PRIMATES, PLANTS, AND PARASITES: THE EVOLUTION OF ANIMAL SELF-MEDICATION AND ETHNOMEDICINE

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Summary

Early in the co-evolution of plant–animal relationships, some arthropod species began to utilize the chemical defenses of plants to protect themselves from their own predators and parasites. It is likely thus that the origins of herbal medicine have their roots deep within the animal kingdom. Humans have looked to wild and domestic animals for sources of herbal remedies since prehistoric times. Both folklore and living examples provide accounts of how medicinal plants were obtained by observing the behavior of animals. Animals too learn about the details of self-medication by watching each other. To date, perhaps the most striking scientific studies of animal self-medication have been made on the African great apes. The great ape diet is often rich in plants containing secondary compounds of non-nutritional value that suggest medicinal benefit from their ingestion. Chimpanzees, bonobos and gorillas are known to swallow whole, and defecate intact, leaves. The habit has been shown to be a physical means of purging intestinal parasites. Chimpanzees and humans co-existing in sub-Saharan Africa are also known to ingest the biter pith of *Vernonia amygdalina* Delile (Compositae) for the control of intestinal nematode infections. Phytochemical studies have demonstrated a wide array of

biologically active properties in this medicinal plant species. In light of the growing resistance of parasites and pathogens to synthetic drugs, the study of animal self-medication and ethnomedicine offers a novel line of investigation to provide ecologically sound methods for the treatment of parasites using plant-based medicines in people and their livestock living in the tropics.

1. Introduction

A growing body of evidence has given momentum to the study of self-medication in animals in recent years, often referred to as 'zoopharmacognosy.' The original definition of this term given by Eloy Rodriguez and Richard Wrangham included only the use of medicinal plants and their pharmacological properties, hence the term zoopharmacognosy. Advancement of this field in recent years has shed new light on known and new behaviors incorporating non-plant materials and indeed non-pharmacological means of parasite control using plants. No doubt, future research will further deepen our understanding of these behavioral strategies. For these reasons, in this chapter the term self-medication is used and defined as those behavioral strategies by which animals avoid or suppress disease transmission, treat or control disease and/or its symptoms, thereby directly or indirectly enhancing their health and reproductive fitness. The study of self-medication is devoted to understanding how animals respond to potential threats to their health and reproductive fitness and how these behaviors are maintained within a population. It has also provided a "bio-rationale" for the exploration and exploitation of novel secondary plant compounds and new insights into how they can be used for the management of health in humans and livestock.

The amount of detailed information on self-medication in animals gathered thus far is greatest in primates, in particular the African great apes. The basic premise of animal self medication is that animals utilize plant secondary compounds or other non-nutritional substances to combat or control disease. The hypothesis being developed from investigations of this behavior in the great apes is that it aids in the control of intestinal parasites and provides relief from related gastrointestinal upset. However, given the obvious adaptive significance that self-medication implies, it is expected to occur in response to a variety of illnesses throughout the animal kingdom. Parasite infection and other diseases can have a strong affect on the behavior and reproductive fitness of an individual, making the need to counteract such pressure of extreme importance to survival. At our current level of understanding, health maintenance and self-medicative behaviors can be classified into five levels:

- *'sick behaviors'* (lethargy, depression, anorexia, reduction in grooming, behavioral fever, basking behavior);
- *optimal avoidance or reduction of the possibility for disease transmission* (avoidance of feces contaminated food, water, substrates);
- *the dietary selection of items with a preventative or health maintenance affect* (items eaten routinely in small amounts or on a limited basis),

- *ingestion of a substance for the curative treatment of a disease or the symptoms thereof* (use of toxic or biologically active items at low frequency or in small amounts, having little or no nutritional value), and
- *application of a substance to the body or a living area for the treatment or control of a disease or condition* (fur rubbing, anting, nest lining).

Antiparasitic behavior occurs in animals ranging from arthropods to primates, and is undoubtedly the product of a long evolutionary process. Ethnographic literature and recent ethnomedicinal research suggests that humans have long been aware of the use of medicinal plants by animals and have looked to them for clues about the medicinal properties of plants.

