CHEMICAL MIMICRY

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Summary

Animals, particularly insects, rely on chemical signals or cues for mating, food-seeking, alarm or defense, and social integration. This reliance makes them susceptible to exploitation by predators seeking a meal, plants recruiting pollination services, and social parasites seeking shelter and food. Chemical mimicry is more difficult to observe than visual mimicry, but is likely to be very common. The chemical mimics may produce the signals with their own biochemical machinery or they may acquire the resemblance by sequestering or adsorbing chemical compounds from their environments. The mimic's goal may be to broadcast a false signal that elicits an overt response from a duped responder (mimicry in a strict sense), or alternatively may attempt to go undetected in a background of chemical odors generated by a social host (chemical stealth). Typically the relationships between the mimic, the model, and the duped parties are extremely specialized, and thus are best illustrated by specific examples from a rapidly growing literature.

1. Introduction

Some of the most striking examples of biological adaptations are those in which unrelated organisms share physical characteristics. The only general rule for these often complex relationships is that the mimic benefits from the resemblance, and the duped party (not necessarily the model) loses. Batesian mimicry illustrates one type of relationship between model and mimic. The model could be a colorful insect that is protected by chemical defenses. The mimic is an unrelated animal that shares the coloration pattern, but lacks the toxins. In Batesian mimicry a third party, such as a predatory bird, is fooled by the resemblance. When this duped party learns to avoid feeding on the colorful but toxic prey, learning carries over and protects the edible insect (the mimic). In this case mimicry is favored, in an evolutionary sense, by natural selection imposed by the predator. Sometimes the resemblance between model and mimic is mutually beneficial, and two parties are both models and mimics, as in Mullerian mimicry.

Wolfgang Wickler, in a stunningly illustrated and now classic book on “mimicry in plants and animals,” provided an excellent summary of the subject. Of course in 1968 when this book was published the interdisciplinary field of chemical ecology was in its infancy, so most attention still focused on visual mimicry. Wickler was well aware of the potential critical role of olfactory stimuli. He emphasized that examples of olfactory-based mimicry must exist, and that mimicry could not be understood without an understanding of the impact of all of the sensory modalities. Visual mimicry is striking because we are deceived by the resemblance in the same manner as birds and other visually hunting predators. For animals, such as arthropods, which rely primarily on olfaction (smell) and gustation (taste), visual mimicry may be less important than chemical mimicry. While Wickler did discuss some apparent cases of chemical mimicry, most discoveries in this area have been facilitated by advances made with chemical analysis and bioassays in chemical ecology. Today, a keen eye for the unusual continues to be the key to new discoveries.

By definition, chemical mimicry requires a chemical resemblance between a mimic and a model; and the resemblance must have a positive effect on the fitness of the mimic because some other organism is fooled. Conceptually it can be very difficult to build a scientific case for chemical mimicry. Chemical characteristics of an organism are usually complex. However, it may be a small subset of these characteristics that have the potential to influence the duped party. This difficulty is not limited to the chemical modality. For example, two species thought to be Batesian mimics certainly can be distinguished at some level of visual examination. The issue is whether a would-be predator would or could rely on this fine visual discrimination. Thus it is apparent that the sensory capabilities of the exploited party set the baseline for detecting differences. Because our sensory capabilities will differ from those of the exploited party, we must rely on behavioral assays to gauge the effectiveness of the deception.

The best case for chemical mimicry can be built on six types of interrelated scientific information. First, and most obvious, there must be chemical similarities between the model and mimic. Second, one would expect to find species that are closely related to the mimic that do not share these similarities to the model. In other words, the chemical resemblance has evolved, and thus the mimic has chemical characteristics that distinguish it from closely related species. Third, the duped species must not distinguish model from mimic (this is where an effective bioassay is required). Fourth, the duped species should be able to discriminate between the mimic and species that are closely related to the mimic. In other words, a close phylogenetic relationship is not by itself adequate to explain the resemblance. Fifth, the duped species must not discriminate between chemical extracts that characterize the model and the mimic. Sixth, the duped species should be able to discriminate between chemical extracts of the mimic and closely related species. These last two points would provide evidence that mimicry is in the chemical modality. These criteria are almost never all met within a single scientific study, and there are undoubtedly many exceptions to any one criterion. It seems unrealistic to always expect such complete and definitive evidence. In particular cases circumstantial evidence for chemical mimicry can be quite convincing, as will be illustrated in some of the examples provided below.

2. Propaganda

Manipulation of the public via the selective use of information or disinformation (propaganda) is common throughout human history. In a broader sense, this term also applies to deception that occurs amongst species of animals, in which an illicit signaler gains some advantage over receivers by disseminating misinformation. Because the behavioral responses of some animals, particularly insects, to signals or cues are automatic rather than flexible, exploiters have evolved mimetic signals that manipulate the behaviors of their victims. Sexual and food-seeking behaviors are most susceptible to manipulation.

