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Popular Article

Self- Medication in Insects

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Introduction

We often suffer from different kinds of diseases and these are the main cause of human suffering and death around the world. According to the centers for disease control and prevention, 94% of the total deaths recorded in the year 2020 are due to diseases like heart disease, cancer, covid 19, stroke, respiratory diseases, etc.

If we see the global life expectancy over the years it shows that in the beginning of 19th century no country had a life expectancy longer than 40 years. Almost everyone in the world livedin extreme poverty and we had little medical knowledge. Over the next 150 years, some parts of the world achieved substantial health improvements. Such improvement in life expectancy was a landmark sign of progress. According to UN estimates global average life expectancy in the year 2019 was 72.6 years which is higher than any country back in 1950. The main reason behind this advanced life expectancy is better medical care and sufficient food along with other reasons like hygiene, sanitation, etc. In the last 3 years as well, we have seen and many of us have experienced the ill effects of covid 19 and the struggles of patients to hold their last breath. Thanks to thedoctors and other health care workers and most importantly it was the medicines and vaccines that could help us from the pandemic.

We are not the only medical doctors who heal our wounds. a lot of animals out there in the world like elephants, chimpanzees, porcupines, sheep, goats, dogs, birds, etc. take medicines themselves. Chimpanzee drinks Juice of the plant -*Vernonia amygdalina* to get rid of intestinal parasites, baboons Eat bark of the albizzia tree to overcome gastrointestinal disorders, Dogs consume grass to overcome upset stomachs and parasites in the gut. Birds like Red and green

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macaws eat clay rich in sodium which can help in digestion and can kill bacteria. Sparrows and finches collect used cigarette butts left by humans and keep them inside their nests to protect themselves and their offspring from ticks and mites. Like vertebrates, Insects are also found to medicate themselves to get rid of ailments

Insect`s first line of defense

Insects face threat from other organisms that prey on them and other microbes that infect and cause diseases. In order to deal with this, insects have evolved a wide range of defense mechanisms. An insect's first lines of defense against infection are structural for example cuticle and peritrophic matrix and midgut membrane that act as barriers to the pathogen entry. Once the pathogen has penetrated the cuticle the innate immune system, which includes melanization, encapsulation and the production of antimicrobial peptides acts on the pathogen to protect it from getting diseased. If these two defenses fail medication will only be the alternative

Medication

Medication in insects is broadly divided into two types- Kin medication and self-medication (Abbots *et al*., 2014). Kin medication is medicating their genetic kin including offspringand other genetic relatives rather than themselves. Whereas self-medication is medicating themselves with the use of organic compounds specifically for the purpose of helping to clear a (parasitic) infection or reduce its symptoms. Kin medication can be transgenerational medication or medication of genetic relatives. Examples for transgenerational medication includes medication in monarch butterfly where the infected monarch females lay eggs on the milkweed plants which are rich in cardenolides to protect their offspring from infection. And drosophila melanogaster selectively lays eggs in food rich in ethanol if the fly notices an activity of parasitic wasp which canattack fly larva. And the parasitic wasps are not observed to lay eggs on fly feeding on ethanol-rich food. Medication of genetic relatives is largely seen in eusocial Hymenoptera. ants and bees collect resin from the plants and store them in their nests which helps to prevent the attack of parasites.

Self-medication

Self-medication is not necessarily the consumption of medicinally active compounds; it can be achieved by contact with biologically active natural compounds as well. these biologically active compounds can be plant derivatives, sources of fungi, microbes and minerals (Abbots *et al*., 2014). Self-medication helps insects to clear the parasitic infection, reduce symptoms of infection

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and to increase resistance or tolerance to infection. Self-medication is of two types one is prophylactic self-medication; another one is therapeutic self-medication. Prophylactic self-medication is the consumption of biologically active substances before the infection. It occurs when the infection risk is more. It is often exhibited by insects when the risks and costs of infection are high relative to the costs of the medication behavior. Examples for prophylactic self-medication is medication in honey bee and fruit fly. Therapeutic medication is the consumption of biologically active substances after the infection. therapeutic medication is triggered by an actual parasite infection. Examples for therapeutic self-medication is medication in wooly bear caterpillar and Spodoptera.

