Life lessons to be learnt from social insects (Ants) – A take away for managing pandemic situations

K. Murugasridevi, P. Logesh Kumar and K. Hari Priya

Over the years, disease has ravaged mankind, sometimes the course of history has changed and at times the ends of whole civilizations are signaled. Of which, coronavirus is an important disease attacking both human beings and animals. In 2019, a novel coronavirus was identified and became a pandemic throughout the world due to its rapid spread. In February 2020, the World Health Organization (WHO) designated the disease COVID-19, which stands for coronavirus disease 2019. The virus that causes COVID19 is designated severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). In this situation, to contain the spread of COVID-19 within the communities and help human societies, we shall find some clues from the social insects.

Social insects, in general, adore group-level defense mechanisms *viz.*, avoidance behavior (Cotter and Kilner, 2010), hygienic behavior (Wilson-Rich *et al.*, 2009), collection of antimicrobial resin (Simone *et al.*, 2009), spread of metapleural gland secretions (Yek and Mueller, 2010), behavioral fever (Starks *et al.*, 2000) and allogrooming (Walker and Hughes, 2009). Ants are one of the social insects living in large colonies, most often in close quarters. Their colonies, usually ruled by one or more queens depending on the species, are highly organised with each ant having a specific job to do. While the queen lays the eggs, worker ants forage for food, care for the queen's offspring, work on the nest, and protect the community. We, humans have many lessons to learn from the ants to escape ourselves from this pandemic crisis.

1. Social distancing

Until the COVID-19 epidemic, social distancing was primarily a strange concept to modern people. Nevertheless, it is a habit with deep evolutionary roots that is found in animals all throughout the world. The foraging ants that confront potentially fatal fungal pathogens outside the colony socially separate from the queen ant, her immature stages and nursing worker ants. Ants are extremely altruistic, therefore they want the colony's entire population to thrive. Black garden ant, *Lasius niger* was evolved to reduce the risk of disease transmission in colonies where the ants live in close proximity (Pull and Cremer,2017).

The older ants become foragers, which means they leave the nest to seek for food or defend their territory and they are less essential to the colony because they're already much older and on the verge of dying. Inside the colony, ants will take additional precautions to ensure that the younger nurse ants and the valuable queen are not vulnerable. Immediately after pathogen contamination, *L. neglectus* stop brood care and leave the brood chamber. When ants, *Camponotus aethiops* and *Temnothorax unifasciatus* are close to death due to disease or old age, they reduce their interaction rates with others, sometime by decreasing food sharing behavior and then leave their nests to die. The importance of these behavior to disease transmission remains unaccountable, but can offer an interesting parallel to the phenomenon, which preserves the organism's health of inflammatory and non-inflammatory programmed cell death (e.g., pyroptoses and apoptosis).

Stroeymeyt *et al.* (2018) placed a barcode-like QR labels on the backs of ants to observe how they reacted when a potentially infected individual returned to the colony, allowing a camera-equipped computer to monitor their activities. When few ants become infected by the pathogen, among the healthy ones inside the colony, there was an increase in social distancing between the nurses and the foragers. An extreme version of this happened when the ants were infected with fungal pathogens, as they were ill, they abandoned the colony in order to safeguard it.

2. Self isolation

Generally, moribund ants leave their nest and die in isolation and some reports also have found that infected ants spend less time with the brood. The carpenter ant, *Camponotus aethiops* when infected with generalist insect pathogenic fungus, *Metarhizium brunneum* shown that afflicted ants change their behavior dramatically over time to minimize the threat of colony infection. Infected individuals seemed to have reduced social interactions, did not communicate with brood and spent the majority of their time outside the nest from after three days of infection until death. Furthermore, infected ants were also more hostile towards non-nestmates. Eventually, infected ants' cuticular chemical profiles did not change, implying that sick individuals do not communicate their physiological status to their nestmates (Bos *et al.*,2012).

3. Nest hygiene

The importance of a clean nest environment for colony success can always be underlined. When their nest gets excessively polluted, social insects may selectively choose pathogen-free breeding locations, restrict nest entrances that are close to a pathogen source, or even relocate the entire nest to a different location. Social insects often collect and line their nests with antimicrobial chemicals gathered from the environment, *viz.,* resin or even venom. Wood ants, *Formica paralugubris* employ conifer resin in their nests to prevent further spread of infection, which serves as a prophylactic defense rather than a curative defense. When the colony is affected with a pathogen, worker ants do not increase collection, yet nests with resin have lower microbial contents than nests without resin (Brütsch *et al.*,2017).

