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Different pigmentary alterations of a carotenoid-based patch in the Great Tit *Parus major*: two cases to discuss

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Alterations in bird plumage coloration such as albinism and melanism have been widely cited in ornithological literature. Some types of plumage coloration are the consequence of pigment molecules stored in the feathers: carotenoids provide the red and yellow colours; and melanins are responsible for black, reddish and brown colours. This paper describes two records of alterations in the yellow breast (a carotenoid-based colour) of Great Tits *Parus major*: a nestling that was probably a total albino to carotenoids; and a fledgling with melanism. Possible proximate causes of both pigmentary alterations are discussed. Plumage alterations have been well documented through an observational perspective but experimental work with these alterations could be useful in understanding the functions of plumage in social and sexual contexts.

Key words: Great Tit, *Parus major*, albinism, melanism, plumage colour, Catalonia.

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Over the years considerable attention has been paid to alterations in the plumage coloration of birds (e. g. Chapman 1892, Smith 1908). A recurrent alteration in plumage is the lack of pigmentation in teguments, which is usually known as "albinism" or "leucism". Albinism may be classified into four groups (Gross 1965a,b, Rintoul & Kennedy 2002): true albinism has a genetic basis, and individuals show a total lack of pigmentation, not only in their plumage but also in pigmentary teguments, notably the bare skin and the eyes; incomplete albinism refers to the complete absence of pigmentation in one or two of the three aforementioned areas; "imperfect albinism" refers to a reduced, or diluted, form occurring in any or all of the three areas; and partial albinism occurs when pigment is absent in particular patches. Jehl (1985), however, only considered the first of these as "albinism", the others being treated as "leucism". Another form of alteration in plumage is related to an excess of pigmentation. One such type is "melanism", which is the extra production of melanin on the integument structures (Gross 1965a, Blight & Stevens 2000). Melanism has recevied far less attention than albinism in ornithological literature (Gross 1965a).

An alteration of the pigmentation process may be the cause of abnormal colour modifications in plumage. There are two main types of pigment responsible for feather coloration: carotenoids; and melanins. Carotenoids are involved in the production of many red and yellow colours and cannot be synthesized by birds. Therefore, carotenoids must be ingested with the food (Fox 1976). Melanins provided the dark (eumelanin), brown, and some reddish (phaeomelanin) colours, are produced by the organism and, contrary to carotenoids, their deposition is mainly under genetic control (Jawor & Breitwisch 2003, Roulin & Dijkstra 2003).

In this paper two independent observations of alterations in plumage of the Great Tit *Parus major* are reported: a nestling that was a probable total albino to carotenoids, and a fledgling with melanism, both anomalies affecting the coloration of the usually yellow breast, a typically carotenoid-based patch. The possible proximate causes of both pigmentary alteration are discussed.

Description of the cases

The Great Tit is a passerine of 15-19 g that displays a yellow patch on the breast and abdomen (Cramp & Perrins 1993). In tits, this yellow coloration works as a signal of nutritional condition (Senar *et al.* 2003); foraging and parental ability (Senar *et al.* 2002); resistance to endoparasites (Dufva & Allander 1995, Horak *et al.* 2001); and is related to survival (Horak *et al.* 2001).

During a survey of Great Tits breeding in nestboxes in the Collserolla Park, Barcelona (north-eastern Iberian Peninsula), I encountered a nestling Great Tit (1st June 2004) that was possibly an albino to carotenoid-based coloration. Neither parents nor the six siblings showed any sign of abnormal pale pigmentation and, interestingly, the areas pigmented with other kinds of coloration, such as melanin-based colour, had the normal appearance (Plate 1A). The nestling was 12 days old (day 1 = hatching day) when it was found and, although biometric measurements were not recorded (these data were usually taken on day 16), basic description of plumage was done. Four of the seven nestlings were one day older and clearly larger than the other three; the pale bird belonged to the first group. None of the typically carotenoid-based pigmented parts of the nestling, such as the breast, abdomen, back or corners of the beak, had any indication of yellow, on the contrary than its siblings. Unfortunately, when the nest was revisited, on day 16, three of seven nestlings had already left the nest. This was indicated by the recent excrements found in the nestbox entry tube. One of the absent nestlings was the pale one. Although nestlings remain in the nest for 16-22 days (Cramp & Perrins 1993), this was a second brood, and in such cases nestlings usually leave the nest earlier (Gosler 1993, Quesada & Senar own data). Unfortunately, this nestling was not recaptured in subsequent sessions.

