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The Reliability Theory of Aging and Longevity

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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.

1. Introduction

Extensive empirical studies on species aging and longevity have proved successful in establishing many important facts and details about the aging process (Finch, 1990; Jazwinski, 1996, 1998) that have yet to be explained and understood. Empirical observations on this issue have become so numerous and abundant that a special encyclopedia, *The Macmillan Encyclopedia of Aging*, is now required for even partial coverage of the accumulated facts (Ekerdt, 2001). To transform these numerous observations into a comprehensive body of knowledge, a general theory of species aging and longevity is required.

Attempts to develop a fundamental quantitative theory of aging, mortality, and lifespan have deep historical roots. In 1825, the British actuary Benjamin Gompertz discovered a law of mortality (Gompertz, 1825), known today as the Gompertz law (Strehler, 1978; Finch, 1990; Gavrilov

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