4. Waste and corpse removal

The elimination of waste that poses a sanitary threat is essential for nest hygiene. Leaf-cutter ants must frequently replace the fresh leaf substrate in their fungus gardens, resulting in a continual waste stream. In this case, waste removal is especially crucial, since the fungal food source may be threatened by the fungus *Escovopsis*, a specialized garden pathogen. Parasitism by this fungus inhibits food production and leads to colony extinction. To safeguard their fungus garden from infection, the ants weed their garden by dumping the contaminated fungal food and old substrate into trash heaps or middens. Spatial separation prevents transmission from the waste dumps to the clean garden in the nest center, which is strengthened by behavioral separation. Fungus garden workers do not enter the midden; instead, they deposit the waste along the periphery, where garbage workers pick it up. This means that only indirect contact exists between the two working classes, lowering the risk of infection and pathogen transmission. If a garbage worker penetrates the clean nest site, her conspecifics will fight her ferociously, probably to prevent sickness from spreading to other parts of the colony (Diez *et al.*,2012; Zelagin *et al.*,2018).

Infection hazards arise from physical contact with deceased conspecifics. Both insect and human communities deploy sanitary burial techniques to avoid disease transmission concerns. The relevance of such practices is obvious during disease outbreaks where transmission occurs through direct contact. For example, during the 2014 Ebola outbreak in West Africa, the adherence of WHO-recommended burial customs suggesting limited contact with the dead lowered disease transmission and likely shortened the epidemic's length.

Social insect societies have developed intricate corresponding protocols to deal with their deceased colony members. Many ant species bury their dead in specialized nest chambers (such as graveyards) or outside the nest, a process known as necrophory (Maák *et al.*,2020). Furthermore, ants will disembowel the carcasses and deposit them in nest building material. These activities, in general, enhance spatial separation from potential pathogen sources, lowering the likelihood of pathogen exposure and infection among colony members.

5. Sanitary response

Despite these widespread hygiene practices, contamination of colony members cannot always be evaded, demanding thorough cleaning methods targeted at exposed individuals to prevent infection after pathogen exposure. To cope with infection of their colony members, social insects have evolved mechanical removal of infectious particles by grooming and chemical disinfection with antimicrobials. Both defenses frequently coexist with one another.

5.1. Pathogen Avoidance

The first line of defense for an individual or a colony is parasite or pathogen avoidance. Although absolute avoidance is rare due to the possibility of disease contamination in food sources *viz.*, flowers and insect remains, there is evidence that ants shun contaminated food sources. Shared resources like flowers can act as a transmission hotspots. Hence, the ecology of insect species may play a role in its avoidance behavior.

Leaf-cutter ants, *Atta cephalotes* have evolved sophisticated mechanisms to avoid parasite and pathogen intake into the colony. Workers of this species collect plant material and carry it back to their nests where it serves as a substrate for their fungus gardens, which provide food for the entire colony. At specific periods of the year, parasitic flies cluster around ant foraging sites to lay their eggs on the ants. The worker ants are beheaded after emergence of the adult fly. To avoid parasitism by these flies, the ants change their foraging times from diurnal to nocturnal to avoid parasitism. Likewise, *Atta* ants have a small worker caste that rides on the leaf parts as they return to the nest. The small workers weed the cut leaves, cleaning them of infectious particles and inhibit the phorid flies from parasitizing their sisters. This small worker caste is an especially a great illustration of a caste that is specialized for parasite avoidance (Cremer *et al.,*2018).

5.2. Grooming

Pathogen-infected colony members use self-grooming and evoke allogrooming from their fellow colonists. Workers lick the pathogen-exposed colony members and remove infectious particles from their body surface. Ants employ allogrooming to remove the infectious conidiospores of fungal entomopathogens, which adhere to and subsequently penetrate the insect host's cuticle. This behavior is quite effective and increases the chances of contaminated individual's survival. Allogrooming is more efficient than self-grooming because it targets body regions that the individual would otherwise be unable to reach. In addition, it is typically carried out by a group of nestmates. The groomed-off debris is gathered in infra-buccal pouches in the groomer's mouth, where it is compacted, treated with antimicrobial gland compounds, and then discharged as pellets.

5.3. Antimicrobial treatment

Allogrooming can be used in conjunction with the use of self-made antimicrobial chemicals. Specialized glands actively produce or squirt these chemicals. In the Formicine ants, poison gland secretions contain formic acid, a potent antimicrobial that is effective in inhibiting fungal germination and bacterial growth. When workers of *L. neglectus* groom their fungus-contaminated nestmates, they extract poison from their poison gland located at their posterior and store it in their mouth. Then, they smear it over the cuticle of the infected individuals while grooming. This greatly reduces the germination of the fungal conidiospores that were not eliminated during grooming. Antimicrobial use is both preventive and induced in response to pathogen exposure, implying that chemical disinfection works in combination with mechanical removal to protect colony members from being infected.

