Zoopharmacognosy

Self-Medication in Wild Animals

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The study of parasites and their likely influence on optimal foraging and mate-selection in animals has attracted much attention in recent times. The possible effects of parasites on the host include the manipulation of host behaviour by parasites and the emergence of host behavioural adaptations for protecting against parasitism. Self-medication in wild animals is believed to be the behavioural adaptation evolved primarily against parasites and associated diseases. In this article, we have briefly reviewed some types of unusual behaviour observed in mammals, birds and insects which can be considered as self-medication.


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Introduction

The concept of self-medication in non-human vertebrates was first proposed by Daniel H Janzen (1978), an ecologist at the University of Pennsylvania [1]. He is the first one to compile all the anecdotal accounts of possible self-medicating behaviour in a variety of animals. Janzen argued that energy requirement alone is not sufficient to explain these unusual feeding habits and raised the possibility that animals can use plant secondary metabolites as stimulants, laxatives, antiparasitic and antibiotics or as antidotes for previously consumed toxins. The term 'zoopharmacognosy' therefore describes the process by which wild animals select and use specific plants with medicinal properties for the treatment of diseases and protection from parasites.

Biologists the world over have now started accepting the concept of animal self-medication after observing many unusual feeding habits exhibited by the animals of their interest. Previously, it was thought that the main selective pressure which would have possibly favored the evolution of foraging behaviour is to get nutrition-

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ally adequate diet. However, it is now recognized that some features of diet selection seems to have evolved to reduce the risks of parasitism and it has been proposed that diet-selection can be shaped such a way as to reduce or control parasites.

Parasitism: A Prime Selective Pressure

In addition to competition and predation, one of the important biotic stresses in animal societies is the problems associated with parasites, either external or internal in origin. Though parasites often coexist with their hosts without causing considerable deleterious effects, they can be opportunistic also, and can quickly increase in number and overwhelm a host weakened by other forms of stress such as malnutrition or reproduction. Mammals and birds are often exposed to a diverse array of parasites and infectious diseases, many of which affect host survival and reproductive fitness (*Box* 1). In a variety of animal hosts, it has been evidently shown that the problems associated with parasites are undoubtedly costly to manage. Parasites can weaken the host's immune system by either of the two following ways: the haematophagous parasites directly reduce host fitness by continuously sucking blood and nutrients from the body, or parasites can be reservoirs for many deadly transmittable diseases and can act as disease carriers (vectors) among host

Box 1. The Importance of Being the Fittest

In biology, 'fitness' is a measure of an individual's ability to survive and reproduce. It is measured by the number of viable offspring an animal can produce compared to other individuals in the same population. A wild animal has to be healthy and fit in order to compete successfully with others to reproduce. Parasites play a crucial role in mate-selection by directly affecting host fitness. Recent studies on mate-selection in birds and mammals have evidently shown that females preferred non-parasitized male over the parasitized one. Choosy females may indirectly use secondary sexual characters as an indicator for the presence of effective genes. In mammals, many empirical studies have evidently shown that females can discriminate between healthy and diseased males on the basis of their odour and it has also been demonstrated that females prefer the odour of non-parasitized males. It has been believed that females could avoid infection and gain genetic benefits in terms of more viable offspring by mating with non-parasitized males. Therefore, being the fittest is vital in the life time of any organism that competes for mate.

populations. Thus, parasites can affect host fitness and may eventually have an influence on the evolution of overall life history strategies in animal societies. Therefore, one of the main selective pressures which would have led the animals to use medicinal plants is believed to be parasitic pressure [2].

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To overcome the fitness loss due to parasitism, animals have evolved a variety of anatomical, physiological and behavioural adaptations. In addition to the immunological defence, avoidance and removal of parasites are the two behavioural strategies animals use to reduce parasites. Other behavioural adaptations evolved against parasites may also include the avoidance of food materials which are potential sources of parasites, the use of prophylactic substances and the consumption of therapeutic substances [2]. In general, animal self-medication has been categorized into two types – preventative (prophylactic – act of using medicinal plants without any symptoms of infection or before infection) and curative (therapeutic – act of using medicinal plants only after infection or illness).

