Biodemography of Human Longevity: Mortality Laws and Longevity Predictors

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Biodemographic Laws of Mortality

1. Gompertz-Makeham law
2. Compensation law of mortality
3. Old-age mortality deceleration (?)

The Gompertz-Makeham Law

Death rate is a sum of age-independent component (Makeham term) and age-dependent component (Gompertz function), which increases exponentially with age.

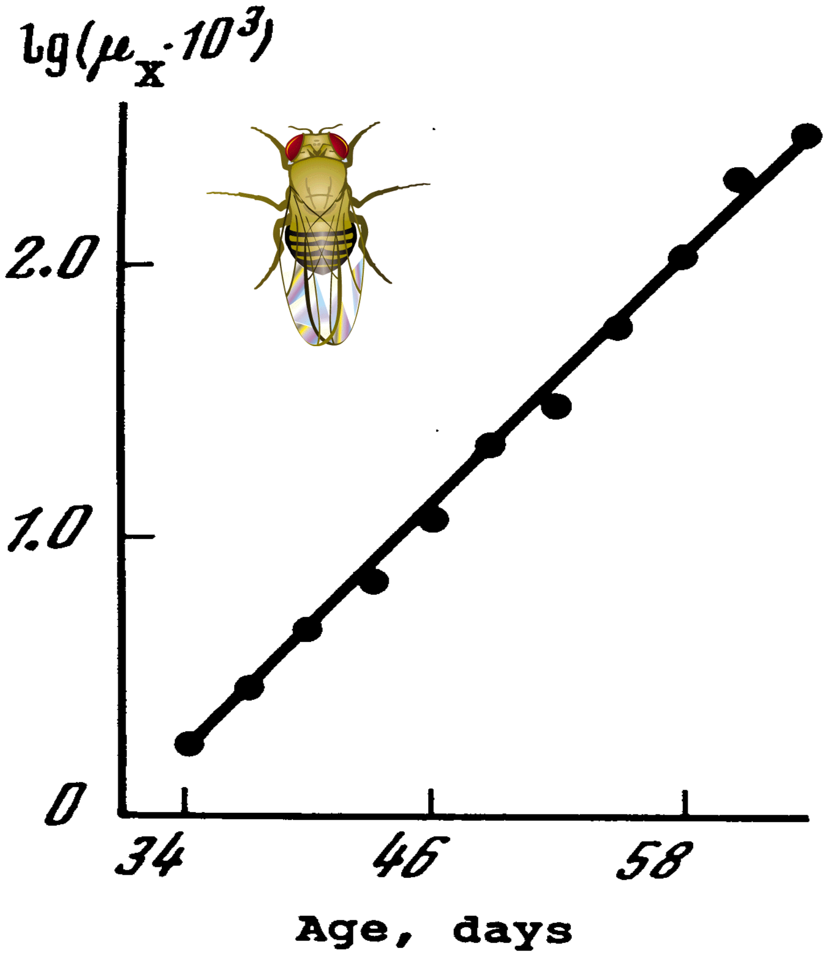
$$\mu(x) = A + R\,e^{\alpha x}$$

risk of death

A – Makeham term or background mortality

$R\,e^{\alpha x}$ – age-dependent mortality; x - age

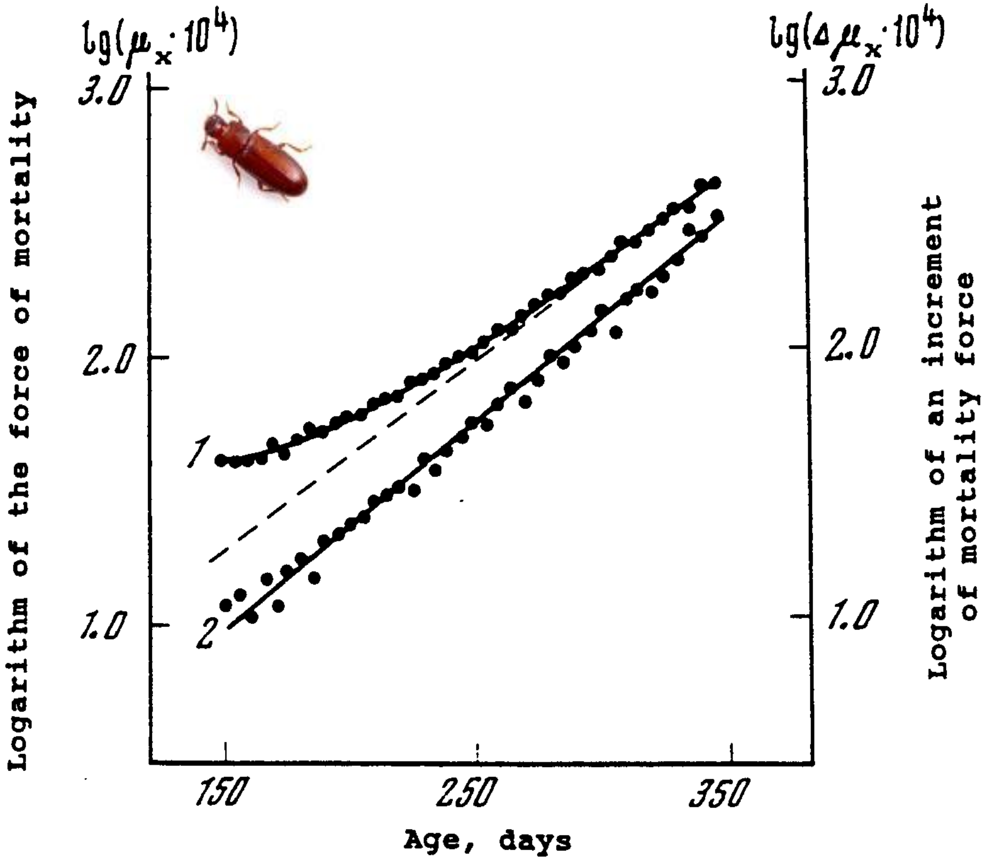
Gompertz Law of Mortality in Fruit Flies



Based on the life table for 2400 females of *Drosophila melanogaster* published by Hall (1969).

Source: Gavrilov, Gavrilova, "*The Biology of Life Span*" 1991

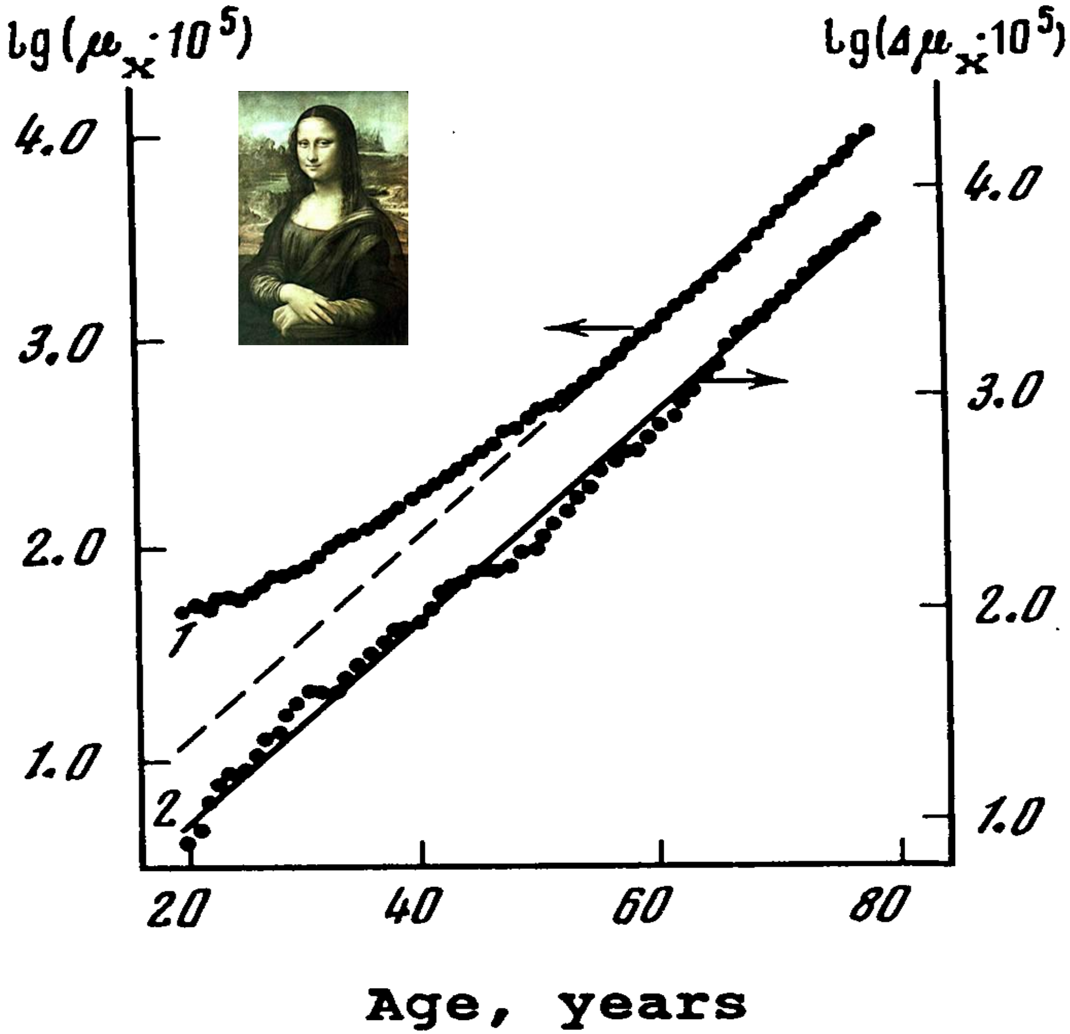
Gompertz-Makeham Law of Mortality in Flour Beetles



Based on the life table for 400 female flour beetles (*Tribolium confusum* Duval). published by Pearl and Miner (1941).

Source: Gavrilov, Gavrilova, "*The Biology of Life Span*" 1991

Gompertz-Makeham Law of Mortality in Italian Women



Based on the official Italian period life table for 1964-1967.

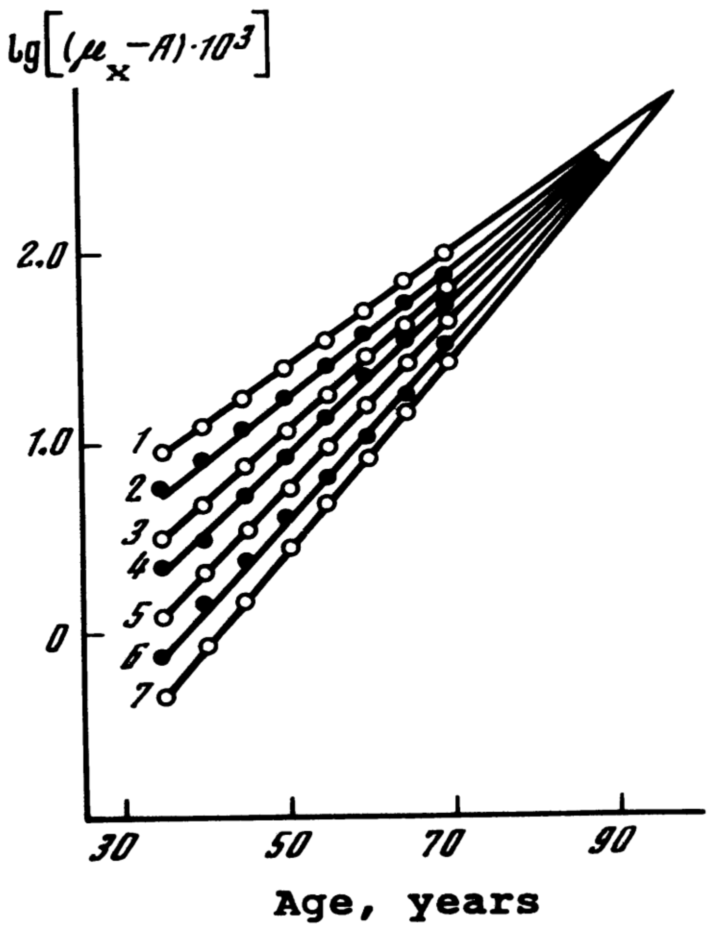
Source: Gavrilov, Gavrilova, "*The Biology of Life Span*" 1991

Compensation Law of Mortality (late-life mortality convergence)

Relative differences in death rates are decreasing with age, because the lower initial death rates are **compensated** by higher slope (actuarial aging rate)

Compensation Law of Mortality

Convergence of Mortality Rates with Age

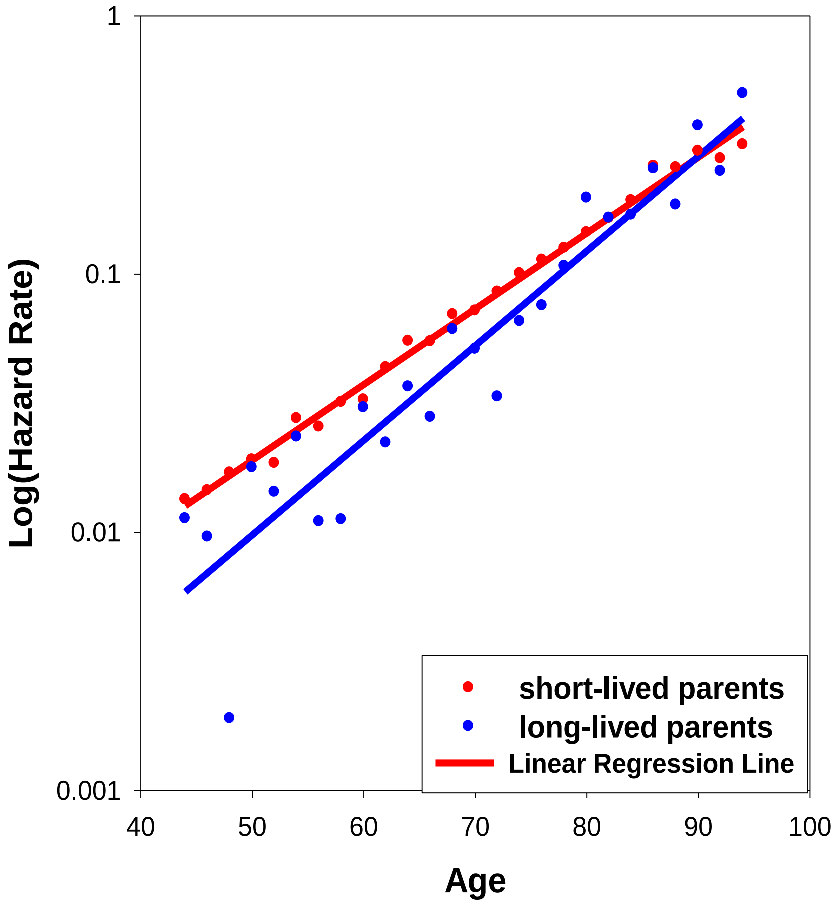


1 – India, 1941-1950, males
2 – Turkey, 1950-1951, males
3 – Kenya, 1969, males
4 - Northern Ireland, 1950-1952, males
5 - England and Wales, 1930-1932, females
6 - Austria, 1959-1961, females
7 - Norway, 1956-1960, females

