Micro-CT as a tool for investigating the dynamics of ant nest excavation

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Aims

The nests of social insects, including ant nests, are examples of complex three-dimensional structures, the relative scale of which are rivaled only by the structures produced by humans (1-3). However, unlike our own buildings with blueprints and an architect, there is no knowledge of the overall plan at the individual level and the structure of a nest is an emergent property of self-organization, produced by individuals acting on local information through interactions with other individuals and the environment (1, 4-8). The variety and seemingly complex architectures of ant nests have been suggested to be species-specific (9-13). It is equally possible, however, that different species of ants follow the same behavioural rules and the different nest architectures that are observed are a by-product of features within the environment.

The extent to which the variation in ant nest excavation and nest morphology is explained by behavioural or environmental differences is as yet unknown. Previous investigations on ant nest excavation dynamics have largely involved two-dimensional scenarios (8, 14). Micro-CT scanning provides an unparalleled technique for being able to investigate the three dimensional growth of ant nests and other biological structures. We used micro-CT scanning to record the first high-resolution, non-destructive, time series data on the excavation of individual ant nests and to test the hypothesis that the architecture of the nest is influenced by the distribution of bedding planes in the sediment.

Methods

We collected six colonies of the yellow meadow ant, *Lasius flavus*, from Wiltshire, UK. Each colony was subdivided into ten sub-colonies consisting of 100 workers and 25 brood items. For each of the six colony replicates, three sub-colonies were used to excavate nests under three experimental treatments whilst the remaining seven sub-colonies formed the controls. The three experimental treatments consisted of: (1) ants excavating nests in containers with un-layered sediment, (2) containers with three layers of sediment, and (3) containers with five layers of sediment. The controls were in containers with un-layered sediment. Each experimental treatment nest was scanned in a SkyScan 1172 micro-CT scanner at intervals of 3, 6, 9, 12, 18, 24, 36 and 48 hours after excavation began. The seven controls were scanned once each at 6, 9, 12, 18, 24, 36 or 48 hours to test that there was no adverse effect of repeated scanning in the un-layered experimental treatment nest compared to the controls. The resulting scans were processed with CTAn in order to produce three-dimensional reconstructions. Changes in volume of the nest over time were quantified and correlations between the distribution of excavated volume and the position of planes between layers of sediment were investigated.

Results

Preliminary analysis of the results demonstrate the existence of common elements in nest excavation, with three to five tunnels orientated diagonally in the vertical plane being initiated during the early stages of excavation. Horizontal tunnels and expansions are also found and correspond to the position of some of the horizontal planes between the layers of sediment (Figure 1).

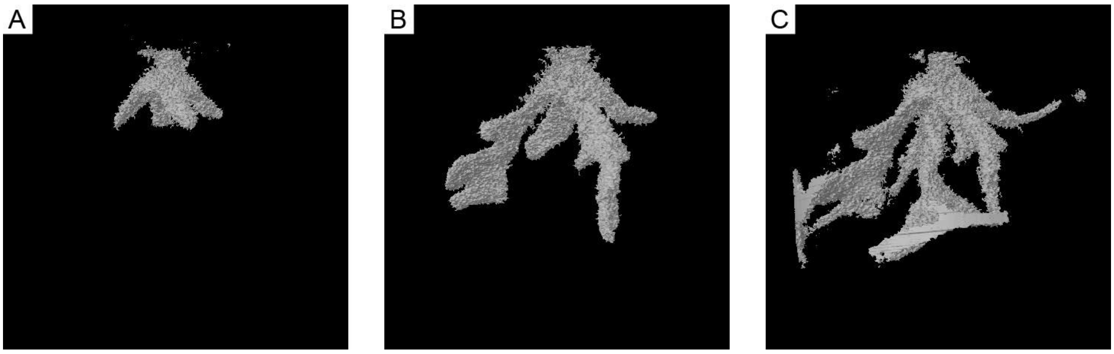

Figure 1: Three-dimensional reconstructions of the nest of *Lasius flavus* sub-colony D-3L excavating in a container with three layers of sediment. (A) 9 hours after excavation began. (B) 18 hours after excavation began. (C) 48 hours after excavation began. Nest produced in 50 mm depth of sediment in a container with an internal diameter of 63 mm.

Conclusions

This study uses micro-CT scanning to provide the first detailed insights into the three-dimensional growth and architecture of ant nests. The results demonstrate how aspects of the sediment can influence the form of the structures produced by animal activities. It also highlights and opens up the novel application of CT-scanning for studying the growth of other biological structures such as plant roots. The results will contribute to the formulation of a general model for complex structure formation that will have applications to other areas of biology, as well as areas of engineering such as computing, transport, and online social networks.

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