A crucial assumption underlying most models of sexual selection is that sexual advertisements honestly reflect the phenotypic and/or genetic quality of their bearers (1). Here we show that experimental activation of the immune system is rapidly mirrored in the expression of a carotenoid-based secondary sexual trait in male blackbirds (Turdus merula). This result shows that sexual advertisement honestly signals male health and can be reliably used by conspecifics as a cue of individual quality during intra- and/or intersexual interactions.

Male blackbirds exhibit a black plumage with a yellow to orange bill, whereas females are brownish with a brown bill. Recent studies have suggested that bill color is a sexually selected trait in blackbirds (2, 3). For example, resident male blackbirds are more aggressive to mounts with orange bills than to mounts with yellow bills (2). Bill pigmentation might therefore provide a signal used during contests between males (2). In addition, male blackbirds with orange bills are mated with females in better body condition and fledge more offspring than males with yellow bills (3). Overall, these results suggest a role for bill color in sexual selection, possibly as an indicator of male phenotypic quality.

Carotenoids are common components of colored signals used in animal communication (4). They are also important in the up-regulation of various aspects of the immune functioning (5) and cellular protection against free radicals (6). This suggests that a trade-off may exist between allocation of carotenoids to sexual signaling versus immune defenses (4).

Using an autosampler high-performance liquid chromatographer, we determined the presence of carotenoids deposited in the bill of male blackbirds [see note (S1)] (7). The analysis of the absorption spectrum revealed the presence of α- and β-carotene, β-cryptoxanthin, zeaxanthin, and lutein (Fig. 1A). To investigate whether bill color reflects immune status, we immunized captive male blackbirds with a suspension of sheep red blood cells (SRBC) in both spring 1999 (n = 19) and spring 2002 (n = 13). A control group (n = 15) was injected with a phosphate-buffered saline solution (PBS) for control in 2002. Only the 2002 immunized males, the likelihood of becoming duller was significantly correlated with the intensity of the anti-SRBC response as determined from the haemagglutination test (logistic regression, Wald $\chi^2 = 5.12$, P = 0.023, n = 32), whereas neither year nor initial bill color entered the logistic regression model ($P > 0.1$).

Overall, these results demonstrate the existence of a trade-off between sexual advertisement and immune activation in male blackbirds. This finding has important consequences for both the evolution of secondary sexual traits and the cost of immune function. Assessment of opponent quality during male-male competition or mate quality during female choice based on a dynamic trait, such as bill color, might have evolved if it honestly reflects health status of the individual (1). The activation of the immune system by an infectious process is rapidly mirrored in the color of the bill. Contrary to feather ornaments that are produced during the annual molt, dynamic traits might therefore convey a continual update on male health.

Carotenoids, such as astaxanthin, lutein, and β-carotene, used for sexual signaling have been shown to enhance in vitro and in vivo antibody production to SRBC (8) and to provide protection against free radicals (6). Our results suggest that the activation of the immune system withdraws carotenoids to enhance immune functioning as well as to deal with free radicals produced during the immune response, at the expense of sexual signaling.

**References and Notes**

7. Notes (S1) and (S2) are available on Science Online.
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**Supporting Online Material**

[www.sciencemag.org](http://www.sciencemag.org/cgi/content/full/300/5616/103/DC1)

Notes S1 and S2

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