Scientists reveal one of the secrets of nature for which there is no apparent explanation

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Research news

An international team of scientists, led by the Andalusian Earth Sciences Institute (CSIC-UGR), shows that Australian stingless bees produce their honeycombs by following complex patterns, yet they have no prior plan, nor do they coordinate with the other worker bees

This is a beautiful example of the applicability of mathematics to nature: bees build their honeycombs following the same mathematical rules as atoms or molecules attaching to a crystal

An international team of scientists, led by the Andalusian Institute of Earth Sciences (IACT, a mixed centre of the Spanish Higher Council for Scientific Research/ CSIC and the University of Granada), has revealed for the first time one of nature's best-kept secrets: the mathematical patterns followed by bees in order to make such perfect honeycombs.

The researchers, who have published their results in the Journal of the Royal Society Interface, demonstrated, in a beautiful example of the applicability of mathematics to nature, that Australian stingless bees (Tetragonula carbonaria, endemic to that continent) build their combs following complex patterns without any planning and with no overall coordination with the other worker bees.

The study concludes that bees produce their combs following the same mathematical rules as atoms or molecules attaching to a crystal. Thus, the honeycombs form the same terraced patterns that are observed in minerals, such as in the mother-of-pearl produced by molluscs.

“Tetragonula carbonaria honeycombs present surprising patterns that can be spirals, double spirals, or in a bull’s-eye-like formation,” explain **Bruno Escribano Salazar and Antonio J. Osuna Mascaró**, two of the IACT researchers who participated in this study. Until now, it was only known that worker bees build hives by adding new cells at the end of each layer or terrace of the honeycomb, but there was no convincing explanation as to how these Australian bees are able to form such complex patterns. “It was originally thought that some kind of coordination and communication between workers would be necessary, possibly through chemical signals,” they add.

No master plan

Now, in this study led by the UGR (in which scientists from the University of Cambridge and the University of Veterinary Medicine, Vienna, collaborated), a mathematical model has been developed that explains how bees produce these patterns without the need for any master plan or overall coordination.

By examining the structures and order that emerge in the combs, the researchers have identified a model of minimal complexity in which each individual worker bee only needs the minimal information about its closest environment to contribute to the structure, without the need for group coordination or superior intelligence. The patterns observed by the scientists are, therefore, an emergent phenomenon resulting from the localised behavior of the workers.

The researchers have simplified the model to just two parameters: (R) the typical size of the bee and (α) a random term related to the variability in the honeycomb cells. By modifying these parameters, the model is able to generate all the patterns observed in the honeycombs.

The recent discoveries regarding the cognition of bees and bumblebees are astonishing. “We know that bumblebees learn by watching others; that the behaviour of bees is affected by their emotional states, and that they can even respond to concepts such as ‘the same’ and ‘different’”, explain the authors. “There is also evidence of intelligence when building their honeycombs: they resolve occasional construction problems and they do it in a flexible way that suggests they are not acting solely on instinct.”

‘Inflexible’ behaviours

But, as is well known, they also have a series of simple, ‘inflexible’, and innate behaviours that enable the hive to function. In bee colonies, these innate behaviours form part of a phenomenon known as stigmergy, in which complex results can be achieved through the simple actions of many individuals, without the need for any planning between them.

“Bees coordinate their actions by modifying their environment, they do not need a master plan … in this case, they do not even need to communicate!” the researchers observe. All they have to do is modify their environment locally, and self-organisation emerges almost out of nowhere. “The structures that we describe here are the result of an emerging phenomenon, it is not a plan but the outcome of simple accumulated actions,” they explain.

The researchers had previously applied the same model to crystal growth on a microscopic scale, albeit with some differences in its parameters (https://www.pnas.org/content/106/26/10499). Yet, although both systems are very different, the same patterns emerged as a result of the same rules of self-organisation.

UGR researchers Bruno Escribano Salazar and Antonio J. Osuna Mascaró.

Bibliography:

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