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Myosin – a monarch of pigment transport?

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To investigate the molecular basis of the nivosus phenotype, Zhan and colleagues sequenced the genomes of 12 Hawaiian monarchs, five white and seven orange wild-type individuals, three of which were first- or second-generation descendants of white monarchs. They then scanned SNP genotypes within the genomic data set and that of 101 other monarchs from around the world, whose genomes were sequenced as part of a large-scale study aimed at identifying genes linked to the migratory behaviour of North American monarchs published in the same study for segregation patterns that matched the Mendelian inheritance pattern of the nivosus phenotype. This analysis reports markers in a single gene, DPOGS206617 (sequence available at http://monarchbase.umassmed.edu/tools3/Get_gene.cgi?id=DPOGS206617), that segregate with the white phenotype. In their report, Zhan et al. indicate that this gene encodes a myosin motor protein and suggest that this putative myosin might function in a similar fashion to mammalian myosin-Va in pigment organelle transport in pigment cells (melanosomes in melanocytes).

Myosin-Va is a type V alternative myosin (equivalent to type IX in plants), and this class of highly conserved myosin plays important roles in intracellular transport of organelles (such as melanosomes), mRNA and other cargo (Hammer and Sellers, 2012; Trybus, 2008). In common with other myosins, myosin-V heavy chain contains three hallmark domains (from the N-termius); a motor/head domain that binds and hydrolyses ATP and allows reversible association with F-actin tracks, a neck domain/lever arm which binds to light chains/calmodulin and amplifies the small ATPase-dependent conformation changes in the motor domain to generate the power-stroke, and a tail domain that allows cargo binding. Typically type V myosins have adaptations to these core domains that facilitate their role as transporters. Firstly, the tail domain contains a series of amphipathic alpha-helices that allow dimerization of the heavy chains. Secondly, the motor domain has a high duty ratio, that is it spends ~80% of the ATPase cycle in high affinity contact with F-actin, meaning that it does not diffuse away from the actin track. Finally, the lever arm is extended and comprises six IQ motifs that can bind three calmodulin light chains and allow the myosin-V dimer to span the 36 nm helical pitch of F-actin. These adaptations allow myosin-V to walk hand-over-hand along actin filaments and thus drag cargo through the cytoplasm. In melanocytes, the tail of myosin-Va also allows its attachment to the melanosome membrane, via interaction with the small GTPase Rab27a and its effector melanophilin, and regulates the transport of melanosomes along F-actin into peripheral cytoplasmic extensions known as dendrites (Evans et al., 2014). Melanosome accumulation in dendrites is essential for their subsequent transfer to keratinocytes and thus skin and hair pigmentation. Consistent with this, mutations in the MYOVA gene (as seen in Griscelli syndrome type I patients and dilute mutant mice) cause partial albinism (a.k.a. pigment dilution) due to perinuclear melanosome clustering and defects in the transfer of melanosomes from melanocytes to keratinocytes (Hume and Seabara, 2011).

However, in spite of the suggestion that the DPOGS206617 might encode a myosin motor protein, sequence analysis reveals that the similarity between the predicted DPOGS206617 protein and other myosins is rather limited. Briefly, DPOGS206617 encodes a 360 residue protein that appears to contain three IQ motifs (http://prosite.expasy.org). While the presence of tandem IQ motifs supports the idea that DPOGS206617 could represent a novel pigment transporting myosin, the finding that it lacks an obvious myosin motor domain argues strongly against this. Although IQ motifs are characteristic of the lever arm of myosins they function in Ca2+/calmodulin signalling and are also found in a number of other types of protein, for


Exploring the molecular basis of monarch butterfly color pattern variation

A response to A. Hume’s ‘Myosin - a monarch of pigment transport?’

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Dear Editor,

The monarch butterfly, Danaus plexippus, sequesters toxic cardiac glycosides from its milkweed host plant as a larva and then uses these compounds to defend itself from bird predators as an adult (Brower and Glazier, 1975; Reichstein et al., 1968). Like other examples of warning coloration, the bold orange wing pattern of D. plexippus helps deter predators by enhancing predator learning and distinguishing it from co-occurring palatable species. Wing pattern also serves a central role in mediating mimicry between D. plexippus and the viceroy butterfly, Limenitis archippus (Ritland and Brower, 1991). Across most of its range, the monarch displays a largely similar color pattern variation, yet it is clear that this protein in monarch pigmentation even though it is clearly not the gene responsible for albinism in the nivosus mutant.

Nevertheless, this raises interesting questions as to the function of this novel IQ domain containing protein and the mechanism by which it might regulate pigmentation in the monarch butterfly that should be the subject of future research. Furthermore, it will be of interest to know how the mutation(s) underlying the nivosus phenotype affect the function of the DPOGS206617 protein as these were not revealed by Zhan et al. in their report.

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References