Phytochemicals as Natural Medicine

Plants produce a variety of secondary metabolites which supposedly do not have any obvious role in further metabolism [3]. Secondary metabolites are produced and stored in various parts of the plant (mainly in peripheral regions) (*Box* 2). Previously, it was thought that the secondary metabolites are the waste products

Box 2. Secondary Plant Metabolites

Secondary plant metabolites are those that occur usually only in special, differentiated cells and are not directly essential for the plant's survival but may be useful for the plant as a whole. The chemical structure of secondary metabolites is invariably more complex than that of primary metabolites. Plant cells produce a vast amount of secondary metabolites. Many of these are highly toxic and more than 30,000 different substances have been identified so far (e.g. Alkaloids, Terpenes, Polyisoprenes, Glycosides, Phenolic compounds, Plant amines, etc). In plants, they are used as defenses against predators, parasites and diseases, for interspecies competition and to facilitate the reproductive processes (coloring agents, ovipositor and pollinator attractants, etc). Secondary metabolites also help in defending plants from insect herbivory or mammalian grazing by acting as feeding deterrents.

The anubis baboons and hamadryas baboons in Ethiopia use fruits and leaves of *Balanites aegyptica* to control schistosomiasis.

of primary metabolism and are stored in cells because of the absence of an efficient excretory system. However, later it has been recognized that these secondary metabolites are part of plant's defense mechanism (chemical defense) to deter insects and herbivores from feeding on them, to protect from disease causing microorganisms and to attract the beneficiary organisms which are crucial for their propagation, namely pollinators and seed dispersers [3]. Recently, it has also been recognized that synthesizing these compounds are certainly costly for the plants. It has also been presumed that animals using plant secondary metabolites can also protect themselves from parasites and diseases [4].

Plants as Stimulants

Chacma baboons (*Papio ursinus*) in South Africa are known to consume each day a little quantity of leaves of specific plants, which are well known for their stimulant property. The plants were found available throughout the day and their availability is not limited, but baboons were found to feed on them occasionally and only in small quantities. These plants were not classified under baboon's regular diet, instead, are grouped as 'euphorics'. The consumption of such plants is not directly related to any illness or a diseased state but shows stimulant activity. These include *Croton megalobotrys* (Euphorbiaceae), *Euphorbia avasmontana* (Euphorbiaceae), *Datura innoxia* and *D. stramonium* (Solanaceae) [5]. However, there is still no empirical study reporting the plant's specific pharmacological benefits [2], [4].

Antischistosomal Drug Use by Baboons

The anubis baboons (*Papio anubis*) and hamadryas baboons (*Papio hamadryas*) in Ethiopia use fruits and leaves of *Balanites aegyptica* to control schistosomiasis[1]. The Awash River valley in Ethiopia is separated into two distinct habitats by the waterfalls, one up in the hills where the water flows rapidly and the second is located at the lower part of the hills, where the water flow is gentle. Though the baboon population and the plant *B. aegyptica*

[1] Schistosomiasis is a parasitic disease caused by trematode flatworms of the genus *Schistosoma*. Larval forms of the parasites which are released by freshwater snails penetrate the skin of people in the water. In the body, the larvae develop into adult schistosomes, which live in the blood vessels. The females release eggs, some of which are passed out of the body in the urine or faeces. Others are trapped in body tissues, causing an immune reaction.

are distributed in both habitats, the baboons only in the lower part of the valley were observed to feed on the plant and interestingly the population in the lower valley had higher infestation of the parasite. The only difference between these two distinct habitats is a species of snail (*Biomphalaria* sp.), an intermediate host for the development of *schistosoma* sp., found downstream of the river valley. *B. aegyptica* fruits contain diosgenin, a hormone precursor which presumably hinders the development of schistosomes [2], [6].

