Organism diversity: Fast-evolving genes control developmental differences in social insects

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Social insects exhibit a sophisticated social structure in which queens reproduce and workers engage in tasks related to brood-rearing and colony defense. By investigating the evolution of genes associated with castes, sexes and developmental stages of the fire ant *Solenopsis invicta*, researchers at Georgia Tech and the University of Lausanne explored how social insects produce such a diversity of form and function from genetically similar individuals. Credit: Georgia Tech/Eric A. Hoffman and Michael A. D. Goodisman

Genes essential to producing the developmental differences displayed by social insects evolve more rapidly than genes governing other aspects of organismal function, a new study has found.

All species of life are able to develop in different ways by varying the genes they express, ultimately becoming different shapes, sizes, colors

and sexes. This plasticity permits organisms to operate successfully in their environments. A new study of the genomes of social insects provides insight into the evolution of the genes involved in this developmental plasticity.

The study, which was conducted by researchers at the Georgia Institute of Technology and the University of Lausanne in Switzerland, showed that genes involved in creating different sexes, life stages and castes of fire ants and honeybees evolved more rapidly than genes not involved in these developmental processes. The researchers also found that these fast-evolving genes exhibited elevated rates of evolution even before they were recruited to produce diverse forms of an organism.

A study conducted by researchers at the Georgia Institute of Technology and the University of Lausanne showed that genes involved in creating developmental differences in honeybees and fire ants -- such as the caste system shown here by a queen and worker fire ant -- evolved more rapidly than genes not involved in these developmental processes. Credit: Georgia Tech/Eric A. Hoffman and Michael A. D. Goodisman

"This was a totally unexpected finding because most theory suggested that genes involved in producing diverse forms of an organism would evolve rapidly specifically because they generated developmental differences," said Michael Goodisman, an associate professor in the School of Biology at Georgia Tech. "Instead, this study suggests that fast-evolving genes are actually predisposed to generating new developmental forms."

The results of the study will be published in the Sept. 20, 2011 issue of the journal Proceedings of the National Academy of Sciences. This research was supported by the National Science Foundation.

The project was an international collaboration between Goodisman, associate professor Soojin Yi and postdoctoral fellow Brendan Hunt from the Georgia Tech School of Biology, and professor Laurent Keller, research scientist DeWayne Shoemaker, and postdoctoral fellows Lino Ometto and Yannick Wurm from the Department of Ecology and Evolution at the University of Lausanne.

Social insects exhibit a sophisticated social structure in which queens reproduce and workers engage in tasks related to brood-rearing and colony defense. By investigating the evolution of genes associated with castes, sexes and developmental stages of the invasive fire ant Solenopsis invicta, the researchers explored how social insects produce such a diversity of form and function from genetically similar individuals.

"Social insects provided the perfect test subjects because they can develop into such dramatically different forms," said Goodisman.

Microarray analyses revealed that many fire ant genes were regulated differently depending on whether the fire ant was male or female, queen or worker, and pupal or adult. These differentially expressed genes exhibited elevated rates of evolution, as predicted. In addition, genes that

were differentially expressed in multiple contexts -- castes, sexes or developmental stages -- tended to evolve more rapidly than genes that were differentially expressed in only a single context.

A new study shows that genes involved in creating developmental differences in fire ants evolved more rapidly than genes not involved in these processes. Shown here are fire ants of different castes, sexes and life stages: (top-bottom) worker, male and queen fire ants; (left-right) adult and pupal fire ants. Credit: Georgia Tech/Eric A. Hoffman and Michael A. D. Goodisman

To examine when the genes with elevated rates of evolution began to evolve rapidly, the researchers compared the rate of evolution of genes associated with the production of castes in the fire ant with the same genes in a wasp that does not have a caste system. They found that the genes were rapidly evolving in the genomes of both species, even though only one produced a caste system. These results were also replicated for the honeybee Apis mellifera.

"This is one the most comprehensive studies of the evolution of genes

involved in producing developmental differences," Goodisman noted.

This study helps explain the fundamental evolutionary processes that allow organisms to develop different adaptive forms. Future research will include determining what these fast-evolving genes do and how they're involved in the production of different sexes, life stages and castes, said Goodisman.

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