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Opinion

The Evolutionary Legacy of Germline-Mediated Somatic Aging and Death

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Introduction

Darwin's "descent with modification" has left a trail of genetic, physiological and procedural continuity, that can provide a deeper understanding of biological and patho(physio)logical processes by "unearthing the fossil record" of the genome [1-3]. The natural lifestyle of microbes is characterized by inherent "feast and famine" cycles, limiting amounts of nutrients being rather the rule than the exception, long periods of nutritional deprivation being punctuated by short periods that allow fast growth. The feast-to-famine transition is not merely a response to a drop in nutrient availability; this transition also involves cooperative cell-to-cell signaling pathways and social aggregation, the results of which range from sporulation to fruiting body and complex pattern formation. Under metabolic stress, Bacillus subtilis, Streptococcus pneumonia and a host of other bacterial species commit siblicide/fratricide and cannibalism, using the remains of their kin in an otherwise resource-depleted environment as resource for sporulation, competence for genetic transformation or biofilm formation. Both the bacteria Myxococcus Xanthus and amoeba Dictyostelium disodium are single celled under abundant resources but socialize under metabolic stress. Largely stochastic processes route clonal cells into different cell fates. Cells destined to become metabolically dormant and resilient spores (the future germline cells) coerce other cells into apoptotic death by means of toxins. This "phenotypic fossil trail" links unicellular apoptosis and differentiation with metazoan semelparous reproduction-associated death and iteroparous, more gradual aging and death. For example, matricidal behavior occurs in extremely resource-limited habitats in which the parental organism serves well to nurture the progeny [4]. Several examples of maternal death (endotokia matricida) that occurs during matricidal hatching are provided by Caleb Finch (1990, p. 102). Facultative endotokia matricida has been observed in a variety of parasitic and free-living oviparous nematodes as a response to food limitation.

In a series of 32 articles [5], I identified three axes advancing the progression of somatic aging: consumption of resources/metabolism, germline signals, and stress responses. Ecosystem budgets constrain the resource budget within which organisms that compete for limited resources have to reproduce [6]. The consumption of resources and metabolic activity is measured by anabolic agents like insulin and target of rapamycin, the aging ratchet [7]. Evolution "appointed" the germline cells, the prospective individuals of the next generation, as guardians of limited resources and mediators of population regulation. Specifically, germline signals (e.g. sexual hormones) degenerate the pineal-hypothalamic-pituitary-gonadal-immune pathways of their parental "host" and eliminate their parents to preserve scarce resources [8]. In this capacity, at reproductive maturity, signals of germline cells acutely (in semelparous organisms) or more or less gradually (in iteroparous organisms) degenerate parental immune competence, undermine stress response pathways and proteostasis, and derange mitochondrial energy homeostasis. Moreover, the reproductive activity of organisms limits itself, restricting the number of offspring depending on the ecological birth-death balance [9].

Evolutionary biology is replete with controversies. Many of these controversies are based on the evidence that a multitude of evolutionary phenomena violate the paradigm of "individual fitness maximization". In an evolutionary transition in individuality (ETI), collectives become units of selection in their own right. One observation used to identify the completion of an ETI is an increase in collective-level performance accompanied by a decrease in particle-level performance, referred to as fitness decoupling [10]. The evolution of somatic aging and death [4, 5], sexual selection [11], cooperation/altruism [12], parental care, reproductive senescence [9], cannibalism, reproductive restraint, bet hedging [13], and population regulation fulfill these criteria. All of these various processes foster the persistence of lineages and most of them exhibit one common feature: they prevent the overexploitation of resources, and are ecologically sustainable [13, 12].

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Conflict of Interest

No conflict of interest.

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