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How ants self-organize to build their nests

Ants collectively build nests whose size can reach several thousand times that of individual ants and whose architecture is sometimes highly complex. However, their ability to coordinate several thousand individuals when building their nests remains a mystery. To understand the mechanisms involved in this process, researchers from CNRS, Université Toulouse III – Paul Sabatier and Université de Nantes[1] combined behavioral analysis, 3D imaging and computational modeling techniques. Their work shows that ants self-organize by interacting with the structures they build thanks to the addition of a pheromone to their building material. This chemical signal controls their building activity locally and determines the shape of the nest. Its breakdown over time and due to environmental conditions also enables the ants to adapt the shape of their nests. This work is published in *PNAS* on 18 January 2016.

The nest of black garden ants, *Lasius niger*, consists of an underground part made up of a network of galleries, and a mound of earth composed of a large number of bubble-shaped chambers closely interconnected with each other. Using 3D imaging techniques such as X-ray tomography[2] and a 3D scanner, the researchers characterized the 3D structures made by the ants as well as the construction dynamics. In addition, they analyzed the individual building behavior of the ants.

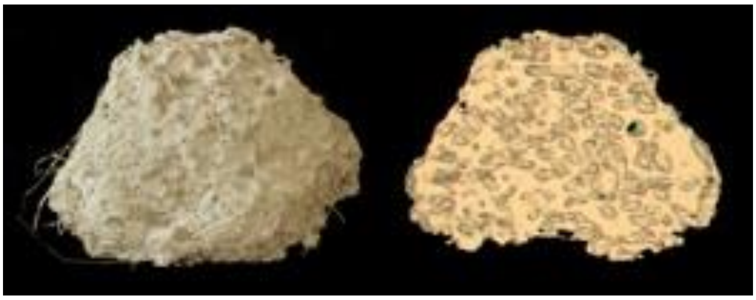
In the part located above ground, the insects pile up their building materials forming pillars that encircle the chambers. The ants preferentially deposit their soil pellets in areas where other clusters of pellets have already been created. They add a pheromone to their material, which stimulates the other ants to build on the same spot, leading to the formation of regularly spaced pillars. When the columns reach a height equal to the average body-length of an ant, the workers build caps on top of the pillars. They use their body size as a template to determine when they should stop building vertically and begin to deposit pellets laterally. The ants thus use two types of indirect interactions in order to build complex architectures.

In addition, the pheromone breaks down over time at a rate that depends on climate conditions, which enables construction to adapt to the environment. For instance, in a dry environment the amount of pheromone rapidly decreases and so fewer pillars are built. The chambers are

[1] *at the Centre de Recherches sur la Cognition Animale (CNRS/Université Toulouse III – Paul Sabatier) and the Laboratoire d'Informatique de Nantes Atlantique (CNRS/Université de Nantes/Ecole des Mines de Nantes).*
[2] *X-ray tomography is a non-destructive imaging technique that can be used to reconstruct the shape of an object in 3D by assembling virtual slices.*

therefore larger, which enables the ants to cluster there in order to preserve what little humidity there is. On the other hand, in a humid environment, the pheromone persists for a longer time, which leads to a greater number of pillars and to smaller chambers.

The researchers then developed a 3D mathematical model of nest construction, obtained by analyzing the individual behavior of the ants. The model shows that the two types of indirect interactions used by the ants to coordinate their activity faithfully reproduce the construction dynamics and the structures built during the experiments. It also highlights the key role played by the building pheromone in the growth dynamics and shapes of the nests.



Nest of the black garden ant,* Lasius niger*, whose colonies comprise around five to fifteen thousand individuals. *Left, epigeous part. Right, X-ray tomography image showing the internal structure made up of a large number of bubble-shaped chambers closely interlinked with each other.*

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Worker ants of the species* Lasius niger *moving over the structures resulting from their building activity. *The soil pellets that the ants make and then assemble to build their nest can be clearly made out.*

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Regularly spaced pillars and walls built under experimental conditions by groups of 500 ants of the species* Lasius niger*.

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Reference

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Contacts

CNRS scientist I Guy Théraulaz **I T +33 (0)5 61 55 67 32 I** guy.theraulaz@univ-tlse3.fr
CNRS press office I Véronique Etienne **I T +33 (0)1 44 96 51 37 I** veronique.etienne@cnrs-dir.fr