Chapter 1

Preface

James W. Vaupel

The advance of the frontier of survival is documented, verified, and brought to life in this monograph.

A dedicated international team has worked for two decades to gather data on supercentenarians, aged 110+, in 12 European countries, Japan, Quebec and the United States. For the last several years, additional information has been compiled on semi-supercentenarians, aged 105–109. The findings are stored in the International Database on Longevity (IDL), which was founded by Jean-Marie Robine and me, originally housed at INSERM, the French National Institute of Health, in Montpellier, France and now managed by the Max Planck Institute for Demographic Research in Rostock, Germany, in collaboration with the French Institute for Demographic Studies (INED). An updated version of this database will be released at the same time this book is published. The database is meticulously described in Chap. 2 by Jdanov, Shkolnikov and Gellers-Barkman, key researchers in the Laboratory of Demographic Data at the Max Planck Institute. France Meslé and Jacques Vallin at INED, as well as Jean-Marie Robine, at INED and INSERM, Bernard Jeune at the University of Southern Denmark, Michel Poulain at the Université catholique de Louvain and many of the authors of chapters in this book and its predecessor (Maier et al. 2010) helped develop the database.

In addition to the IDL data, carefully validated reports based on painstaking scholarship have been prepared on specific individuals with extraordinarily long lifespans. Some of these reports are presented in Chaps. 14, 15, 16, 17, 18, 19, 20, 21 and 22. Other reports were published in our 2010 monograph *Supercentenarians*. Chapter 14 provides references to additional case studies, including the book *Validation of Exceptional Longevity* (Jeune and Vaupel 1999). The exacting research

J. W. Vaupel (✉)

Danish Centre for Demographic Research, University of Southern Denmark,
Odense, Denmark

Max Planck Institute for Demographic Research, Rostock, Germany
e-mail: jamesw.vaupel@gmail.com

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to verify very long lives is impressive—and it is fascinating to read about extreme longlivers and how their lifespans were documented. The case studies in this monograph are the crown jewels of the laborious endeavors of the supercentenarian research team.

As briefly described in Chap. 14 and more fully discussed in Jeune and Vaupel (1999), most alleged supercentenarians were considerably younger than reported. The credulity of those who accept claims of very long lives is characteristic of the trust in naïve beliefs and acceptance of unproven claims that has obscured knowledge about the outposts of human life. Ignorant assertions based on shoddy research or canonical but questionable views are still being made about exceptional lifespans and about the trajectory of mortality at advanced ages. As Kestenbaum observes in Chap. 6, publications “that are clearly incorrect should serve as a reminder to the research community of the folly of using data for the extreme aged without questioning and evaluating them.”

The 22 chapters in this monograph contribute substantial advances in verified facts about exceptional lifespans and in the application of analytical strategies to understand trends and patterns in the rare lifespans on the frontier of human existence.

This scrupulous, demanding research is important because it sheds light on “how long can we live?,” a question of fundamental scientific, social and individual interest. The question can be posed “what is the maximum human lifespan?” This pre-judges the answer because there may not be a limiting lifespan that is fixed over time. As knowledge advances, the maximum might also advance, perhaps gradually but without a definite limit. On the other hand, a biologically-determined maximum might constrain the lifespans of humans—and other species. As often asserted in the gerontological literature, every species may have its characteristic maximum, its species-specific lifespan.

“There is one and only one cause of death at older ages and that is old age and nothing can be done about old age.” This dreary view is now discredited (Vaupel 2010) although it is still widely held. It is now known that the evolutionary theories of aging devised by Medawar, Williams, Hamilton and Kirkwood do not imply a maximum duration of life (Baudisch 2008; Baudisch and Vaupel 2010; Jones et al. 2014) although many biologists cling to the outdated dogma. It appears that the age-pattern of senescence, of growing old, is not fixed but is being postponed to higher ages as life expectancy increases (Oeppen and Vaupel 2002; Vaupel 2010; Colchero et al. 2016).

Still unanswered, however, is the fundamental question of whether human lifespans are approaching an intractable limit. If so, the advance of the frontier of survival documented in this monograph will slow and then cease. The pace of increase in life expectancy will decline and then stop.

