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Editorial: Adaptations to subterranean environments

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Editorial on the Research Topic
Adaptations to subterranean environments

The subterranean realm is a fascinating world that still holds many secrets and wonders (Culver and Pipan, 2019; Ficetola et al., 2019). Species that have successfully colonized caves and other subterranean environments have often had to deal with novel and unique conditions that promoted the appearance (or disappearance) of specific traits (Howarth and Moldovan, 2018; Soares and Niemiller, 2020). Several morphological, behavioral, and physiological traits are considered adaptive; however, an exhaustive list of adaptive traits documented in subterranean species remains to be assembled. Recent studies continue to uncover evidence for the evolution of traits in subterranean environments that were previously unrecognized (e.g. Hesselberg; Lunghi and Bilandžija), especially thanks to new methods that expand our research possibilities (Bierbach et al., 2018; Mammola et al., 2021). Historically, the morphological phenotype was used as an exclusive criterion for recognizing obligate cave species (Christiansen, 1962). Among them, the loss or reduction of eyes, depigmentation, and elongation of appendages have been recognized as defining traits for living in complete darkness (Bilandžija et al., 2012; Gonzalez et al., 2017). Selection pressures imposed by subterranean environments are often so strong that even conspecific individuals can exhibit divergent phenotypes depending on their habitats (Jeffery, 2020; Lunghi and Zhao, 2020), as two studies on fish (Enriquez et al.) and newts (Guillaume) published in this Research Topic also show. Other less conspicuous traits should also be included within the array of adaptations to cave life. For example, behavioral adjustments may be the first changes individuals need to make in a novel subterranean environment (Lunghi et al., 2023). All behaviors based on visual inputs must be replaced by new ones that rely on other sensory stimuli, such as chemical or mechanical cues (Plath et al., 2004; Yoshizawa et al., 2012). Consequently, the nervous system, for example, should undergo specific modifications of its structure and function to adapt to the new conditions. Further, many cave species have modulated their metabolism to better withstand long periods of starvation in generally food-deprived subterranean environments (Hervant, 2012; Lipovšek et al., 2019). This Research Topic on *Adaptations to Subterranean Environments* aimed to assemble some of the latest studies on adaptive traits in obligate and facultative cave species and to highlight new research perspectives (Culver and

Pipan, 2015; Culver et al.). Thirteen papers are included in this Research Topic, including five reviews on specific topics, such as biomimetics (Hesselberg), chemoreception (Berning and Gross), and electroception (Soares et al.). Eight original research articles address various aspects of adaptation to subterranean life, including the genetic mechanisms that enable the establishment of the specific trait in the population (Arcila et al.; Bondareva et al.). Various model species were used for these studies, including less-studied species such as mammals (Luna et al.) and microorganisms (Frumkin et al.). On the other hand, more conventional model species of subterranean invertebrates were used to properly understand the phylogeography of congeneric species (Kováč et al.) and to test whether widely accepted theories such as Island and Rensch's rules can also apply to subterranean species (Herczeg et al.). The array of different studies in this Research Topic not only provide a general overview of subterranean adaptations and demonstrate the growing interest and scope of research on this topic, but also provide new insights into which and how specific adaptive traits evolve in species that have colonized the subterranean realm.

Author contributions

EL: Writing – original draft, Writing – review & editing. MN: Writing – review & editing. HB: Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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