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Supercentenarins and the Theory of Heterogeneity

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Most reports, around the world and over time, of exceptional longevity have been errors or falsehoods. Hence reports of people aged 110+ (supercentenarians) have to be carefully checked against birth certificates and other records. A large group of diligent demographers has now succeeded in assembling reliable data on about 800 true supercentenarians in the United States, Japan, France, Italy and other countries. The data are part of the International Database on Longevity (IDL), a collaborative project of INSERM, INED and the Max Planck Institute for Demographic Research and managed by Jean-Marie Robine. The data show a very rapid increase in the number of supercentenarians.

A key question about human mortality is whether the force of mortality (1) continues to rise with age, (2) asymptotically approach a limit or (3) falls after some advanced age. Previous attempts to ascertain the answer have been plagued by problems of inaccurate or selection-biased data.

Using the accurate, representative IDL data we find that human mortality levels off after age 110 at a q, annual probability of death, of about .5.

Recent work in mathematical reliability theory shows that if mortality levels off, then (1) a proportional-hazards model is valid but an accelerated-aging model is invalid, (2) the force of mortality must rise exponentially for individuals and (3) individual frailty (relative risk of death) must follow a gamma distribution. In the Gompertz equation (a exp(bx)), frailty influences the level of a but b is the same for all individuals. An equation derived by Vaupel shows that if q levels off at about .5, then b must be about .14 and the variance of the gamma distribution must be about .2.

The finding that human morality levels off at a q of about .5 is consistent with the ages attained by the record holder, Jean Calment (122), and the second longest-lived individual in our dataset, Sarah Kraus (119).

Historical data on mortality in Sweden and other countries is consistent with the hypothesis that human mortality asymptotically approached a limit at q equal to

about .5 in the past as well as today—and that a b of about .14 and a variance in frailty of about .2 were also valid in the past.

Given values for b and the variance in frailty, it is possible to estimate the force of mortality for a standard individual of frailty 1. Then the rate of progress in reducing mortality over time can be studied, without the confounding effect of mortality selection (because the frail tend to die first). If the rate of progress is estimated from population data on mortality, then it appears that the pace of improvement declines dramatically with age at the highest ages. Using estimates of mortality for standard individuals, however, the decline is much less.

These results suggest a new strategy for closing out lifetables at advanced ages.

The results also imply rough upper and lower limits to the number of genes that substantially affect longevity.