A problematic report in *Nature* (Dong et al. 2016) asserts that the limit to lifespans has already been reached and is about 115 years, with cases of lifespans above this limit, as documented in Chaps. 14, 18, 19, 21 and 22 of this book, being random outliers. The statistical analysis underpinning the claim of a 115-year maximum is questionable (Van Santen 2016a, b; De Beer et al. 2017; Hughes and Hekimi 2017; Lenart and Vaupel 2017; Newman and Eastaugh 2017; Rootzén and Zholud 2017;

Roizing et al. 2017). Furthermore, the authors did not take into account the intricate nature of the IDL data they extracted from a 2007 compilation intended to supplement our 2010 volume on *Supercentenarians*. In Chap. 2 of this book, Jdanov, Shkolnikov and Gellers-Barkmann assiduously explain the complicated observational plans used for different countries in the database, some data pertaining to birth cohorts and other data to periods starting and ending at various years, some data left truncated, some data right truncated, some data right censored and some data interval censored.

In Chap. 3, Gampe shows how carefully and subtly the variegated IDL have to be handled. Her chapter follows up on a similar chapter in our earlier book (Gampe 2010) but now with data on 1219 verified supercentenarians, almost twice as many as available earlier. She confirms her earlier conclusion that the annual probability of death between ages 110 and 114 is constant and about 50% per year. The number of observations is too scanty to allow estimation of death rates after age 114. Differences in mortality between the sexes cannot be detected because males are too few in number. The risk of death in Japan might be somewhat lower than in Europe or the United States, but again the small number of observations precludes a firm conclusion.

Demographers use different measures of mortality, including the annual probability of death and the hazard of death or “force of mortality”, which is usually close to the death rate estimated by dividing the number of deaths at some age by the number of people exposed to death at that age. Gampe presents most of her results in terms of the hazard of death. This value is the negative logarithm of 1 minus the probability of death. Hence, when Gampe reports a hazard of death of 0.7, this value implies a probability of death of 0.5.

Gampe’s key finding—that the annual probability of death is about 50/50 after age 110—is important because if the plateau continues to hold after age 114, then the number of people reaching more advanced ages will increase as the number of people attaining age 110 increases. The mathematics of this are explained in Chap. 5 by Lenart, Aburto, Stockmarr and Vaupel. The finding is also important because it implies that the current longevity record—Jeanne Louise Calment’s lifespan of 122.45 years—is not implausible and that it is also not implausible that her record, which was set in 1997, has not yet been broken. As shown in Chap. 5, these are implications of Gampe’s 50/50 plateau.

The plateau is predicted by a theory of mortality in heterogeneous populations that postulates that individuals continue to grow weaker even after age 110, with the annual risk of death rising at perhaps about 14% per year (Vaupel 2010; Vaupel et al. 1979; Vaupel and Missov 2014; Missov and Vaupel 2015). The constant risk of death for the surviving population is the result of an equilibrium between two forces. Half the cohort dies, including many of its weaker members, leaving a more robust population of survivors. These survivors, however, grow a year older—and weaker. The plateau is reached when the death of the frail counterbalances the aging of the survivors.

Constant hazards of death after 110 are inconsistent with the claim by Dong, Millholland and Vijg (2016) that the maximum human lifespan is 115. If this were true, mortality should sharply rise at advanced ages, imposing a wall of death at age

115. Perhaps annual survival is constant from 110 to 114 and then steeply falls: this seems implausible but more analysis is needed to refute the conjecture. People have lived beyond 115, including those documented in Chapters 14, 18, 19, 21 and 22, so a wall of death at 115 would have to have a hole to let the outliers through. An upper bound on age-specific death rates at the highest ages could be estimated by careful study of how high the hazard of mortality after 114 could rise without precluding the validated super-supercentenarians, aged 115+. The mathematics developed in Chap. 5 indicates that the annual risk of death after age 114 cannot rise much above 50% unless Jeanne Louise Calment's rigorously documented lifespan of 122.45 is fraudulent.

In short, like many previous assertions about limits to human life expectancy and lifespans (Oeppen and Vaupel 2002), the claim that humans cannot live longer than 115 years adds more noise than knowledge to the study of longevity. Some more nuanced version of the claim might be correct: human lifespan records may not increase significantly. It seems more likely that lifespan records in specific countries and globally will be broken again and again as more people survive to become supercentenarians and super-supercentenarians (115+).

The Gavrilovs have achieved some notoriety by proclaiming that cohort death rates continue to rise exponentially even at the most advanced ages (e.g., Gavrilova et al. 2017). As documented by Villavicencio and Aburto in Chap. 4, the Gavrilovs reach this result by applying weak statistical methods to artfully selected data. Sophisticated tools have been developed to analyze censored data with age at death not observed for some individuals. Sophisticated tools have also been developed to analyze data on the lifespans of individuals, taking advantage of knowledge of exact dates of birth and death. The Gavrilovs, however, drop cohorts with censored data and group individuals by time periods of birth and death, greatly reducing the power of their analysis. In contrast, Gampe in Chap. 3 dissects the full individual-level information in the intricate IDL dataset by applying state-of-the-art statistical scalpels.

