

The queen's perfume

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Can a smell affect social behaviour? Without a doubt. Let off an unpleasant one and those closest to you will move somewhere else. Likewise, an agreeable scent will keep them hovering in your vicinity. It's an old trick. Flowers and animals have been using smells for millions of years to ward off predators or to attract individuals for the sake of reproduction. So it does not come as a surprise to learn that ants use the same kind of technique as a means of communication and social interaction. However, it is not so much the odour but the capacity to detect it that is at the basis of two types of social behaviour in a species of red fire ant, *Solenopsis invicta* – the ecological pest. This particular ant either belongs to a colony that has only one queen (monogyne) reigning over it or to a far larger colony which is ruled by several queens (polygyne). In the 1990s, scientists discovered that the basis of a monogyne or a polygyne colony amounted to the existence of only one protein: pheromone-binding protein.



An ant, Nathan Walker illustrations, etc.

Courtesy of the artist

Social behaviour is a complex process. Even in the world of a worm. So can one gene be responsible for a type of royalty? It seems to be the case. What scientists observed is that the *Solenopsis invicta* red ants have two social organisations: colonies with only one queen or colonies with many hundreds. Gp-9 protein had been widely used as a marker to determine population genetic structure in fire ant populations – hence its name: General protein-9. In 1997, a research team noticed that social

organisation seemed to be governed, one way or another, by this particular protein. The question was how?

In an attempt to answer, the scientists collected a number of *Solenopsis invicta* red ants which belonged to mono-queen colonies, and a few from poly-queen colonies. They then had a closer look at their Gp-9 proteins. To cut a long story short, they found two Gp-9 alleles which they called B and b. To their astonishment, they then discovered that the mono-queen *Solenopsis invicta* red ants were all BB homozygotes, while the poly-queen ones were Bb heterozygotes. This implied that the basis of mono- or poly-queen colonies is hereditary. That is to say, the social organisation of ants – with regards to the existence of one or more queens – is orchestrated by a gene.

Gp-9 is in fact a pheromone-binding protein, i.e. it binds these odourless molecules which can govern the behaviour of many creatures. Humans included. Such pheromone receptors are found on the ants' antennae and once its ligand is bound to it, it transfers it to receptors on olfactory sensory neurons, which relay the pheromone message to the brain. And what would be the message such a pheromone relays? In this case, two different messages are relayed depending on the phenotype – BB or Bb – the ant carries. A worker ant will either accept an extra queen ant in its colony or it will not. It sounds simple, yet it is not...

A BB queen has all it needs to found its own colony. It is hugely overweight and can provide for itself and its eggs. Once it has mated with a male ant – in midair if you please – it will fly off and find a nice spot to lay its eggs and look after its brethren, which will subsequently become the workers that will not only look after their queen mother but will also look after the nest and fend for her. All the possible BB queen ants the original queen mother gave birth to will be sacrificed. And if any other BB queen stumbles upon the colony, it will also be killed. This behaviour occurs by way of the ‘BB pheromones’ given off by the BB queens, which signal to the BB worker ants that any other queen must be eliminated. A sorry fate.

In colonies where many queens cohabit, the workers – like the queens – are Bb heterozygotes. How do they behave? It seems that their pheromone-detecting capacities are impaired. As a consequence, Bb red ants can ‘smell’ BB queen ants a mile off and they’ll kill them. However, these same heterozygous ants miss the Bb queens because they can’t detect them. So poly-queen colonies seem to exist simply because Bb ants don’t have the means to smell them. And the bb homozygotes? These ants are not viable – they are also very skinny – and die before they are sexually mature. What is more, Bb queens are far leaner than their BB counterparts and would not be able to form their own colony without the help of workers. So royal chubbiness also seems to be related to Gp-9!

On the molecular level, not much is known about Gp-9. It probably acts as a homodimer.

However, its 3D structure is still misunderstood and besides imagining that the two alleles – B and b – probably engender two different binding structures, their architectural difference is still a blur. A number of the mutations which create the two distinct Gp-9 alleles most probably affect the ligand pocket region. The B allele would be intact, while the b allele would be faulty. This could explain why the BB homozygotes are very good at smelling out the BB and the Bb queens, whereas the Bb heterozygotes can only cope with the BB queens but are not fine-tuned enough to spot the Bb queen pheromones.

Much has yet to be understood but the discovery is paramount and perhaps even a little disturbing. Here is a gene – Gp-9 – that orchestrates social behaviour. Not only does it define whether a red ant will be part of a mono-queen or a poly-queen colony – with all the interactions this implies – but it also plays some part in the chubbiness of the queen. The obvious question is: Is there any form of human social behaviour which is driven by genes solely? Or do we have our say in matters? Does free-will really exist? The usual answer is: Human social interaction is so complex that there is no way that any one form of behaviour could be pinned down to one gene. And the environment also has its say. But before the role of Gp-9 was uncovered, the same was said about ants. The wonderful thing about humans though is that we all own that beautiful talent called imagination which we can use to ensure us of our freedom. Gp-9 or not.

Cross-references to Swiss-Prot

Pheromone-binding protein Gp-9, *Solenopsis invicta* (Red imported fire ant) : Q8WP90

References

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