Anting is reported in more than 200 species of songbirds and it has been suggested that it is used to soothe irritated skin, help with feather maintenance and repel or reduce ectoparasites.

External Application of Substances to the Body

'Anting' is a behaviour in which birds rub crushed ants throughout their plumage and some birds let the ants to crawl over their plumage by directly lying on ant nests. Anting is reported in more than 200 species of songbirds and it has been suggested that it is used to soothe irritated skin, help with feather maintenance and repel or reduce ectoparasites. The most commonly used ants by birds for anting are those species which contain formic acid. Subsequent empirical studies with bird lice revealed that formic acid is harmful to feather lice [7]. Birds have also been observed anting with other invertebrates like millipedes, plant parts such as lime fruits and inanimate objects like mothballs (napthalene), all of which have some antiparasitic property. Though anting was primarily reported in birds, recently similar behaviour has also been observed in some mammals.

Figure 1. A white-faced capuchin monkey (Cebus capucinus).
Credit: Dave Pearce, www.primates. com

'Fur rubbing' is a typical behaviour of rubbing masticated plant materials and other objects such as insects on the external surface of the body by animals. In Costa Rica, it was observed that the Capuchin monkeys (*Cebus capucinus*) rub their fur with several species of *Citrus* fruits (Rutaceae) and leaves and stems of *Piper marginatum* and *Clematis dioica* (Ranunculaceae) [8]. Fur rubbing has been reported in a variety of primates, like *Cebus capucinus* (*Figure* 1), *C. olivaceus*, *C. paella*, *Ateles geoffroyi*, *A. belzebuth*, *Aotus boliviensis*, *A. lemurinus griseimembra*, *A. nancymaae* and *Eulemur macaco* [6]. It has been suggested that fur rubbing serves to repel or kill ectoparasites.

In Venezuela, capuchin monkeys (*Figure* 1) rub highly toxic millipede secretions into their fur during the humid wet season when insect bites are high. The millipede secretions contain benzoquinones, which are well known for their insect repellent property [9].

White-nosed coatis (*Nasus narica*) have been observed coating their body with the resin of *Trattinnickia aspera* (Burseraceae) [10]. This may also serve to control ectoparasites[2] and thus should be considered as self-medication [2].

[2] A parasite that lives on or inside the skin but not within the body, it obtains nourishment from the host without benefiting or killing the host. Fleas, lice, tick and mites are common ectoparasites of animals. Infestation with an ectoparasite is called an ectoparasitosis.

Inclusion of Antimicrobial Foliage Inside Nests

To date, at least 50 species of birds are known to include fresh plant materials inside their roosting environment that does not constitute as a part of their nest structure. So far, a number of hypotheses have been proposed for this peculiar behaviour. It was noted that the included plants are rich in volatile secondary compounds and hypothesized that birds should be using these plants to repel or kill ectoparasites [11]. Subsequent empirical tests [12] have shown that the preferred plants are effective in reducing the hatching success of bird lice (*Menacanthus* sp.) and also inhibit the bacterial growth. The leaves of wild carrot (*Daucus carota*, Umbelliferae), a preferred species, significantly reduces the number of fowl mites (*Ornithonysus sylviarum*) in starling nests [12].

The dusky-footed wood rats (*Neotoma fuscipes*) place bay foliage around their sleeping nests and it has been experimentally shown that the inclusion of bay foliage significantly reduces the flea larval survival [13].

The leaves of wild carrot significantly reduces the number of fowl mites in starling nests.

The wood ants, *Formica paralugubris* often incorporate large quantities of solidified conifer resin into their nests. By creating resin-free and resin-rich experimental nests, it was demonstrated that the included resin inhibits the growth of pathogenic microorganisms inside ant nests [14].