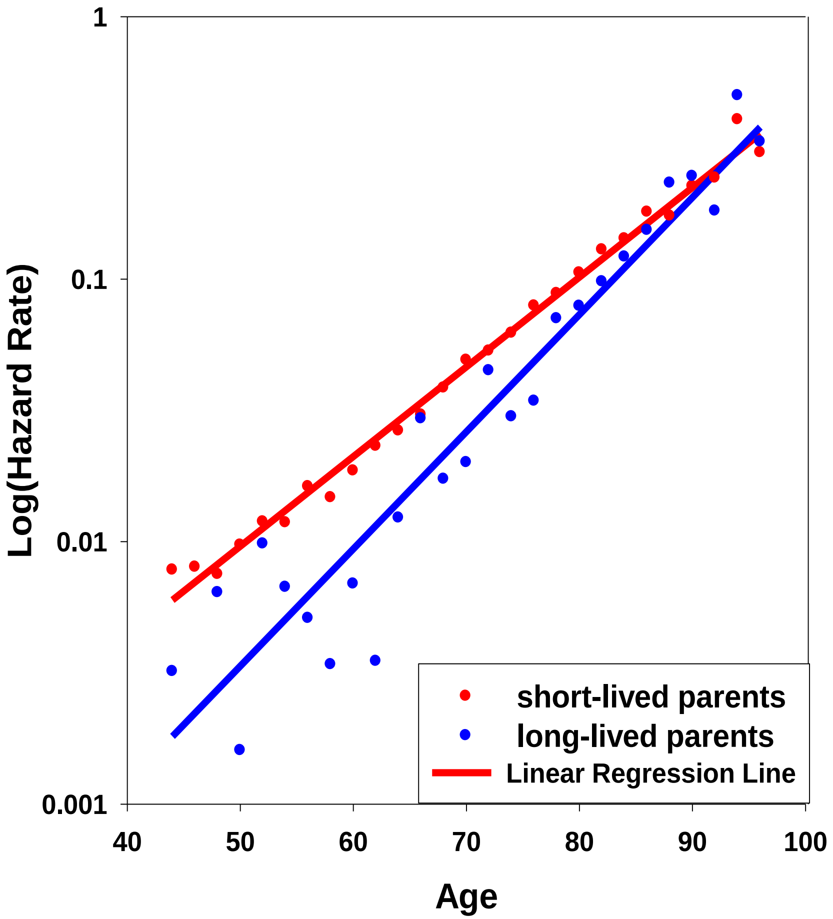
Source: Gavrilov, Gavrilova, "*The Biology of Life Span*" 1991

Parental Longevity Effects

Mortality Kinetics for Progeny Born to <u>Long-Lived</u> (80+) vs <u>Short-Lived</u> Parents



Sons

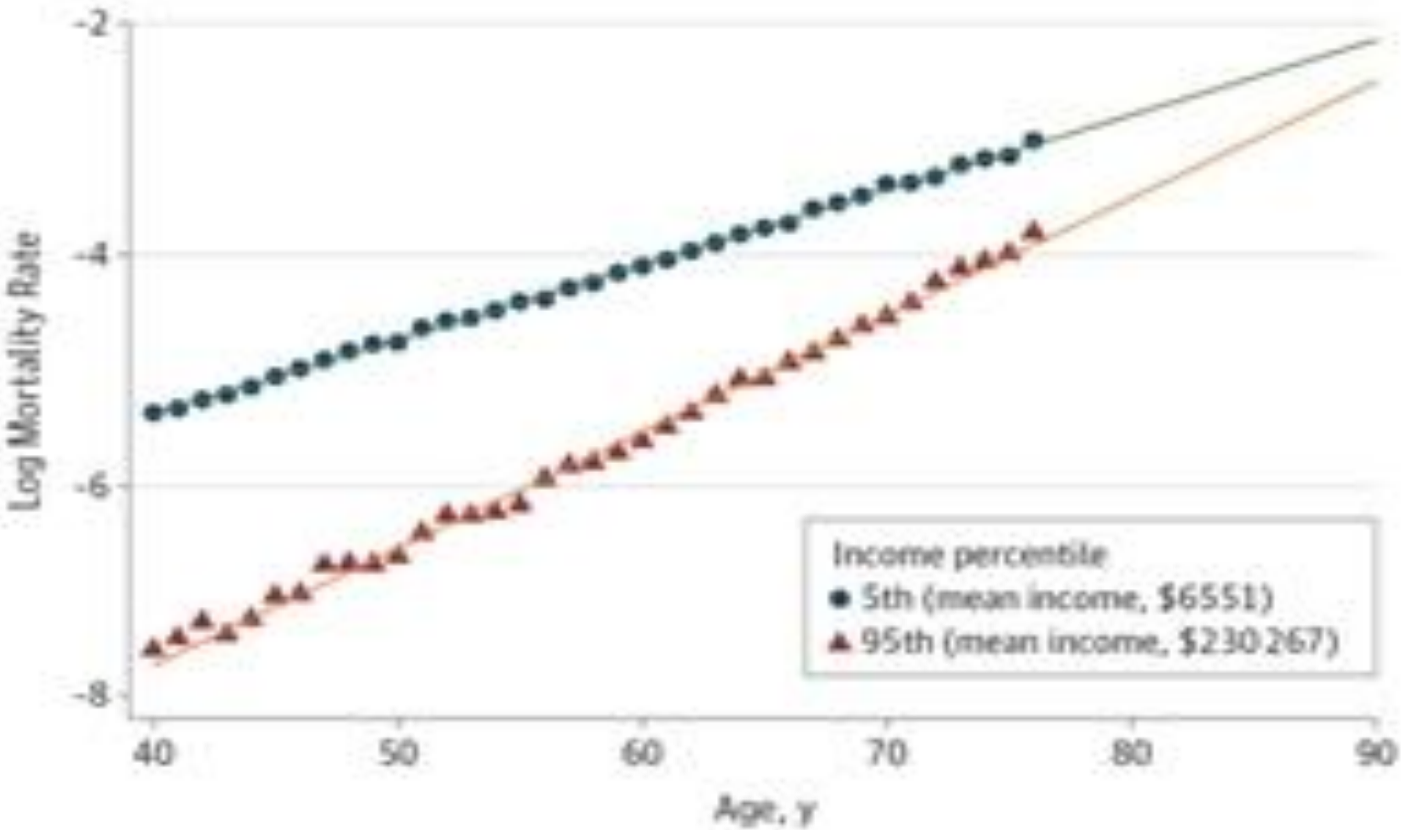


Daughters

Data on European aristocracy

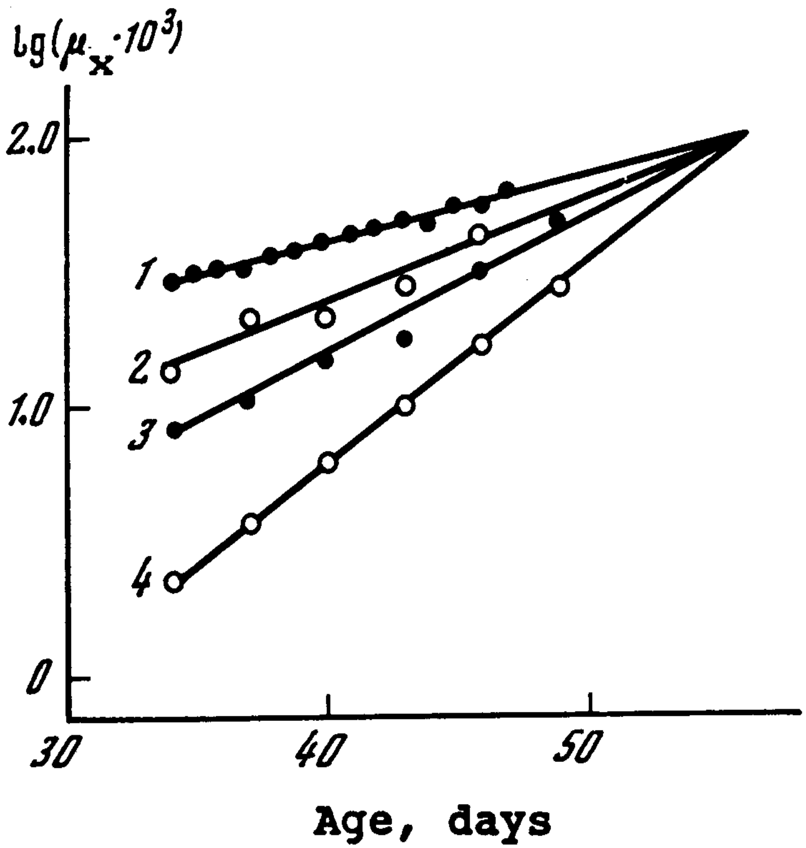
Compensation Law of Mortality

The Association Between Income and mortality of men in the United States, 2001-2014



Source: JAMA. 2016;315(16):1750-1766. doi:10.1001/jama.2016.4226

Compensation Law of Mortality in Laboratory *Drosophila*



1 – drosophila of the Old Falmouth, New Falmouth, Sepia and Eagle Point strains (1,000 virgin females)

2 – drosophila of the Canton-S strain (1,200 males)

3 – drosophila of the Canton-S strain (1,200 females)

4 - drosophila of the Canton-S strain (2,400 virgin females)

Mortality force was calculated for 6-day age intervals.

Source: Gavrilov, Gavrilova,

"*The Biology of Life Span*" 1991

Implications

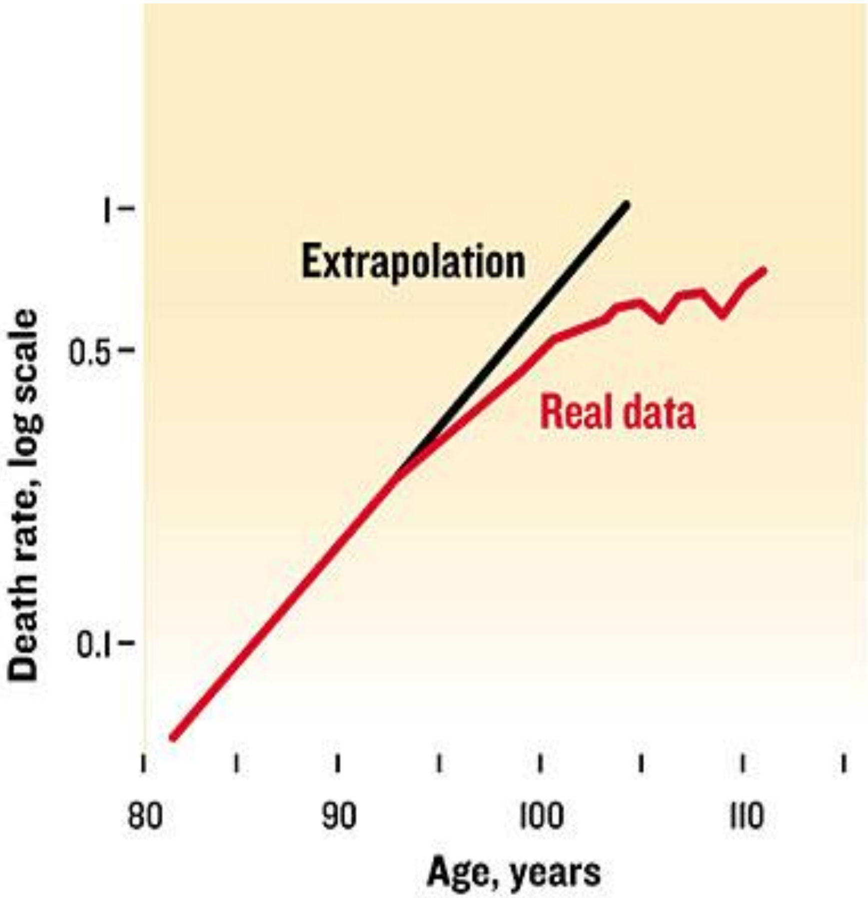
- Be prepared to a paradox that higher actuarial aging rates may be associated with higher life expectancy in compared populations (e.g., males vs females)
- Be prepared to violation of the proportionality assumption used in hazard models (Cox proportional hazard models)
- Relative effects of risk factors are age-dependent and tend to decrease with age

The Late-Life Mortality Deceleration

(Mortality Leveling-off, Mortality Plateaus)

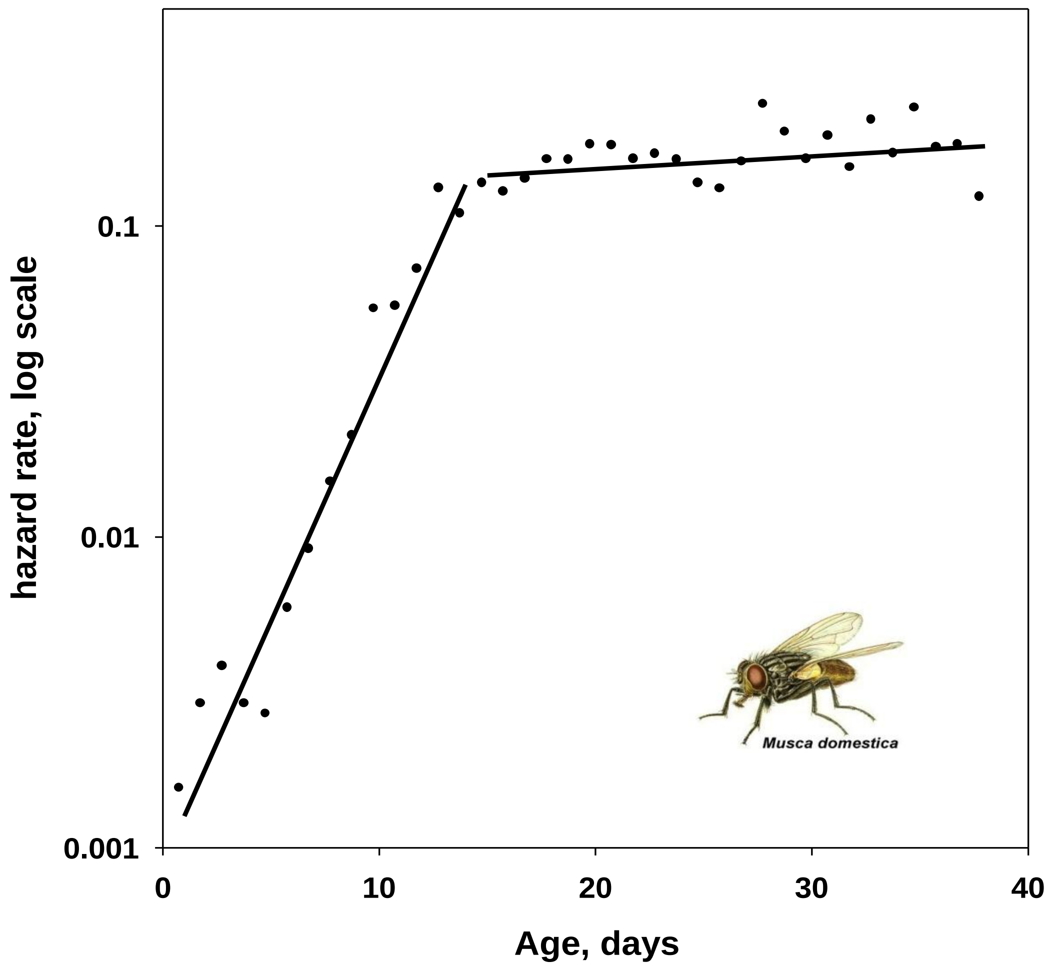
The late-life mortality deceleration law states that death rates stop to increase exponentially at advanced ages and level-off to the late-life mortality plateau.

Mortality deceleration at advanced ages.



