Butterfly Wings

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Pictures in their Patterns

By

Philip Howse

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To Clive Farrell, Hon. Fellow of the Royal Entomological Society, in recognition of his tireless and enthusiastic efforts to share his fascination with butterflies and moths with a wide international public.

Don't you know that we need to be childish to understand? Only a child sees things with perfect clarity, because it hasn't developed all those filters which prevent us from seeing things that we don't expect to see.
—Douglas Adams

Photo: K Dolbear.

> *'Look! The beauty – but that is nothing – look at the accuracy, the harmony. And so fragile! And so strong! And so exact! This is Nature – the balance of colossal forces. Every star is so – and every blade of grass stands so – and the mighty Kosmos in perfect equilibrium produces – this. This wonder; this masterpiece of Nature – the great artist.'*
>
> —Joseph Conrad, *Lord Jim*

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AUTHOR'S PREFACE

In midlife, fortunately not too late in my career, I discovered surrealist art, and became excited about the way artists questioned our perception and the nature of reality. Simon Barnes, the brilliant nature writer and the only one I know who lost his job for writing about conservation issues, falsely accused me - tongue-in-cheek I thought at the time - of indulging in psychotropic drugs because of my ability to see patterns in butterfly wings that, apparently, others could not see.

The discovery of art and my apparent aberration of perception led me to write the book that was first published by Papadakis as '*Seeing Butterflies. New Perspectives on Colour, Pattern and Mimicry.*' My aim in writing it was to take further the hypothesis that I developed in '*Butterflies, Messages also of From Psyche'* (Papadakis 2010), namely that many butterflies and moth were not just mimics of other insects, but have evolved as mimics of many kinds of toxic animals, including reptiles, amphibians and birds, and plant part, like dead leaves and seed pods. I now believe that the patterns on the wings of all butterflies and moths serve a defensive purpose. To become aware of the numerous examples of this, you have to reboot your processes of visual perception: teach yourself to recognise simple key images that other animals respond to - what the Nobel laureate Niko Tinbergen called 'sign stimuli'. Then you can perhaps for a moment become aware of what a hungry bird or lizard experiences. The important thing to remember here is that birds and lizards that are the main predators on insects usually get only a fleeting glimpse their prey and are in a similar position to someone trying to identify the driver of a car speeding past them,

My hypothesis had been received with scepticism (and still is) by some members of the scientific community. Like the evolutionary theories of Darwin and Wallace, there was almost no peer-reviewed experimental evidence available to justify it Hence I realised that for the idea to gain greater acceptance I would have to provide a greater wealth of (hopefully) convincing examples. *Seeing Butterflies* was my attempt to do this, but since that book was published in 2014, a number of excellent websites have become accessible with many thousands of photographs taken in the field by skilled amateur and professional photographers. This means that biologists like myself are no longer heavily dependent upon specimens in museum cabinets, but have access to images of live insects taken in their natural environment and these can be viewed by we humans to some extent as they are by their predators. I then found many more examples of what I have christened 'Satyric mimicry' to shore up my conclusions, which I am now including in the present work. I also found many examples of this form of mimicry in the British and European insect fauna, and have introduced more of these into this book to make it more relevant to those interested in the natural history of Britain and Europe.

The availability of a cornucopia of colour images of animals of all kinds, taken in their natural environment in their typical postures has also led me to publish what is, in effect, an extension of the present book: *The Spider-winged Cupid and the Platypus*. The eponymous Cupid butterfly has a clear image of a spider on its wings, and the Platypus is an example of a creature that has a highly ambiguous body form that confused biologists about identity and its place in nature for many years - much as I assume that the colours and wing patterns of butterflies and moths confuse their predators.

