Behavioural Defence Mechanism in Insect

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Abstract

Behavioural immunity in insects refers to the set of behaviours that insects exhibit to protect themselves against pathogens and parasites. This type of immunity helps insect to avoid infection or limits its spread within population. It encompasses multiple strategies that either reduce exposure to infections or mitigate their impacts. Behavioural immunity includes a range of strategies that organisms employ to reduce infection risks and mitigate pathogen impact before physiological immune responses are activated. In insects, these behaviours include qualitative and quantitative resistance, as well as tolerance, manifesting through grooming, avoidance of infected individuals, and selective feeding. The study of behavioral immunity provides novel insights into host-parasite coevolution, the costs of immunity, the evolution of canonical physiological immunity, the evolution of parasite virulence, and the local adaptation.

Keywords: Behavioural immunity, grooming, defence mechanism, insect

Introduction

Behavioural immunity refers to a range of behavioural strategies employed by organisms to reduce the risk of infection and mitigate the harmful effects of pathogens and parasites. In insects, these behaviours include qualitative resistance, quantitative resistance, and tolerance (Roode *et al.*, 2012). These behaviour carries grooming, avoidance of infected species, and selective feeding, serving as a primary defence mechanism prior to the activation of physiological immune responses (Vigneron *et al.*, 2019). In social insects, such as termites, grooming behaviour and antennal olfactory detection play critical roles in removing fungal conidia and minimizing pathogen spread within colonies (Chen *et al.*, 2023). Behavioural immunity not only contributes to individual and group survival but also influences evolutionary trade-offs with other life history traits, such as reproduction and energy allocation (Wilson-Rich *et al.*, 2009). Despite its importance, behavioural immunity has often been under-represented in host-parasite interaction studies, potentially leading to incomplete understandings of host defence mechanisms. Incorporating behavioural immunity into research frameworks is essential for a comprehensive grasp of host-pathogen dynamics and could inform innovative pest management strategies. This study underscores the critical role of behavioural immunity and advocates for its inclusion in future ecological and evolutionary immunology research.

The integrated action of various system, in response to the changes in external and internal environment is called as Behaviour. It is mainly defined as the way the organism respond to their environment and to the internal signals. Ethology is considered as the scientific study of animal behaviour in context of natural environment. Immunity in insects often considered to embrace all aspects of resistance against external and internal environments. Behavioural immunity in insects refers to the set of behaviours that insects exhibit to protect themselves against pathogens and parasites. This type of immunity helps insect to avoid infection or limits its spread within population. It encompasses multiple strategies that either reduce exposure to infections or mitigate their impacts. This phenomenon is crucial in enhancing insect survival and preventing disease transmission.

Patterns of behaviour

Insects exhibit innate and learned behaviours

1. **Innate behaviours:** Innate behaviours are genetically encoded and largely independent of environmental influences. It is always heritable, intrinsic, inflexible, and consummate. It's included, reflexes, orientation, kinesis, and taxes are common behavioural mechanisms aiding in survival.

- **Reflexes -** It is involuntary and rapid response to the stimulus automatically.

E.g.- Extending of proboscis for feeding in butterflies

- **Orientation -** It refers to the capacity and activity of the organism to control location and attitude in space and time. Eg- Prey capturing and host locating.
- **Kinesis -** Indirect locomotory reactions to stimulus which varies according to source and intensity of the stimulus. E.g.- Tsetsefly – *Glossina* sp. are active in arid atmosphere than in humid atmosphere. It is of following types:
  - **Orthokinesis -** Response to intensity of stimulus
  - **Klinokinesis –** Response to insect turn according to frequency of stimulus
  - **Hygrokinesis –** Response to moisture
  - **Chemokinesis-** Response to odour
- **Taxes -** Directed movement towards or away from stimulus. Eg. – Phototaxis, chemotaxis, Thigmotaxis, Animotaxis, Geotaxis etc.