Antibiotic and anthelmintic resistance is an increasingly serious problem in human health care and livestock husbandry in Africa and around the world. The study of self-medication in nature and tradition based diet and herbal medicines in humans can provide alternative and important insights into dealing with these problems. Detailed behavioral, ethnomedicinal, pharmacological and parasitological investigations are currently underway to elucidate the full potential of self-medication in animals for the prevention and control of illness. Multi-disciplinary investigations of chimpanzee behavioral strategies in the wild and ethnoveterinary/ethnomedicinal surveys of traditional African medicine are being conducted by a multiregional, multidiscplinary research consortium, called The CHIMPP Group. This chapter reviews some of the literature and recent findings in animal self-medication and suggests future directions of research.

2. Animal self-medication and ethnomedicine

Throughout the history of humankind people have looked to animals for sources of herbal medicines and narcotic stimulation. Anecdotal reports of the possible use of plants as medicine by wild animals such as the elephant, civet, jackal, and rhinoceros are abundant (Table 1). The Navajo living in southwestern USA acknowledge the bear for their knowledge of the antifungal, antiviral and antibacterial properties of *Ligusticum porteri* Coult & Rose (Umbelliferae).

Tabernanthe iboga Baill. (Apocynaceae) contains several indole alkaloids, and is used as a powerful stimulant and aphrodisiac in many secret religious societies in Gabon. In 1968 Harrison speculated that because of the widespread reports from local people of gorilla, bush pig and porcupine going into wild frenzies after digging up and ingesting the roots, they probably learned about these peculiar properties of the plant from watching the animals' behavior. The most active principle, found in the root, is called ibogaine and is shown to affect the central nervous system and the cardiovascular system. Two other known similarly active compounds in the plant are tabernanthine and iboluteine. The stimulating effects are similar to caffeine. The sloth bear and local people of central India are noted to become intoxicated from eating the fermented madhuca flowers. Reindeer and the indigenous Lapps consume fly agaric mushrooms known for their intoxicating effects.

Species	Plant species (Family)	Comments
Malay elephant	*Entada schefferi* Ri (Leguminosae)	For stamina before long walk, possible pain killer?
African elephant	Boraginaceae family	Induce labor; used by Kenyan ethnic group to induce labor and abortion. Similar story related to Huffman about observations made in Tanzania
Indian buffalo	*Holarrhena antidysenteri* Wall. *ex* A.DC (Apocynaceae)	Bark regularly consumed. Species name suggests anti-dysenteric action.
Wild Indian boar	*Boerhavia diffusa* (Nyctaginaceae)	Roots are selectively eaten by boar and is a traditional Indian antihelmintic
Pigs	*Punica granatum* (Lythraceae) Pomegranate	Root sought after by pigs in Mexico. Alkaloid in roots toxic to tapeworms.
Indian tigers, wild dogs, bears, civets, jackals	*Careya arborea* Ro (Lecythidaceae), *Dalbergia lateriflora* (Fabacea)	Fruits of various species eaten by large carnivores. Possibly helps in elimination of parasites ingested along with contents of intestines of herbivore prey.
S. American wolf	*Solanum lycocarpus* A.St.I (Solanaceae)	Rotting fruit said to be eaten to cure stomach or intestinal upset.
Asiatic two-horned rhinoceros	*Ceriops candolleana* A (Rhizophoraceae)	Tannin rich bark eaten in amounts large enough to turn urine bright orange. Possible use in control of bladder and urinary tract parasites.
Black howler monkey, spider monkey	No plant name available	Indigenous peoples living in primate habitats of the Neotropics claim that some monkey species are parasite-free because of the plants they eat.

Table 1. Some anecdotal evidence for self-medication in animals.

One version of the discovery of coffee is that the chance observation by a shepherd of goats becoming stimulated after grazing on the berries of wild coffee plants in the highlands of Ethiopia provided the clue for humans to exploit the plant as a stimulant. Dr. Jaquinto, the trusted physician to Queen Ann, wife of James I in seventeenth century England, is said to have made systematic observations of domestic sheep foraging in the marshes of Essex which led to his discovery of a successful cure for consumption. In the foothills of the Himalayas near Mt. Everest the use of the roots of ‘chota-chand’ as a potent antidote for snake bite is said to have been learned by observing mongooses feeding on the plant before fighting with cobras. All of these examples suggest the occurrence of self-medication in a variety of animal species and ways that humans may have learned about the medicinal value of plants from them.

