<u>Toxic teamwork and the Müllerian mimicry mystery</u>

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A bird scans a forest clearing for prey, its sharp beady eyes searching for the smallest sign of movement. A bright orange butterfly flutters into view, a contrast from the dull browns of the insects that try to remain unseen. Seeing an easy meal, the bird swoops in, giving chase. Eventually triumphant, it brings the limp body of its prey to a nearby branch to take its first bite, only to be overwhelmed by an acrid, bitter taste – poison. The predator stops eating and reflects on its mistake. It attacked several butterflies with that wing pattern recently, and each one was inedible and not worth the energy spent catching. Perhaps, the predator decides, it will start avoiding this prey in future.

Poisons and other noxious or foul tasting chemical defences are no rarity in nature, but this is not a story about those. There is a twist to this tale – without knowing it, the predator had been feeding on two completely different poisonous species all along.

<u>The imitation game</u>

"Natural Selection explains almost everything in Nature, but there is one class of phenomena I cannot bring under it,—the repetition of the forms and colours of animals in distinct groups, but the two always occurring in the same country and generally on the very same spot" – letter by Alfred Russel Wallace to Charles Darwin, 1860.

Being an insect is tough. Competition for scarce food, plants that resist being eaten, and of course, predators. The threat posed by predators is evident in the vast range of different approaches to antipredator adaptations found in insects. Hiding, camouflage, flight, fighting back, mass simultaneous hatching, or distasteful/toxic chemicals to discourage attack, to name a few. Naturally, some species try to get a free ride on poisonous species by imitating them, without producing any defences of their own. Predators mistake them for something they'd rather not attack, and give them a wide berth. This scenario of the harmless imitating the poisonous, so-called "Batesian mimicry" (after its discoverer, Henry Walter Bates) is intuitive, and easy to understand. Why though, would a poisonous species want to copy another?

This was the question that came into the mind of the German naturalist Fritz Müller as he observed *Heliconius*, *Ituna*, and *Thyridia* butterflies flying together in Brazil. All shared the same wing pattern and were known to be toxic – indeed, Müller noted that these species were flying out in the open and were undisturbed by predators. To find the answer to this puzzle, we need to see the world through a predator's eyes.

<u>Entering the mind of a predator</u>

No predator is born knowing which prey make the best meals, and which to avoid. Instead, they learn from experience as they go along. As a result, a predator needs to eat several poisonous individuals before it is sufficiently "educated" to avoid that prey. Well-defended prey use bright and distinctive colours to aid predator learning, aiding their distinction from other prey.

Because of predator learning, poisons and bright warning colours are not a free pass to total immunity from predators. To reap the benefits of their defences, the prey first have to educate the predator, which still costs lives. These species lose much fewer individuals to predators than other, edible species, but these losses are still an issue. Naturally, species have tried to reduce this burden further.

A problem shared is a problem halved

Another way of looking at the above problem would be to see that the cost of predator education is always more or less fixed. It doesn't matter how big or small the prey population is – each predator has to "sample" a fixed number of prey (every so often) to learn to avoid it. The larger the prey population becomes, the smaller this fixed cost becomes as a fraction of the total population. Thus, the per-individual chance of being eaten by an uneducated predator goes down the more fellow prey there are. It's safety in numbers! What better way to bolster your effective population size than by joining forces with another species? By converging on the same wing pattern or other warning signal, two species can become indistinguishable to predators (although not to a wily entomologist) and both contribute to predator education together.

Müller's Hypothesis

Müller's explanation was visionary and ground-breaking for its time, and is still well supported today. Not only did it provide further support for Darwin's theory of evolution by natural selection, but it was the very first mathematical model of frequency based selection in history. Unlike Müller himself however, you needn't travel to the Amazon to spot Müllerian mimicry in action – look no further than the shared yellow and black warning signals of the bees and wasps in your own back garden!

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