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INSIDE JEB

# Dung beetles play hot and cold cycling differently

A rainbow scarab (*Phanaeus vindex*) dung beetle. Photo credit: Dan Mele.

They may not have the most charismatic name, but dung beetles certainly play a crucial role in the environment's perennial recycling circus. 'They provide many ecosystem services, including nutrient cycling, soil aeration and secondary seed dispersal', says Kimberly Sheldon from the University of Tennessee, USA. For *Phanaeus vindex*, which also go by the more glamorous name of rainbow scarabs, the pace of their industrious lives depends on the temperature of their surroundings. Yet, most studies exploring the insects' physiological and biological responses to temperature have been carried out at constant temperatures, even though temperature in the real world is rarely that stable. As the area around the University of Tennessee campus is teaming with the glittery mini-beasts, Sheldon and Katie Marshall from the University of British Columbia, Canada, decided to find out how these dung beetles cope physiologically as the temperature in the local environment cycles from dawn to dusk.

'Rainbow scarabs are not difficult to find', says Sheldon, explaining that the insects are keen to amble into traps baited with their favourite delicacy: human poo. 'They come to us', she chuckles. Sheldon then travelled to the University of Oklahoma– where Marshall was based at the time – to find out how the beetles fared, as the duo, with help from Mojgan Padash, varied the temperature over 24 h cycles, either from 15 to 25°C or between 8 and 32°C. 'The largest temperature cycle included the highest and lowest temperatures that these beetles experience during their breeding season', says Sheldon. Then, the team recorded how much $CO_2$ the beetles exhaled, as a measure of their metabolic rate, at temperatures between 10 and 25°C to find out how the daily temperature cycles had affected the insects' metabolism.

However, when Amanda Carter (University of Tennessee) and the team compared the metabolic rates, it appeared that living in the variable environment wasn't particularly costly. If anything, it was slightly less so than life at a stable 20°C. And when the team collected samples of the fats and carbohydrate energy reserves stored in the insects' bodies, they all fell within the same range; even extreme daily temperature cycles don't pose too much of an energetic challenge for these arch recyclers.

But, when Sheldon, Padash and Marshall collected mRNA from 15 females to find out which genes were most activated when the beetles experienced the two temperature cycles, they were surprised to see that the insects' physiological responses were dramatically different. Although all of the beetles increased the expression of 120 genes, regardless of whether the temperature fluctuation was small or large, the beetles that experienced the greater temperature extremes increased transcription of an additional 174 genes, while those in the smaller temperature range increased transcription of 274 alternative genes. And, when the team painstakingly analysed which families the activated genes fell into, it seemed that the beetles that had experienced the greatest temperature variation had increased expression of genes that package DNA in chromosomes, making their DNA more accessible when the temperature variation was largest and increasing the chances that other genes could be expressed.

'We were particularly surprised that high-amplitude temperature fluctuation isn't just "more of the same" at the transcriptomic level, but instead causes distinct responses compared to low-amplitude fluctuation', says Marshall. And the team warns scientists that they had better pay attention to the environmental fine print when investigating how temperature affects animals, as the devil may be in the detail of the natural variations experienced by creatures on a daily basis.

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