Individuals who have reached exceptional ages can be compared with cut and polished jewels—precious diamonds, rubies, emeralds, sapphires and opals, each unique with its own facets and tints. Exacting, state-of-the-art strategies should be deployed to extract the fullest information from knowledge about the rare humans on the marchlands of survival. Gampe does this in Chap. 3 and Villavicencio and Aburto in Chap. 4 indicate how the Gavrilovs could have done better. Lenart, Aburto, Stockmarr and Vaupel in Chap. 5 focus on Jeanne Louise Calment, the current longevity record holder: they debunk claims to the contrary by showing that (1) her lifespan is not implausible, (2) it is not surprising that her record still holds, and (3) her record might not be broken for decades.

Kestenbaum in Chap. 6 relates yet another sorry failure to treat longevity data with appropriate care and skepticism. In the United States annual estimates of the number of deaths by age for centenarians are distorted by unreported or unrecorded deaths and by age misstatement. Errors in reporting and recording and in age misreporting are even more severe with regard to the number of living centenarians. Hence death rates at advanced ages have to be estimated with care. Kestenbaum

documents unacceptable estimates by the U.S. National Center for Health Statistics and outlines steps that can be taken to improve the estimates.

What are the causes of death at very old ages? Meslé and Vallin in Chap. 7 use data from France and Kaalby, Skytthe, Andersen-Ranberg and Jeune in Chap. 8 use data from Denmark to address this question. In Chap. 8, the question is posed: “As most centenarians suffer from multiple diseases, they are at high risk of dying—but what do they ultimately die of?” In both France and Denmark, cardio- and cerebrovascular diseases account for a third or so of deaths at high ages. Perhaps the most intriguing finding of both chapters is that with age cancer becomes a less important cause of death. In Denmark cancer was listed as the cause of death for only 3–4% of centenarians compared with 15% of those 85–99 years old; the decline with age in cancer as a cause of death was similarly dramatic in France.

Ill-defined or unspecified causes become increasingly important with age and are becoming more important over time, perhaps because of underdiagnosis of specific diseases. In France the cause of more than 40% of supercentenarian deaths was recorded as ill-defined or unspecified. Meslé and Vallin conclude that “daily care is more crucial to the survival of the oldest old than any conventional medical care or treatment. Supercentenarians tend to be so frail that any minor health event or brief lapse of attention on the part of caretakers can be lethal.”

As Gampe documents in Chap. 3, the annual probability of death appears to be constant after age 110 for the IDL data analyzed as a whole. At what age is this plateau reached? To study this question, the IDL is expanding its coverage to semi-supercentenarians, aged 105–109. In four countries—Italy, France, Japan and the United States—numbers of observations are now sufficient to permit serviceable estimates.

An analysis of the Italian data by Barbi, Lagona, Marsili, Vaupel and Wachter was published in June 2018 in *Science*. The authors found a plateau starting at age 105 and extending to age 108, after which the data are too sparse to permit estimation. The plateau is at a level of about a 50% chance of death per year but with a modest decline in this level over successive cohorts. The theory of mortality in heterogeneous populations (Vaupel et al. 1979; Vaupel 2010; Missov and Vaupel 2015 and Vaupel and Missov 2014) predicts that death rates approach a plateau and get closer and closer to it with advancing age. As death rates decline prior to advanced old age, the plateau is approached at later ages. A reasonable hypothesis is that the plateau is not declining for successive Italian cohorts but that it is being reached at later ages. If so, estimates of the level of the plateau after age 105 based on the average level of mortality after 105 would be slight misestimates and somewhat lower for more recent cohorts.

In Chap. 9 of this monograph, Ouellette, Meslé, Vallin and Robine analyze the data at ages 105+ for France. They supplement Chap. 2 by providing further details about the nature and accuracy of the French data. They conclude that for French females “probabilities of death...appear to level off at 0.5 between ages 108 and 111....After age 111, however, data become too scarce to assess the trend.”

Mortality of centenarians and supercentenarians in Japan is the focus of Chap. 10, by Saito, Ishii and Robine. This chapter details the characteristics of the available

data. Figure 2 shows the rise in the highest reported ages at death in Japan since 1963: for the longer-lived and more numerous females, the rise is roughly linear, with no indication that a limit at age 115 is being approached. Concerning the mortality plateau, the authors conclude that “for the cohorts born between 1894 and 1900, mortality seems to increase at least up to age 107 among males and up to age 111 among females.” My reading of their Fig. 5b suggests that probabilities of death for females may reach a plateau starting at age 111 at a level of perhaps 55% per year. The data, however, are too sparse to be confident about this. In Chap. 3 Gampe applies her estimation strategy to the Japanese data and concludes that given the small number of observations it is not clear if and at what age a mortality plateau is reached but that if there is a plateau the annual probability of death might be about 45%.