Philip Howse
Dorset 2024

PREFACE TO THE FIRST EDITION

(*Seeing Butterflies. New Perceptions on Colour, Patterns and Mimicry*. P.E. Howse. 2014, Papadakis Publisher)

Many hundreds of books about insects are published each year, but it is only once every decade or so that one arrives that takes the breath away, transforming our perception of an apparently familiar subject with fresh ideas, new insights, and unsuspected revelations of beauty. Bert Hölldobler and Ed Wilson famously achieved this in 1990 with their Pulitzer prize-winning book The Ants, and for me, Philip Howse's Messages from Psyche (2010) had no less an impact. It was here that Howse first propounded his intriguing idea that many of the bizarre colour patterns of insects could be explained by what he termed "satyric mimicry", whereby the hitherto inexplicable shapes seen, for example, on moth and butterfly wings, had evolved to deter a swathe of insect-eating enemies, whose perceptions of their miniature world were somewhat different from those seen by human eyes.

It is a great pleasure therefore to welcome an equally wonderful sequel, aptly named Seeing Butterflies. Here, Philip Howse develops his intriguing ideas about insect appearances, supporting them with a diverse array of weird and wonderful new examples, each beautifully illustrated with astounding images. The reader is first taken through the reasons how and why butterflies and moths may have evolved this fantastic array of shapes, postures, colours and patterns, not only in the adult insect but also in caterpillars, pupae and even eggs. He then presents successive chapters describing the main groups of butterflies, and many moths, giving novel interpretations to their markings. Never again shall I look at a comma butterfly at rest and be content to admire its remarkable resemblance to bark or a dead leaf: nesting within this camouflage is a second, more sinister image - that of a rodent - subtly imprinted on the lower wings.

Some years ago, when discussing with the late Miriam Rothschild what defines a great natural history book - and why excellence was so rarely achieved - we agreed that to attain this accolade it should possess at least two out of three attributes: it should be a work of scholarship, providing fresh information and enlightenment of its subject; it should ideally also be a lovely illustrated work of art; and it should stand as a work of literature, elegantly written in prose that is a pleasure to read. Philip Howse clearly succeeds on all three fronts, with a book that will be read with fascination and delight by amateur naturalists, keen schoolchildren, and serious entomologists alike.

Jeremy Thomas OBE
Professor Emeritus of Ecology, University of Oxford.

CHAPTER 1

SEEING:
ILLUSION, DECEIT AND SURVIVAL

...Your little wings display
big pupils, lashes.
What faces do these lashes
of dye portray?
Is it a belle, a bird?
Or maybe neither
—From *'Butterfly'* Joseph Brodsky

In the great Creation masterpiece of Hieronymus Bosch, The Garden of Earthly Delights, painted between 1490 and 1510, there sits, among the other symbolic phantasmagoria, a Meadow Brown butterfly with the head and beak of a bird. This draws your attention to the bird-like eye-spot on the butterfly's wings and the affinity between butterflies and birds. Henry Bates, the renowned Victorian naturalist- explorer relates[1] that Amazon Indians he met firmly believed that the Brazilian Hummingbird hawk-moth (*Macroglossum titan*) and Hummingbirds are of the same species, so great is the resemblance, and that one can metamorphose into the other.

This raises the very intriguing question:' Do insect-eating birds also fail to distinguish the two, and does this help the survival of the moths?

You may find it very surprising to learn that, engraved on the wings of many butterflies and moths, among the rainbow colours and the opalescence, are images which closely resemble, among other things, millipedes, salamanders, frogs, snakes, lizards, falcons, spiders, hornets, bats, large canine teeth, claws, caterpillars, wolves, and owls. These have been overlooked in the past because even the most patient observer has failed to be convinced that the illusory images are more than coincidences. And, anyway, the visual acuity of birds is far greater than ours, isn't it? So there is little chance that they will be taken in by any superficial resemblance of a butterfly to another

[1] Bates H.W. 1863. The Naturalist on the River Amazons, Murray, London.

creature. The flaw in this view is that the visual perception of birds and probably all other animals, is not the same as ours: their world is very different.

