et al.[4] present an example of such a process in social insects. Their careful experimentation has revealed how the behaviour of individual workers of the ant *Messor sancta* produces spatial patterns in a colony's disposal of corpses — the so-called ant cemeteries.

In the first series of Theraulaz and colleagues' experiments, the ants had access to a circular arena in which ant corpses were homogeneously distributed along the perimeter. The ants had a strong tendency to follow the wall of the arena — so this is effectively a one-dimensional situation, which facilitates mathematical analysis of the process. The authors monitored the formation of clusters of dead ants and the dynamics of their spatial distribution. The result that emerged was puzzling. Instead of quickly choosing one or a few fixed locations for piles of corpses, the ants formed many clusters, some of which grew while others disappeared after some effort had already been made to build them. The number of clusters first grew, reaching a maximum after three hours. Later it decreased and remained constant when a stable spatial pattern was finally established. Subsequent experiments were performed to estimate the parameters of individual ant behaviour, such as the probabilities that a given ant would pick up or drop a corpse, or would make a U-turn while carrying a corpse along the perimeter. For this purpose the authors manipulated cluster size.

The observations indicate that a mechanism of short-range activation and long-range inhibition is at work. The activation would consist of a behavioural tendency to drop corpses with a probability that increases with the density of corpses in the immediate neighbourhood. This mechanism leads to local amplification of corpse density, unless it is overridden by the inhibitory process. Inhibition occurs through the ants' tendency to pick up corpses and carry them for considerable distances, leading to the long-range depletion of the clusters.

Theraulaz *et al.* developed a mathematical model for the process of ant cemetery construction. This model is similar to one by Gierer and Meinhardt[2] that has been applied to seashell pattern formation[3]. The ant cemetery model explained not only the final formation of a stable distribution of large piles but also the intermediate occurrence of clusters that then disappear. For the dynamics of how the average number of clusters changes with time and when its maximum is reached, the model predictions were in close agreement with the experiments. Furthermore, as the inhibition–activation structure of the model suggests, cluster formation did not occur if the initial density of corpses was too low. Results such as these show that pattern formation can be understood at a deep level and that the behavioural mechanisms behind it are very simple.

What general insights do we gain about the ants? Given that their behaviour followed the mathematical model so closely, it seems as though they have no mental concept of the large-scale process in which they participate. When they move corpses in the cemetery, their actions are guided mainly by aspects of the local temporal and spatial environment, and possibly by chance, but not by foresight and planning. One could then say that the structures simply appear as a by-product of the ants' shortsighted way of dealing with corpses. Would this be adaptive in the evolutionary sense? At first glance the ants seem to act inefficiently. But it might well be a better use of a small brain not to attempt to be an excellent architect. The robustness of the procedure that structures the cemetery could outweigh a certain waste of time and energy.

Ants in the wild do not have access to a circular arena, but the same mechanisms that lead to periodic patterns in the arena are likely to be operating. The structures of the natural cemeteries of *M. sancta* have not been studied systematically, so it is not known whether they sometimes consist of several piles or whether the ants' behavioural mechanisms usually produce a single pile. Nevertheless, the experiments with the circular arena reveal how simple mechanisms can act to create structure in a controlled and simple world for which it is easy to compare theoretical and empirical findings.

This is notable because the results reported by Theraulaz *et al.*[4] are likely to have parallels in other collective processes. For instance, decisions in morphogenesis are made by cells, which are difficult to envisage in the role of architects. Organisms and 'superorganisms' of social insects thus share a problem, so ants might teach us valuable lessons about morphogenesis. The potential of this analogy was recognized 25 years ago by Deneubourg[5]. We now know that various cases of patterns on seashells[3] and the formation of piles in ant cemeteries might be explained by similar underlying principles. These principles exemplify the basic conceptual model of activation and inhibition that Gierer and Meinhardt[2] created to make Turing's[1] abstract ideas about morphogenesis amenable to observation and experiment. The ants may indeed be on a Turing trail. ■

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NATURE

100 YEARS AGO

A few examples of the practical application of scientific education in Germany are given in the *Journal* of the Society of Arts. The sugar industry is the first illustration of the progress of industry through science. In 1840, 154,000 tons of beetroot were crushed, from which 8000 tons of raw sugar were produced, showing about $5\frac{1}{2}$ per cent. of raw sugar extracted from the root. Twenty years later, 1,500,000 tons were treated which produced 128,000 tons of sugar, or about 8 per cent. Last year about 12,000,000 tons were crushed, which produced 1,500,000 tons of raw sugar, raising the percentage to 13. This advance is due entirely to scientific treatment. The production of dry colours, chemicals and dyes in Germany shows a corresponding increase in production and dividend-paying capacity... A great advance has also been made in the scientific instrument industry. The value of the exports from Germany of scientific instruments in the year 1898 was about 250,000*l.* — three times what it was in 1888 — and the work gave employment to 14,000 people.

From *Nature* 10 July 1902.

50 YEARS AGO

***The Mitotic Cycle.* By Dr. Arthur Hughes. It is rightly emphasized on the dust-cover of this valuable monograph that the process of cell division presents one of the most difficult problems the experimental biologist has yet attempted to solve, and if this present account of the mitotic cycle is not an easily flowing and well-balanced narrative, the reflexion is not on the author but on the present state of our knowledge of the subject. There is a large and widely scattered literature of unequal relevance and of uneven quality. The lines of advance have been largely dictated by considerations of the materials and techniques available, and a strong medical bias is also evident. Thus we now have an extensive knowledge of the early cleavage of a certain few eggs, of the growth in culture media of a certain few tissues, of the methods of induction of cancerous growths, and of the methods of mitotic inhibition by a multitude of diverse substances. The obvious questions posed by the mitotic activity of normal animal and plant tissues have been almost entirely neglected, although very recently a start has been made towards their solution.**

From *Nature* 12 July 1952.