Fossil record

Magnetic skeletons in Davy Jones' locker

from Richard B. Frankel

MANY fossils of ancient plants and animals are embedded in sedimentary deposits but, by comparison, the fossil record for bacteria is sparse. Now, however, Petersen *et al.* on page 611 of this issue[1] and Stolz *et al.*[2] present evidence that magnetotactic bacterial microfossils litter the deep ocean sediments.

Various species of magnetotactic bacteria inhabit freshwater and marine sediments throughout the world[3]. Magnetotaxis (orientation and migration along geomagnetic field lines) is based on magnetosomes, chains of membrane-enclosed magnetite (Fe_3O_4) particles in cells. The chain of magnetosomes imparts a permanent magnetic dipole moment of the order of 10^{-12} electromagnetic units to each cell, sufficient for it to be passively oriented in the geomagnetic field at ambient temperatures. Thus magnetotactic bacteria are self-propelled magnetic compasses — as E.M. Purcell once remarked, "this is a case of the compass steering the ship."

Magnetosomes and their arrangement in the cell are a masterpiece of permanent magnet design[4]. First, magnetosomes have a narrow size distribution, typically 400–1,000 Å, which is in the permanent, single magnetic size range for Fe_3O_4. They are too small to lower their magnetostatic energy by forming magnetic domains, yet are too large to be superparamagnetic, that is, for thermally activated relaxation of their magnetic dipole moments. Second, dipole–dipole interactions between the magnetosomes in a chain cause the individual particle moments to orient parallel to each other along the chain direction. Thus the whole magnetosome chain is an elongated, permanent, single magnetic domain.

The single magnetic domain properties of the magnetosome chains can persist in sediments as magnetic microfossils after the bacteria die, making a substantial contribution to the remanent magnetization of the sediments. In their new study, Petersen *et al.*[1] report fossil magnetosome chains in deep-ocean sediments from the South Atlantic dating from 5 to 50 million years ago. The identification is primarily based on the narrow size distributions, shapes and arrangements of the magnetite particles extracted from the sediments. Magnetotactic bacteria are known to produce magnetosomes with diverse, species-specific morphologies[3,5,6] which can be distinguished from nonbiogenic magnetite. In a related paper, Stolz *et al.*[2] report living magnetotactic bacteria and magnetosome chains in the upper layers of deep-sea sediments from the Santa Barbara basin. Blakemore[7] and Kirschvink and Chang[8] previously reported magnetosome-shaped particles in sediments, but Petersen *et al.* and Stolz *et al.* now claim that magnetosomes are the primary carrier of stable magnetic remanence in deep-sea sediments.

How far back in the geological record might one expect to find magnetic microfossils? Magnetotactic bacteria are microaerophiles, requiring trace amounts of molecular oxygen for magnetosome formation[9]. Thus they currently inhabit the relatively restricted microaerobic zone in sediments. Blakemore *et al.*[9] argue that originally magnetosome formation would have been possible only in microhabitats such as algal mats where O_2 was being produced. However, as free O_2 began to accumulate in the global atmosphere about 2×10^9 years ago, the Earth's surface would have been microaerobic by today's standards and microaerophiles, including magnetotactic bacteria, might have been the most prevalent organisms. Thus they may have played a major part in the deposition of iron-rich minerals including magnetite in the widespread banded iron formations that accumulated at that time. □

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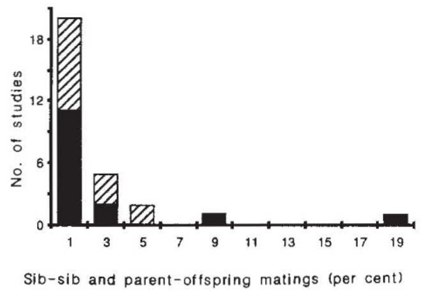
Inbreeding

Do animals avoid incest?

from Paul H. Harvey and Katherine Ralls

SEVEN years ago in these columns, Robert M. May wrote a prophetic article entitled "When to be incestuous"[1]. He reviewed the then current literature on inbreeding depression and inbreeding avoidance in human and other animal populations. He went on to develop a model that estimated the likely costs of mating with relatives of differing degree. But the connections between model and data were tenuous, and May argued that "piece after piece can too easily be added to build an enchanting castle that rises free, constrained to earth with too few anchorlines of fact". He concluded with a plea for more data on kinship structure and other relevant variables from natural populations. Simply because of the lack of data, several unresolved arguments have since appeared in the literature about the importance of inbreeding avoidance as a force influencing mating patterns in natural populations of vertebrates. Various new studies provide the data to answer some of these questions.



Frequency of inbreeding in natural populations of birds (▬) and mammals (▨)[2].

How common is incest? If we define incest as matings between parents and their offspring or between siblings, then a review of many long-term field studies of birds and mammals reveals that incestuous matings are usually less than 2 per cent of the total[2] (see figure). This compilation refutes one claim[3] that "Relatively high frequencies (10 – 100 per cent of matings) of parent – offspring or full sibling incest have... been documented in natural populations of... various vertebrates". The six studies of birds and mammals that were cited in support of the statement either show a frequency of less than 10 per cent or contain no relevant data at all. The only reported study with a frequency of incestuous matings in the 10–100 per cent range is of 19.4 per cent in a population of the cooperatively breeding splendid wren (*Malurus splendens*)[2].

Knowledge of the frequency of incestuous matings is of limited use because we do not know the frequency that would be expected if such matings are not avoided. For example, in most species of birds and mammals, males and females move different distances from their birthplace to their breeding site[4]. Consequently, matings between siblings become less likely. Are