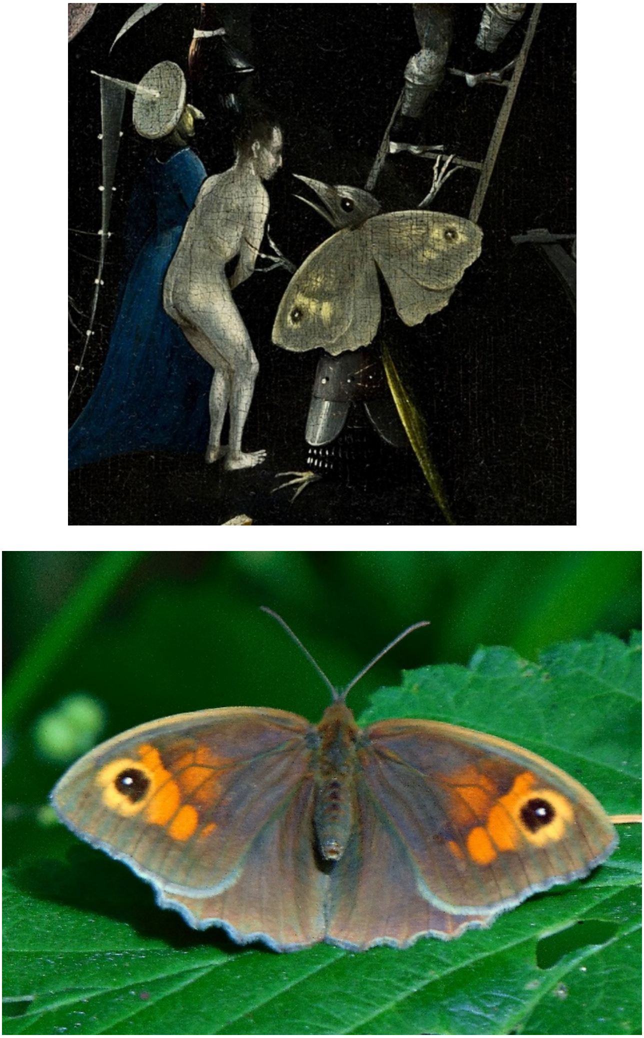

Fig. 1 Meadow Brown butterfly (*Maniola jurtina*) and detail from Bosch's 'The Garden of Earthly Delights'.

The conventional explanation for the colour patterns on butterfly wings is that they enable one individual to recognise others of the same species and so prevent interbreeding. I have always wondered, if that is so, why wing patterns should be so intricate, complex and unique in butterflies such as tortoiseshells and peacocks, and yet in the chequered brown European fritillary butterflies, for example, the patterns remain remarkably similar in around fifty different species (not to mention sub-species) found in Britain and western Europe, not to mention around thirty fritillary species in North America.

There are also numerous species of blue butterfly in the western world, some of which are extremely difficult to identify without resort to minor anatomical details only visible under a microscope.[2] The answer to this conundrum, as we shall see, is that the wing patterns of many butterflies and moths do not solely help them to find the right mate (in which pheromones specific to each species are also of great importance), but also create illusions. These illusory features are very difficult for *us* to perceive, but they have evolved, not to deceive human beings but to deceive insect-eating predators, whose visual world is very different from ours and who we know see many features to which we pay no attention, or to which we are effectively blind. Conversely, we see many patterns, shapes and designs that most animal species almost certainly do not.

Visual illusions are part of everyday life. Unlike Narcissus, who believed his reflection was a real person with whom he immediately fell in love, you know your reflection in the mirror is an illusion. But it may be even less ‘real’ than you may think. An anorexic person may see a seriously overweight person in the mirror and refuse to believe that this is not the reality. A mirror image is reversed from left to right, and is also smaller: try breathing on a mirror and tracing the outlines of your head with your finger if you doubt this. And if you have a computer with a web-cam, try to trace the outlines of your image on the screen: you will probably find it quite perplexing.

