

environmental factors) [10,16]. Near-neutrality might arise when stabilizing forces are relatively weak, and equalizing forces are strong, and is likely to be more pertinent to some taxa and environmental settings, than to others.

Despite this caveat, these recent papers point to an emerging reconciliation of niche and neutral perspectives in community ecology. Ecologists should now systematically explore these issues across a wide array of community models and, perhaps more importantly, devise critical experimental tests of these ideas. For instance, in microbial communities, ecological and evolutionary dynamics occur on a manageable timescale; the quasi-species that are observed in viral evolution are not dissimilar from the clusters of species that emerge in the models of Scheffer and Nes [7] and Bonsall *et al.* [14], and so these systems might provide empirical tests of these theories. In field systems, if patterns of relative abundance are due to drift, then perturbations that change the initial patterns of relative abundances (without causing extinctions) should tend to persist, rather than rapidly returning to the initial state of the community.

Niche and neutral perspectives have quite different implications for how one should manage natural resources and craft conservation strategies. A unified theory of communities that judiciously blends both perspectives is needed if ecologists are to understand the processes governing biodiversity at a fundamental level and then apply this understanding to the urgent problem of maintaining diversity in our rapidly changing world.

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Letters

Muscling out malaria

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Recent updates in *Trends in Parasitology* [1] and *Trends in Ecology and Evolution* [2] highlighted the back-to-back articles in *Science* [3,4] that demonstrated the potential biocontrol of malaria by targeting mosquitoes with entomopathogenic fungi (*Metarhizium* and *Beauveria* spp.). The wide impact of the original articles and the need to find alternatives to pesticidal control are likely to encourage the incorporation of these fungi into biocontrol programs, although several concerns have been raised [1,2,5]. Here, we detail some of these and advocate an inclusive

approach to malarial biocontrol that proceeds with a full appreciation of the complicated biology of the pathogenic fungi concerned.

There is a long history of using *Metarhizium* and *Beauveria* in insect biocontrol [6] with ‘Green Muscle’, a broad consortium set up to control locusts using *Metarhizium*, as an excellent example (for more information, see <http://www.lubilosa.org>). Green Muscle developed from the initial conception that spores could be suspended in oil to facilitate germination in arid regions [7], which made infecting mosquitoes feasible [4]. However, failures in biocontrol have been more common than successes and are often due to the ‘ephemeral and amateurish activities’

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[6] of biologists failing to appreciate the complexity of the task at hand. Such damning assessments by mycologists are not new (Petch, 1925 cited in [6]) and reflect, in particular, a lack of attention to the basic biology of the fungal biocontrol agents (Harry Evans, pers. commun.).

The *Science* papers did pay attention to the biology of *Metarhizium* [8], which is understandable given that a senior author of one (Matt Thomas) participated in Green Muscle [9], which should now, ideally, serve as model for developing a commercial mycopesticide against *Anopheles* mosquitoes. However, the Green Muscle programme took ten years to develop a product and had a total price tag of ~US\$15 million [10], thus it could be tempting to be less rigorous this time around. Given the sensitive political situation in many areas where malaria is endemic, humanity cannot afford shortcuts, because any failures owing to poor management or premature implementation will reduce local governmental support rather than enhance it (Andrew Read, pers. commun.). Therefore, if we are to 'muscle out malaria', well-coordinated interdisciplinary approaches are necessary and basic mycological research will have to be a key component of these joint efforts.

Both in the original papers, popular media and the *Trends* updates, much was made of an apparent lack of resistance. However, it is premature to award 'silver bullet' status to these pathogens, as this notion is based mainly on studies in temperate and depauperate agricultural ecosystems. Recent experiments showed that significant variation for resistance against *Metarhizium anisopliae* exists in leafcutter ants that are not known to suffer much from this pathogen in the field [11]. In addition, suggestive examples of behavioural resistance [12] add to these concerns because avoidance of fungal-treated sites by locusts occurred during the development of Green Muscle and is apparently strain specific (Harry Evans, pers. commun.). Knowing how insects recognise fungal spores is clearly of key importance, and the new focus on fungal biocontrol of malaria should therefore act as a catalyst for further research on the basic biology of fungal pathogens.

Understanding morphological, biochemical or immune system-based resistance to insect pathogenic fungi will be easier if we know their biology in ancestral habitats. *Metarhizium* and *Beauveria* spp. evolved in Southeast Asian rainforests, escaping to become specialised associates of agricultural systems*. Insects killed by these two fungal diseases are extremely rare in tropical rainforests, but when they are found they display host specificity (Nigel Hywel-Jones, unpublished data); consistent with a large variety of fungal strains that can be isolated from tropical soil samples [13]. Again, the contrast with 'common knowledge' from temperate agricultural systems is striking, which underscores the need for coordinated biodiversity surveying as part of interdisciplinary programs, comparable to expeditions organised by the British Mycological Society (<http://www.britmycolsoc.org.uk> [14]).

Finally, both *Metarhizium* and *Beauveria* are 'anamorphic' asexual states of fungi that are confusingly known as *Cordyceps* when they express their 'teleomorphic' sexual state. *Cordyceps* is common in rainforests and might regulate insect populations [6]. The nature of sexual spore transmission in rainforest environments means that behavioural avoidance by insects is more difficult. Therefore, immune system-based resistance in insects might have evolved towards *Cordyceps* and, given that *Metarhizium* and *Beauveria* are genetically identical to *Cordyceps*, this would be important when considering the potential evolution of resistance in mosquitoes.

In conclusion, we agree that insect pathogenic fungi such *Metarhizium* could well become important for the future control of malaria, but the road towards muscling out malaria in a sustainable way will be narrow, winding and littered with obstacles that only integrated research with major mycological components can remove [8].

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