2. **Learned behaviours:** Learned behaviours develop through experience. It is non-heritable, extrinsic, adaptable and progressive. Insects learns in the following ways: -

- **Habituation and sensitization -** It is decrease in response to stimulus after repeated exposure and sensitization is the increased responsiveness to stimulus if it is intense or noxious. Both help organism to adapt to their environment efficiently.
- **Classical conditioning -** This learning process demonstrate how organisms associate stimuli with specific outcome. Eg- Honey bees extend its proboscis as conditional response to coumarin in absence of sugar.
- **Latent learning -** It is the subconscious retention of information without any reward or punishment. Eg- Social insect learn the characteristics of immediate vicinity of their nest to find their way back.

Types of behavioural immunity

Islam *et al*. (2023) classifies behavioural immunity into three major categories: Qualitative resistance, Quantitative resistance, and Tolerance.

1. **Qualitative resistance** (Anti-infection resistance or avoidance): This includes behavioural strategies that help insects avoid infection, such as:

- **Spatial avoidance** – Insects avoid habitats with high parasite loads (e.g., water striders avoiding parasitoid-infested waters).
- **Temporal avoidance** – Insects adjust their activity patterns to avoid peak parasite activity (e.g., leaf-cutter ants shifting foraging times to avoid parasitoid flies, During the wet season, when phorid parasitoids are dormant, termitophagous ants (*Pheidole titanis*) switched from diurnal to nocturnal foraging.
- **Trophic avoidance** – Avoidance of contaminated food sources (e.g., gypsy moth larvae detecting and avoiding virus-contaminated foliage).
- **Prophylactic medication** – Insects consume substances that prevent infections (e.g., wood ants incorporating resin into nests for antimicrobial protection).
- **Sexual behaviours** – Preference for mates with resistance traits, increasing overall immunity in populations (In the two-spotted ladybird, *Adalia bipunctata* mates infected with the sexually transmitted mite, *Coccipolipus hippodamiae* were impossible for either male or female to avoid).
- **Decreased social contacts** – Infected social insects may isolate themselves to reduce transmission risk. (Ants infected with *Metarrhizium* spend less time with the brood, reduce social behaviours like grooming and trophallaxis, and leave their nests to die alone.)
- **Grooming –** Grooming is a powerful, non-specific defense mechanism that contributes to the both qualitative and quantitative resistance of insects against a wide range of parasites and pathogens. It plays a critical role in maintaining individual and colony health, particularly in social insects such as ants, bees, and termites for removing pathogens.

2. **Quantitative resistance:** When infection occurs, insects can employ mechanisms to minimize pathogen impact:

- **Therapeutic medication –** Consumption of substances that reduce infection severity. a set of actions, whether mediated by defensive or nutritional qualities, by which infected hosts take advantage of other species or substances to lessen or eradicate infections. When parasitized, woolly bear caterpillars (*Grammia incorrupta*) increase their taste for certain toxins, such as alkaloids found in larval food plants, and *Drosophila* larvae use ethanol-rich food to kill parasitoid wasps.
- **Behavioural thermoregulation –** Adjusting body temperature to inhibit parasite growth. By behaviourally increasing or decreasing their body temperature, insects can eradicate infections or prevent the growth of parasites. For instance, when infected with the prokaryotic parasite *Rickettsiella grylli*, crickets prefer higher temperatures; they do not alter their thermo-preference when exposed to a protozoan gut parasite, a tachinid fly parasitoid, or a bacterium (*Serratia marcescens*). Indirect defence mechanisms include behavioural thermoregulation and therapeutic medication, which allow hosts to use environmental factors (temperature and food) to lessen parasite burdens.