Distortion and illusion, though, are not uniquely features of human visual perception. We know from experiments that birds can be very easily deceived by simple models or crude copies of other creatures. I will now try to show how the wing patterns of insects exploit this susceptibility and so

[2] The author Vladimir Nabokov, also well-known as an entomologist, spent five years at Harvard University Museum separating blue butterflies on the basis of minor differences in their genitalia.

help them to survive.

How to catch a butterfly (or moth)

Butterflies and moths are ‘cold-blooded’, meaning that they must warm up before they can fly properly. One way they do this is by basking in the sun in the early morning sitting on flowers or walls and opening their wings towards the sun. On hot days they may risk overheating, but they are then able to cool their bodies by closing their wings, changing the angle of their wings to the sun, or flying into the shade.

Fig. 2 A Burnished Brass moth (*Diachrysia chrysitis*) shivering. Iridescent areas on its wings reflect light and make it seem to glow – perhaps this is a distraction for predators.

Most moths, on the other hand, fly at night, and need to generate their own body heat before they can do so. If you disturb a moth in the early morning, you will notice that it has difficulty flying away immediately. Some species, like the Red and Yellow Underwing moths, can manage a quick emergency burst of energy and fly a short distance, at the same time flaunting their bright red or yellow underwings, but most must first beat their wings rapidly while staying on the spot– this is termed, appropriately, ‘shivering’. The rapid, almost isometric, muscle activity raises their temperature, and when the body temperature starts to rise above 30°C (our body temperature is always about 37°C), their muscles begin to work effectively and they can fly away. Moths with large bodies can spend several minutes shivering when ambient temperatures are low. For example, the Robin Moth of North America (*Hyalophora cecropia*) which is very large-bodied, has been found to take eight minutes to warm up from 15°C.[3] During the warm-up period, of course, moths are tremendously vulnerable to predators.

The best time to catch or photograph a butterfly is therefore when it is basking in the sun in the early morning or at the approach of sunset: in the heat of the day, it is off the mark too quickly. And the best time to catch a moth is when it has been concealed in the shadows and the temperature is low. Insectivorous birds tend to hunt at dawn and dusk for the same reasons.

Butterflies and moths protect themselves from predators in many different ways, such as simply concealing themselves in crevices or choosing resting places where they are well camouflaged. Some are able to protect themselves still further by suddenly displaying bright colours when disturbed (as in the Red Underwing moth, for example). Many butterflies open and close their wings so that colours and patterns on the upper surface of the wings alternate with contrasting ones on the under surfaces. In a great many instances, the differences are radical and create a shock, such as happens when a conjuror appears to turn his silk handkerchief into a live dove. This is one of the fundamental strategies that butterflies use to confuse predators. In some species, the bright colours of the upper wing surfaces appear to flash like a warning light – which can be startling. But there are other intriguing ways in which insects defend themselves, which have been largely overlooked.

Imagine you are hunting in tropical forest. You are potential prey as well as predator. Suddenly something leaps out from behind a bush in front of you. You need to find out extremely quickly whether it is a deer or a leopard; get it wrong and you might be dead within a few seconds (and your offspring might die from starvation as well). You may have to rely on easily recognised features that are fleetingly glimpsed, like black spots on the body or a set of sharp teeth. You may not have time to take a close look.

A bird hunting for moths in a bush is in a rather similar position: what could be a tasty caterpillar or moth might be the head of a venomous snake, or a

[3] Bartholomew, G.A. and Casey T.M. Effects of ambient temperature on warm-up in the moth *Hyalophora cecropia. Journal of Experimental Biology* 58: 503-507, 1973.

partially concealed bird of prey. Again, an instant decision is needed, based on easily recognisable clues. The bird could be taking a big risk if it pecked at the object right away, but if it hesitates for even a fraction of a second, the insect, if that is what it is, has had a chance to escape.

