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SUPPLEMENTARY INFORMATION

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Microbial ageing and longevity

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Supplementary Box 1 — Ecological conditions favoring the evolution of microbial aging (reproductive asymmetry) versus non-aging (reproductive symmetry).

Both microbial longevity and senescence can have evolutionary advantages, depending on the ecological circumstances. Mechanistically, longevity is characterized by processes of cellular repair and maintenance that directly combat damage, while senescence is characterized by accumulation of damage and the processes of asymmetric reproduction that sequester it[1] (see **Mechanisms of microbial aging** section). The relative costs and benefits of repair and maintenance versus asymmetric reproduction—reproduction-longevity tradeoffs—will determine whether senescence evolves[2,3]. Combating damage expends ATP, time, and other resources[4–7]. Repair promotes longevity, but spending too much time and energy on damage repair could cause an organism to lose the opportunity to reproduce, perhaps due to extrinsic mortality or to insufficient energy resources remaining for reproduction.

Resource-rich environments support rapid rates of cellular activity, metabolism, growth, and reproduction, which as a byproduct can increase the rate of macromolecular damage. When macromolecular damage is high, repair is insufficient or too inefficient to cope with damage, and the evolution of asymmetric reproduction with its associated possibility of senescence can be favored[2,3,8–13]. The benefits of the ability to quickly make use of resources for growth and reproduction in an energy-rich environment outweigh the cost of senescence.

On the other hand, the strategy of cellular repair excels in circumstances when damage is low enough to be kept in check[3,13]. This would typically occur in stable, low-energy environments where metabolic efficiency is advantageous and where slowed metabolic rates also slow the incidence of damage[3,14–18]. As one might expect if low-energy environments select for repair and longevity, the long-lived microorganisms inhabiting ecosystems like the deep biosphere commonly exhibit signatures of cellular repair[14,15,19]. Selection for repair and longevity in low-energy conditions may even provide an evolutionary basis for the observation that a low energy diet or dietary restriction extends lifespan in both unicellular and multicellular taxa[20,21].

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