The second record was of a melanic fledgling captured by Sergi Sales in a ringing session of the SYLVIA programme in Vacarisses, Barcelona, on 14th July 2004. This bird was captured in mist-nets and showed the yellow breast patch "soiled" black (Plate 1B). Yellow coloration was still present in the patch suggesting no interaction between carotenoid and melanin pigmentations. This individual was simultaneously captured with three other normally pigmented nestlings. Since nestlings remain with their parents until two weeks after leaving the nest (Cramp & Perrins 1993), we can speculate that all individuals belonged to the same family (Sergi Sales, pers. comm.).

Discussion

In spite of the complete lack of visual evidence of yellow coloration in the first bird, it would be inappropriate to talk about a total albinism to carotenoids, as the pigment content of the feathers was not measured using biochemical techniques. A range of environmental and genetic factors can affect the expression of carotenoid-based colorations (Tschirren *et al.* 2003), and any of these could have caused this anomaly. The simplest explanation would be that the bird might simply have allocated fewer carotenoids to feather coloration than normal, due to lack of carotenoid ingestion. However, the main form of prey (caterpillars) typically given to broods contains considerable quantities of carotenoids (Stradi 1998). A related study, carried out the same year in the same study area, corroborated that the main types of prey given to chicks were spiders and caterpillars (Quesada & Senar, unpubl. data). One possible cause for reduced ingestion of carotenoids could be asymmetry in the feeding allocation by the parents, involving less food with carotenoids being given to the pale nestling. However, a recent article demonstrated that in the Great Tit chick plumage does not influence begging behaviour or parental provisioning, suggesting a lack of discrimination between chicks (Tschirren *et al.* 2005).

Proximate mechanisms that are responsible for carotenoid expression in feathers could also influence this anomaly. The pathways involved in the expression of carotenoid colorations include different steps such as assimilation, transport, modification and deposition into feathers (Brush 1990). Since Great Tit parents do not discriminate between the colour intensity of

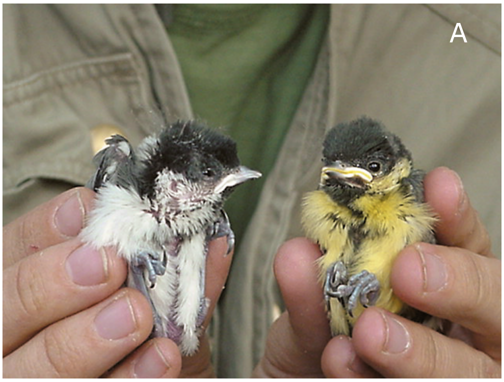

Plate 1. A) A Great Tit chick showing a possible complete lack of carotenoid-based coloration (left) compared to its sibling (right). (Photo: J. Quesada). B) A fledgling of the same species with melanism on the yellow breast compared to a normal fledgling captured in the same ringing session. Melanins are typically absent in the yellow patch (Photo: S. Sales).
A) Un poll de Mallerenga Carbonera que mostra una possible total absència de coloració basada en carotenoids (esquerra) comparat amb el seu germà (dreta). B) Un volander de la mateixa espècie amb un cas de melanisme al pit groc comparat amb un altre volander capturat al mateix temps. Les melanines estan absents en el pit groc.