Avoiding capture by predators depends not just on how fast an animal can swim or fly, but on the time it takes to detect a threat and react. We can take up to a second to focus on something that has caught our eye and work out whether or not it has triggered a false alarm. The delay in changing the direction of gaze and re-focusing also affects us in our ability to cope with many things in life, including, incidentally, the highly controversial offside rule in football in which the position of the ball, the goal keeper and three other players must be determined at exactly the same moment.

When you first see an object coming into your visual field it takes your eyes an average of just over a quarter of a second (270 milliseconds) to move in line with it. It then takes another 120 ms for both eyes to centre on the object so that the brain can compute the distance the object is away from you; until you can do that you don't know exactly where it is relative to everything else you can see. The eye focuses on an object by changing the curvature of the lens – a process that takes 640 ms when you change from looking at something in the distance to something close to you. And if you blink, that takes 400 ms – a period of blindness of which we are completely unaware. Experiments have shown that monkeys and budgerigars can distinguish between different kinds of object in about half the time it would take you or me, but this still means that insects that detect a bird in front of them (and are already warmed up for flight) have a good margin of time to escape before the bird can focus accurately on them.

This explains why it is so difficult to catch a butterfly. Unless you can get very close to it and bring a large net down in a fraction of a second, it will have escaped you, so, like a bird, you have to guess where it will be within the next second to have a chance of capturing it.

Take-off times calculated from high-speed video recordings of several butterfly species show that it takes them around 3ms to lift off and a further 4ms to move one wingspan away.[4] Using a timed flash to photograph four

[4] Howse, P E., "Lepidopteran wing patterns and the evolution of satyric mimicry," Biological Journal of the Linnean Society, 2013, **109**, 203–214.

species of Brazilian skipper butterfly (Hesperiidae), Andrei Sourakov[5] found that they could detect the flash and leap into the air in less than 17 ms; one of the fastest recording times in the animal kingdom. Sourakov has since found that many other butterflies, mostly skippers, He also found that the iridescent blue nymphalid, *Myscelia cyaniris,* closes its initially open wings presenting its dull undersides in the same period of time.

Fig. 3 The American Orsis Bluewing *Myscelia cyaniris*, closing its wings.

Now imagine you are a bird and you have spotted a butterfly sitting in the sun on a flower. The next thing is to get within pecking distance. This is extremely difficult because the butterfly will detect the slightest movement and be off in a flash. The fastest peck recorded is that of a woodpecker, which takes 40ms, but that gives the butterfly ample time to escape if it has seen your beak begin to move; if you hesitate, confused, for example, by the weird patterns in front of you, and have to refocus from these to the body, you will almost certainly miss and the butterfly will already be out of reach.

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[5] Sourakov A. Extraordinarily quick visual startle reflexes of skipper butterflies (Lepidoptera: Hesperiidae) are among the fastest in the animal kingdom, *Florida Entomologist* 92(4): 653-655, 2009.

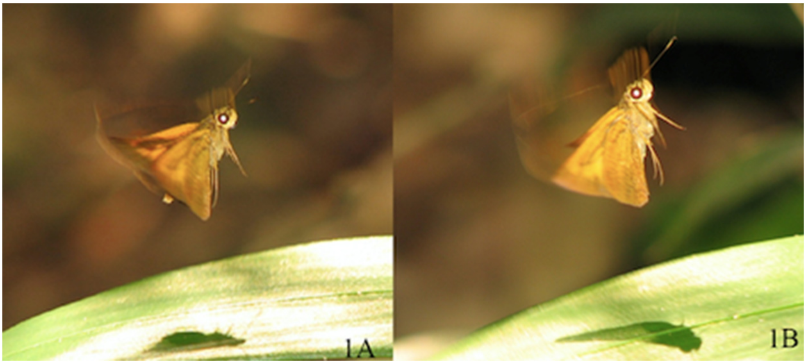

Fig. 4 Images of the Brazilian Skipper species, *Anthoptus epictetus,* captured after 17ms of exposure to a photographic flash.