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Bibliography

Akino, T., Knapp, J.J., Thomas, J.A., and Elmes, G.W. (1999). Chemical mimicry and host specificity in the butterfly *Maculinea rebeli*, a social parasite of *Myrmica* ant colonies. *Proceedings of the Royal Society of London B*. 266, 1419-1426. [An interesting example of how a social parasite penetrates a colony of ants].

Bagnères, A-G., Lorenzi, M.C., Dusticier, G., Turillazzi, S, Clément, J.-L. (1996). Chemical usurpation of a nest by paper wasp parasites. Science. 272, 889-892. [A wasp that is a social parasite of another wasp must match its host chemical profile to control the nest]

Cremer, S., Sledge, M. F. and Heinze, J. (2002). Male ants disguised by the queen's bouquet. Nature. 419, 897. [This example illustrates that chemical mimicry is not only found in interactions between species. In this case docile males that mimic the queen's pheromone gain reproductive opportunities by escaping aggressive males.]

Dettner, K and Liepert, C. 1994. Chemical mimicry and camouflage. *Annual Review of Entomology*. 39,129-154. [A very useful review, with a thoughtful discussion of terminology].

Eberhard, W.G. (1980). The natural history and behavior of the bolas spider *Mastophora dizzydeani* sp. N. (Araneidae). *Psyche*. 87, 143-169. [Here Eberhard provides convincing circumstantial evidence that bolas spiders mimic sex pheromones of moths].

Eisner, T., Hicks, K, Eisner, M., and Robson, D.S. (1978). "Wolf-in-sheep's-clothing" strategy of a predaceous insect larva. Science 199, 790-794. [Illustrates one predatory advantage of resembling prey.]

Gibson, R.W. and Pickett, J. A. 1983. Wild potato repels aphids by release of aphid alarm pheromone. Nature 302, 608-609. [Presents a very unique way that a plant can defend itself against herbivores; manipulation of the aphids defensive reactions].

Haynes, K.F., Gemeno, C., Yeargan, K.V., Millar, J.G., and Johnson, K.M. (2002). Aggressive chemical mimicry of moth pheromones by a bolas spider: How does this specialist predator attract more than one species of prey? *Chemoecology*. 12, 99-105. [A bolas spider may change it's allomonal blend over the course of the night. Citations in this paper give more background on aggressive chemical mimicry in bolas spiders].

Kite, G. and Hetterschieid, W.L. 1997. Inflorescence odours of *Amorphophallus* and *Pseudodracontium* (Araceae). *Phytochemistry* 46, 71-75. [Some flowers may smell bad to attract carrion insects as pollinators].

Raguso, R. A. and Roy, B. A. (1998). 'Floral' scent production by *Puccinia* rust fungi that mimic flowers. *Molecular Ecology* 7, 1127-1136. [Insects are attracted by visual and chemical mimicry of flowers by rust fungi that leads to fungal outcrossing].

Schiestl, F. P., Ayasse, M., Paulus, H.F., Löfstedt, C., Hansson, B.S., Ibarra, F. and Francke, W. (2000). Sex pheromone mimicry in the early spider orchid (*Oprys sphegodes*): patterns of hydrocarbons as the key mechanism for pollination by sexual deception. *Journal of Comparative Physiology A*. 186, 567-574. [This paper provides direct chemical evidence of aggressive chemical mimicry].

Sledge, M. F., Dani, F. R., Cervo, R. Dapporto, L., and Turillazzi, S. (2001). Recognition of social parasites as nest-mates: adoption of colony-specific host cuticular odours by the paper wasp parasite *Polistes sulcifer*. *Proceedings of the Royal Society of London B.* 268, 2253-2260. [A social parasite adopts colony-specific odors as it takes over a host nest.]

Stowe, M. K., Tumlinson J. H., Heath R. R. (1987). Chemical mimicry: bolas spiders emit components of moth prey species' sex pheromones. *Science*. 236:964-967. [This paper established the first chemical evidence of aggressive chemical mimicry by bolas spiders].

Yeargan K.V. (1994). Biology of bolas spiders. *Annual Review of Entomology*. 39, 81-99. [An excellent review of what was known about bolas spiders, including their use of aggressive chemical mimicry].

Biographical Sketch

Professor Kenneth F. Haynes received his Ph.D. from the University of California, Davis in 1982. He joined the faculty of the University of Kentucky in 1986, after conducting postdoctoral research at the University of California, Riverside. He teaches courses dealing with insect biology and behavior. The primary focus of his research is the influence of sex pheromones and other semiochemicals on the behavior of insects, particularly moths. His interest in chemical mimicry began when he was introduced to the bolas spiders of Kentucky, USA in 1986. He has authored over 70 papers in the area of chemical ecology. In addition, he co-authored a book on "Insect Pheromones" with Dr. Martin C. Birch and he co-edited two volumes dealing with "Methods in Chemical Ecology" with Professor Jocelyn Millar. His research program has been supported by the National Science Foundation (USA) and the United States Department of Agriculture, National Research Initiative.