5.4. Removing the source of infection

After establishing an infection in a host, a pathogen goes through multiple rounds of replication, improving its potential of dissemination to other members of the colony. When *L. neglectus* fails to prevent fungal infections of *Metarhizium* spp. from establishing in their pupae despite early grooming and disinfection, these fatally infected pupae evoke a modified chemical signature (*i.e.,* cuticular hydrocarbon profile) several days after infection. This is comparable to contaminated cells in a vertebrate body emitting "find me – eat me" signals that attract immune cells (cytotoxic T cells) to begin their elimination. The ant’s action is triggered by a change in the chemical pupal signature, which is referred to as “destructive disinfection”. Workers first remove the silk cocoon that surrounds the pupae, then bite holes in the cuticle and spray poison directly from their acid pore onto the afflicted pupae. This behavior causes the fatally infected pupae to die prematurely during the incubation period and totally eliminates the pathogen lifecycle by blocking fungal proliferation and sporulation, similar to how antigen recognition by cytotoxic T cells in vertebrates kills the pathogen lifecycle. Pathogen propagation in individual vertebrates and the super-organismal colony is prevented by both antigen recognition by T cells and destructive disinfection (Pull *et al.,* 2018).

6. Building immunity through vaccination

Successful disease transmission involves not just the eradication of an infectious source, but also the reduction of host susceptibility. Susceptibility to pathogens might vary depending on previous exposure. Immunity can be acquired by immunological memory (vertebrates) or immunological priming (Invertebrates). At the colony level, a similar phenomenon known as social immunization might occur. Immunization happens at all levels of an organization when a previous pathogen exposure gives protection against a subsequent exposure to the same disease. Social immunization provides colony level protection, because social contact with a pathogen-exposed individual reduces susceptibility and increases survival of conspecifics after re-exposure to the same disease. Ants display social immunization against both fungal and bacterial infections, implying that it is a regular phenomenon in social insects.

In particular, social insects may provide passive immunization to their colony members through the transfer of immune effectors, similar to the treatment with antibodies given to humans following an acute rabies infection. The protection of nestmates of carpenter ants, *Camponotus pennsylvanicus*, injected with heat-killed bacteria, *Serratia marcescens*, has been postulated as a technique of passive immunization by transfer of protective chemicals dispersed to its colony members by the infected person (Hamilton *et al.*,2010). Injected individuals had higher antimicrobial activity in their guts than controls, and they regurgitated their gut contents to their naive nestmates, who had better survival after being exposed to live bacteria.

Social immunization against fungal pathogens (*Metarhizium* spp.) occurs via an alternative mechanism: active immunization of colony members by immunological activation caused by low-level pathogen transmission. This is similar to inoculation, an early kind of vaccination that employed a low dose of live pathogens, as compared to modern immunizations that employ dead or attenuated infectious agents. In *L. neglectus*, individuals exposed to infectious particles of the *Metarhizium* are allogroomed extensively by their naive nestmates, who thereafter get low-level fungal infections. Low-level infections do not cause sickness or death, but they do activate the immune system, resulting in increased antifungal and immunological activity (i.e., upregulation of antimicrobial peptides and the phenoloxidase cascade, involved in melanization of fungal pathogen in the body). In the past, inoculation with a sublethal dosage of the smallpox virus had a similar protective effect in people when reinfected with the virus, dramatically lowering the death rate from the terrible disease. In eusocial insect societies, such a response may be adaptive since they are likely to meet the same disease several times while performing foraging tasks, therefore carrying a low-level, protective infection may be beneficial to colony fitness.

7. Resisting antimicrobial resistance

The world is facing an antibiotics crisis. Antibiotics are in short supply around the world. Many once-effective medications have become ineffective against some strains of deadly microbial infections as a result of overuse. As a result, scientists are looking for novel strategies to combat dangerous microorganisms. In a recent study, antibacterial activity of 20 ant species with populations ranging from 80 to 220,000 inhabitants was reported (Penick *et al.*, 2018). External secretions were tested against *Staphylococcus epidermidis*, against which 60 percent of the ant species produced antibiotic secretions. Amazingly, 40 per cent of the people didn't come up with an antibacterial that might kill the bacteria. Furthermore, species in bigger colonies were no more likely than those in small colonies to have antibacterial action. This is surprising because it is commonly assumed that disease spreads faster in larger colonies. Whereas, the 40 per cent of ants that do not have antimicrobial activity have different ways of regulating bacterial spread. This supports the notion that ants could be a promising source of novel drugs. Ants not only create their own antimicrobial compounds, but they can also promote the growth of other beneficial microorganisms.