chicks during food provisioning (Tschirren *et al.* 2005), and they typically do not regulate brood number (Lack 1968, Gosler 1993), we could assume that parents fed the presumably albino chick similarly to their siblings. The first possibility for such an abnormality could be the bird's inability to absorb carotenoids through its intestinal tract. Absorption of carotenoids is mediated by intestinal mucus diffusion with no implication of any enzymatic mechanism (Parker 1996). Thus, a possible genetic mutation in enzymatic machinery could not have caused an inability in the absorption of carotenoids. Although transport of carotenoids at this level is poorly known (Brush 1990), we should not expect a fault in mucous transport to be the cause, as other lipids for vital functions are absorbed in the same way. Since there is not biochemical evidence of a total lack of carotenoids in the feathers, the possibility of an environmental factor determining the observed lack of pigmentation in this bird should be addressed. Some viruses and coccidia affect carotenoid absorption in the intestinal tract (Parker 1996), implying a decrease in the yellow coloration of chicks (i. e. pale-bird syndrome) (Tyczkowski *et al.* 1986, Brawner *et al.* 2000). This possibility is, however, unlikely as the pathogens are transmitted in the nest orally, by contact with faecal material or by ectoparasites (Aiello 2003) and all the chicks in the nest would probably have been infected or, at least, partially affected, as the parents feed and remove the nestlings' faeces with the bill (Cramp & Perrins 1993). Plate 1A clearly shows that the yellow plumage coloration of the sibling were strongly different from the abnormal chick.

The second step in carotenoid acquisition is transport in the bloodstream. Carotenoids, like other lipids, are bound to lipoproteins (Parker 1996). An enzymatic mutation in these proteins could impede the binding of carotenoids to the protein. However, in this case the transport of carotenoids essential for normal physiological functions, such as retinol (Vitamin A), would also be affected (Parker 1996).

The next step in carotenoid acquisition in birds may be a metabolic transformation of ingested carotenoids. Some birds transform the ingested carotenoids in order to change the colour properties of pigments (Stradi 1998). However, in the case of the Great Tit, no metabolic transformation occurs, and lutein and zeaxanthin are the only pigments incorporated into the feathers (Stradi 1998).

Finally, the carotenoids are deposited in the follicle. Since carotenoid deposition in the follicle is a pleiotropic process (Brush 1990), a plausible cause of the lack of pigmentation in this individual could be related to a setback in any step of the deposition process. However, the processes involved in the deposition of carotenoids in follicle are poorly known (McGraw *et al.* 2003).

Thus, although this finding is only observational, the hypothesis of an environmental affectation to explain this pale coloration seems less probable than a genetic mutation in transport or deposition into follicle, although this conclusion is necessarily speculative. Interestingly, the expression of melanin coloration appeared normal in this otherwise pale individual probably because the metabolic pathways to synthesize melanin and carotenoids are independent. This supports previous suggestions that in the Great Tit information signalled by melanin and carotenoid patches differ (Senar *et al.* 2003).

Voisin *et al.* (2002) suggested that environmental or genetic causes could explain some melanism found in penguins. This can also be applied to the melanic Great Tit reported in this study. On the one hand, chromatic abnormalities in teguments may be the consequence of hyper-hypo vitaminosis. In the Great Tit, the environmental influence of ectoparasites on a melanin-based patch has been documented (Fitze & Richner 2002), but no evidence of a link between melanin production and nutritional status has been reported in tits, probably because melanin is synthesised *de novo* by animals so that they do not have to ingest it (Jawor & Breitwisch 2003; but see Veiga & Puerta 1996, and Griffith *et al.* 1999). Furthermore, it is well documented that synthesis of both types of melanin (phaeomelanin and eumelanin) are mainly under genetic control (Jawor & Breitwisch 2003, Roulin & Dijkstra 2003), which might offer support for a genetic origin of this chromatic aberration. Black patches in the Great Tit are presumably mainly composed of eumelanin. Melanogenesis takes place in melanocytes and depends on tyranosinase activity, which is controlled by the hormone αMSH and a protein receptor MC1R (Jawor & Breitwisch 2003). Mutations in MC1R determine a variation in melanin expression in birds (Voisin *et al.* 2002, Mundy *et al.* 2004). Thus, the untidy distribution of melanin in the yellow patch could probably be related to this genetic effect. Again, the observational nature of this work makes the interpretation of the causes speculative.

