A New Theory on Aging, Living Long, and Dying

Body System Redundancies and "the thousand natural shocks that flesh is heir to" are key to why we age and when we die

This is a lightly edited press release; original is at <http://www.src.uchicago.edu/~gavr1/press_release.html>.

Our bodies' backup systems don't prevent aging, they make it more certain. This is one proposition of a new "reliability theory of aging and longevity" by two researchers at the National Opinion Research Center at the University of Chicago. Authors Leonid Gavrilov and Natalia Gavrilova, in their paper, "The Reliability Theory of Aging and Longevity," published in the *Journal of Theoretical Biology* (**213**, 527-545), have offered a comprehensive, groundbreaking theory to understand why people (and other biological species) deteriorate and die more often with age. Interestingly, the relative differences in mortality rates across nations and gender decrease with age. That is, although people living in the U.S. have longer life spans on average than people living in countries with poor health and high mortality, those who achieve the oldest-old age in those countries die at rates relatively similar to the oldest-old in the U.S.

Humans are built from the ground up. We start off with a few cells that differentiate and multiply to form the systems that keep us operating. Even at birth, the cells that make up our systems are full of faults and defective elements that would kill primitive organisms that lack the redundancies that are built into us. " It's as if we were born with our bodies already full of garbage," said author Gavrilov. "Then, during our life span we are assaulted by random destructive hits that accumulate in further damage. Thus we age. At some point one of those hits causes a critical system without a back-up redundancy to fail, and we die."

All those in the world who have achieved the oldest-old age have very few redundancies remaining; therefore they can't accumulate many more defects. They simply die when the next random shock hits a critical system. Hence, the mortality rates tend to level off at extreme old ages, and people all over the world die at relatively similar rates on average. The initial differences in body reserves (redundancy) eventually disappear.

This fundamental theory of aging and longevity is grounded in a predictive mathematical model that accounts for questions raised by previous models that have addressed the mechanisms of aging, mortality, survival, and longevity.

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Abstract and Description of the Model

Abstract

Reliability theory is a general theory about systems failure. It allows researchers to predict the age-related failure kinetics for a system of given architecture (reliability structure) and given reliability of its components. Reliability theory predicts that even those systems that are entirely composed of non-aging elements (with a constant failure rate) will nevertheless deteriorate (fail more often) with age, if these systems are *redundant* in irreplaceable elements. Aging, therefore, is a direct consequence of systems redundancy. Reliability theory also predicts the late-life mortality deceleration with subsequent leveling-off, as well as the late-life mortality plateaus, as an inevitable consequence of *redundancy exhaustion* at extreme old ages. The theory explains why mortality rates increase exponentially with age (the Gompertz law) in many species, by taking into account the *initial flaws (defects)* in newly formed systems. It also explains why organisms "prefer" to die according to the Gompertz law, while technical devices usually fail according to the Weibull (power) law. Theoretical conditions are specified when organisms die according to the Weibull law: organisms should be relatively free of initial flaws and defects. The theory makes it possible to find a general failure law applicable to all adult and extreme old ages, where the Gompertz and the Weibull laws are just special cases of this more general failure law. The theory explains why relative differences in mortality rates of compared populations (within a given species) vanish with age, and mortality convergence is observed due to the exhaustion of initial differences in redundancy levels. Overall, reliability theory has an amazing predictive and explanatory power with a few, very general and realistic assumptions. Therefore, reliability theory seems to be a promising approach for developing a comprehensive theory of aging and longevity integrating mathematical methods with specific biological knowledge.

Description of Model

The phenomena of mortality increase with age and the subsequent mortality leveling-off are theoretically predicted to be an inevitable feature of all reliability models that consider aging as a progressive accumulation of random damage. …In short, if the destruction of an organism occurs not in one but in two or more sequential random stages, this is sufficient for the phenomenon of aging (mortality increase) to appear and then to vanish at older ages. Each stage of destruction corresponds to one of the organism's vitally important structures being damaged. In the simplest organisms with unique, critical structures, this damage usually leads to their deaths. Therefore defects in such organisms do not accumulate, and the organisms themselves do not age— they just die when damaged. In more complex organisms with many vital structures and significant redundancy, every occurrence of damage does not lead to death because of this redundancy. Defects do accumulate, therefore, giving rise to the phenomenon of aging (mortality increase). Thus, aging is a direct consequence (trade-off) of systems redundancy that ensures increased reliability and lifespan of organisms. As defects accumulate, the redundancy in the number of elements finally disappears. As a result of this redundancy exhaustion, the organism degenerates into a system with no redundancy, that is, a system with elements connected in series, with the result being that any new defect leads to death. In such a state, no further accumulation of damage can be achieved, and the mortality rate levels off. (Pp. 530-531).

The full text of the paper is available online at http://www.src.uchicago.edu/~gavr1/JTB-01.pdf. Contact Julie Antelman for hard-copy. Also available for science correspondents/reporters is a set of brief comments on the paper made by other experts who have given permission to be quoted by journalists.