How does insect`s medicate?

Insects that are infected by the parasitoid actively change their diet composition or ingest antiparasitic toxins or alter their nutritional uptake. The infected female or the female when they find the chances of parasitoid attack, they change their ovipositional sites to prevent the attack of parasitoids or to escape from the parasitization, insects are also observed to collect and store antimicrobial compounds.

One cannot simply assume that an insect is self-medicating if it is found feeding on some plant where it is usually not found. So, there is a list of 4 criteria given by different scientists to establish that the insect is self-medicating.

Criteria for self- medication

1.The substance must be deliberately contacted

2.The substance must be detrimental to parasites

3.Detrimental effect on parasites must lead to increased host fitness

4.The substance must have a detrimental effect on the host in absence ofparasites

The first criterion to be met is that the substance must be deliberately contacted. This criterion clearly separates self-medication from other phenomena such as the role of enemy-free spacein determining niche. The second criterion says that the substance must be detrimental to one or more parasites and the third criterion is that the detrimental effect of the substance on parasites must lead to increased host fitness. from the second and third criteria, it is clear that; a substance that doesnot reduce parasite fitness and increase host fitness can hardly be considered medicinal... These threecriteria were given by Clayton and Wolfe (1993). The problem with these 3 criteria is that they donot include any information about the effect of the medicinal substance on the uninfected individual. And also, it does not differentiate between diet choice and medicine. Because of this, Singer *et al.* (2009) added a fourth criterion to those suggested by Clayton and Wolfe (1993) that is the substance must have a detrimental effect on the host in the absence of parasites.

Table 1. Classification of self-medication

	Before infection for prevention	After infection for treatment
Self	Prophylatic self medication	Therapeutic self medication
Offspring	Prophylatic transgenerational medication	Therapeutic transgenerational medication
Other member of the species	Prophylatic social medication	Therapeutic social medication`

Medication given to itself before infection is prophylactic self medication and after the infection is therapeautic medication. Medication given to offsprings before infection is prophylactic transgenerational medication and after the infection is therapeutic transgenerational medication and given to other members before infection is prophylatic social medication and after the infection is therapeutic social medication (Table 1).

Table 2. Recent evidence of Self-medication in insects

Insect	Agent	Substance used	Prophylactic or therapeutic	Life stage	Self or kin
Woolly bear caterpillar	Parasitoid flies	Pyrrolizidine alkaloids	Therapeutic	Larva	Self
Bumble bees	Gut parasite	Toxic nectar	Therapeutic	Larva	Self
Army worm	Virus, bacteria	Protein	Therapeutic	Larva	Self
Ants	Fungus	Reactive oxygen species	Therapeutic	Adult	Both
Fruit fly	Parasitoid wasp	Ethanol	Both	Larva	Both
Monarch butterfly	protozoans	Cardenolides	Prophylactic	Larva	Kin

Self-medication in woolly bear caterpillar

Wooly bear caterpillar *Grammia incorrupta* Edwards are broad generalist grazers. In nature *G. incorrupta* caterpillars are attacked by three parasitoids like *Carcelia reclinate* and *Exorista mella* both belonging to the tachinidae family and braconid parasitoid *Cotesia phobetri*. These parasitoids lay eggs in caterpillar hosts, feed and develop as larvae inside their hosts, then emerge to pupate, leaving the hosts dead. This wooly bear caterpillar is found to ingest pyrrolizidine alkaloids from certain host plant species. Once these compounds are ingested, they aresequestered in the blood and integument of the caterpillar so Singer and coworkers conducted a fewexperiments to study self-medication in wooly bear caterpillars.Two experiments were conducted inthis study (Singer *et al*., 2009).

Self-medication in fruit flies

Fruit fly *Drosophila melanogaster* are mainly attacked by larval endo parasitoids like *Leptopilina boulardi* and *Leptopilina heterotoma*. In the fruit fly, both therapeutic and prophylactic transgenerational medication are seen. In therapeutic self-medication, Infected larvae of fruit fly prefer to feed on food with more ethanol content (Milan *et al*., 2012), and in the case of prophylactic transgenerational medication the female lay eggs in the food containing a higher amount of alcohol when they notice the activity of female wasps (Kascoh *et al*., 2012) .

