Genetic switch that turned moths black also colors butterflies

June 1 2016

Heliconius melpomene butterfly. The Cambridge-Sheffield study shows that the same gene that influences these butterflies' bright and colorful patterns also turned the peppered moth black during the industrial revolution. Credit: Chris Jiggins, St John's College, Cambridge.

The same gene that enables tropical butterflies to mimic each other's bright and colourful patterning also caused British moths to turn black amid the grime of the industrial revolution, researchers have found.

Writing in the journal *Nature*, a team of researchers led by academics at the Universities of Cambridge and Sheffield, report that a fast-evolving gene known as "cortex" appears to play a critical role in dictating the colours and patterns on butterfly wings.

A parallel paper in the same journal by researchers from the University of Liverpool shows that this same gene also caused the peppered moth to turn black during the mid-19th century, when it evolved to find new ways to camouflage itself; a side-effect of industrial pollution at the time.

The finding offers clues about how genetics plays a role in making evolution a predictable process. For reasons the researchers have yet to understand in full, the cortex gene, which helps to regulate cell division in butterflies and moths, has become a major target for natural selection acting on colour and pattern on the wings.

Chris Jiggins, Professor of Evolutionary Biology and a Fellow of St John's College, University of Cambridge, said: "What's exciting is that it turns out to be the same gene in both cases. For the moths, the dark colouration developed because they were trying to hide, but the butterflies use bright colours to advertise their toxicity to predators. It raises the question that given the diversity in butterflies and moths, and the hundreds of genes involved in making a wing, why is it this one every time?"

Dr Nicola Nadeau, a NERC Research Fellow from the University of Sheffield added: "It's amazing that the same gene controls such a diversity of different colours and patterns in butterflies and a moth. Our study, together with the findings from the University of Liverpool, shows that the cortex gene is important for colour and pattern evolution in this whole group of insects."

Butterflies and moths comprise the order of insects known as Lepidoptera. Nearly all of the 160,000 types of moth and 17,000 types of butterfly have different wing patterns, which are adapted for purposes like attracting mates, giving off warnings, camouflage (also known as "crypsis"), and thermal regulation.

These wing patterns are actually made up of tiny coloured scales arranged like tiles on a roof. Although they have been studied by biologists for over a century, the molecular mechanisms which control their development are only now starting to be uncovered.

Heliconius melpomene butterfly. The Cambridge-Sheffield study shows that the same gene that influences these butterflies' bright and colorful patterns also turned the peppered moth black during the industrial revolution. Credit: Chris Jiggins, St John's College, University of Cambridge

The peppered moth is one of the most famous examples of evolution by natural selection. Until the 19th Century, peppered moths were predominantly pale-coloured, and used this to camouflage themselves against lichen-covered tree trunks, which made them almost invisible to predators.

During the industrial revolution, however, the lichen on trees in some parts of the country was killed by pollution, and soot turned the trunks black. A corresponding change was seen in the in peppered moths which turned black as well, helping them to remain camouflaged from birds. The process is known as industrial melanism - melanism meaning the development of dark coloured pigmentation.

The Liverpool-led team found that this colour change was produced by a mutation in the cortex gene, which occurred during the mid 1800s, just before the first reported sighting of black peppered moths. Fascinatingly, however, the Cambridge-Sheffield study has now shown that exactly the same gene also influences the extremely bright and colourful patterns of *Heliconius* - the name given to about 40 different closely-related species of beautiful, tropical butterflies found in South America.

Heliconius colour patterns are used to send a signal to potential predators that the butterflies are toxic if eaten, and different types of *Heliconius* butterfly mimic one another by using their bright colours as warning signals. Unlike the dark colouring of the peppered moth, it is therefore an evolutionary development that is meant to be seen.

The researchers carried out fine-scale mapping, looking for parts of the DNA sequence that were specifically different in butterflies with different patterns, in three different *Heliconius* species, and in each case the cortex gene was found to be responsible for this adaptation in their patterning.

Because *Heliconius* species are extremely diverse, the study of what causes variations in their patterning can provide more general clues about the genetic switches that control diversification in species.

In most cases, the genes responsible for these processes are known as "transcription factors" - meaning that they are responsible for turning other genes on and off. Intriguingly, what made cortex such an elusive switch to spot was the fact that it does not do this. Instead, it is a cell cycle regulator, which means that it controls when cells divide and thus when different coloured scales develop within a butterfly wing.

"It's a different gene to the one we might have expected and we still need to do more to understand exactly what it's doing, and how it's doing it," Jiggins said. Dr Nadeau added "Our results are even more surprising because the cortex gene was previously thought to only be involved in producing egg cells in female insects, and is very similar to a gene that controls cell division in everything from yeast to humans."

The study, The gene cortex controls mimicry and crypsis in butterflies and moths, is reported in the June 2 issue of *Nature*.

More information: Nicola J. Nadeau et al, The gene cortex controls mimicry and crypsis in butterflies and moths, *Nature* (2016). DOI: 10.1038/nature17961

Related paper: *Nature*, DOI: 10.1038/nature17951

Provided by St John's College, University of Cambridge