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Fight Exists in Insects Too: A Tale of Drosophila Fight

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When we think of insects, we often picture them flying from flower to flower, feeding on leaves, or pollinating crops. It is difficult to imagine that such tiny creatures also fight for survival. Surprisingly, many insects display organized aggressive behaviour to defend food, territory, and mating opportunities. Among them, the common fruit fly, *Drosophila melanogaster*, has become one of the most important model organisms for understanding aggression. Although only about 2–3 mm long, the fruit fly exhibits remarkably complex social behaviour. It can recognize opponents, remember previous fights, establish dominance, and even change its fighting strategy based on experience. These discoveries have transformed this tiny insect into a powerful model for studying genetics, neuroscience, behaviour, and evolution. More importantly, the knowledge gained from *Drosophila* research is helping scientists develop innovative, environmentally friendly pest management strategies for economically important insect pests.

For over a century, *Drosophila melanogaster* has been one of the most widely studied insects in biological research. It is easy to rear in the laboratory, has a short life cycle of about ten days, and produces a large number of offspring. More importantly, its entire genome has been sequenced, making it an excellent model for studying the relationship between genes and behaviour. Scientists have discovered that nearly three-fourths of human disease-related genes have counterparts in *Drosophila*. As a result, this tiny insect has contributed significantly to advances in genetics, developmental biology, ageing, neuroscience, and behavioural studies. Today, it is often referred to as the **"Jack of all trades" in biology**, reflecting its immense contribution to modern science. Aggression is a natural behaviour observed throughout the animal kingdom. In fruit flies, fighting is not random; it is a carefully organized strategy to secure valuable resources.

A fight begins long before physical contact

Fruit fly fights follow a surprisingly predictable sequence. When two male flies encounter each other, they first orient themselves toward the opponent and exchange chemical information through brief contact using their forelegs. Wing flicks and wing threats serve as warning signals, allowing each individual to assess its rival before the conflict escalates. Only when neither individual retreats does the fight become physical. At this stage, the flies display highly stereotyped aggressive actions that can be easily recognized under laboratory observation.

Male and female flies have different fighting styles

One of the most fascinating discoveries in *Drosophila* research is that males and females use different methods of attack. Male aggression is characterized by behaviour such as **lunging**, **boxing**, **holding**, and **tussling**. Among these, lunging is considered the hallmark of male aggression. During a lunge, a male rise on its hind legs, lifts its wings for balance, and strikes downward at its opponent. Females, however, rarely lunge. Instead, they perform rapid

headbutts and **shoves**, briefly attacking rivals before returning to feed or search for egg-laying sites. Unlike males, females often alternate between competition and peaceful sharing of resources. These behavioral differences, known as **sexual dimorphism**, demonstrate that aggression is shaped by the biological roles of males and females.

Who wins the battle?

Repeated interactions eventually produce a clear winner and loser among male fruit flies. The winning fly becomes dominant and gains priority access to food resources and potential mates. The defeated fly gradually becomes submissive and often avoids future confrontations with the same rival. Interestingly, females rarely establish such long-term dominance relationships. After brief aggressive encounters, competing females frequently return to sharing the same food resource, particularly when suitable egg-laying sites are limited. This remarkable contrast highlights the distinct ecological roles played by the two sexes.

Do fruit flies remember their opponents?

Perhaps the most surprising discovery is that fruit flies possess a simple form of social memory. Scientists observed that flies separated after a fight behaved differently when reunited. Losers tended to avoid familiar winners, whereas they became more willing to challenge unfamiliar opponents. Winning individuals also retained their dominant status for some time after the initial encounter. These findings clearly demonstrate that fruit flies do not merely react instinctively; they are capable of learning from previous experiences and modifying their future behaviour accordingly. Such observations have greatly expanded our understanding of insect intelligence and social interactions.

Genes that decide how flies fight

Aggressive behaviour is not controlled solely by the environment - it is also deeply influenced by genetics. Among the most important genes identified is the **fruitless (*fru*) gene**, often regarded as the master regulator of male courtship and aggression. This gene controls the development of specific neural circuits responsible for male-specific fighting behaviour. Remarkably, researchers found that altering the expression of the *fruitless* gene can completely reverse fighting styles. Males engineered to express the female form of the gene abandon lunging and boxing and instead perform female-like headbutts and shoves. Conversely, females expressing the male form of the gene begin displaying typical male aggressive behaviours. Another key gene, **doublesex (*dsx*)**, enables flies to distinguish males from females through chemical cues, preventing unnecessary aggression towards potential mates. Together, these discoveries demonstrate how genes shape complex social behaviour even in tiny insects.

Mate guarding: Fighting for fatherhood

Aggression in fruit flies extends beyond defending food resources; it also plays a crucial role in ensuring reproductive success. After mating, male *Drosophila* often remain close to their mates and aggressively repel rival males attempting to court the female. This behaviour, known as **mate guarding**, significantly increases the chances that the guarding male will father most of the offspring. Experimental studies have shown that males in the mate-guarding phase exhibit significantly higher aggression than non-guarding males. Guard males chase away intruders, spend more time defending the food patch where mating occurs, and reduce the opportunity for rival males to remate with the female. Consequently, females are less likely to mate again, increasing the paternity success of the guarding male. This fascinating strategy highlights how aggression has evolved as an adaptive behaviour that directly enhances reproductive fitness.