Plumage alterations have been well documented in ornithological literature mainly from an observational perspective. However, scientists are blinded to eco-ethological consequences of such plumage alteration in ethological contexts. Since pigment-based traits may have a communicative function in birds, these alterations could be a good opportunity for understanding the evolutionary function of these ornaments in sexual and social contexts from an experimental perspective.

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Resum

Alteracions del plomatge basades en carotenoids en la Mallerenga Carbonera *Parus major*: dos casos a discussió

Les alteracions en la coloració del plomatge de les aus, com l'albinisme o el melanisme, s'han citat extensament en literatura ornitològica. Algunes coloracions del plomatge són conseqüència de molècules de pigment emmagatzemades en les plomes: els carotenoids proporcionen les coloracions vermelles i grogues, i les melanines són responsables de les coloracions negres, vermelloses i marrons. En aquest article es presenten dues observacions d'alteracions que afecten al plomatge normalment groc del pit (una coloració basada en carotenoids) en la Mallerenga Carbonera *Parus major*: un pollet possiblement albí als carotenoids i un volantó amb melanisme. D'altra banda, es discuteixen les causes pròximes possibles d'ambdues alteracions pigmentàries. Les alteracions del plomatge s'han documentat des d'una perspectiva observacional, però treballs experimentals amb aquestes alteracions podrien ser útils per entendre contextos de selecció sexual i social.

Resumen

Alteraciones del plumaje basadas en carotenoides en el Carbonero Común *Parus major*: dos casos a discusión

Las alteraciones en la coloración del plumaje de las aves, tales como el albinismo o el melanismo, se han

citado extensamente en literatura ornitológica. Algunas coloraciones del plumaje son consecuencia de moléculas de pigmento almacenadas en las plumas: los carotenoides proporcionan las coloraciones rojas y amarillas y las melaninas son responsables de las coloraciones negras, rojizas y marrones. En este artículo se presentan dos observaciones de alteraciones que afectan al plumaje normalmente amarillo del pecho (una coloración basada en carotenoides) en el Carbonero Común *Parus major*: un pollo posiblemente albino a los carotenoides y un volantón con melanismo. Por otra parte, se discuten las posibles causas de ambas alteraciones pigmentarias. Las alteraciones del plumaje se han documentado desde una perspectiva observacional, pero trabajos experimentales con estas alteraciones podrían ser útiles para entender contextos de selección sexual y social.

References

Aiello, S.E. 2003. *The Merck Veterinary Manual*. Whitehouse Station, NJ: Merck & Co., Inc.

Blight, L.K. & Stevens, S. 2000. Partial melanism in King Penguins (*Aptenodytes patagonicus*). *Mar. Ornithol*. 28: 83.

Brawner, W.R., Hill, G.E. & Sunderman, C.A. 2000. Effects of coccidial and mycoplasmal infections on carotenoid-based plumage pigmentation in male House Finches. *Auk* 117: 952–963.

Brush, A.H. 1990. Metabolism of carotenoid pigments in birds. *FASEB J.* 4: 2969–2977.

Chapman, F.M. 1892. Melanism in a caged Wood Thrush. *Auk* 9: 303–304.

Cramp, S. & Perrins, C.M. 1993. *The Birds of the Western Palearctic*. Volume VII. Oxford: Oxford University Press.

Dufva, R. & Allander, K. 1995. Intraspecific variation in plumage coloration reflects immune response in Great Tit (*Parus major*) males. *Funct. Ecol.* 9: 785–789.

Fitze, P.S. & Richner, H. 2002. Differential effects of a parasite on ornamental structures based on melanins and carotenoids. *Behav. Ecol.* 13: 401–407.

