Arboretum are convinced that many insignificant looking plants will eventually prove to be extremely useful to man. Is *Aristolochia* one of these? In retrospect we see how *Aristolochia* has taken Ceratopogonids, universally decried as treacherous and a scourge on the earth, and used them to advantage. Likewise, a specific lineage of Swallowtail Butterflies has been able to use the "poisonous" *Aristolochia* to advantage as a larval food plant. Now *Homo sapiens*, perhaps the most opportunistic of creatures, needs to take a detailed look at *Aristolochia*, using the most modern research technology, to see if we can't turn it uniquely to our advantage.

Postscript. After the above article was written our son Marcus A. Crosswhite, while researching another topic at the UA Science Library, called our attention to the September-October (1984) issue of the *Journal of Natural Products* in which is found an article by Raul G. Enriquez, Marco A. Chavez, and William F. Reynolds, entitled "Phytochemical Investigations of Plants of the Genus *Aristolochia* 1. Isolation and NMR Spectral Characterization of Eupomatenoid Derivatives." In this article four compounds were isolated from a specimen of Guaco purchased in the Sonora Market in Mexico City, two of which seem to have pharmaceutical properties.

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