

Butterfly wing patterns make motion hard to read

Gopal Murali

Movement can expose camouflaged prey, yet whether colour patterns help moving prey to avoid capture is a long-standing puzzle. Butterfly wings might offer an answer. **See p.958**

“The importance of stillness as an aid to concealment can hardly be overestimated,” wrote zoologist Hugh Cott¹. Yet prey cannot always remain still. Movement is among the most powerful cues that animals use to detect and track objects, creating a fundamental problem: even the best camouflage can fail once an animal moves². Certain high-contrast patterns in prey, such as a zebra’s stripes, have long been proposed^{1,3} as an alternative defensive strategy during motion, but gaining supporting evidence has proved surprisingly difficult⁴. On page 958, Hancock *et al.*⁵ put this century-old idea to a new test in butterflies.

By 1909, painter Abbott Thayer had proposed that certain colour patterns could make moving animals more elusive to predators³. For example, he suggested that snakes with stripes running head to tail were harder to track than those with bands running across their body.

During the First World War, a similar approach was tried with ships. In 1917, marine painter Norman Wilkinson persuaded the UK Admiralty to paint ships in bold, contrasting ‘dazzle’ patterns that were intended to make the ships’ course and speed harder for enemy submarine commanders to judge⁶. By the war’s end, thousands of ships had been painted in this way, but whether the design worked as intended was never established⁶.

The question has since moved from ships to animals, but the answer has proved no easier to find. Laboratory studies with human observers chasing patterned targets have shown that such dazzle patterns have some effects on perceived speed and direction⁷, but studies of the protective effects of patterning have sometimes provided inconsistent results, with striped targets performing worse than the non-striped alternatives. Hancock and colleagues took a clever approach to address this question, combining motion modelling, experiments and comparative analyses on real butterflies.

Butterflies make an ideal test case: their wings are boldly and variously patterned (Fig. 1), yet they beat slowly enough for birds to see their movement. Using a motion-detection

model tuned to the eyesight of a small bird, the authors obtained a standardized measure of how strongly various wing patterns distort apparent motion during flight.

Isolating the effect of pattern from the effect of movement is rarely possible in a live animal; however, the authors found a way. They filmed five species taking off, including the red admiral (*Vanessa atalanta*) and the swallowtail (*Papilio machaon*; Fig. 1), then digitally replaced the natural patterns with

plain grey, black or white to assess the specific effects of pattern, leaving shape and wingbeat frequency unchanged. The authors then ran the footage through the motion-detection model, which compares successive frames to estimate the direction of apparent movement. For a butterfly flying forwards, most of the signal should point forwards. Instead, natural patterns generated more apparent motion towards the rear and sides than did the unpatterned versions. The authors call this imbalance motion confusion, which could make a butterfly’s speed or direction harder to judge. But results from five species hardly amount to a rule.

To find out how widespread the effect is, the authors simulated the flight of hundreds of European butterfly species and investigated which wing features were associated with stronger motion confusion. The effect was found in many species, and stronger confusion was linked to features such as high forewing contrast, vertical stripes and trailing hindwing tails, several of which resemble patterns that have long been proposed to interfere with how predators perceive moving prey⁴. Crucially, apparent backward motion arose only during flapping flight, whereas gliding produced

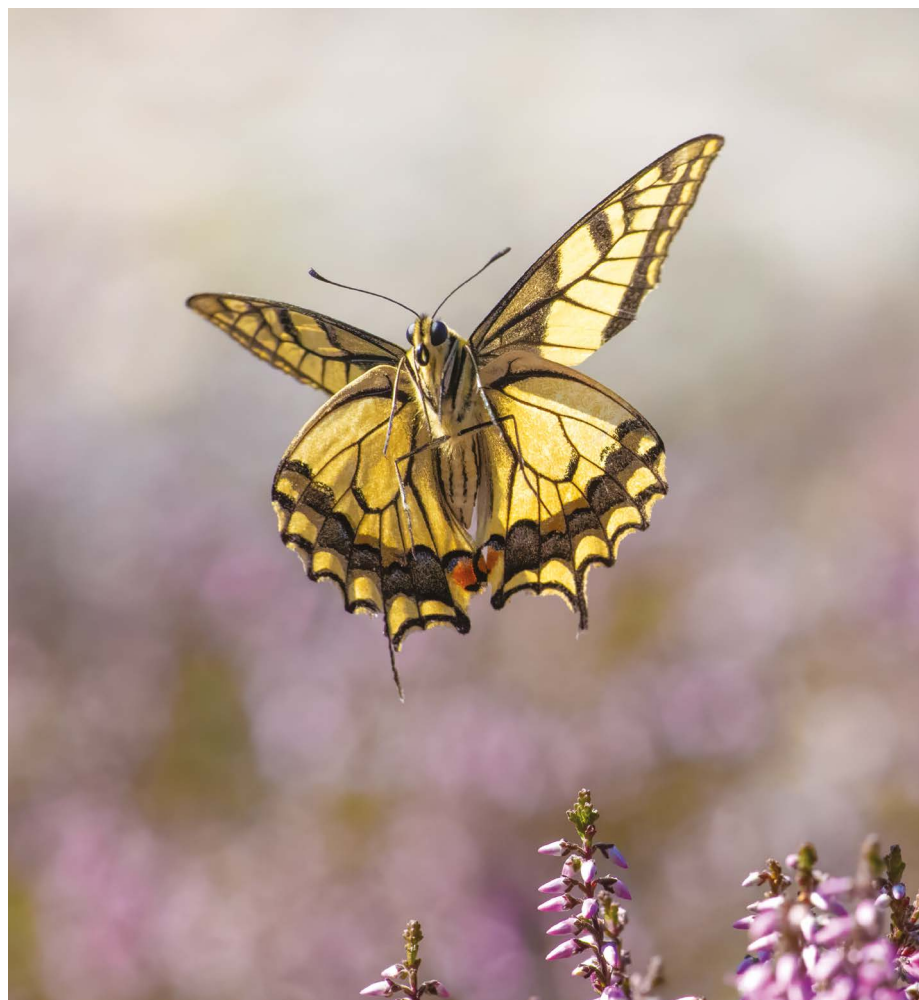


Figure 1 | A swallowtail butterfly (*Papilio machaon*).

sideways motion. Pattern and movement, in other words, act together.