Hunger makes flies more aggressive

Environmental conditions strongly influence aggressive behaviour. Among these factors, **food availability** is one of the most important. When food becomes scarce, fruit flies compete more intensely for available resources. Moderately hungry males display more

aggressive encounters, spend longer periods defending food patches, and challenge rivals more frequently than well-fed individuals. However, prolonged starvation produces the opposite effect. Extremely hungry flies conserve their limited energy and avoid unnecessary fights because survival becomes more important than competition. This behavioral flexibility demonstrates that aggression is not fixed but changes according to the physiological condition of the insect. Such adaptations allow fruit flies to balance energy expenditure with survival under varying environmental conditions.

Can tiny microbes influence aggression?

One of the most exciting recent discoveries in insect behaviour is the role of the **gut microbiome**. Scientists found that fruit flies reared on antibiotic-treated diets, which removed most of their beneficial gut bacteria, became significantly more aggressive than untreated flies. These flies also produced higher levels of aggression-associated pheromones such as **cis-vaccenyl acetate (cVA)** and **(Z)-9-tricosene**. Interestingly, when beneficial bacteria such as *Lactobacillus brevis* and *Lactobacillus plantarum* were reintroduced, aggressive behaviour declined to normal levels. These findings reveal an unexpected connection between microorganisms, chemical communication, and insect behaviour. The gut microbiome is now considered an important factor influencing the nervous system and social interactions of insects, opening exciting new avenues for behavioural and microbiological research.

Female aggression: An emerging area of research

Although male aggression has been extensively investigated, female aggression has only recently attracted scientific attention. Researchers have discovered that virgin female fruit flies actively attack mating pairs, primarily directing their aggression towards the mating female. Surprisingly, these aggressive interactions do not reduce mating duration, egg production, or egg hatchability. Instead, they appear to represent competition for valuable reproductive resources. Interestingly, females that have recently mated become less aggressive towards other mating pairs, whereas mated females defending feeding territories often exhibit stronger aggression than virgin females. These findings suggest that reproductive status strongly influences female behaviour and that aggression in females serves functions different from those observed in males.

What controls aggression in fruit flies?

Aggression in *Drosophila* is regulated by the interaction of several biological and environmental factors rather than by a single mechanism.

Major factors include:

- **Genetic regulators** such as *fruitless (fru)* and *doublesex (dsx)*.
- **Neurotransmitters** including serotonin, dopamine, octopamine, tachykinin and neuropeptide F.
- **Internal factors** such as hunger, age, sex and mating status.
- **External sensory cues**, including pheromones, vision, smell, taste and movement.
- **Environmental conditions**, particularly food availability and social interactions.
- **Gut microbiota**, which influence pheromone production and behavioural responses.

The integration of these signals enables fruit flies to display context-dependent aggression that maximizes survival and reproductive success.

Agricultural relevance

At first glance, studying aggression in a tiny laboratory insect may appear to have little relevance to agriculture. However, the knowledge gained from *Drosophila melanogaster* has far-reaching implications. Several species belonging to the genus *Drosophila*, particularly the spotted-wing drosophila (*Drosophila suzukii*), are among the most destructive pests of cherries, strawberries, blueberries, grapes, raspberries and several other fruit crops. Understanding how fruit flies communicate, compete for territories, locate mates and respond

to environmental cues provides valuable information for designing behaviour-based pest management strategies.

Modern Integrated Pest Management (IPM) increasingly relies on environmentally friendly approaches such as pheromone-based monitoring, attract-and-kill systems, habitat manipulation and behavioural disruption. Research using *Drosophila melanogaster* provides the scientific foundation for developing these sustainable technologies while reducing dependence on synthetic insecticides. Furthermore, studies on aggression, chemical communication and gut microbiota may open new possibilities for manipulating insect behaviour without causing environmental pollution or harming beneficial organisms.

Future perspectives

Despite decades of research, many questions remain unanswered. Scientists are continuing to investigate how memories of previous fights are stored in the brain, how microbial communities influence neural signalling, and how environmental changes alter aggressive behaviour. Future studies integrating behavioural ecology, molecular genetics, neurobiology and microbiology will undoubtedly reveal additional mechanisms regulating insect aggression. Such discoveries may eventually contribute to novel pest management tools that are safer, more selective and environmentally sustainable.

Conclusion

Aggression in *Drosophila melanogaster* is far more sophisticated than previously imagined. These tiny insects establish dominance, remember previous opponents, defend territories, guard mates and modify their behaviour according to environmental conditions and internal physiological states. Their aggression is controlled by an intricate network involving genes, neurotransmitters, sensory signals, gut microorganisms and learning. Although *Drosophila melanogaster* itself is primarily a laboratory model, the insights gained from its behavioural studies have significantly advanced our understanding of insect biology and are contributing to the development of innovative, behaviour-based pest management strategies. This remarkable insect reminds us that even the smallest organisms can provide profound lessons for science and sustainable agriculture.

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