© 2020. Published by The Company of Biologists Ltd | Journal of Experimental Biology (2020) 223, jeb223693. doi:10.1242/jeb.223693

INSIDE JEB

# African pygmy mouse upgrades mitochondria to compensate for size

African pygmy mice *Mus mattheyi*. Photo credit: Laurana Serres-Giardi licensed under the Creative Commons Attribution-Share Alike 3.0 Unported.

There's a reason why so few warm blooded (endothermic) animals are super tiny. It's simply too costly for them to keep their internal central heating turned up. This is because the tiny powerhouses (mitochondria) that produce the energy (ATP) required for warmth and activity become less efficient as animals scale down and their metabolic rates increase. The few mammals that have miniaturised tend to conserve energy by hibernating and dropping their body temperature while inactive. However, Mélanie Boël, Damien Roussel and Yann Voituron from the Université de Lyon, France, wondered whether the mitochondria of these minute mammals could have improved their efficiency, by producing less waste heat to augment their ATP supply. The team decided to compare the performance of mitochondria from three species of mice – two members of the smallest mouse family, African pygmy mice *Mus mattheyi* (~5 g) and *Mus minutoides* (~7 g), and larger house mice, *Mus musculus* (~22 g) – to find out whether any of the minuscule mammals benefit from boosted mitochondria.

First, Boël recorded the animals' oxygen consumption and carbon dioxide production rate for 4 days to calculate their metabolic rate as they scampered around their individual cages. Not surprisingly, the heavyweight house mice had the lowest active metabolic rate (~0.03 W $g^{-1}$) compared with those of the pygmy mice, which tipped the scales at ~0.04 W $g^{-1}$ (*M. minutoides*) and ~0.06 W $g^{-1}$ (*M. mattheyi*). But would their mitochondria prove to be as inefficient as those of other diminutive warm-blooded creatures?

After collecting samples of the animals' foreleg muscles, Boël measured the respiration rate of muscle fibres before painstakingly collecting mitochondria from the muscles and liver, which together account for almost half of an animal's basal metabolic rate. Then, she recorded their oxygen consumption and determined how much ATP and waste heat the mitochondria produce. 'To perform our study, we needed quite a large amount of isolated mitochondria', says Boël, who had to alter the method used by most researchers to collect sufficient mitochondria from the minute (0.3 g) muscles.

Sure enough, the mitochondria of the bulkier house mice and one of the pygmy mice (*M. minutoides*) performed exactly as they expected based on the animals' respective sizes; the mitochondria of *M. minutoides* were relatively inefficient compared with those of the house mice. However, when Boël analysed the mitochondria of the smallest mouse on the planet (*M. mattheyi*), the team was astonished. The muscle and liver mitochondria were as efficient as those of the house mice. Instead of generating large amounts of waste heat while producing ATP, the mitochondria of *M. mattheyi* were able to produce as much ATP per molecule of oxygen as the house mice. 'The hypothesis of a mitochondrial adaptation, by which extremely small species could avoid … associated energy wastage in order to maintain their cellular energy homeostasis, is thus verified in two tissues of *M. mattheyi*', says Boël.

Even though minute *M. mattheyi* can hibernate to conserve energy, they have also improved the efficiency of their mitochondria to reduce energy expenditure. And, Boël is eager to discover whether this minuscule titan is unique, 'in order to know if the improvement of mitochondrial efficiency in species below 7 g is a physiological adaptation limiting the high energy cost to maintain their body temperature', she says.

10.1242/jeb.223693

**Boël, M., Romestaing, C., Duchamp, C., Veyrunes, F., Renaud, S., Roussel, D. and Voituron, Y.** (2020). Improved mitochondrial coupling as a response to high mass-specific metabolic rate in extremely small mammals. *J. Exp. Biol.* **223**, jeb215558. doi:10.1242/jeb.215558

**Kathryn Knight**
**kathryn.knight@biologists.com**

Journal of Experimental Biology