But this association could still be coincidental because butterfly wing patterns are shaped by many forces. The authors therefore let artificial wing patterns evolve in a computer system, selecting for motion confusion. The resulting patterns were more similar to the natural ones of European butterflies than to randomly generated patterns or those evolved by chance.

So far, the evidence is indirect. The key question is whether motion confusion translates into altered attacks on a moving butterfly. Because experiments with wild predators would be extremely difficult, the authors used human participants as a stand-in. In 3,000 trials, participants attempted to catch virtual butterflies with realistic flight paths and wing movements. Butterflies with more backwards-pointing apparent motion drew attacks that landed farther back relative to their direction of flight: the difference in attack location between the forms with the most and least motion confusion amounted to about 38% of the average body length. The attacks, in other words, were misdirected, but there was no evidence that the butterflies were harder to catch overall. Nevertheless, such misdirection might still have consequences. For example, in swallowtail butterflies, it could help to explain how wing patterns divert attacks towards their long hindwing tails during flight⁸.

The chain of evidence is compelling, but not every link is equally strong. The study rests on assumptions about how a predator sees a flying butterfly. The modelling assumes specific viewing distances, visual limits, backgrounds, wingbeat frequencies and viewing angles. These assumptions are reasonable given how little is known about butterfly flight and predator vision, but real attacks will vary. Unlike most previous experiments, which have used simplified targets⁴, this study uses filmed butterflies and natural patterns, bringing the evidence closer to the conditions under which natural selection actually operates. The simulated evolution, meanwhile, shows the patterns that selection for motion confusion can produce, but not whether this selection has happened in the real world.

Even so, the larger unknown is whether natural predators respond to these cues as the participants did, tending to strike farther back as motion confusion increases. The decisive test is still wild predators attacking live butterflies.

Taken together, the evidence puts a century-old intuition on a measurable footing. The study gives fresh weight to the idea that some animal patterns have evolved for how they look in motion, rather than at rest. For butterflies, it could help to explain how such striking wings could be advantageous in flight, despite making the animals easy to spot. More broadly, with a way to quantify

how natural patterns alter perceived motion during realistic movement, it is now possible to look beyond butterflies and ask whether the demands of moving prey have helped to shape animal colouration⁹. As Thayer described in 1909, the bold pattern of a butterfly flickering through light and shade “must strongly tend to baffle a pursuer”³. More than a century later, Thayer’s idea has acquired a plausible biological mechanism.

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Neuroimmunology

Pipework issues as cancer spreads to brain boundary

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Analysis of cancer growing adjacent to the brain reveals that bone-eroding cells interfere with lymphatic drainage vessels and hinder anti-tumour immune responses. **See p.1025**

Tumours called dural metastases – those that spread to the outermost membrane surrounding the brain – do not just sit passively at the brain border. A picture is emerging of how extensively they restructure the surrounding area. On page 1025, Zeng *et al.*¹ show that these tumours recruit cells called osteoclasts, which naturally degrade bone. Moreover, the osteoclasts disrupt fluid ‘pipes’ adjacent to the brain called meningeal lymphatic vessels and blunt local anti-tumour immune responses. This evidence reveals several possible targets in efforts to develop therapies.

For decades, the central nervous system (CNS), which comprises the brain and spinal cord, was considered to be immunologically isolated – cut off from the rest of the immune system by several barriers and not connected to the lymphatic system (the body’s fluid-drainage mechanism). This view no longer holds. Cerebrospinal fluid (CSF) circulates continuously around and through the brain, carrying molecular waste into the brain’s ‘drainage pipes’, the meningeal lymphatic system².

The brain sits inside three nested membranes – the innermost pia mater, the arachnoid mater and the outermost dura mater – collectively known as the meninges (Fig. 1). CSF moves between the pia and arachnoid, eventually reaching the dura through dedicated exit routes called arachnoid cuff exit points³. Unlike the brain itself, the dura

is open to circulating molecules and immune cells. It is a border tissue that reflects what is happening immunologically inside the brain⁴.

The dura itself has lymphatic vessels⁵, which drain brain-derived waste to immune-system structures outside the brain called cervical lymph nodes. If this drainage system fails, it results in waste accumulation, which has been linked to various neurological diseases. These vessels also carry protein fragments called antigens, which help immune cells to target defence responses, from the CNS to the periphery, aiding immune responses under both normal and disease conditions, including when brain tumours arise⁶. The dura is also connected directly to the skull’s bone marrow above it through tiny channels in the bone^{7,8}. Brain-derived molecules and CSF can travel through these channels into the marrow, enabling the tissue to sense what is happening in the brain and take part in CNS immune surveillance. This traffic runs the other way, too, with the bone marrow acting as a local supply of immune cells for the CNS and its borders².

But evidence suggests that the marrow does more than just provide cells – it can mount CNS-specific immune responses of its own (probably responding before immune cells in cervical lymph nodes can be primed by antigens draining from the CNS)⁹. The brain borders, including the dura and the bone marrow, are therefore in constant communication.