In general, the best option for insectivores is to search for butterflies that have not warmed up to flight temperature, and it is then that the illusory images on their wings come into play, as they do in moths. Ironically, most experimental research on mimicry has been done with models or static 'prey' in which birds have all the time they need to approach and inspect before striking at a sitting target, with the result that the survival value of images on wings is not put to the same tests as in nature.

Even if a bird tries to catch a butterfly in flight it has a very difficult task. Stephen Dalton, one of the pioneers of high-speed nature photography, had to overcome the formidable problem posed by the speed of movement of insects past the camera. In the one twentieth of a second (50 ms) that it takes a camera shutter to open, the average insect will have moved about 25cm past the point of focus. Within that time, a hoverfly could complete 5-6 wing-beat cycles. The small tortoiseshell butterfly, *Aglais urticae*, has a take-off velocity of approximately 1.1 to 1.6 metres per second[6] so 50ms after lift-off it will have moved over 50cm.

Try this simple experiment. Place an ink spot on the edge of your thumb (which is normally about 2cm wide) and place the outer edge on the surface of a watch with a second hand. Now, getting as close as you can, focus on the spot and then shift your focus to the second hand of the watch. You will find that it will have moved on by almost a second by the time you

[6] Almbro, M. Kullberg, Impaired escape flight ability in butterflies due to low flight muscle ratio prior to hibernation. Journal of Experimental Biology 2008. 211: 24-28.

accomplish this – ample time for a butterfly to become airborne.

Some butterflies, such as many of the blues and whites, are slow fliers, and they will tend to fly for long periods in and out of vegetation or make so many frequent twists and turns that birds have difficulty in predicting where they will be in the next fraction of a second, as Robert Graves described in his poem *Flying crooked*: '*…a cabbage-white, (His honest idiocy of flight) / Will never now, it is too late, /Master the art of flying straight.'*

Distracting the gaze

Reaction times are relevant in a subtle way to the evolution of eye-spots on the wings of butterflies. The eye is always drawn towards images of eyes, a tendency that has been exploited by surrealist artists such as Miró and Salvador Dalí, and we can safely assume that this applies also to birds and other vertebrate predators. Butterflies with eye-spots tend to half open and close their wings rhythmically while feeding, so that the eye-spots move relative to the body. Our eyes tend to remain fixated on them. When the wings are more than half-closed, the eye-spots in the Peacock butterfly, for example, are about 2 cm above the body. In order to capture a butterfly, a bird must change the focus of its eyes from the eye-spots to the head or body. Remember also that the outlines of the body are obscured in most butterflies by black areas on the wings (which also help, incidentally, in temperature regulation) or by stripe patterns that break up the outline.

Pecking at the eye-spots may be a defensive, pre-emptive strike against a perceived bird with an open beak. The possession of a series of eye-spots on a dark background, which we find again and again in the brown (Satyrid) butterflies, may confuse a bird still further because it will make the true head more difficult to locate. The focus change will take longer in the shade or in poor light. Lifting the wing as part of the opening and closing cycle will bring the eye-spots towards the observer, which may also be threatening and could offer an explanation for the peck marks that are frequently found around butterfly eye-spots (a point we will come to again later).

We can imagine that a predator might also briefly be confused, as we are, by the unfamiliar juxtaposition of symbols (such as eye-spots) on the wings of a butterfly, and the moments of uncertainty will give valuable time for the insect to get away or defend itself. We get an indication that this trickery works also against other animals: budgerigars take twice as long to recognise a 'scrambled' picture of another budgerigar with the features of the head in the wrong place: for example, if the eye is on the neck. Macaque monkeys also take longer to recognise a human face if the features are jumbled although still symmetrically placed. The interpolation of images of parts of another creature on insect wings can be seen as a form of mimicry, called ‘satyric mimicry’ which will be discussed in the next chapter.

Fig. 5 Ringlet (*Aphantopus hyperantus)* with multiple eye-spots, each with light-reflecting centres that draw the observer’s attention away from the body. Note the peck mark against one of them.