FEATURED PHOTO

CAROTENISM IN THE PURPLE FINCH

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On 18 January 2016, at the Wildhorse Golf Club in Davis, Yolo County, California, Robert Walsh and Samuel Lei encountered an adult male Purple Finch (*Haemorhous purpureus*) whose carotenoid-based plumage color was unexpectedly orange-yellow (back cover) rather than the typical raspberry red.

Most of the orange, yellow, and red colors in birds derive from carotenoid pigments. Unlike melanin pigments, which render black and brown colors, carotenoids cannot be synthesized. Instead, birds must obtain carotenoid pigments from their foods. The pigments may then be deposited in feathers unchanged or may be metabolically altered to form different colors. In *Haemorhous* finches, for example, yellow carotenoids are acquired from the diet and oxidized into red keto-carotenoid pigments (Stradi et al. 1997, Inouye et al. 2001). In most species with carotenoid-based plumage coloration, the plumage is normally consistent in color from individual to individual. The crest of a Pileated Woodpecker (*Dryocopus pileatus*) is reliably flame-red, the underparts of a Western Kingbird (*Tyrannus verticalis*) are predictably sulfur-yellow, and the head of an adult breeding male Western Tanager (*Piranga ludoviciana*) is unwaveringly burnt orange. The same is true of the male Purple Finch—its carotenoid-based plumage color is nearly always raspberry red. The closely related House Finch (*Haemorhous mexicanus*) represents a well-known exception to this pattern of color consistency. While most commonly rose-red, the adult male's carotenoid-based plumage color normally ranges from pale yellow to bright red. This color variation results largely from the differential expression of varying combinations of 13 carotenoids (Inouye et al. 2001, McGraw et al. 2006). Because feathers with carotenoid coloration can be tipped brown when fresh, feather wear can also contribute to color variation, from rose-red in fresh plumage, for example, to scarlet in worn plumage (Grinnell 1911). However, the main factor in determining the expression of carotenoid-based plumage coloration in the House Finch and other species with carotenoid-based plumage coloration is probably the condition of the individual bird (Hill 2011, 2014, Hill and Johnson 2012). The concept of condition is complex and has been defined as an individual's "capacity to maintain optimal functionality of vital cellular systems" or more simply as an individual's "capacity to withstand environmental challenges" (Hill 2011). This concept means that multiple interrelated genetic and physiological processes influence carotenoid coloration. Such processes include gene expression, genetic quality, immune function, endocrine function, maternal effects, oxidative pathways, and nutrition. Those processes themselves are influenced by many factors including cancerous cell lines, autoimmune imbalances, toxins, oxidative stress, parasitism, physical injury, availability of food resources, and age (reviewed by Hill 2011). These factors can compromise the condition of an individual bird, which in turn can diminish the expression of carotenoid coloration.

Whether genetically or physiologically induced, the disorder that affects the normal expression of carotenoid pigments in the integument of birds has been termed carotenism (Davis 2007). Carotenism can arise from (1) a change in the normal distribution or extent of carotenoid pigments, (2) an increase or decrease in carotenoid pigment concentration, (3) a change in carotenoid pigment types (Hudon et al. 2017), or (4) the total absence of carotenoid pigments (Davis 2007).

In contrast with the relatively common occurrence of orange or yellow adult male House Finches, yellow or orange adult male Purple Finches are rare enough to be considered abnormal and therefore carotenistic. Such aberrant Purple Finches have

been reported as all orange, all yellow, a combination of orange and yellow, or a combination of orange, yellow, and raspberry red. In some cases only part of the plumage normally colored by carotenoid pigmentation (e.g., the underparts; Whittle 1928a) has been affected, in others all such areas (Whittle 1928b, Isted 1985). Carotenism has also been reported rarely in the Cassin's Finch (*Haemorhous cassinii*) (Bell 2010). Therefore, among the three species of *Haemorhous*, intraspecific variation in the adult male's carotenoid coloration is routine only in the House Finch.

Carotenism in the Purple Finch could result from physiological factors, genetic factors, or both. For example, limited access to typical carotenoid-containing foods or intake of atypical carotenoid-containing foods prior to or during molt might produce orange or yellow phenotypes (Hill *et al.* 2002). Likewise, poor nutrition (Hill 2000), high parasite loads (Thompson *et al.* 1997), or abnormal levels of testosterone (Stoehr and Hill 2001) might also produce such variants. Alternatively or coincidentally, genetic effects could alter the normal metabolic regulation or deposition of carotenoid pigments, resulting in the abnormal orange or yellow coloration (Roulin and Ducrest 2013). Whatever the proximate cause, carotenism in the Purple Finch probably indicates the affected individual's condition was compromised in some way.

Because carotenoid coloration is inextricably tied to an individual's condition, it can play an important role in honestly signaling quality to prospective mates or dominance to rivals (Walsh *et al.* 2011, Bulluck *et al.* 2017). Whether carotenoids function in this way in the Purple Finch has evidently not been studied. Therefore, what orange or yellow carotenoid-based plumage color in the Purple Finch might signal to rivals or prospective mates is unknown.

Although carotenistic Purple Finches are occasionally reported, the photograph featured on this issue's back cover may be the first one of this aberration published.

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