Why should any of this really surprise us? After all, from an evolutionary standpoint, preservation of health is a basic principle of survival and all species living today can be expected to have evolved a variety of ways of protecting themselves from predators and parasites, large and small, in their environment.

Where did this all begin? In the plant world, a common line of defense is to produce a variety of toxic secondary compounds such as sesquiterpenes, alkaloids, and saponins (Table 2) that prevent predation by animals. At some point in their co-evolutionary history, probably starting with the arthropods, animals began to take advantage of the plant kingdom's protective chemical arsenal to protect themselves from predators and parasites and to enhance their own reproductive fitness. For example, adult danaine butterflies of both sexes utilize pyrrolizidine alkaloids for defense against predators and males have also been shown to depend on it as a precursor for the biosynthesis of a pheromone component needed for courtship. The monarch butterfly is reported to feed on *Asclepias* species containing cardiac glucosides, which makes birds sick, conditioning them not to feed on the species. Such tri-trophic level interactions are likely to have provided the foundation for the evolution of a more sophisticated level of self-medication seen in the higher vertebrates.

Class of compounds	**Effects (comments)**
terpenoid alkaloids	modulation of ion channels (highly toxic)
isoquinoline alkaloids	DNA intercalation, interaction with receptors, causes spasms (toxic and bitter)
quinolizidine alkaloids	binding to ACH receptor (toxic and bitter)
tropane alkaloids	inhibition of ACH receptor (highly toxic)
pyrrolizidine alkaloids	mutagenic & carcinogenic (liver toxic)
cyanogenic glycosides	inhibition of respiration
cardiac glycosides	inhibition of Na+ /K+ -ATPase (highly toxic)
terpenes	diuretic (bitter taste)
volatile terpenes	antibiotic, irritant
volatile monoterpenes	antibiotic (aromatic smell)
saponines, amines	detergent for biomembranes (bitter)
triterpene saponines	detergent for biomembranes (toxic, emetic)
sesquiterpenes, pyrrolizidines	PA are mutagenic & carcinogenic, irritant (cytotoxic, liver tox
convallatoxin	inhibition of Na+ /K+ -ATPase (highly toxic and bitter)
anthraquinones	purgative (toxic)
phenolics	astringency, reduces digestibility
cellulose, hemicellulose, ligni silica	undigestible

Source: Wink et al., 1993; Howe & Westley, 1988

Table 2. Some common plant secondary compounds and their effects on animals

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Biographical Sketches

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Mike is currently Associate Professor in the Section of Ecology, Primate Research Institute, Kyoto University. He was born in November 1958 in Denver, Colorado, and first moved to Japan in 1978 under a study abroad program lasting three years. There he began field research on Japanese monkeys outside of Kyoto City and pursued Japanese and cultural studies at Kansai University for Foreign Studies, Osaka. He obtained a B.Sc. in Natural Sciences, with added focus on Anthropology and Archeology, from Fort Lewis College, CO in 1983. He returned to Japan the same year and resumed field studies as a graduate student in the Faculty of Science, Kyoto University. Mike obtained a M.Sc. (1985) and D.Sc. (1989) from Kyoto University in Zoology for field research on the behavior and ecology of Japanese macaques and chimpanzees. He now conducts primatological and ethnobotanical studies at field sites in Japan, Tanzania and Uganda and travels extensively in Europe, Asia and North America conducting collaborative multi-disciplinary research and lectures.

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Sylvia was born in Czechoslovakia, and raised in Zambia, Transkei (South Africa), and the USA. She earned a BA from Cornell University in 1995, and a PhD from Columbia University in 2005. She also received an Advanced Certificate in Environmental Policy from Columbia University. She currently resides in St. Thomas, USVI, with her husband and dog, where she is developing at new Master of Marine and Environmental Science program at the University of Virgin Islands.