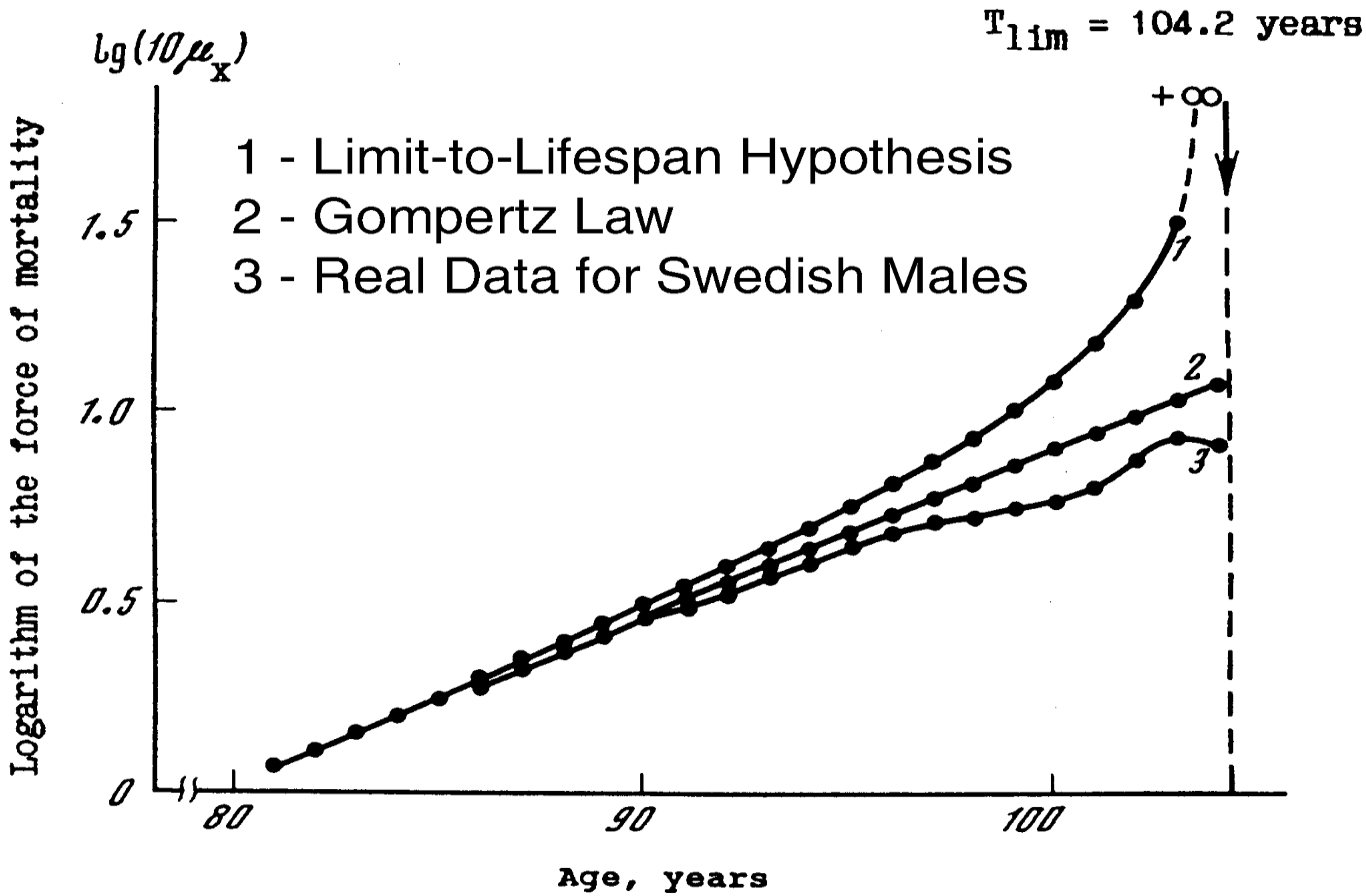
- **After age 95, the observed risk of death [red line] deviates from the value predicted by an early model, the Gompertz law [black line].**
- Mortality of Swedish women for the period of 1990-2000 from the Kannisto-Thatcher Database on Old Age Mortality
- Source: Gavrilov, Gavrilova, "Why we fall apart. Engineering's reliability theory explains human aging". *IEEE Spectrum*. 2004.

Mortality Leveling-Off in House Fly
Musca domestica



Based on life table of 4,650 male house flies published by Rockstein & Lieberman, 1959

Testing the "Limit-to-Lifespan" Hypothesis



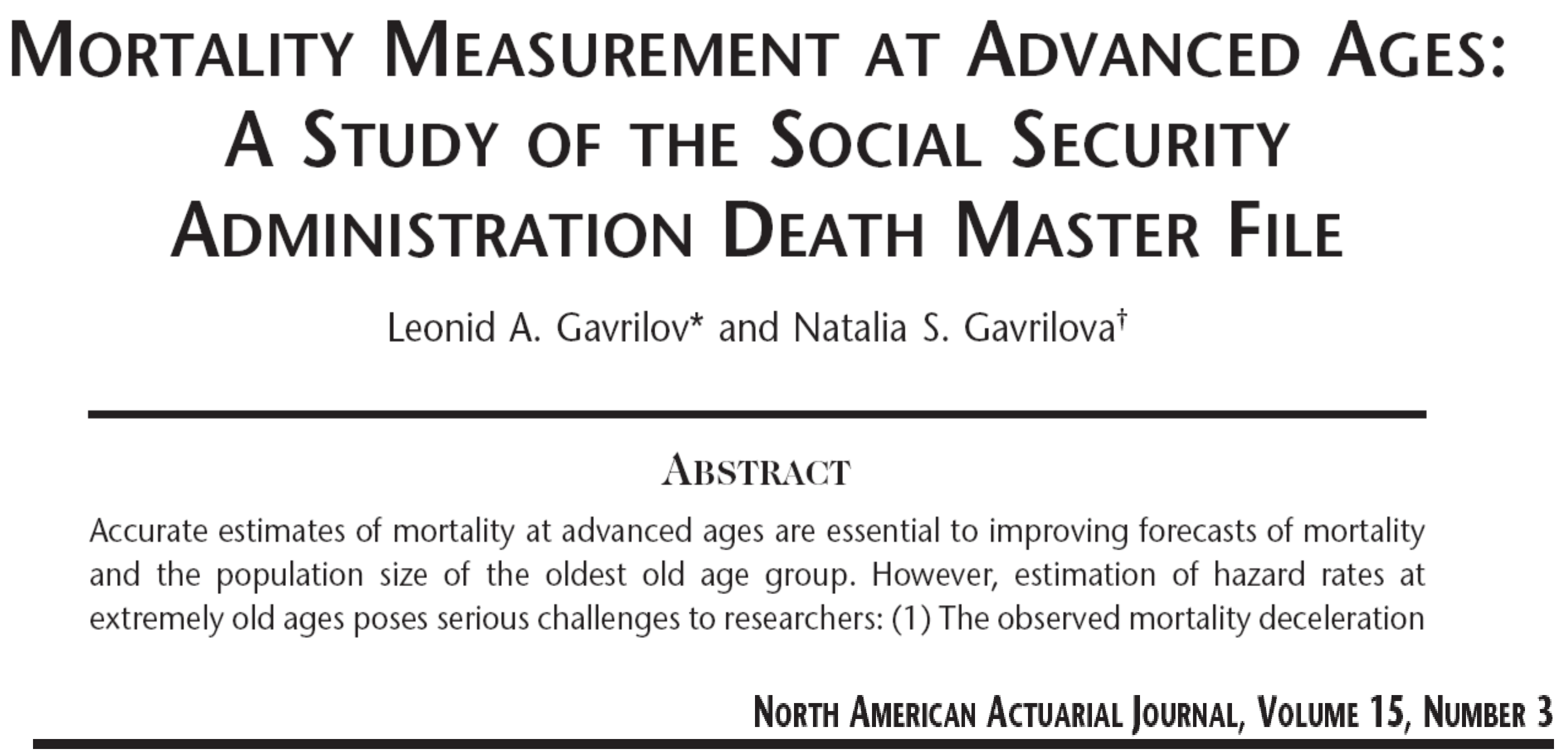
Source: **Gavrilov L.A., Gavrilova N.S. 1991.** ***The Biology of Life Span***

Latest Developments

Was the mortality deceleration law overblown?

A Study of the Extinct Birth Cohorts in the United States

Study of the Social Security Administration Death Master File


MORTALITY MEASUREMENT AT ADVANCED AGES: A STUDY OF THE SOCIAL SECURITY ADMINISTRATION DEATH MASTER FILE

Leonid A. Gavrilov* and Natalia S. Gavrilova†

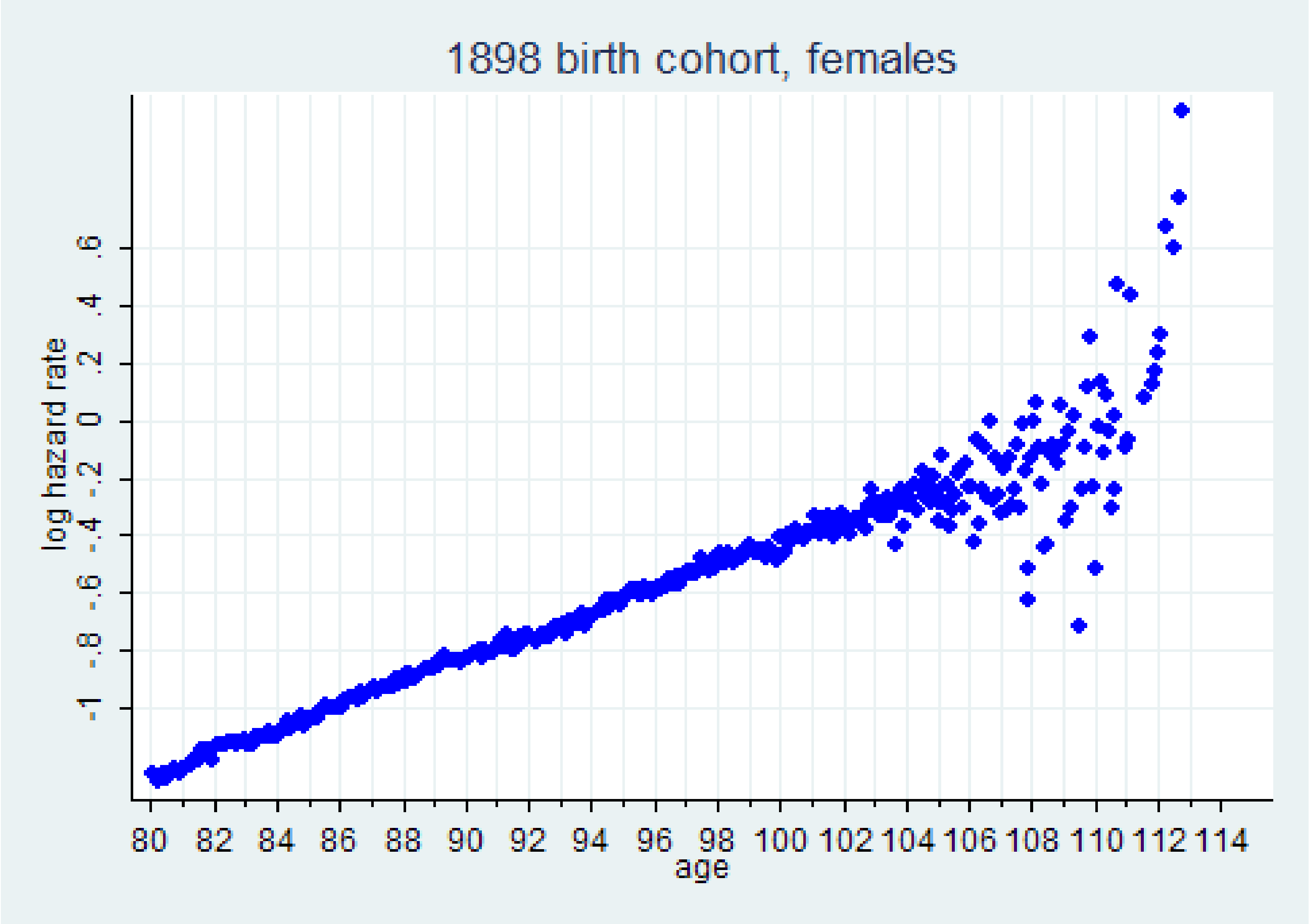
ABSTRACT

Accurate estimates of mortality at advanced ages are essential to improving forecasts of mortality and the population size of the oldest old age group. However, estimation of hazard rates at extremely old ages poses serious challenges to researchers: (1) The observed mortality deceleration

NORTH AMERICAN ACTUARIAL JOURNAL, VOLUME 15, NUMBER 3

***North American Actuarial Journal*, 2011, 15(3):432-447**

U.S. birth cohort mortality



Nelson-Aalen monthly estimates of hazard rates using Stata 11

Data from the Social Security Death Index

Conclusion

Study of 20 single-year extinct U.S. birth cohorts based on the Social Security Administration Death Master File found no mortality deceleration after age 85 years up to age 106 years (Gavrilov, Gavrilova, NAAJ, 2011).

Study of the U.S. cohort death rates taken from the Human Mortality Database

Journals of Gerontology: BIOLOGICAL SCIENCES
Cite journal as: J Gerontol A Biol Sci Med Sci
doi:10.1093/gerona/glu009

Biodemography of Old-Age Mortality in Humans and Rodents

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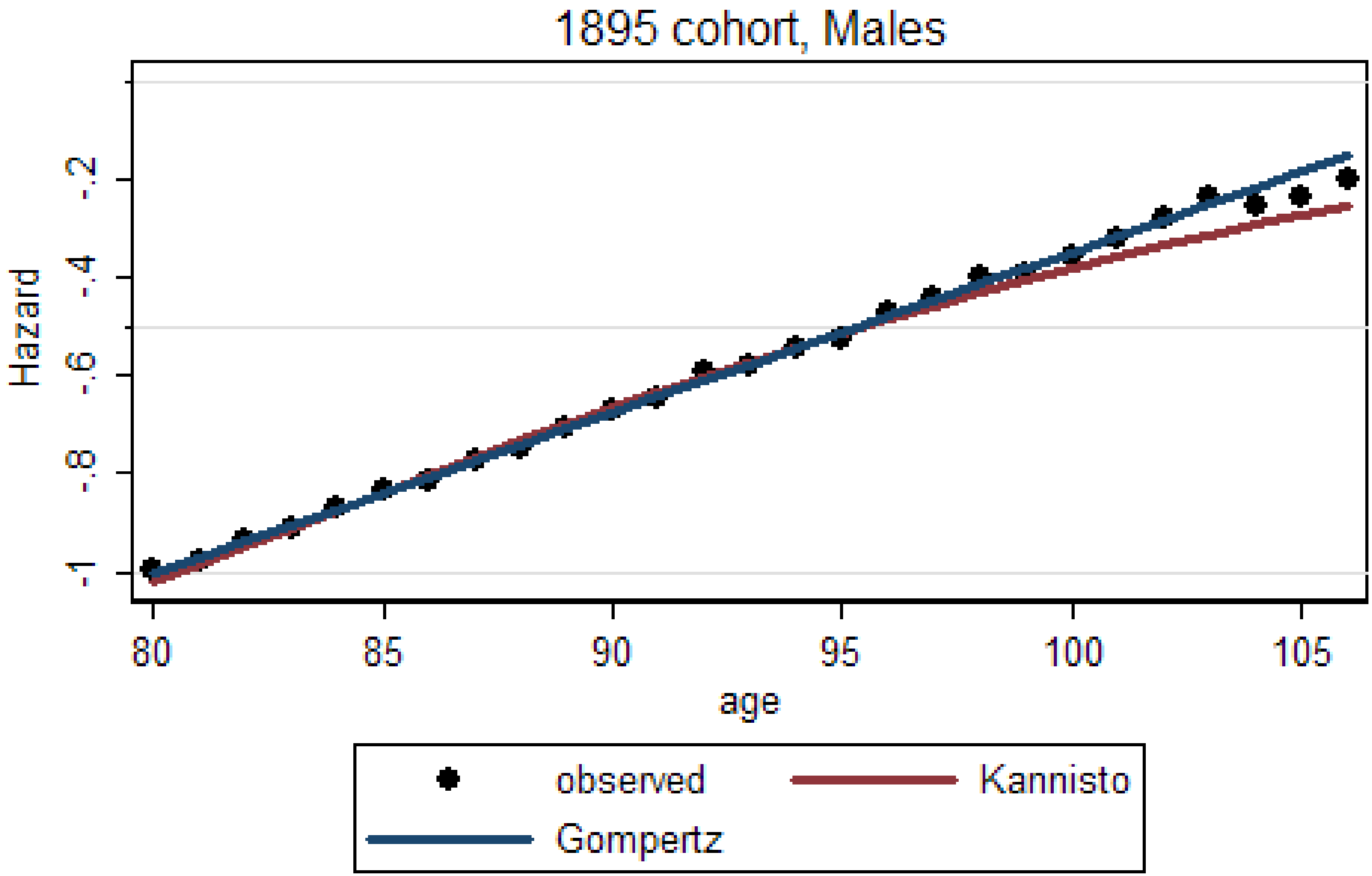
The growing number of persons living beyond age 80 underscores the need for accurate measurement of mortality at advanced ages and understanding the old-age mortality trajectories. It is believed that exponential growth of mortality

Fitting mortality with Kannisto and Gompertz models, HMD U.S. data



Mortality at advanced ages is the key variable for understanding population trends among the oldest-old

THE WALL STREET JOURNAL.
WSJ.com

THE NUMBERS GUY | March 2, 2012, 7:00 p.m. ET

Death Gets in the Way of Old-Age Gains

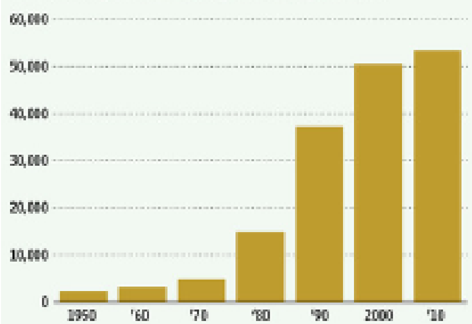
By CARL BIALIK

A new research paper, and a census surprise, are calling into question some long-held beliefs about a morbid bit of math: how much mortality rates increase with age.