Conclusion

Millions of years of evolution in a high-risk environment have made ants a potential source of vital antimicrobials. These compounds must still be developed into useful medications and validated in humans. Apart from this, we can learn more about the disease-fighting tactics used by ants, to combat the menace of resistant pathogens and disease. In microbe-rich habitats like soil or decomposing wood, social insects live in big, dense, multigenerational families. As a result, we can argue that disease propagation and/or spread within and among colonies is naturally promoted by nest conditions. Colony social structure, life cycle flexibility and cooperative social defensive activities, on the other hand, minimize the chance of infection and decrease transmission risk among colony members, which we should learn from these magnificent creatures amidst the pandemic situation. Hence, we emphasize on unique cooperative behaviors to follow social distancing, sophisticated hygiene with a sanitary care, self-isolation when gets infected and fundamental organizational mechanisms that make up the building blocks of social immunity which the insect communities have evolved to battle the disease threats.

References

Bos N, Lefèvre T, Jensen A B, d'Ettorre P. 2012. Sick ants become unsociable. Journal of evolutionary biology. 25(2):342-351.

Brütsch T, Jaffuel G, Vallat A, Turlings T C, Chapuisat M. 2017. Wood ants produce a potent antimicrobial agent by applying formic acid on tree-collected resin. Ecology and Evolution. 7(7):2249-54.

Cotter S C, Kilner R M. 2010. Personal immunity versus social immunity. Behavioral Ecology. 21(4):663-8.

Cremer S, Armitage S A, Schmid-Hempel P. 2007. Social immunity. Current biology. 17(16): 693-702.

Diez L, Deneubourg J L, Detrain C. 2012. Social prophylaxis through distant corpse removal in ants. Naturwissenschaften. 99(10):833-42.

Hamilton C, Lejeune B T, Rosengaus R B. 2011. Trophallaxis and prophylaxis: social immunity in the carpenter ant Camponotus pennsylvanicus. Biology letters. 7(1):89-92.

Maák I, Tóth E, Lenda M, Lőrinczi G, Kiss A, Juhász O, Czechowski W, Torma A. 2020. Behaviours indicating cannibalistic necrophagy in ants are modulated by the perception of pathogen infection level. Scientific Reports. 10(1):1-3.

Osti J F, Rodrigues A. 2018. Escovopsioides as a fungal antagonist of the fungus cultivated by leafcutter ants. BMC microbiology. 18(1):1-11.

Penick C A, Halawani O, Pearson B, Mathews S, López-Uribe M M, Dunn R R, Smith A A. 2018. External immunity in ant societies: sociality and colony size do not predict investment in antimicrobials. Royal Society open science. 5(2):171332.

Pull C D, Cremer S. 2017. Co-founding ant queens prevent disease by performing prophylactic undertaking behaviour. BMC evolutionary biology. 17(1):1-10.

Pull C D, Ugelvig L V, Wiesenhofer F, Grasse A V, Tragust S, Schmitt T, Brown M J, Cremer S. 2018. Destructive disinfection of infected brood prevents systemic disease spread in ant colonies. Elife. 7:e32073.

Simone M, Evans J D, Spivak M. 2009. Resin collection and social immunity in honey bees. Evolution: International Journal of Organic Evolution. 63(11):3016-22.

Starks P T, Blackie C A, Seeley T D. 2000. Fever in honeybee colonies. Naturwissenschaften. 87(5):229-31.

Stroeymeyt N, Grasse A V, Crespi A, Mersch D P, Cremer S, Keller L. 2018. Social network plasticity decreases disease transmission in a eusocial insect. Science. 362 (6417): 941-945.

Walker T N, Hughes W O. 2009. Adaptive social immunity in leaf-cutting ants. Biology Letters. 5(4):446-8.

Wilson-Rich N, Spivak M, Fefferman N H, Starks P T. 2009. Genetic, individual, and group facilitation of disease resistance in insect societies. Annual review of entomology. 54:405-23.

Yek S H, Mueller U G. 2011. The metapleural gland of ants. Biological Reviews. 86(4):774-91.

Zelagin D M, Hund A K, Breed M D. 2018. Spatial aspects of corpse removal in the western harvester ant, *Pogonomyrmex occidentalis*. Journal of Insect Behavior. 31(3):241-54.

AUTHORS

K. Murugasridevi (corresponding author)*, Dhanalakshmi Srinivasan Agriculture College, Affiliated to Tamil Nadu Agricultural University, Perambalur-621212, Tamil Nadu, India

P. Logesh Kumar and K. Hari Priya, Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India. *E-mail: sridevivetri.2109@gmail.com