REPLY TO: Timing of puberty: body size or reproductive optimization?

Gillian R Bentley, Barry A Bogin, Ben Bar-Sadeh, Reinhard Stöger and Philippa Melamed

We appreciate the comments by Koziel and Limony[1] on our Review (Bar-Sadeh, B. et al. Unravelling the role of epigenetics in reproductive adaptations to early-life environment. *Nat. Rev. Endocrinol.* **16**, 519–533 (2020))[2] in suggesting that pubertal development might be related to achieving a target height.

The authors state that: "...the change in the timing of puberty is aimed primarily at achieving target height and so at optimizing body size." Our approach is taken from the perspective of life history theory, which argues that energy availability is allocated between growth, maintenance and reproduction, and that trade-offs exist to optimise Darwinian fitness as in reproductive success[3,4]. However, in their correspondence, Koziel and Limony suggest that height is the currency of optimization in the process of pubertal maturation as opposed to fitness. We would argue instead that changes in the timing of puberty reflect endocrine responses to available energy, and that adjustments to that availability are reflected in the plasticity, facilitated by epigenetic mechanisms that influence reaction norms. This viewpoint is supported in animal studies, as noted in our review[2]; we find it difficult to reconcile how Limony's theory regarding target height translates across the animal kingdom.

We read Limony et al.'s earlier article in which they described an association between height gap (that is, difference between the actual height and the genetically-determined 'target height') and age at onset of puberty[5], and which appears to provide the basis for their Correspondence. We would respectfully point out that James Tanner described and analysed 'target heights' and catch-up growth in his *Nature* article nearly 60 years ago, including relevance to the timing of pubertal onset[6]. Moreover, the connection between the onset of the adolescent growth spurt and height were documented in the first decades of the twentieth century[7,8]). The concept of a 'height gap' was also discussed by Tanner[6] and revisited by Barry Bogin in 1980[9]. However a mechanistic explanation for Limony's theory is lacking, as clinical studies do not support direct effects of accelerated increase in bone length on the timing of pubertal onset[10], though other aspects of the metabolic state clearly do exert such effects, as discussed in our review[2]. Furthermore, we would draw attention to the still valid and crucially important comments stressed repeatedly by Frank Shuttleworth that, "Correlations between menarcheal ages and physical data do not imply causal interactions. Rather they point to antecedent factors presumably in the endocrine organization of the individual"[8]. We

believe that our epigenetics review stands on the shoulders of such major figures in auxology in emphasizing and pushing forward scholarship precisely to identify these antecedent factors and determine how they explain the mechanisms responsible for endocrine architecture of individuals during development.

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Competing interests

The authors declare no competing interests.

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