It's no surprise that the older a group of people get, the higher the percentage of them who will die in any given time period. Benjamin Gompertz, a 19th-century British mathematician, charted the increase in mortality rates as very regular. His Gompertz law of mortality says that each additional period brings a constant percentage increase in mortality rates.

Survivors

The increase in the number of centenarians in the U.S. has begun to slow, raising questions about gains in old-age survival.



Note: Numbers prior to 1990 are estimates, revised from census counts to fix flaws in data.
Source: U.S. Census Bureau
The Wall Street Journal

In the 20th century, though, as the world population aged and demographers' data improved, Gompertz started to look fallible. Researchers have found that, starting around age 80, mortality keeps increasing, but more slowly. More 100-year-olds die before turning 101 than 80-year-olds do before their 81st birthday, but the difference was less than Gompertz predicted.

But Gompertz may be right after all. In a study published last year and publicized last month, two longtime researchers of aging and believers in the late-life mortality slowdown reported that they and others were wrong. Death rates among Americans born between 1875 and 1895 kept on climbing steadily as they aged, they found, all the way through age 106, when their numbers got too sparse to follow.

This is bad news for anyone who wants to reach the century mark, but could provide an odd measure of relief for pensions, retirement programs and medical insurers, whose costs rise as people live longer.

Recent projections of the U.S. Census Bureau significantly overestimated the actual number of centenarians

Views about the number of centenarians in the United States 2009

Centenarians are the fastest-growing age segment: Number of 100-year-olds to hit 6 million by 2050

BY THE ASSOCIATED PRESS

TUESDAY, JULY 21, 2009, 10:27 AM

New estimates based on the 2010 census are two times lower than the U.S. Bureau of Census forecast

Far fewer centenarians than expected in Census

1

Print Email Share Tweet Like Pin it

Posted Sept. 24, 2011, at 6:19 a.m.
Last modified Sept. 24, 2011, at 7:06 a.m.

NEW YORK — Reports of Americans living beyond the ripe old age of 100, it appears, were greatly exaggerated.

The Census Bureau predicted six years ago that the country would be home to 114,000 centenarians by 2010. The actual number was 53,364, the census reported recently. That represented an increase of 5.8 percent since 2000, compared with a 9.7 percent gain in the nation's population as a whole.

The same story happened in the Great Britain

Financial Times

September 11, 2012 8:20 pm

Long-lived Britons increasing slower than forecast

By Norma Cohen, Economics Correspondent

The rate at which Britons are living into very old age is rising much more slowly than had been forecast only two years ago, a blow for those hoping for a very long life but good news for pension providers and the Treasury which spend hefty sums on the oldest old.

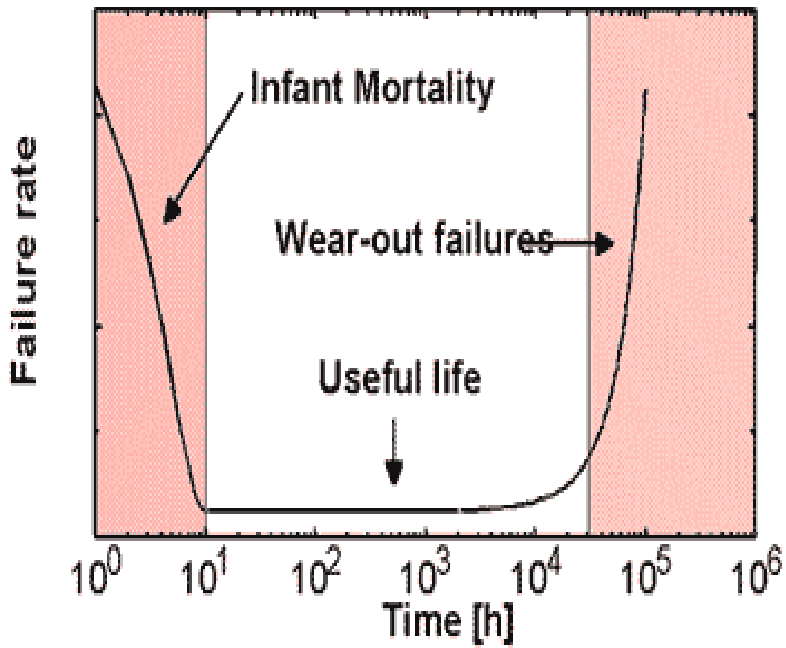
What are the explanations of mortality laws?

Mortality and aging theories

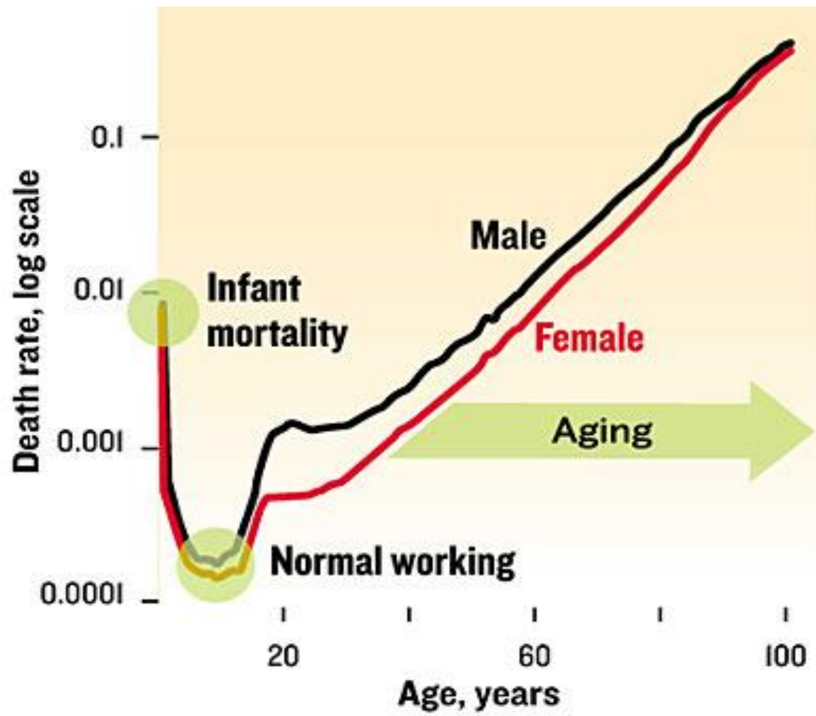
What Should the Aging Theory Explain

- Why do most biological species including humans deteriorate with age?
- The Gompertz law of mortality
- Mortality deceleration and leveling-off at advanced ages
- Compensation law of mortality

Stages of Life in Machines and Humans



The so-called bathtub curve for technical systems



Bathtub curve for human mortality as seen in the U.S. population in 1999 has the same shape as the curve for failure rates of many machines.

The Concept of Reliability Structure

- The arrangement of components that are important for system reliability is called reliability structure and is graphically represented by a schema of **logical connectivity**

Two major types of system's logical connectivity

- **Components connected in series**

  $P_s = p_1\, p_2\, p_3\, \ldots\, p_n = p^n$

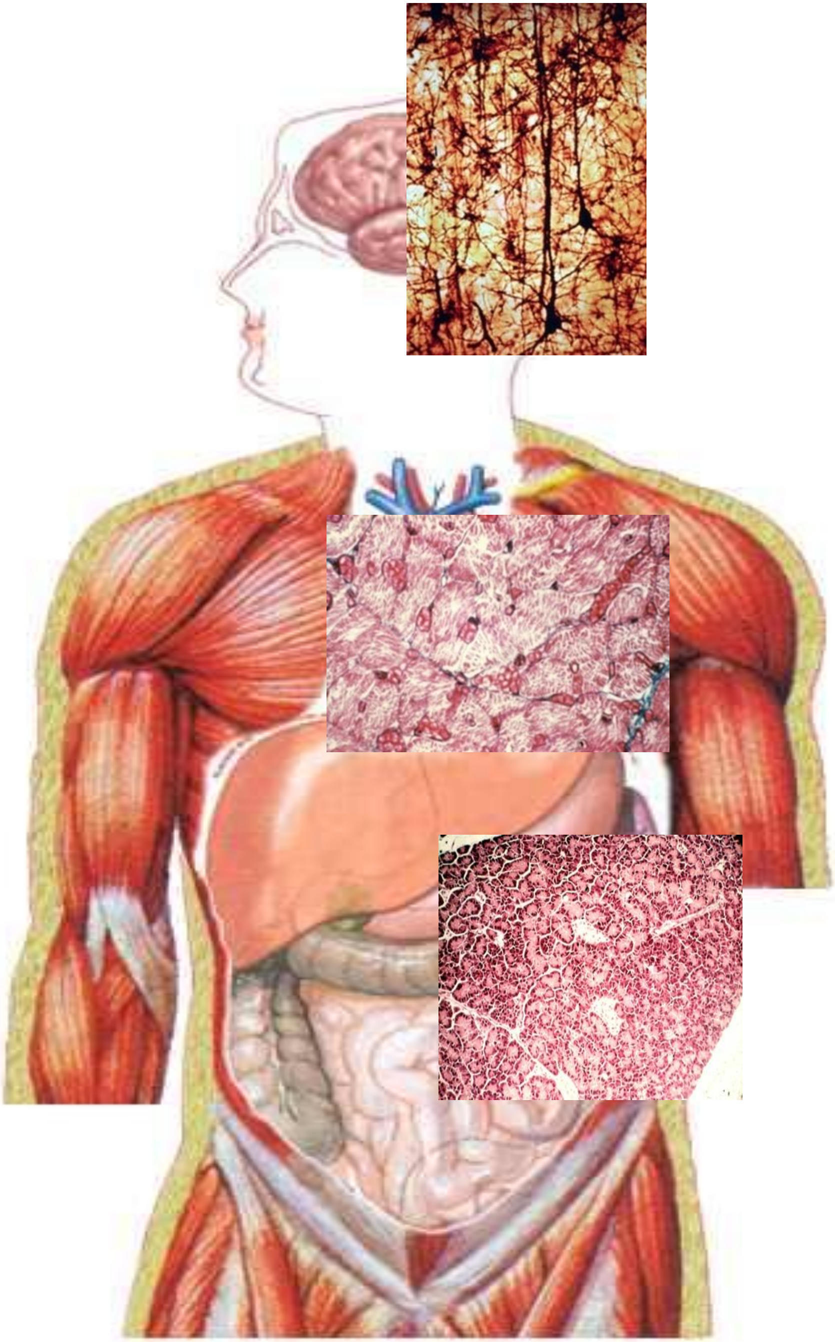
  Fails when the first component fails

- **Components connected in parallel**

  $Q_s = q_1\, q_2\, q_3\, \ldots\, q_n = q^n$

  Fails when all components fail

- **Combination of two types – Series-parallel system**



Series-parallel Structure of Human Body

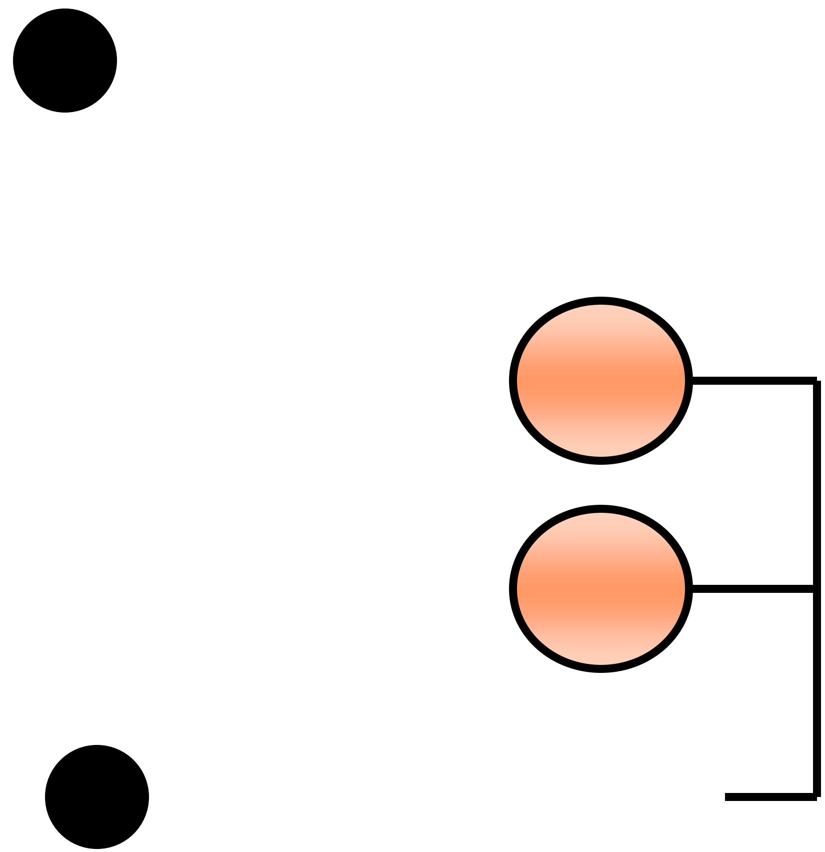
- Vital organs are connected in series

- Cells in vital organs are connected in parallel

Redundancy Creates Both Damage Tolerance and Damage Accumulation (Aging)

System without redundancy dies after the first random damage (no aging)

System with redundancy accumulates damage (aging)



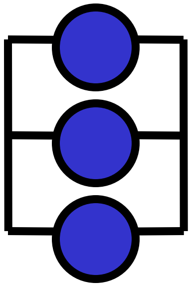
Reliability Model of a Simple Parallel System

Failure rate of the system:

$$\mu(x) = -\frac{dS(x)}{S(x)\,dx} = \frac{nk\,e^{-kx}(1-e^{-kx})^{n-1}}{1-(1-e^{-kx})^{n}}$$

$\approx nk^n x^{n-1}$ early-life period approximation, when $1-e^{-kx} \approx kx$

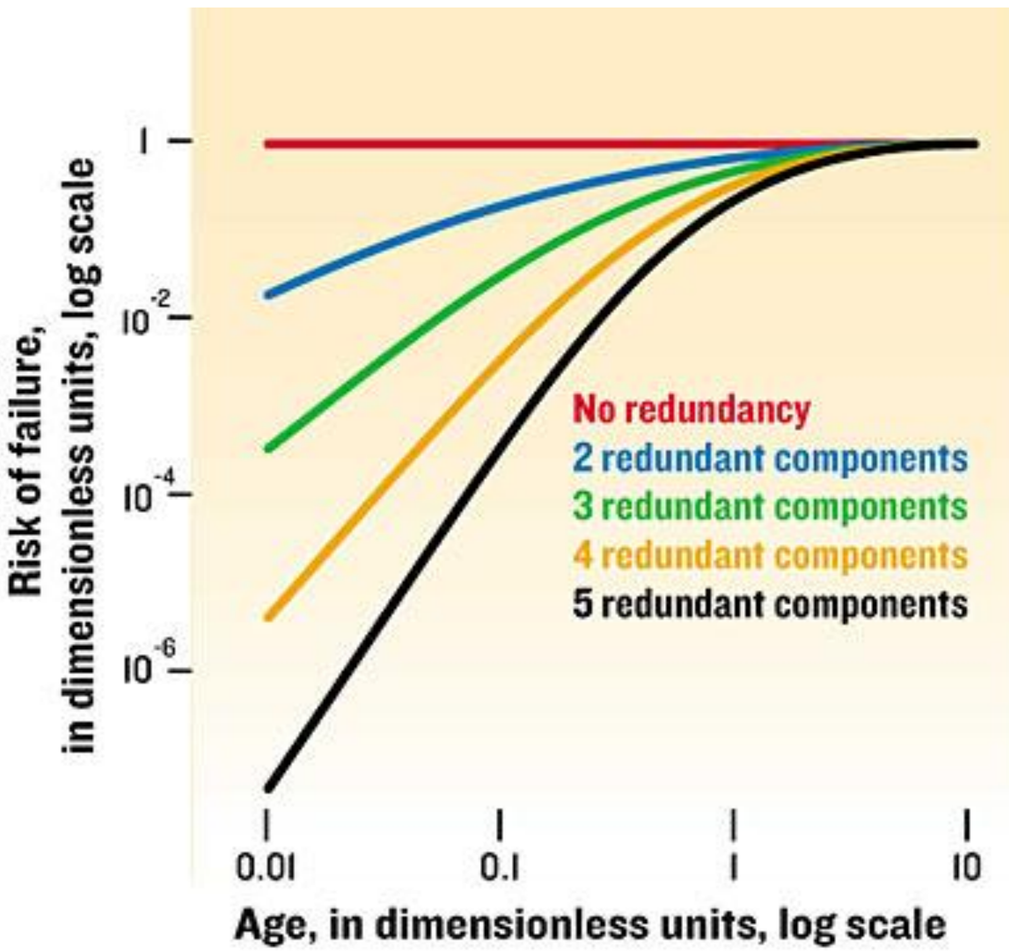
$\approx k$ late-life period approximation, when $1-e^{-kx} \approx 1$