Fox, D.L. 1976. *Animal biochromes and structural colors*. Berkeley, CA: University of California Press.

Gosler, A.G. 1993. *The Great Tit*. London: Hamlyn.

Griffith, S.C., Owens, I.P.F. & Burke, T. 1999. Environmental determination of a sexually selected trait. *Nature* 400: 358–360.

Gross, A.O. 1965a. Melanism in North American Birds. *Bird banding* 36: 240–242.

Gross, A.O. 1965b. The incidence of albinism in North American birds. *Condor* 87: 439–441.

Horak, P., Ots, I., Vellau, H., Spottiswoode, C. & Møller, A.P. 2001. Carotenoid-based plumage coloration reflects hemoparasite infection and local survival in breeding Great Tits. *Oecologia* 126: 166–173.

Jawor, J.M. & Breitwisch, R. 2003. Melanin ornaments, honesty, and sexual selection. *Auk* 120: 249–265.

Jehl, J.R. Jr. 1985. Leucism in Eared Grebes in Western North America. *Condor* 87: 439–441.

Lack, D. 1968. *Ecological adaptations for breeding in birds*. London: Methuen.

McGraw, K.J., Beebee, M.D., Hill, G.E. & Parker, R.S. 2003. Lutein-based plumage coloration in songbirds is a consequence of selective pigment incorporation into feathers. *Comp. Biochem. Physiol. B* 135: 689–696.

Mundy, N.I., Badcock, N.S., Hart, T., Scribner, K., Janssen, C. & Nadeau, N.J. 2004. Conserved genetic basis of a quantitative plumage trait involved in mate choice. *Science* 303: 1870–1873.

Parker, R. 1996. Absorption, metabolism, and transport of carotenoids. *FASEB J.* 10: 542–551.

Rintoul, D.A. & Kennedy, E.D. 2002. Aberrant plumage in a Carolina Wren and two House Wrens from Kansas. *Kansas Ornithol. Soc. Bull.* 53: 21–23.

Roulin, A. & Dijkstra, C. 2003. Genetic and environmental components of variation in eumelanin and phaeomelanin sex-traits in the Barn Owl. *Heredity* 90: 359–364.

Senar, J.C., Figuerola, J. & Domènech, J. 2003. Plumage coloration and nutritional condition in the Great Tit (*Parus major*): the roles of carotenoids and melanins differ. *Naturwissenschaften* 90: 234–237.

Senar, J.C., Figuerola, J. & Pascual, J. 2002. Brighter yellow Blue Tits make better parents. *Proc. Roy. Soc. Lond. B* 269: 257-261.

Smith, A.P. 1908. Albinism of Scaled Partridge. *Condor* 10: 93

Stradi, R. 1998. *The colour of flight: carotenoids in bird plumage*. Milano: Solei Press.

Tschirren, B., Fitze, P.S. & Richner, H. 2003. Proximate mechanisms of variation in the carotenoid-based plumage coloration of nestlings Great Tits (*Parus major* L.). *J. Evol. Biol.* 16: 91–100.

Tschirren, B., Fitze, P.S. & Richner, H. 2005. Carotenoid-based nestling coloration and parental favouritism in the Great Tit. *Oecologia* 143: 477–482.

Tyczkowski, J.K., Hamilton P.B. & Ruff, M.D. 1986. Altered metabolism of carotenoids during pale-bird syndrome in chickens infected with *Eimeria cervulina*. *Poul. Sci.* 65: 1526–1531.

Veiga, J.P. & Puerta, M. 1996. Nutritional constraints determine the expression of a sexual trait in the House Sparrow (*Passer domesticus*). *Proc. Roy. Soc. Lond. B* 263: 229–234.

Voisin, J.F., Mougin, J.L., Segonzac, M. & Ropert-Coudert, Y. 2002. Colour aberrations and physical deformities in the King Penguin (*Aptenodytes patagonicus*) at the Crozet Islands. *Mar. Ornithol.* 30: 1–4.