Consumption of Medicinal Plants by Animals

In 1987, in the Mahale mountains in Tanzania, self-medication by chimpanzee was observed and first documented by Michael Huffman, a primatologist from the Kyoto University, Japan. His work was the first to show that illness in an animal showed improvement after eating a known medicinal plant *Vernonia amygdalina* (Compositae) commonly known as bitter-leaf, a best known example for therapeutic self-medication [15]. The sick chimpanzees alone were found to chew the leaves of this shrub. It was later discovered that the plant is a very strong medicine for local people. African herbalists often prescribe this plant to treat malarial fever, schistosomiasis, amoebic dysentery and other intestinal parasites and stomach disorders. Further phytochemical analysis revealed that the bitter pith of *V. amygdalina* contains seven steroid glucosides, as well as four known sesquiterpene lactones, capable of killing parasites that cause schistosomiasis, malaria and leishmaniasis[3]. The sesquiterpene lactones are antihelminthic[4], antiamoebic, antitumor and antimicrobial [6].

Chimpanzees at the Gombe National Park and Mahale mountains, Tanzania were observed to swallow the whole leaf of *Aspilia pluriseta*, *A. rudis* and *A. mossambicencis* (Compositae). So far, many hypotheses have been proposed for *Aspilia sp*. consumption. Phytochemical analysis of the leaves has not shown any convincing evidence for pharmacological benefits. However, recent studies suggest that *Aspilia sp*. may not be consumed because of its phytochemical properties but because of their rough surfaces, which may aid in the mechanical removal of intestinal parasites [6].

Consumption of Soil and Rock by Animals (Geophagy)

'Geophagy' is an act of deliberately consuming soil, stones and rock by herbivorous and omnivorous mammals, birds, reptiles, and insects. This behaviour is observed and studied in the context of self-medication in Japanese macaques (*Macaca fuscata*), rhesus macaques (*Macaca mulatta*), mountain gorillas (*Gorilla gorilla*),

[3] The leishmaniasis is a disease caused by 20 species of pathogenic protozoa belonging to the genus *Leishmania*. It is transmitted by the bite of certain species of tiny sandfly insect vector, including flies in the genus *Lutzomyia* in the New World and *Phlebotomus* in the Old World. Only the female sandfly transmits the protozoa, infecting itself with the *Leishmania* parasites contained in the blood it sucks from its human or mammalian host.

[4] Antihelminthic is any drug or medicine that destroys or causes the expulsion of parasitic intestinal worms, which also called *helminthagogue*, *helminthic*, *vermifuge*. They are classified as antinematicidal, antitrematicidal, anticesticidal.

Geophagy is suggested as a means to maintain gut pH, to meet nutritional requirement for trace minerals, to satisfy specific hunger for sodium, to detoxify previously consumed plant secondary metabolites and to combat intestinal problems like diarrhea.

chimpanzees (*Pan troglodytes*) and African elephants. Geophagy is suggested as a means to maintain gut pH, to meet nutritional requirement for trace minerals, to satisfy specific hunger for sodium, to detoxify previously consumed plant secondary metabolites and to combat intestinal problems like diarrhea. Soil analyses indicated the presence of three mineralogically similar clays: halloysite, metahalloysite and kaolinite. Interestingly kaolinite is the principal ingredient in the commercially available antidiarrheal formulate Kaopectate™ [2], [4].

Conclusion

In general, the mechanism underlying the selection by animals of specific plants during illness is still unclear. However, it seems that the selection of medicinal plants by an animal involves a fairly complex mechanism of individual and social learning. While taking into account that the costs associated with parasites and diseases, it is likely that almost every organism should have developed many forms of behavioural adaptations against parasites, including self-medication with plant secondary metabolites. Because of the adaptive significance of self-medication, its existence is probably widespread. To recognize this, constant field monitoring and subsequent empirical studies into the self-medicative behavior of wild animals are certainly essential.

Though, it remains difficult to demarcate self-medicating behaviour and many unusual feeding habits of wild animals from the usual foraging activity, the complexity of animals, parasites, plants and their interactions cannot be denied. Studying these interactions in the framework of self-medication may provide an entirely new and novel level to our understanding of animal behavioural ecology.

The mechanism underlying the selection of specific plants during illness is still unclear.

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