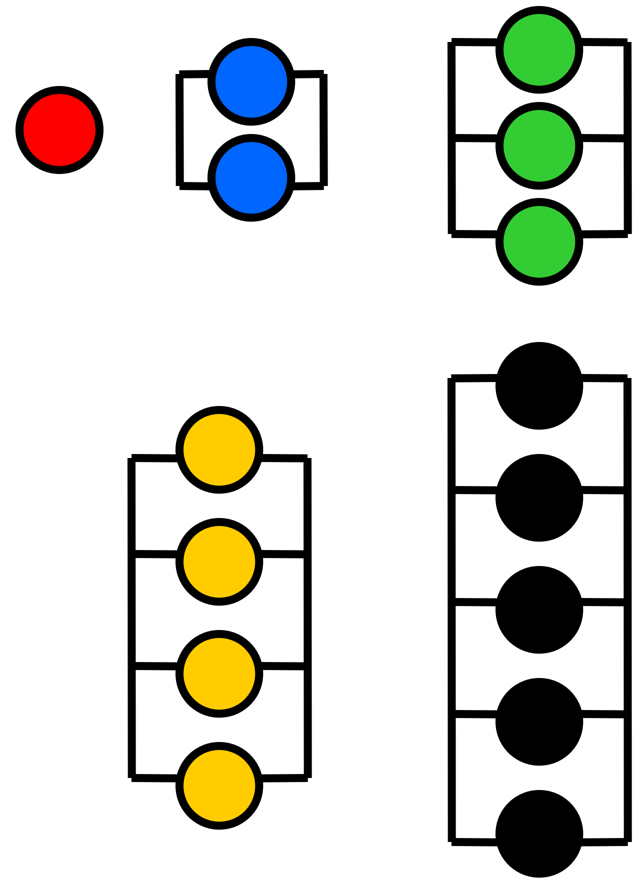


Elements fail randomly and independently with a constant failure rate, ***k***

n – initial number of elements

Failure Rate as a Function of Age in Systems with Different Redundancy Levels





Failure of elements is random

Standard Reliability Models Explain

- **Mortality deceleration and leveling-off at advanced ages**
- **Compensation law of mortality**

Standard Reliability Models Do Not Explain

- The Gompertz law of mortality observed in biological systems
- Instead they produce Weibull (power) law of mortality growth with age

Model of organism with initial damage load

Failure rate of a system with binomially distributed redundancy (approximation for initial period of life):

$$\mu(x) \approx Cmn(qk)^n \left(\frac{1-q}{qk} + x \right)^{n-1} = \alpha(x_0 + x)^{n-1}$$

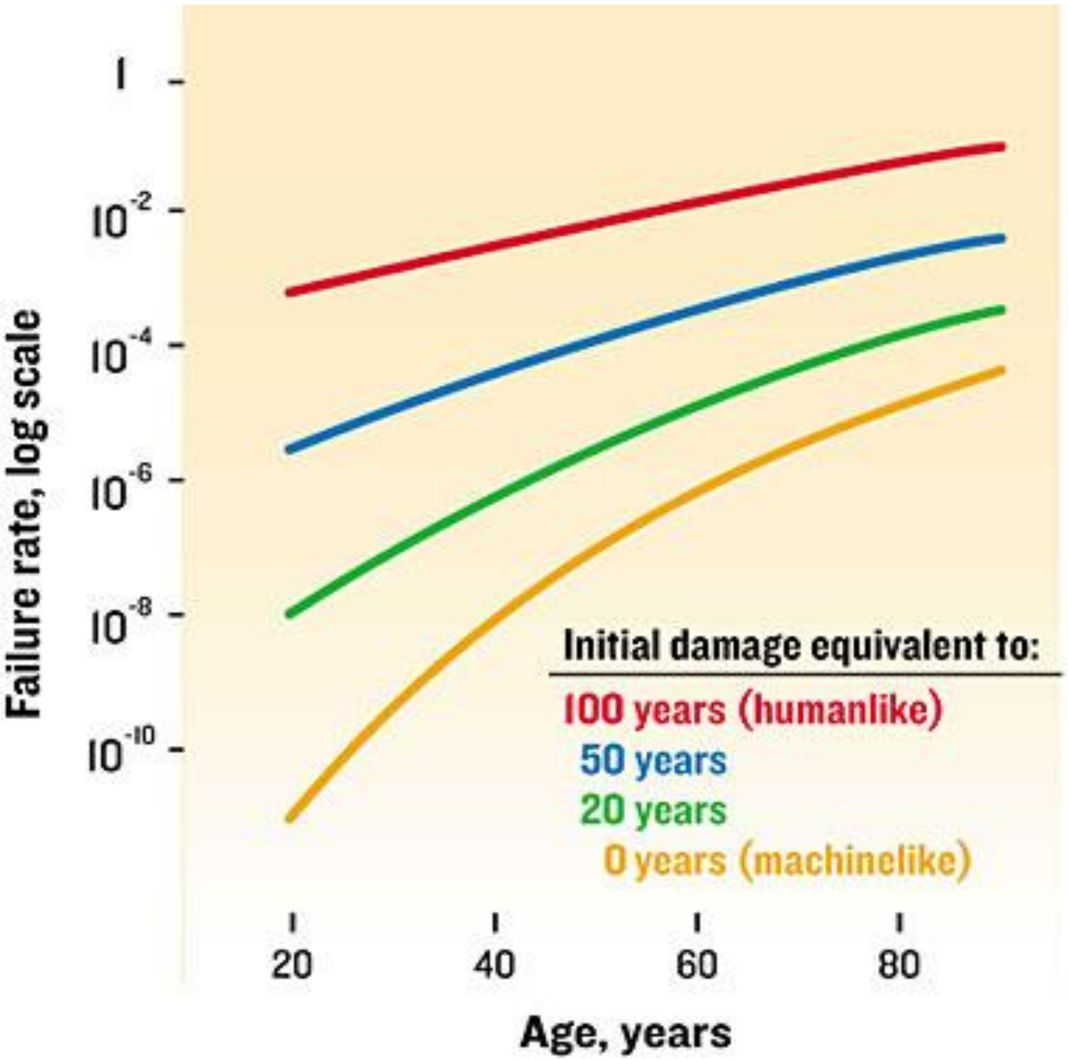
Binomial law of mortality

where $x_0 = \dfrac{1-q}{qk}$ - the initial virtual age of the system

The initial virtual age of a system defines the law of system's mortality:

- $x_0 = 0$ **- ideal system, Weibull law of mortality**
- $x_0 >> 0$ **- highly damaged system, Gompertz law of mortality**

People age more like machines built with lots of faulty parts than like ones built with pristine parts.



- As the number of bad components, the initial damage load, increases [bottom to top], machine failure rates begin to mimic human death rates.

Statement of the HIDL hypothesis: (Idea of High Initial Damage Load)

"Adult organisms already have an exceptionally high load of initial damage, ***which is comparable with the amount of subsequent aging-related deterioration, accumulated during the rest of the entire adult life****."*

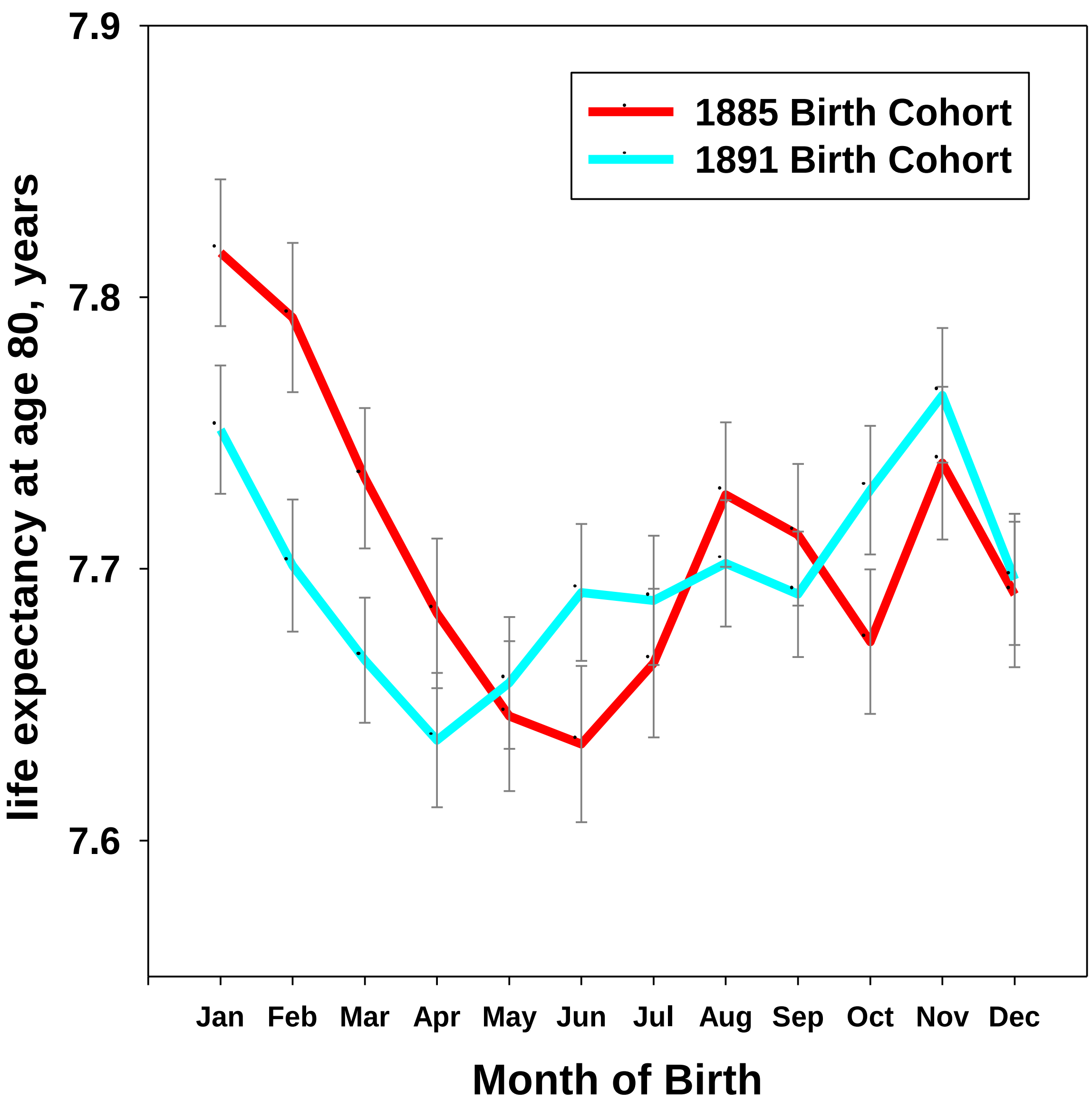
Source: Gavrilov, L.A. & Gavrilova, N.S. 1991. The Biology of Life Span: A Quantitative Approach. Harwood Academic Publisher, New York.

Practical implications from the HIDL hypothesis:

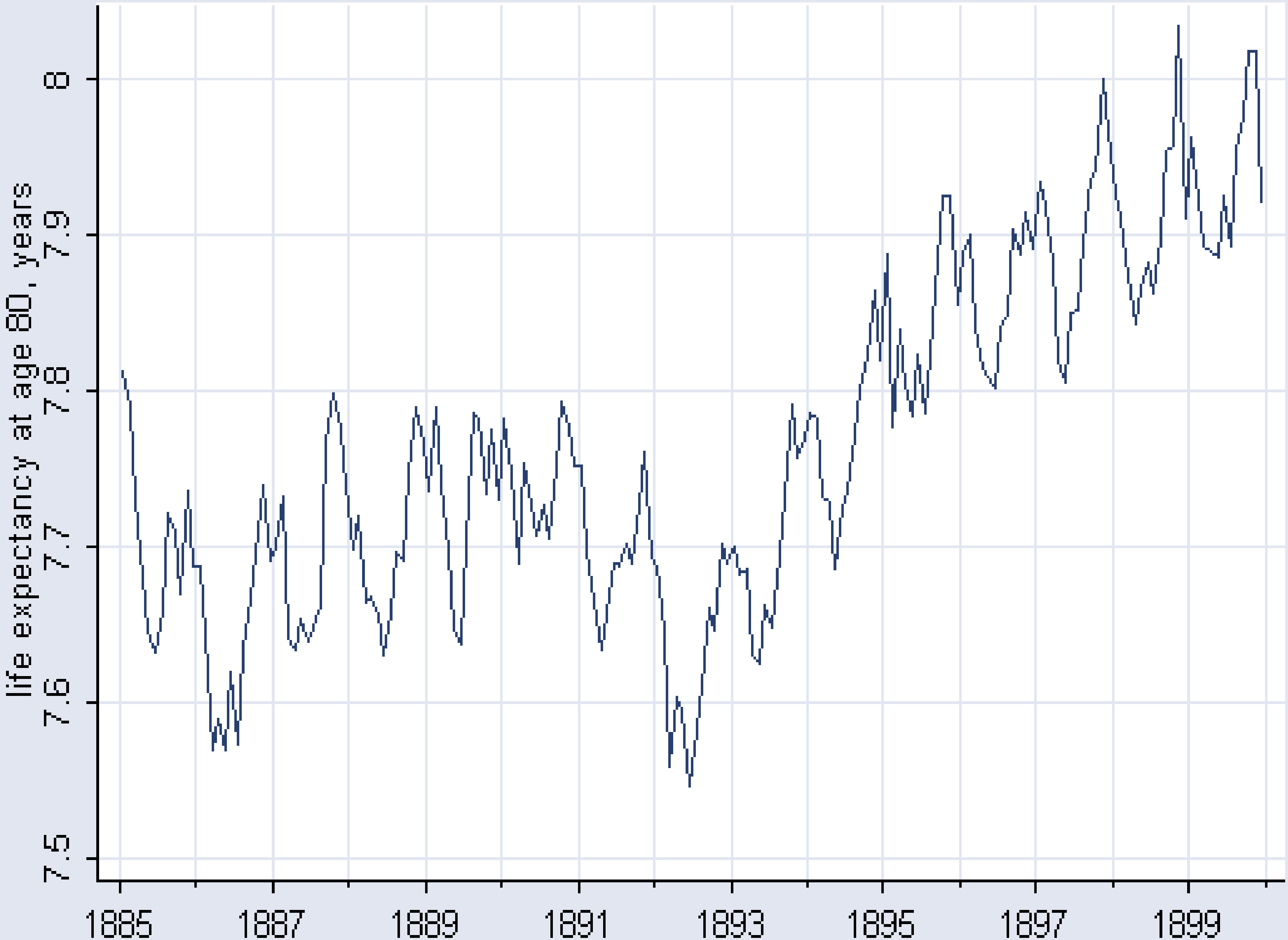
"Even a small progress in optimizing the early-developmental processes can potentially result in a remarkable prevention of many diseases in later life, postponement of aging-related morbidity and mortality, and significant extension of healthy lifespan."

Source: Gavrilov, L.A. & Gavrilova, N.S. 1991. The Biology of Life Span: A Quantitative Approach. Harwood Academic Publisher, New York.

Life Expectancy and Month of Birth



Data source:
Social Security
Death Master File



life expectancy at age 80, years
7.5
7.6
7.7
7.8
7.9
8
1885
1887
1889
1891
1893
1895
1897
1899

Longevity Predictors

Our Approach

To study "success stories" in long-term avoidance of fatal diseases (survival to 100 years) and factors correlated with this remarkable survival success

An example of incredible resilience

Winnie ain't quitting now.