Self-medication in monarch butterflies

Ophryocystis elektroscirrha is a protozoan parasite occurs throughout the distribution of monarch butterflies and has strong detrimental effects on monarch fitness byreducing adult life span, mating ability, fecundity and flight ability. Parasite infection occurs when larvae ingest infective spores deposited on the egg shells and milkweed foliage by infected femalesduring oviposition. Upon ingestion, spores lyse in the larval gut to release sporozoites that traverse the midgut wall and invade the host's hypoderm. Here, the parasite undergoes vegetative asexual replication before completing sexual reproduction during monarch pupation. Upon eclosion, adult butterflies emerge from the chrysalis covered with infective parasite spores on the outside of their bodies. These spores undergo no further replication and must be ingested by larvae to cause new infections. Several scientists have attempted to study the behavioral mechanisms by which monarch butterfly larvae medicate to escape from infection. And they have found that monarch butterfly larvae cannot differentiate eggs or plants with or without infectious parasite spores; infected larvae don't show any preference for therapeutic food plants. To know if infected female butterflies preferentially lay their eggs on medicinal plants that make their offspring less sick Lefevre and coworkers conducted an experiment (Lefevre *et al.,* 2011).

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Self-medication in Bumble bees

A major cost of social life is the increased exposure to pathogens. This cost of sociality is expected to be particularly high for social insects, which live in crowded, persistent, warm and resource-rich nests providing ideal conditions for the development of microorganisms. Social insects like ants and bees have evolved ways to fight against pathogens with the help of plants containing anti-microbial properties. Bumble bees are important pollinators in nature and they are frequently parasitized by a wide range of different microorganisms. *Crithidia bombi* (Trypanosomatidae) is a common gut parasite of bumblebees (Plate 8). It mainly infects adults, and after two-three days of infection, infective cells are released through the feces of bees. Queens infected by *C. bombi* have reduced success in colony founding, and produce fewer reproductive offspring, infected workers experience a higher mortality rate under stressful conditions, which impairs learning and foraging. Plant secondary metabolites are not only found in leaves but are also common in floral rewards such as pollen and nectar. floral nectar contains secondary metabolites like phenols, terpenes and alkaloids (including nicotine, anabasine and gelsemine) (Richardson *et al*., 2015). So To test whether other bumblebees are able to self-medicate using naturally occurring nectar secondary metabolites a series of experiments were conducted using a *B.terrestris* and *C. bombi* as models and nicotine as a natural nectar alkaloid. To determine whether the nectar alkaloid nicotine influences the severity of C. bombi infections in bumblebees, they designed two experiments "Continuous Exposure" test and Delayed Exposure" test. In the Continuous Exposure" test bumblebees were first inoculated with C. bombi and subsequently fed on a daily supply of nicotine solution or sucrose solution (Control). In the "Delayed Exposure" test, C. bombi cells were directly exposed to nicotine or control solutions for two hours before inoculating bees, and then they were fed on a sucrose-only solution. they subsequently compared the parasite load in inoculated bumblebees (Barrachi *et al*., 2015).

Self-medication in ants

Beauveria bassiana is a common entomopathogenic fungus that infect ant. It kills ants of diverse species after 4 days off infection, and the corpses killed by the fungus can further infect ants (Plate 11). To cope with the high pathogen pressure they face, a wide variety of both physiological and behavioral strategies have evolved in ants. One such behaviour is self-medication.

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Conclusion

Self-medication is a widespread and highly variable phenomenon. The evidence that self-medication can and does occur, at least in some insect species, is clear but there are still some unanswered questions like Is frequent contact with the medicinal substance really a prerequisite for the evolution of self-medication, or can chance and individual learning play a role? Are all types of pathogens amenable to the evolution of self-medication, or only some? are only certain types of substances suitable for use in self-medication? What are the mechanisms controlling the activation of self-medication behavior? Therefore, there is much still to be discovered within this fascinating field.

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