3. **Tolerance** (Minimizing the effects of infection): In cases where avoidance and resistance fail, insects can use tolerance mechanisms:

- **Fecundity compensation** – Infected individuals increase reproductive output to compensate for reduced lifespan (For instance, exposure to lipopolysaccharides, which are parts of the bacterial cell wall, or the bacterium *Serratia marcescens* caused crickets to lay eggs more frequently).
- **Tolerance medication** – Consumption of food that aids in survival despite infection. By preferentially consuming food that enables them to maintain their health and fitness, insects can also use additional compounds to increase their tolerance against infections rather than reduce or clear them. For instance, depending on the type of milkweed they consume, monarch butterflies exhibit varying degrees of tolerance to parasitism; therefore, preferential oviposition of infected monarchs on high-cardenolide milkweed not only demonstrates improved quantitative resistance but also greater tolerance (De Roode *et al*., 2008).

Fixed action pattern

It is a sequence of co-ordinated movement that are perform together as a unit. It may be any behavioural pattern whether it be a reaction release, drive, motivation, or appetitive reaction. E.g.- Relative concentration of juvenile hormone and moulting hormone determine spinning behaviour of caterpillar of wax moth.

Host-parasite coevolution

Host-parasite interactions drive evolutionary changes, influencing both behavioural and immune system defences. Behavioural immunity plays a role in shaping parasite virulence and resistance adaptations in host species (Cassidy *et al*., 2021). Parasite host selection is mediated by non-immunological defence mechanisms both before and after infection, in addition to the evolution of immune system-based pathways and processes. Because of the cost defence, immune system-based and non-immunological defences in turn affect how each other and other host processes evolve.

Future prospects

- ✓ **Host-parasite coevolution:** Future studies can investigate the long-term evolutionary dynamics between host behavioral defenses and parasite adaptations.
- ✓ **Climate change impacts:** Assessing the impact of ongoing climate change on insect population, including potentials shift in distribution, abundance, and interaction with other species.
- ✓ **Practical applications:** These findings could contribute to pest management by manipulating insect behaviors or by designing strategies that exploit their natural defense mechanisms against parasites.
- ✓ **Interdisciplinary studies:** Behavioral immunity research could integrate more with genetics, evolutionary biology, and ecology to develop comprehensive frameworks for understanding host defense system

Conclusion

- Although, study of behavioral immunity in insects is still in its infancy, it is cleared that insects display an enormous variety of antiparasitic behaviors *viz.*, qualitative resistance, quantitative resistance and tolerance.
- The study of behavioral immunity provides novel insights into host-parasite coevolution, the costs of immunity, the evolution of canonical physiological immunity, the evolution of parasite virulence, and the local adaptation.

References

Cassidy, S.T., Chapa, J., Tran, T.A., Dolezal, N., Gerena, C., Johnson, G. and Keiser, C.N. (2021). Disease defences across levels of biological organization: individual and social immunity in acorn ants. *Animal Behaviour*, 179: 73-81.

Chen, Y., Zhao, C., Zeng, W., Wu, W., Zhang, S., Zhang, D. and Li, Z. (2023). The effect of ergosterol on the allogrooming behavior of termites in response to the entomopathogenic fungus *Metarhizium anisopliae*. *Insect Science*, 30(1): 185-196.

De Roode, J.C. and Lefèvre, T. (2012). Behavioral immunity in insects. *Insects*, 3(3): 789-820.

De Roode, J.C., Pedersen, A.B., Hunter, M.D. and Altizer, S. (2008). Host plant species affects virulence in monarch butterfly parasites. *J. Anim. Ecol*. 2008, 77: 120-126.

Islam, T., Moore, B.D. and Johnson, S.N. (2023). Silicon fertilisation affects morphological and immune defences of an insect pest and enhances plant compensatory growth. *Journal of Pest Science*, 96(1): 41-53.

Vigneron, A., Jehan, C., Rigaud, T., & Moret, Y. (2019). Immune Defenses of a Beneficial Pest: The Mealworm Beetle, *Tenebrio molitor*. *Frontiers in Physiology*

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*, 405-423.

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