THE SUN, Tuesday, August 28, 2007

LIFE'S A DRAG

Winnie, 100 smokes for 93 YEARS and she ain't quitting now

Wartime memories . . Winnie had her first cigarette in 1914

By GARETH DORRIAN

DEFIANT smoker Winnie Langley celebrates reaching 100 yesterday — by lighting her 170,000th cigarette from a candle on her birthday cake.

Smith G D Int. J. Epidemiol. 2011;40:537-562

International Journal of Epidemiology

Meeting with 104-years-old Japanese centenarian (New Orleans, 2010)

How centenarians are different from their shorter-lived siblings?

Hypothesis:

Ovarian aging (decline in egg quality) may have long-term effects on offspring quality, health and longevity. Down syndrome is just a tip of the iceberg of numerous less visible defects.

Testable prediction:

Odds of longevity decrease with maternal age

Negative impact of maternal aging on offspring longevity

Within-Family Approach

Allows researchers to eliminate between-family variation including the differences in genetic background and childhood living conditions

Computerized genealogies is a promising source of information about potential predictors of exceptional longevity: life-course events, early-life conditions and family history of longevity

Within-family study of longevity

Cases - 1,081 centenarians survived to age 100 and born in USA in 1880-1889

Controls – 6,413 their shorter-lived brothers and sisters

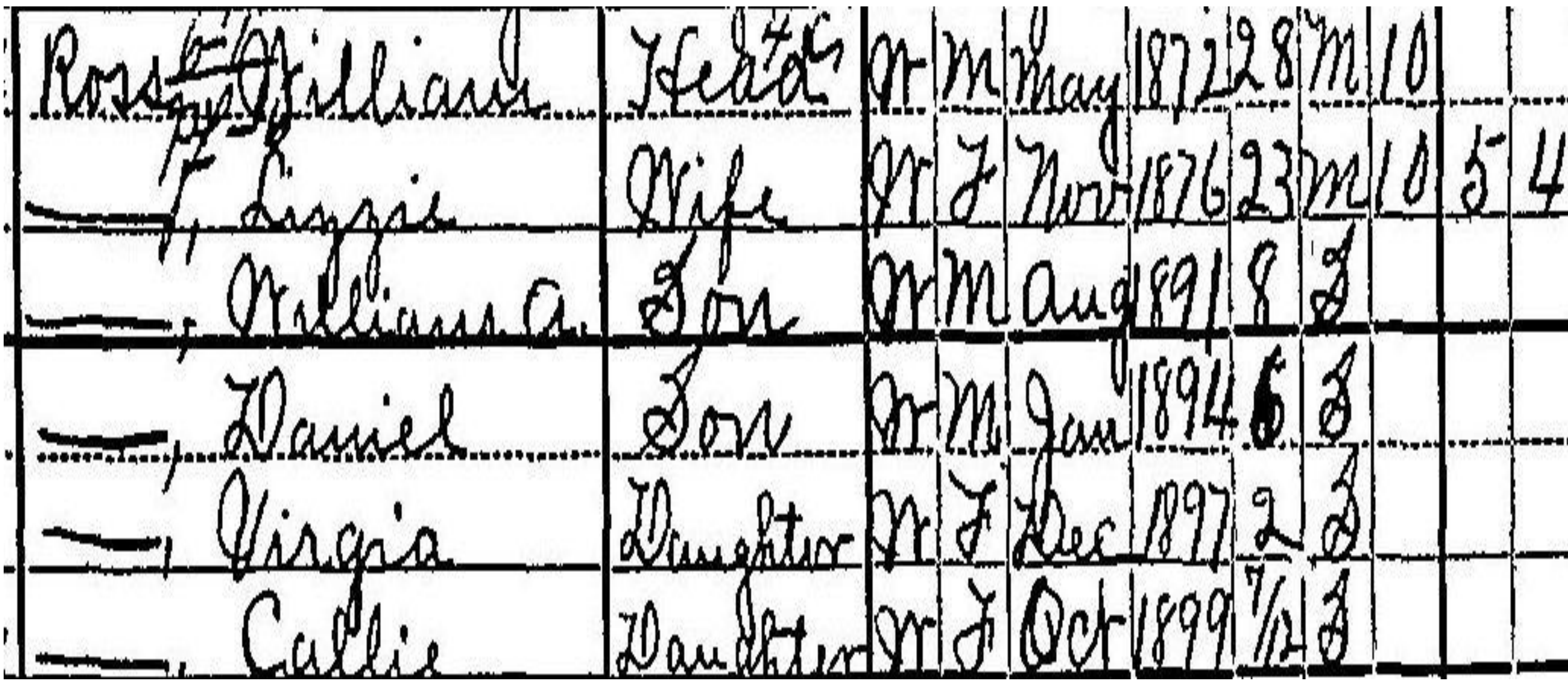
Method Conditional logistic regression

Advantage Allows to eliminate between-family variation

Age validation is a key moment in human longevity studies

- Death date was validated using the U.S. Social Security Death Index
- Birth date was validated through linkage of centenarian records to early U.S. censuses (when centenarians were children)

A typical image of ‘centenarian’ family in 1900 census



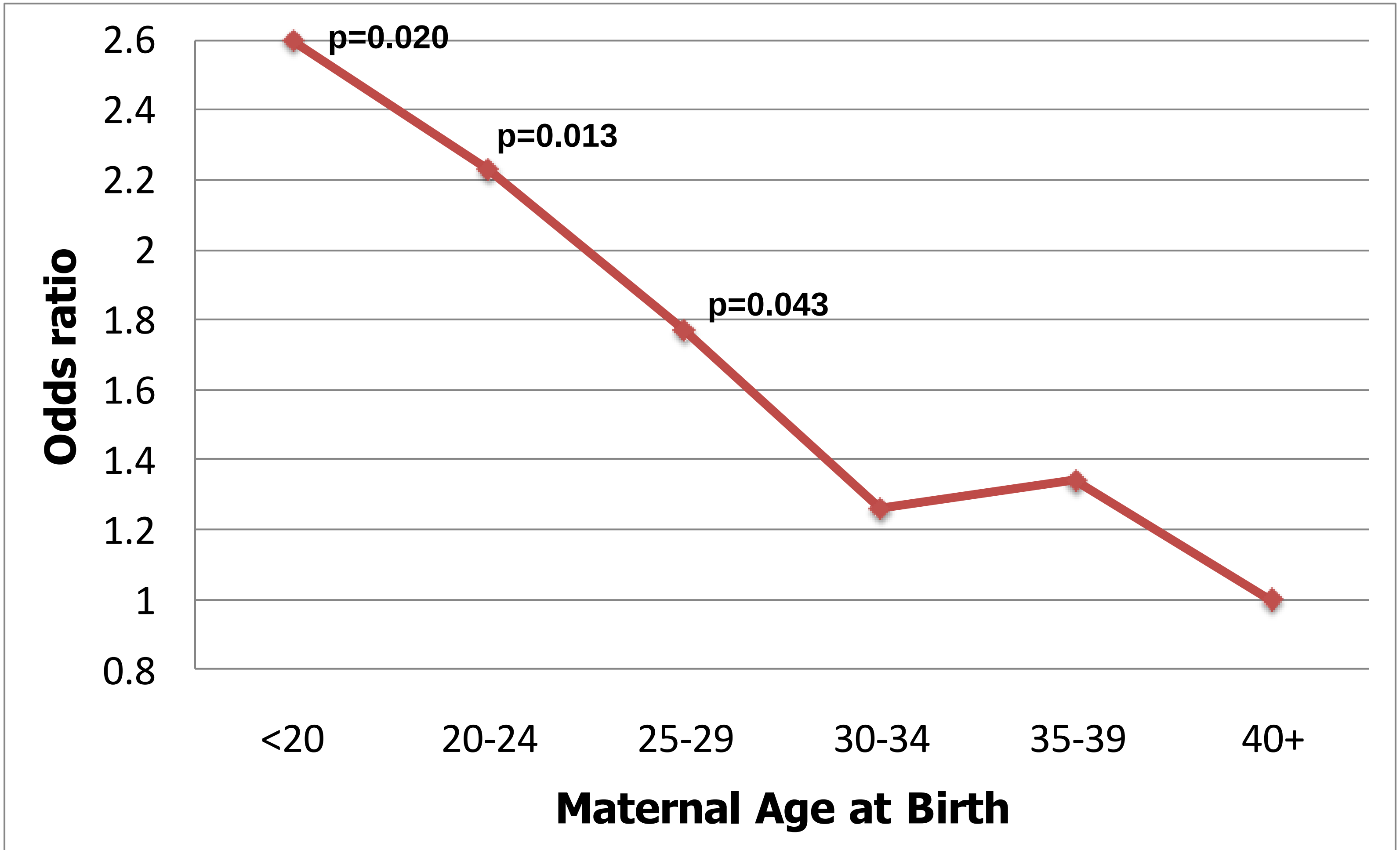
Ross, William	Head	W	M	May	1872	28	M	10		
—, Lizzie	Wife	W	F	Nov	1876	23	M	10	5	4
—, William A.	Son	W	M	Aug	1891	8	S			
—, Daniel	Son	W	M	Jan	1894	6	S			
—, Virgia	Daughter	W	F	Dec	1897	2	S			
—, Callie	Daughter	W	F	Oct	1899	7/12	S			

Maternal age and chances to live to 100 for siblings survived to age 50

Conditional (fixed-effects) logistic regression N=5,778. Controlled for month of birth, paternal age and gender. Paternal and maternal lifespan >50 years			
Maternal age	**Odds ratio**	**95% CI**	**P-value**
<20	**1.73**	**1.05-2.88**	**0.033**
20-24	**1.63**	**1.11-2.40**	**0.012**
25-29	**1.53**	**1.10-2.12**	**0.011**
30-34	**1.16**	**0.85-1.60**	**0.355**
35-39	**1.06**	**0.77-1.46**	**0.720**
40+	**1.00**	**Reference**	

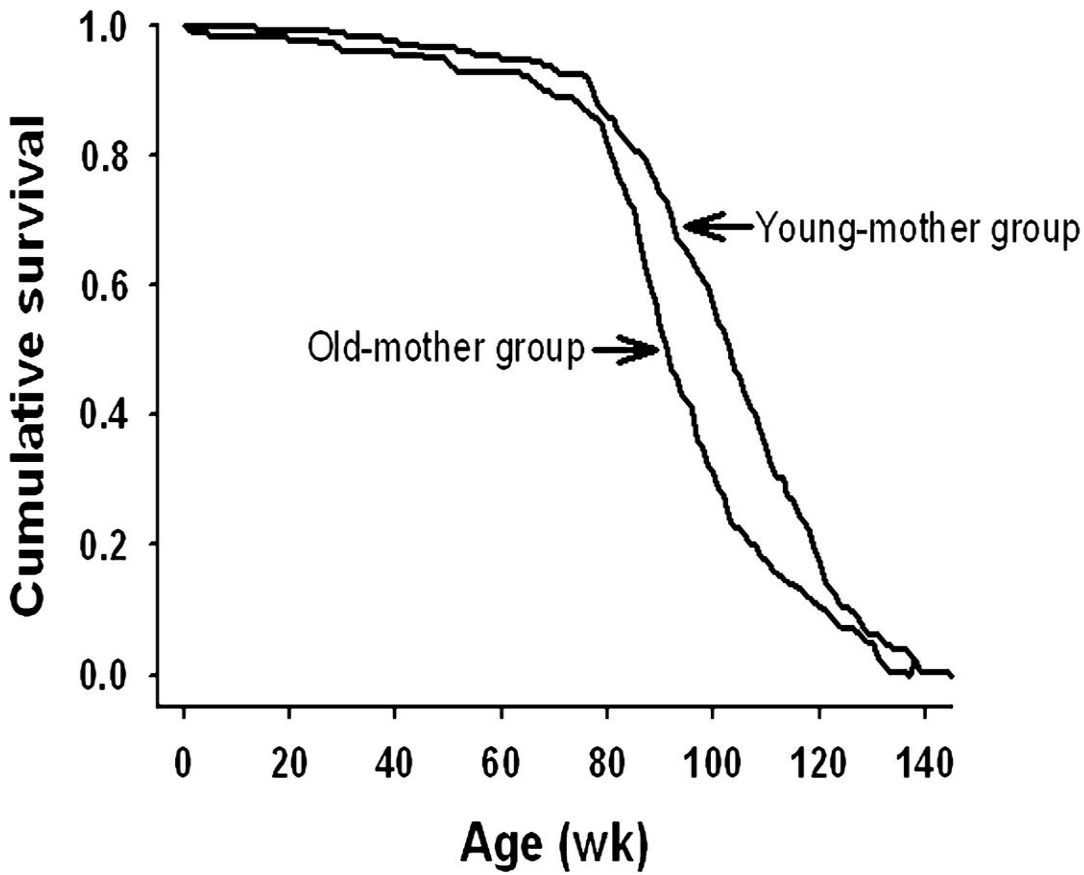
People Born to Young Mothers Have Twice Higher Chances to Live to 100

Within-family study of 2,153 centenarians and their siblings survived to age 50. Family size <9 children.



Source: Gavrilov, Gavrilova, Gerontology, 2015

Being born to Young Mother Helps Laboratory Mice to Live Longer



Source:

Tarin et al., Delayed Motherhood Decreases Life Expectancy of Mouse Offspring.

Biology of Reproduction **2005 72: 1336-1343.**

Similar results on mice obtained by Carnes et al., 2012 (for female offspring)

Possible explanations

- Quality of oocytes declines with age (Kalmbach et al., 2015).
- These findings are also consistent with the 'best eggs are used first' hypothesis suggesting that earlier formed oocytes are of better quality, and go to fertilization cycles earlier in maternal life (Keefe et al., 2005).

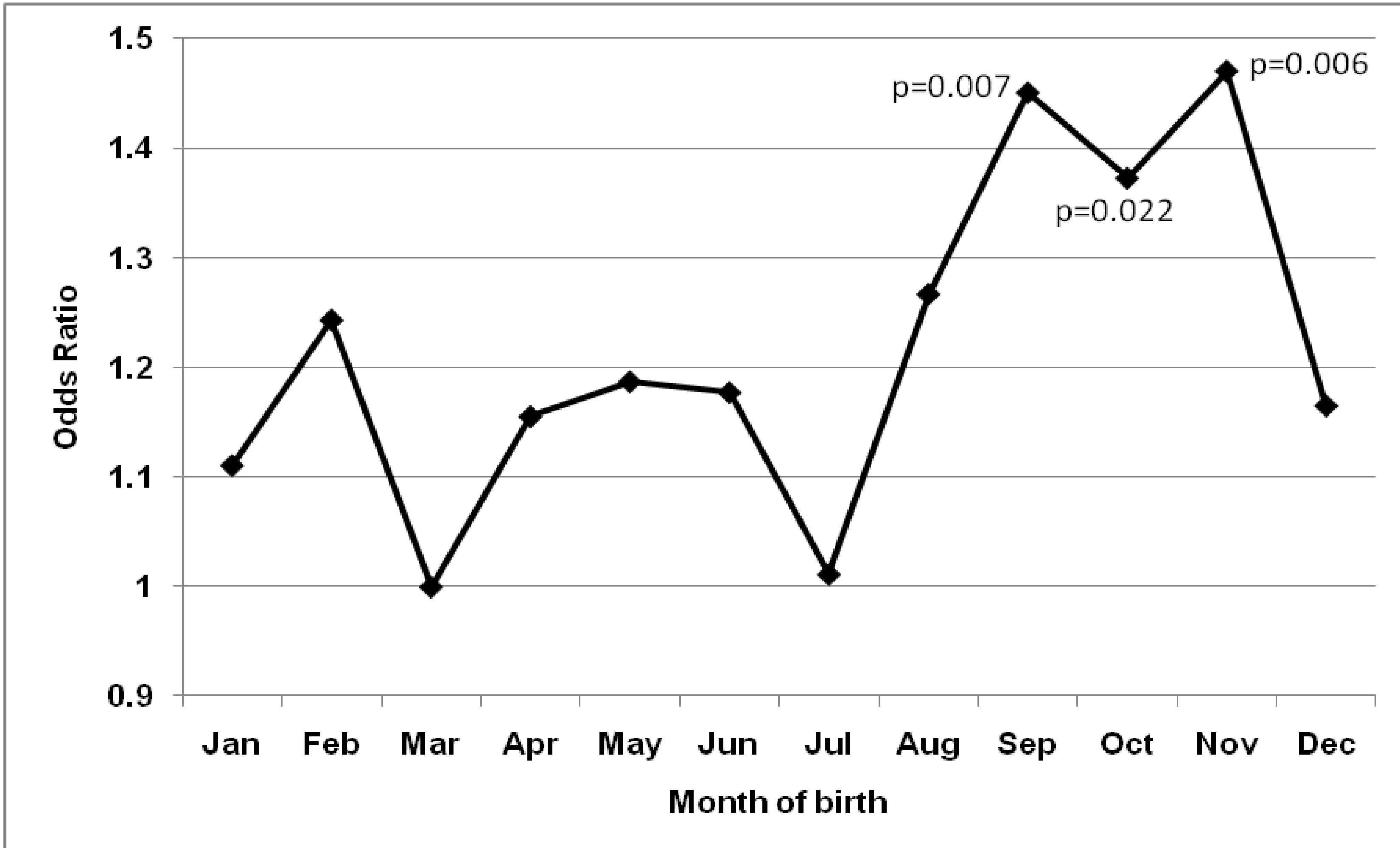
Note: Our original findings were independently confirmed in the study of Canadian centenarians (Jarry et al., *Vienna Yearbook of Population Research*, 2013)

Within-Family Study of Season of Birth and Exceptional Longevity

Month of birth is a useful proxy characteristic for environmental effects acting during in-utero and early infancy development

Siblings Born in September-November Have Higher Chances to Live to 100

Within-family study of 9,724 centenarians born in 1880-1895 and their siblings survived to age 50



Possible explanations

These are several explanations of season-of birth effects on longevity pointing to the effects of early-life events and conditions:

seasonal exposure to infections,

nutritional deficiencies,

environmental temperature and sun exposure.