The fourth country with a substantial number of observations after age 105 is the United States. Kestenbaum discusses the available data in Chap. 13. He concludes that the annual probability of death for men and women increases from age 105–109 “from something below 0.5 to something above 0.5.” Gampe, in Chap. 3, examines the U.S. data above age 110. She finds a plateau at a 51.5% probability of death per year, with a standard error about 2%, with no significant difference between males and females or between earlier and later birth cohorts.

Mortality data for Quebec are of high quality and are available for several centuries. In Chap. 12, Beaudry-Godin, Bourbeau and Desjardins describe the increase in the number of centenarians in Quebec across cohorts born in 1871–1901. They document “remarkable progress realized in old age mortality” and show that the increase in the number of centenarians is largely due to progress in reducing death rates between ages 80 and 100. Their Fig. 5 shows that the trends for males and females in the highest ages at death since 1950 are linear with no sign of a looming limit. Figure 6 presents projections of future centenarian populations in Quebec: in their high scenario, which I favor, the number may increase from 1623 in 2015 to close to 100,000 in 2061.

Up until now, little reliable information has been available on people 100+, 105+ and 110+ in Poland. Kroczyk, in Chap. 11, endeavors to “produce a list, as complete as possible, of validated Polish supercentenarians.” This is a major undertaking, which he clearly documents. He also presents preliminary data on those who reached age 105. And he provides information on the number of centenarians in Poland over time. In doing so, he explains how the complicated history of Poland makes research on exceptional lifespans difficult—but nonetheless possible.

The final chapters of this monograph focus on case studies of exceptional longevity. In Chap. 14, Jeune and Poulain provide an overview. These chapters are remarkable both for their human interest and their remarkable scholarship.

The authors of the chapters of this monograph and various co-researchers in 12 European countries, Japan, Canada and the United States have collaborated on research on exceptional lifespans for almost 20 years. We like each other and enjoyed meeting together to discuss various research issues and findings for a couple of days in:

- June 2000 in Rostock, Germany,
- June 2001 in Sophienberg/Rungsted, Denmark,
- May 2002 in Atlanta, Georgia,
- May 2003 in Montpellier, France,
- June 2004 in Tokyo, Japan,
- Oct. 2005 in Taormina, Italy,
- Sept. 2008 in Montreal, Quebec,
- Jan. 2011 in Madrid, Spain,
- May 2012 in Rome, Italy,
- Sept. 2014 in Paris, France,
- Sept. 2015 in Copenhagen, Denmark,
- June 2016 in Tallinn, Estonia and
- May 2017 in Rostock, Germany.

In 2010 the group produced a monograph called *Supercentenarians* that was edited by Maier, Gampe, Jeune, Robine and Vaupel. This second monograph summarizes our joint research since then. I helped edit the volume, but the bulk of the credit belongs to Heiner Maier at the Max Planck Institute for Demographic Research in Rostock, Germany and to Bernard Jeune at the University of Southern Denmark in Odense, Denmark. Others who have played especially important roles include Jean-Marie Robine from INSERM and INED in France, Jacques Vallin and France Mesle from INED, Vladimir Shkolnikov, Dmitri Jdanov and Sigrid Gellers-Barkmann from the Max Planck Institute, Graziella Caselli from Rome, Italy, and the other authors of the chapters of this monograph and the preceding one.

The history of the study of exceptional lifespans is a sorry saga of mutual-delusion societies, a desire for renown that trumps truthfulness and integrity, naïve credulity, self-serving fraud, egregious exaggeration, foolishly ignorant overconfidence, unquestioning adherence to questionable dogma, firm belief in what “clearly” must be true, trust in gut feelings, argumentation by metaphor, reliance on rhetoric rather than empirical analysis, use of unvalidated data, lack of understanding of the nature of the available data, and reliance on hatchets instead of scalpels to dissect the precious results of meticulous efforts to validate exceptional lifespans. The IDL data are not fodder to be shoveled into the feeding troughs of computers. Even if it does not close the debates, the careful, nuanced research in this monograph—building on what reliable research does exist, as cited in the references—sheds reliable new light on a topic shrouded in nonsense but fundamentally important—how long can we live?

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