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Queen or worker? Flexibility between roles relies on just a few genes

Two insect species from Latin America, the dinosaur ant and the red paper wasp, have been used to uncover the molecular mechanisms underpinning queen and worker roles in social insects. The research by an international team of scientists brings us closer to understanding how genomes are used to generate castes in social evolution.

Researchers from the University of Bristol, the Babraham Institute (Cambridge, UK) and the Centre for Genomic Regulation (Barcelona, Spain) analysed individual wasp and ant brains from queens and workers of both species to see whether caste differences could be explained by variations in how the genome is 'read' and regulated.

As published in the latest issue of PNAS, the two species revealed much more than honeybees about how queen and worker castes evolve in insect societies. Dr Seirian Sumner, a senior author on the paper, and a senior lecturer at the University of Bristol, explains: "Unlike honeybees, who as larvae are fated irreversibly to be a queen or worker, paper wasps and dinosaur ants are able to switch role from worker to queen at any point in their life. This flexibility is thought to represent the first stages of caste evolution, when the simplest societies form."

Queens and workers of paper wasps and dinosaur ants look identical. It was only by observing the insects' behaviours and social interactions that the researchers were able to identify their roles. To do this, the researchers fitted the insects with tiny paint spots or identification tags to study the insects in their natural environments.

Comparing the molecular differences between queens and workers of both species was surprising. "We found very few differences in gene expression and gene functional specialisation between queens and workers in both the ant and the wasp," said Dr Solenn Patalano from the Epigenetics Programme at the Babraham Institute and lead author on the paper. "In both, less than one per cent of the genome showed noticeable differences in expression levels. This was unexpected as many hundreds of genes are involved in differentiating queens and workers in the honeybee."

Instead, the authors found that castes were differentiated by subtle, but non-random arrangements of gene networks. "This suggest that there is no single master gene regulating caste differentiation in these simple societies, and that genes for simple social behaviour act in interconnected networks involving many genes of small effect," explained Dr Sumner.

The authors also looked at whether epigenetic modifications to DNA (DNA methylation) might be regulating these subtle gene networks. "Surprisingly, we found no evidence that queen- and worker-specific gene expression was driven by DNA methylation and more generally the ant and wasp genomes lack strong epigenetic signatures." said Dr Patalano. "We suggest that this absence of molecular commitment keeps the genome open and responsive, facilitating the behavioural plasticity we see in these species."

"As part of this research we are also really excited to be publishing the first genome sequence for a social wasp!" Dr Sumner added. "Genome sequences exist for eleven ant species and three bee species. The sequencing of the first wasp genome completes the trio of the social Hymenoptera (bees, wasps and ants), giving us a more balanced understanding of the molecular basis of sociality in insects, and opens up exciting new avenues of research into a somewhat neglected group of insects."

Professor Wolf Reik, Head of the Epigenetics Programme at the Babraham Institute, associated faculty at the Wellcome Trust Sanger Institute and a senior author on the paper, said: "We are excited about discovering molecular mechanisms which in these wasps and ants allow easy switching between workers and queens. There are some applications of these principles to human stem cells to make them more plastic, potentially leading to better stem cell therapies in the future."

"The work illustrates the relevance of genomic approaches, including genome and transcriptome sequencing, to understand animal behaviour. They help to uncover the genetic basis underlying behavioural traits." added Professor Roderic Guigó, coordinator of the Bioinformatics and Genomics Programme at the Centre for Genomic Regulation in Barcelona, Spain.

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Notes to editors

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Supporting materials:
Files are available from the following link and also via the AlphaGalileo and EurekAlert news services:
https://www.dropbox.com/sh/iiigkedmhjushzv/AAB6Y-Atty4x5uMf2HXXgcs6a?dl=0

Images
- Dinosaur ant, *Dinoponera quadriceps*. Credit: Chris Tranter
- Paper wasp, *Polistes canadensis*. Credit: Solenn Patalano
- Wasps and wasp nest. Credit: Solenn Patalano
- Dinosaur ant tagged with an identification tag. Credit: Claire Asher
- Paper wasp with painted identification marks. Credit: Solenn Patalano
- Art cover: 'Amalgam'. Credit: Solenn Patalano and Philippos Vardakas

Description: Amalgam of graphics and photographs artistically illustrating the entire scientific study.