All these factors were shown to play role in later-life health and longevity.

Limitation of within-family approach

Relatively small number of explanatory variables

How centenarians are different from their shorter-lived peers?

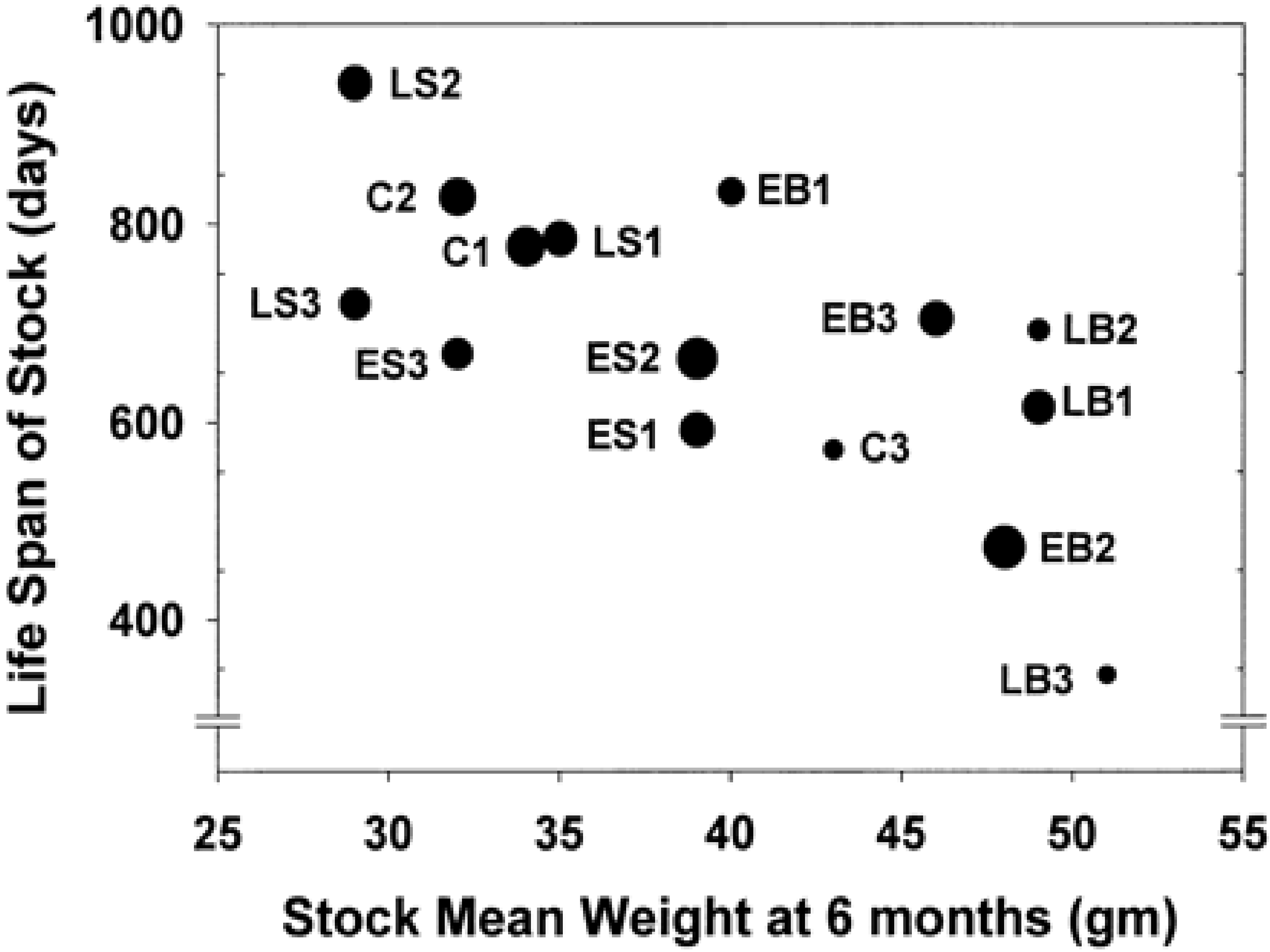
Physical Characteristics at Young Age and Survival to 100

A study of height and build of centenarians when they were young using WWI civil draft registration cards

Small Dogs Live Longer

Miller RA. Kleemeier Award Lecture: Are there genes for aging? J Gerontol Biol Sci **54A:**B297–B307, 1999.

Small Mice Live Longer



Source: Miller et al., 2000. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 55:B455-B461

Study Design

Cases: male centenarians born in 1887 (randomly selected from the SSA Death Master File) and linked to the WWI civil draft records. Out of 240 selected men, 15 were not eligible for draft. The linkage success for remaining records was 77.5% (174 records)

Controls: men matched on birth year, race and county of WWI civil draft registration

Data Sources

1. **Social Security Administration Death Master File**

2. **WWI civil draft registration cards** (completed for almost 100 percent men born between 1873 and 1900)

WWI Civilian Draft Registration

In 1917 and 1918, approximately 24 million men born between 1873 and 1900 completed draft registration cards. President Wilson proposed the American draft and characterized it as necessary to make "shirkers" play their part in the war. This argument won over key swing votes in Congress.

WWI Draft Registration

Registration was done in three parts, each designed to form a pool of men for three different military draft lotteries. During each registration, church bells, horns, or other noise makers sounded to signal the 7:00 or 7:30 opening of registration, while businesses, schools, and saloons closed to accommodate the event.

Registration Day Parade

Attention!

ALL MALES between the ages of 21 and 30 years, both inclusive, must personally appear at the polling place in the Election District in which they reside, on

TUESDAY, JUNE 5th, 1917

between the hours of 7 A.M. and 9 P. M. and

Register

in accordance with the President's Proclamation.

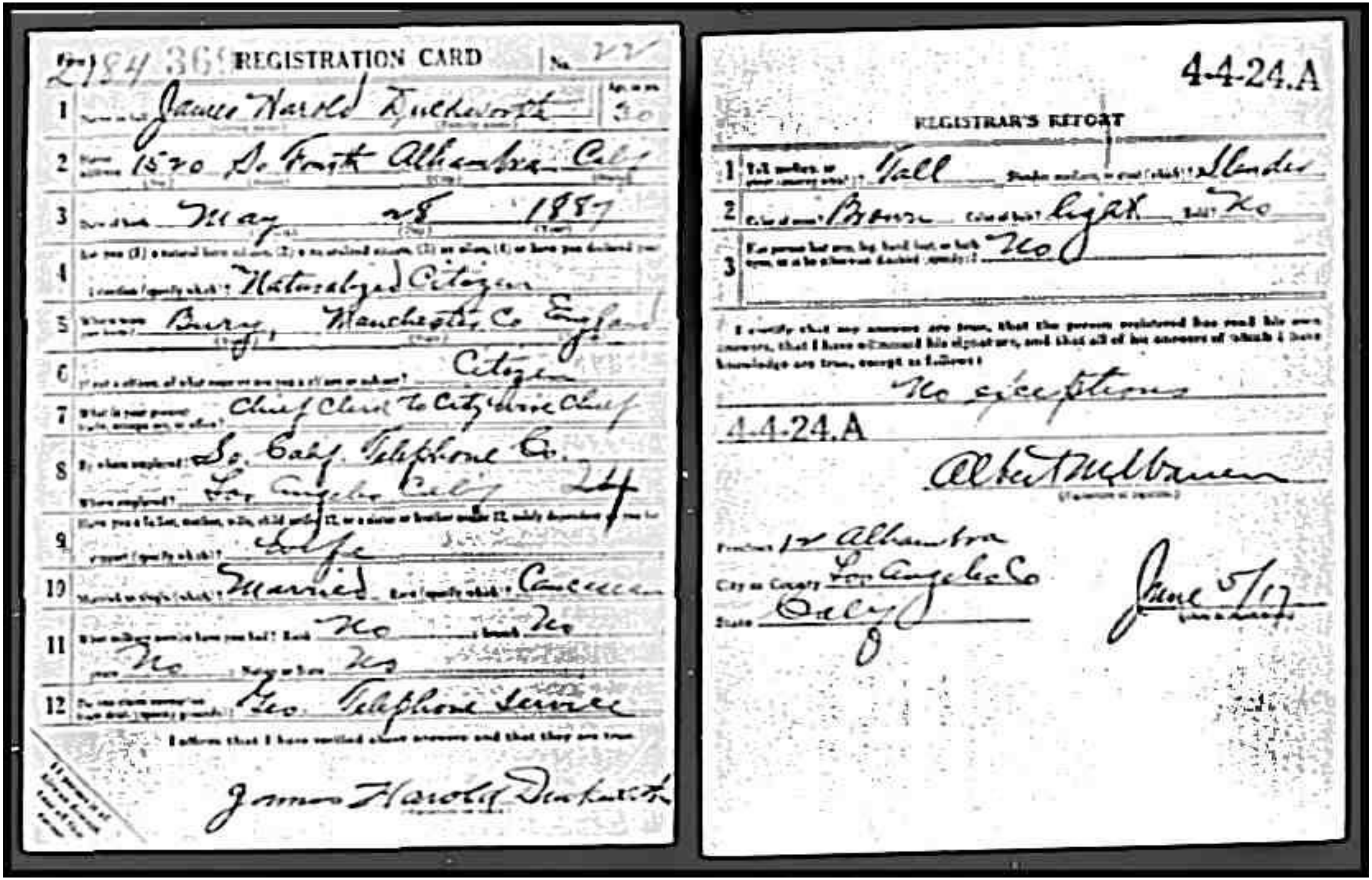
Any male person, between these ages, who fails to register on June 5th, 1917, will be subject to imprisonment in jail or other penal institution for a term of one year.

NO EXCUSE FOR FAILURE TO REGISTER WILL BE ACCEPTED

Information Available in the Draft Registration Card

- age, date of birth, race, citizenship
- permanent home address
- occupation, employer's name
- height (3 categories), build (3 categories), eye color, hair color, disability

Draft Registration Card: An Example



REGISTRATION CARD

1 James Harold Duckworth — 30
2 1520 So. Fourth Alhambra Calif
3 May 28 1887
4 Naturalized Citizen
5 Bury, Manchester Co England
6 Citizen
7 Chief Clerk to City Wire Chief
8 So. Calif. Telephone Co.
Los Angeles Calif
9 Wife
10 Married — Caucasian
11 No — No
No — No
12 Gen. Telephone Service

