Evolution of suicidal signals

Mike Speed and Graeme D. Ruxton

To deter predators, some organisms have evolved protective mechanisms and warning colorations. Innovative mathematical modelling shows how the first animals with these signals might have managed to survive.

Many animals have warning coloration to show that they are best avoided by predators. How such signals initially evolve is a mystery that has entertained biologists for some years. Thomas Sherratt, writing in *Proceedings of the Royal Society*[1], has provided a new and plausible way of tackling the matter.

Almost all elementary textbooks in behavioural ecology present the idea that an animal with a good anti-predator defence should advertise its unprofitability, in order to escape the costs of attacks by predators that have learned (through previous unpleasant experiences) to link the warning signal to unpalatability. This is the explanation for the existence of the conspicuous colorations in toxic or spiky insects (Fig. 1), in venomous snakes and frogs, and perhaps even in some birds[2].

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Figure 1 **Unpalatable advantage. Many insects, such as this sharp-spined *Hyalophora cecropia* caterpillar, defend themselves against attack — and make that clear to predators through conspicuous colouring.**

Dig a little deeper, however, and we uncover a famous evolutionary quandary[3–5]. A warning signal provides protection from predators that have learned to avoid such individuals, but that same signal is likely to make its bearer more obvious to those 'naive' predators that have yet to learn. Possessing a warning signal makes sense if the signal is common, because the cost of educating naive predators is shared among many individuals. But when they originate, new warning signals will be rare and, it seems, their owners should be rapidly snuffed out by naive predators. So the initial evolution of warning signals — making seemingly 'suicidal prey' — presents a serious challenge for evolutionary biology.

Sherratt proposes a mathematical model that allows predators to co-evolve with their prey. Although there have been many attempts to model the evolution of warning signals in the past, this latest attempt is fundamentally different in that it explicitly acknowledges that the decisions made by one predator can help other predators decide which prey are worth attacking and which should be avoided. Sherratt envisages a situation with prey that vary in both their palatability and their conspicuousness. These assumptions match our observations of the world around us, and are essential for his model to work well. If edible prey have lower chances of surviving an attack by a predator than 'defended' individuals, predators will act to filter out the edible prey. When predators act as filters in this way, they soon remove the conspicuous edible individuals, leaving a world in which conspicuous prey are reliably defended and unprofitable to eat, and less obvious prey are mainly edible. After each round of filtering, conspicuousness becomes an increasingly good predictor of unprofitability; in response to this, predators evolve greater wariness of conspicuous prey.

Other researchers[4] have proposed that conspicuousness and predator wariness might become entwined in a runaway co-evolutionary process. But Sherratt formally shows that such a process can indeed occur — one in which, as conspicuousness becomes an increasingly reliable signal of unprofitability, more predators will increase their wariness of novel, detectable prey. So it becomes easier for a diversity of conspicuous warning signals to evolve and populate the world.

An intriguing feature of Sherratt's model is that various sets of circumstances can produce an evolutionarily stable combination of predatory strategies, in which some predators attack novel prey, some attack with caution (treating conspicuousness as a 'go slow' signal[6]) and others do not attack at all. This feature of the model may explain the surprising demonstration[7] that wild birds in the same breeding population can show huge variability in their willingness to sample and incorporate new types of prey into their diets.

Have we at last got an explanation for the paradoxical evolution of suicidal prey? The answer seems to be 'yes and no'. Sherratt has provided a highly stimulating view of the evolution of warning signals, but at the same time he has opened up some quite profound questions about the conditions that precede these signals. Is the correct starting point from which to consider the co-evolution of predators and prey a world in which defended and edible prey come in a wide diversity of forms (as Sherratt assumes in this model)? Or is it one that is overwhelmingly and monotonously drab, with some conspicuous mutants arising only rarely? If the second possibility is more likely, then further work will have to explore whether Sherratt's co-evolution theory produces the same result from this quite different starting place. Finally, we still need to explain why there was a bank of toxic, well-defended, inconspicuous prey from which individuals with warning coloration could arise in the first place. After all, common sense suggests that, to be worth the cost, toxicity needs to be advertised. ■

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