- Aggressive interactions between dinosaur ants. Credit: Claire Asher
  Description: This picture shows immobilisation, which is one of the more extreme aggressive interactions in dinosaur ants - most commonly used to punish workers who try to lay eggs or overthrow the queen. This behaviour can go on for hours (even days) and frequently kills the immobilised ant.

Videos of individual interaction (ants) and video of queen dominance behaviour (wasps)
Aggressive interactions between dinosaur ants. Credit: Fabio Nascimento
Description: This video shows immobilisation, which is one of the more extreme aggressive interactions in dinosaur ants - most commonly used to punish workers who try to lay eggs or overthrow the queen. This behaviour can go on for hours (even days) and frequently kills the immobilised ant.

Dominance behaviour in paper wasp nest. Credit: Solenn Patalano
Description: This video shows several dominance behaviours performed by the wasp queen in her nest. The queen shakes her abdomen to activate her ovaries (highlighted by the label 'queen abdominal waves'); 'aggression' is performed by the queen in order to apply her dominance over one worker who shows an imitation of this behaviour. Every wasp on this nest bears an identification mark (either tag or painted marks).

About the Babraham Institute
The Babraham Institute, which receives strategic funding (a total of £27.3M in 2014-15) from the Biotechnology and Biological Sciences Research Council (BBSRC), undertakes international quality life sciences research to generate new knowledge of biological mechanisms underpinning ageing, development and the maintenance of health. The Institute's research provides greater understanding of the biological events that underlie the normal functions of cells and the implication of failure or abnormalities in these processes. Research focuses on signalling and genome regulation, particularly the interplay between the two and how epigenetic signals can influence important physiological adaptations during the lifespan of an organism. By determining how the body reacts to dietary and environmental stimuli and manages microbial and viral interactions, we aim to improve wellbeing and healthier ageing.
www.babraham.ac.uk

About the University of Bristol
The University of Bristol is one of the most popular and successful universities in the UK. It was ranked within the top 40 universities in the world in the QS World University rankings 2015 and 9th in the country. The University of Bristol is ranked among the top five institutions in the UK for its research, according to new analysis of the Research Excellence Framework (REF) 2014.

Bristol is a member of the Russell Group of UK research-intensive universities, and a member of the Worldwide Universities Network, a grouping of research-led institutions of international standing.

The University was founded in 1876 and was granted its Royal Charter in 1909. It was the first university in England to admit women on the same basis as men.

The University is a major force in the economic, social and cultural life of Bristol and the region, but is also a significant player on the world stage. It has over 16,000 undergraduates and nearly 6,000 postgraduate students from more than 100 countries, and its research links span the globe.
www.bristol.ac.uk

About the Centre for Genomic Regulation

The Centre for Genomic Regulation (CRG) is an international biomedical research institute of excellence whose mission is to discover and advance knowledge for the benefit of society, public health and economic prosperity. The breadth of topics, approaches and technologies at the CRG permits a broad range of fundamental issues in life sciences and biomedicine to be addressed. Nearly 380 scientists from 42 different nationalities work at the CRG on multidisciplinary projects, focusing on a broad range of topics: stem cells, epigenetics, cellular and developmental biology, genomics, cancer, systems biology, to name a few. Researchers receive strong support by cutting-edge technological platforms. Over 200 publications in high quality journals are published every year, and researchers are also active in facilitating the transfer of new basic findings into products for society. The CRG is devoted to excellent training at all the stages of a career in life sciences. The CRG advanced training programme embraces training-through-research, hands-on and theoretical courses, conferences and seminars with leading guest speakers and internal data and journal clubs, to empower researchers with new skills, knowledge and abilities. The CRG also runs a successful international PhD and Postdoctoral Programme, as well as a Summer Internship Programme.
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