James Harold Duckworth

4-4-24.A

REGISTRAR'S REPORT

1 Tall — Slender
2 Brown — Light — No
3 No

No exceptions

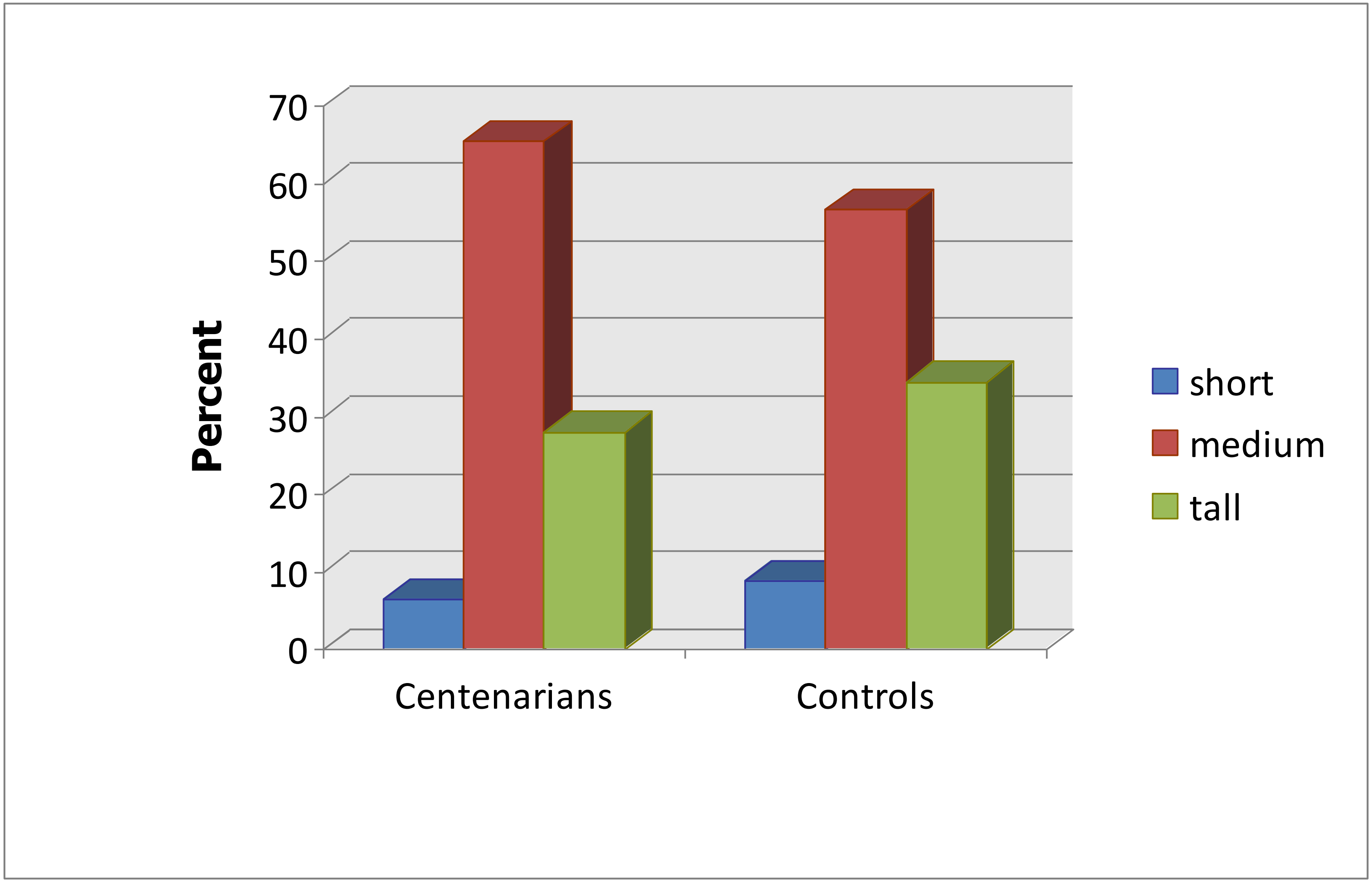
4-4-24.A

Albert McIlvane

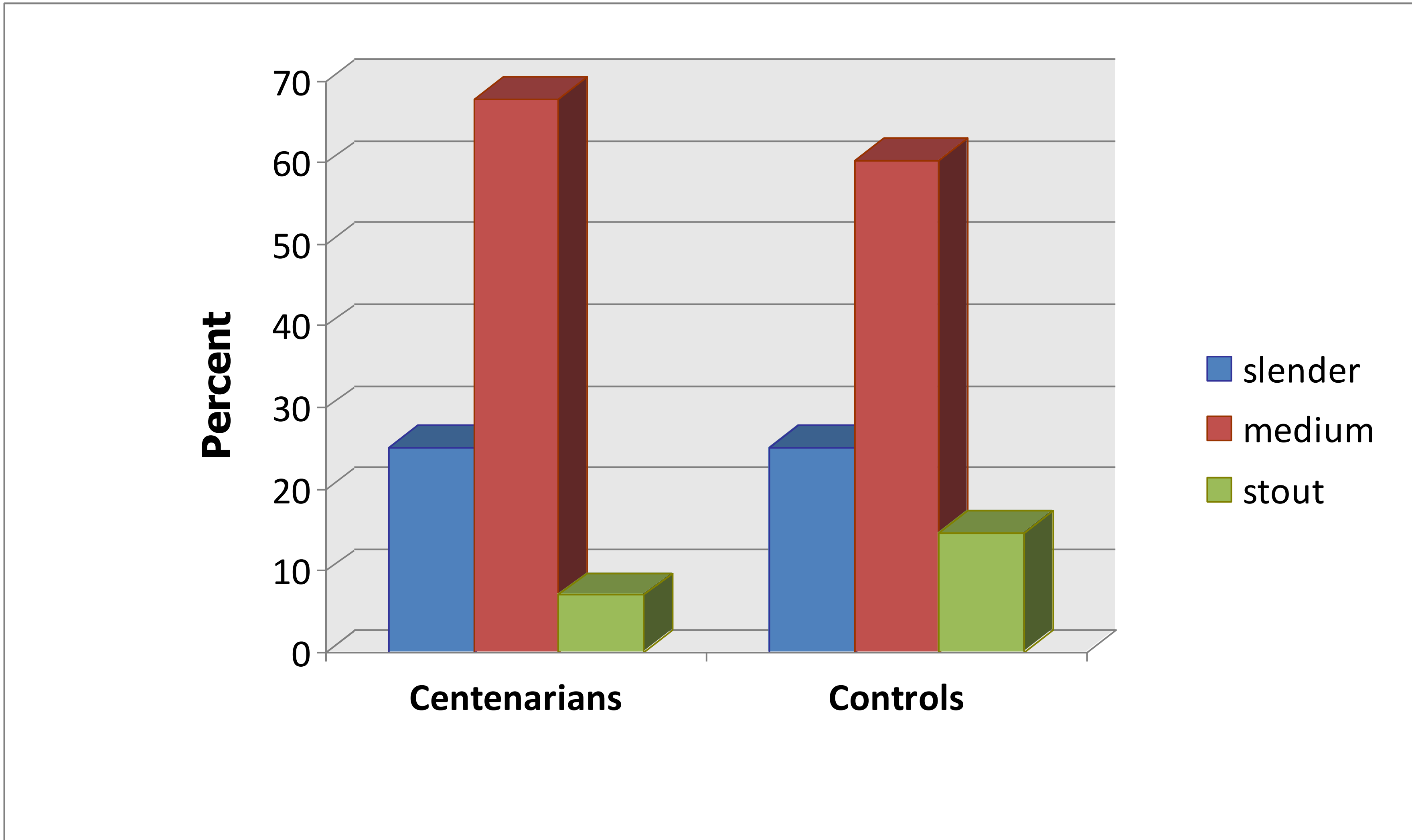
Precinct 1st Alhambra
City or County Los Angeles Co
State Calif

June 5/17

Height and survival to age 100



Body build and survival to age 100



Multivariate Analysis

- **Conditional multiple logistic regression model for matched case-control studies to investigate the relationship between an outcome of being a case (extreme longevity) and a set of prognostic factors (*height, build, occupation, marital status, number of children, immigration status*)**
- **Statistical package Stata-10, command *clogit***

Results of multivariate study

Variable	*Odds Ratio*	*P-value*
Medium height vs short and tall height	1.35	0.260
Slender and medium build vs stout build	**2.63***	0.025
Farming	2.20*	0.016
Married vs unmarried	0.68	0.268
Native born vs foreign b.	1.13	0.682

Having children by age 30 and survival to age 100

Conditional (fixed-effects) logistic regression N=171. Reference level: no children			
Variable	**Odds ratio**	**95% CI**	**P-value**
1-3 children	**1.62**	**0.89-2.95**	**0.127**
4+ children	**2.71**	**0.99-7.39**	**0.051**

Conclusion

The study of height and build among men born in 1887 suggests that rapid growth and overweight at young adult age (30 years) might be harmful for attaining longevity

Other Conclusions

Both farming and having large number of children (4+) at age 30 significantly increased the chances of exceptional longevity by 100-200%.

The effects of immigration status, marital status, and body height on longevity were less important, and they were statistically insignificant in the studied data set.

Centenarians and shorter-lived peers: Factors of late-life mortality

Study Design

- Compare centenarians with their peers born in the same year but died at age 65 years
- Both centenarians and shorter-lived controls are randomly sampled from the same data universe: computerized genealogies
- It is assumed that the majority of deaths at age 65 occur due to chronic diseases related to aging rather than injuries or infectious diseases

Case-control study of longevity

Cases - 765 centenarians survived to age 100 and born in USA in 1890-91

Controls – 783 their shorter-lived peers born in USA in 1890-91 and died at age 65 years

Method Multivariate logistic regression

Genealogical records were linked to 1900 and 1930 US censuses (with over 95% linkage success) providing a rich set of variables

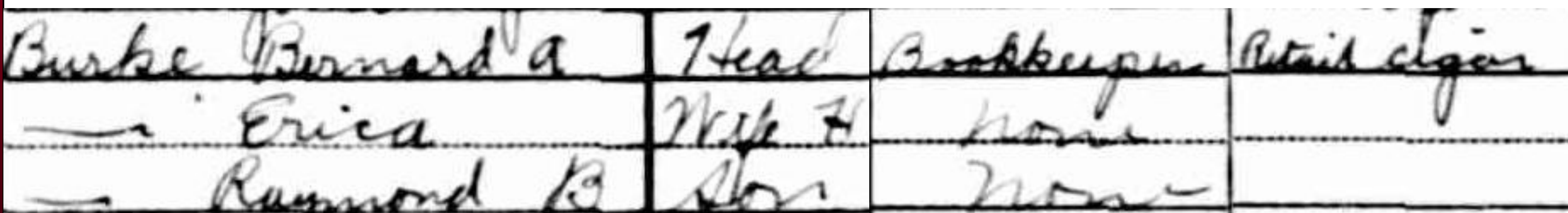
Genealogies and 1900 and 1930 censuses provide three types of variables

Characteristics of early-life conditions

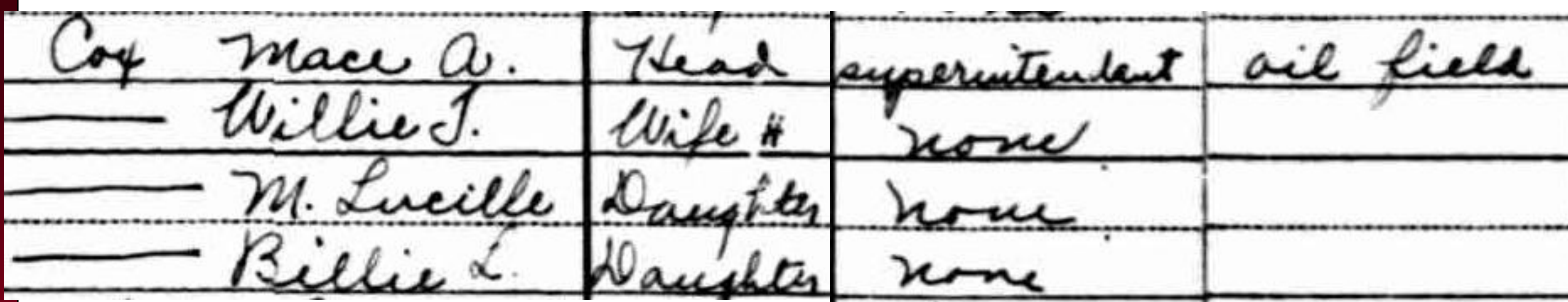
Characteristics of midlife conditions

Family characteristics

Example of images from 1930 census (controls)



Burke	Bernard A	Head	Bookkeeper	Retail cigar
—	Erica	Wife H	None	
—	Raymond B	Son	None	



Cox	Mace A.	Head	superintendent	oil field
—	Willie J.	Wife H	none	
—	M. Lucille	Daughter	none	
—	Billie L.	Daughter	none	

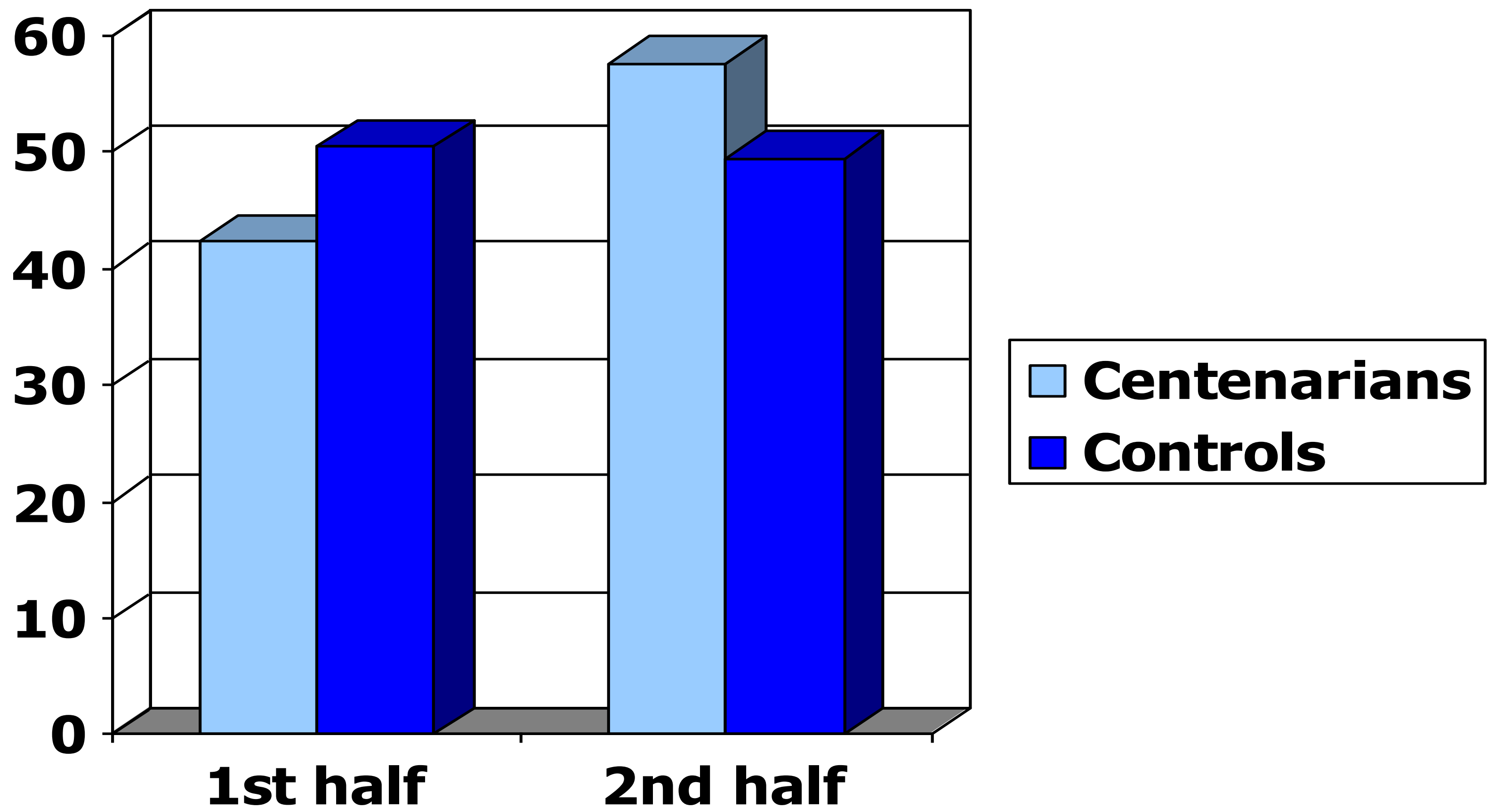
Parental longevity, early-life and midlife conditions and survival to age 100.
Men

Multivariate logistic regression, N=723			
Variable	**Odds ratio**	**95% CI**	**P-value**
Father lived 80+	**1.84**	**1.35-2.51**	**<0.001**
Mother lived 80+	**1.70**	**1.25-2.32**	**0.001**
Farmer in 1930	**1.67**	**1.21-2.31**	**0.002**
Born in North-East	**2.08**	**1.27-3.40**	**0.004**
Born in the second half of year	**1.36**	**1.00-1.84**	**0.050**
Radio in household, 1930	0.87	0.63-1.19	0.374

Parental longevity, early-life and midlife conditions and survival to age 100
Women

Multivariate logistic regression, N=815			
Variable	**Odds ratio**	**95% CI**	**P-value**
Father lived 80+	**2.19**	**1.61-2.98**	**<0.001**
Mother lived 80+	**2.23**	**1.66-2.99**	**<0.001**
Husband farmer in 1930	1.15	0.84-1.56	0.383
Radio in household, 1930	**1.61**	**1.18-2.20**	**0.003**
Born in the second half of year	1.18	0.89-1.58	0.256
Born in the North-East region	1.04	0.62-1.67	0.857

Season of birth and survival to 100



Variables found to be non-significant in multivariate analyses

- Parental literacy and immigration status, farm childhood, size of household in 1900, percentage of survived children (for mother) – a proxy for child mortality, sibship size, father-farmer in 1900
- Marital status, veteran status, childlessness, age at first marriage
- Paternal and maternal age at birth, loss of parent before 1910

Conclusions

- Both midlife and early-life conditions affect survival to age 100
- Parental longevity turned out to be the strongest predictor of survival to age 100
- Information about such an important predictor as parental longevity should be collected in contemporary longitudinal studies

Final Conclusion

The shortest conclusion was suggested in the title of the *New York Times* article about this study

IDEAS & TRENDS

For Centenarians, It All Begins at Birth

By HENRY FOUNTAIN

CENTENARIANS are different from the rest of us, and it's not just that they are a lot older. They are a select group, having persisted through wars, diseases, disasters and accidents that kill tens of millions of ordinary mortals every year.

In looking at what makes a 100-year-old so special — fewer than 2 in every 10,000 Americans live to that age or older — those who study aging cite factors like genetics (particularly having two X chromosomes, as 85 percent of centenarians are women) and environmental influences like good nutrition and health habits.

But a statistical study of centenarians by researchers at the University of Chicago has found some other potential predictors of extreme longevity. Women and men who were the first born in large families, the study found, were two to three times more likely to make it to 100 than later-born children. Those raised in the rural West had a better chance of reaching that age. And people of advanced age who were born in September and November had longer life expectancy than those born in April through June.

So if you are a fall baby, the first child of a farming couple from ...

Genes and environment still rule when it comes to living an ultralong life.

Acknowledgment

This study was made possible thanks to:

- **generous support from the National Institute on Aging grant #R01AG028620**

- **stimulating working environment at the Center on Aging, NORC/University of Chicago**

For More Information and Updates Please Visit Our Scientific and Educational Website on Human Longevity:

http://longevity-science.org

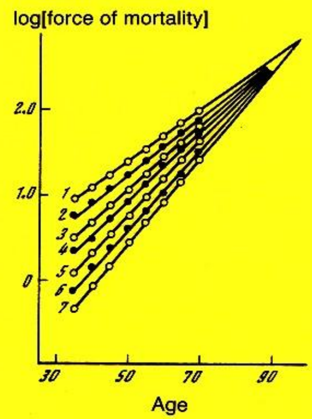
And Please Post Your Comments at our Scientific Discussion Blog:

- **http://longevity-science.blogspot.com/**

The Biology of Life Span: A Quantitative Approach

L. A. Gavrilov and N. S. Gavrilova

Edited by
V. P. Skulachev



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