

**Annotated Bibliography – “Pharmacophagy” and Insects and Secondary Plant Metabolite Functions**

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**Biol 872 – Plant and Animal Interactions Ecology**

Boppre, Michael. **Redefining “Pharmacophagy.”** Journal of Chemical Ecology, Vol 10, No. 7, 1984.

*-Review article about the background and definition of pharmacophagy. Boppre elegantly states that insects don't just use, “plants as grocery stores, but as pharmacies as well.” The definition of pharmacophagy is when an insect searches and obtains another chemical from plants (such as pyrrolizidine alkaloids - PA) that are not its food source. They then use the chemical as a defense mechanism, sexual attractant, or precursor to pheromones; anything but an energy source.*

Boppre et al. **Pharmacophagy in grasshoppers?** Entomologia experimentalis et applicata. 35, 115-117 (1984).

*-True pharmacophagy, in the sense that grasshoppers are strongly attracted to the Z. elegans plant because of its' PA, and not for a source of food. The Z. elegans is not the preferred food of the grasshopper, but solely a source of PA. At this point, it was thought the grasshopper can use the PA as a precursor for developing its androconial organs, in addition to using it as a pheromone attractant, and defense mechanism*

Conner et al. **Chemical defense: Bestowal of a nuptial alkaloidal garment by a male moth on its mate.** PNAS. December 19, 2000. Vol. 97, no. 26. 14406-14411.

*-Note true pharmacophagy because the PA comes from the “food source” plants. Male Cosmosoma myrodora acquire PA from plants, and distribute them to females in two different ways: from their seminal fluid, and from thick cuticular filaments from their abdominal pouch. The filaments are secreted onto the female in order to protect her against spiders, where as the PA-rich seminal fluid is used to protect the eggs.*

Eisner et al. **Chemical basis of courtship in a beetle (Neopyrochroa flabellata): Cantharidin as "nuptial gift."** Proc. Natl. Acad. Sci. USA Vol. 93, pp. 6499-6503, June 1996.

*-Real Pharmacophagy. The male Neopyrochroa flabellata (beetle) uses cantharidin (Spanish fly) as an offering to his female counterpart to both attract the female, and for a defense mechanism – she coats her eggs with it to deter predacious beetles. In the study, male beetles with cantharidin were more successful at attracting mates, and the eggs were almost 100% rejected by predacious beetles. While, beetles without cantharidin were less successful at attracting mates, and all their eggs were eaten.*

Eisner et al. **The chemistry of sexual selection.** Proc. Natl. Acad. Sci. USA Vol. 92, pp. 50-55, January 1995.

*- Not true pharmacophagy, because the source of the P.A. is the “food plant” of*

*the larva. Similar to the Iyengar et al. paper, in the sense that the male contributes to the protection of the females eggs, through PAs passed on with his spermatophore. The one difference in this paper is that the researchers also investigated how the male uses the PAs as precursors to their pheromone, in order to attract the female. Males without PA weren't as successful at attracting females, as the males that did have PAs.*

Gonza'lez et al. **Sexually transmitted chemical defense in a moth (*Utetheisa ornatrix*)**. *Proc. Natl. Acad. Sci. USA* Vol. 96, pp. 5570–5574, May 1999.

*-Not true pharmacophagy, because the moth derives the PA from its "food plant" as larva. Previous work had shown the male uses PA as both a female attractant, and as a gift in his sperm to protect the females' eggs. This paper investigated if the female herself receives defensive benefits from the males PA as well. They took baseline levels of the PA content in both sexes before they mated, and found that the same level of PA the left the males' seminal fluid (minus the amount in her eggs) was found new to the females reproductive system. From these results they deduced that the female does indeed save some of the PA the male offers to the eggs, for herself, for protection too.*

Hee et al. **Transport of methyl eugenol-derived sex pheromonal components in the male fruit fly, *Bactrocera dorsalis***. *Comparative Biochemistry and Physiology, Part C* 143 (2006) 422–428.

*-Not true pharmacophagy, because the fruit fly also uses the methyl eugenol (ME) as food, not just a pheromone precursor – note: the authors define the consumption of the ME as "pharmacophagy" though. The same basic study as the Hee et al 2004 paper, just a more thorough paper (probably because it's a better journal). The authors confirmed that ME was a precursor to the pheromones 2-allyl-4,5-dimethoxyphenol and (E)-coniferyl alcohol, through the use of gas chromatography-mass spectrometry. They found that males converted the ME to their active pheromone metabolite as quick as 15 min after consumption.*

Hee et al. **Male sex pheromonal components derived from methyl eugenol in the hemolymph of the fruit.** *Journal of Chemical Ecology*, Vol. 30, No. 11, November 2004.

*-Not true pharmacophagy, because the fruit fly also uses the methyl eugenol (ME) as food, not just a pheromone precursor – note: the authors define the consumption of the ME as "pharmacophagy" though. Males that consume ME were more successful at finding a mate, due to a higher production of the pheromones 2-allyl-4,5-dimethoxyphenol and (E)-coniferyl alcohol.*

Iyengar, et al. **Female choice increases offspring fitness in an arctiid moth (*Utetheisa ornatrix*)**. *PNAS*, December 21, 1999. Vol. no. 26. 15013–15016.

*- Not true pharmacophagy, because the source of the P.A. is the "food plant" of the larva. They found that the female chooses her mate, based on his size. The larger the male, the more P.A. he carries, and in turn will give the female in his sperm-package. The more P.A. in the sperm-package, the better protected the eggs are against predators.*

Jordan et al. **If you've got it, flaunt it: Ingested alkaloids affect coremata display behavior in the salt marsh moth, *Estigmene acrea*.** Journal of Insect Science. 2005.

*-Not true pharmacophagy because the Lepidoptera (salt moth) consume the PA as larva, as their "food plant." An interesting paper, because it differs from other PA-insect side effects in the sense that PA actually influences development and behavior of the salt moth. The PA is not only a precursor to the male pheromones, but also enhances the development of the male androconial organ (the coremata). Males that consumed PA had more active coremata movement, and in return were more successful at attracting female mates. While, males without PA, had to rely on the females pheromone to find her, thereby making them less successful at finding a mate.*

Nishida, Ritsuo. **Sequestration of Defensive substances from plants by *Lepidoptera*.** Annu. Rev. Entomol. 2002. 47:57–92.

*-A comprehensive review of a variety of Lepidoptera (both moths and butterflies) and their use of plants to find secondary functions to food. Not true pharmacophagy because the examples are all with the larva sequestering the chemicals from their larval "food-plant." The overall theme was how males that consumed plants with PA were more successful and competitive at finding a mate. They could offer the PA as a nuptial gift as a defense mechanism for the female or the eggs, or they could use the PA as a pheromone precursor.*