The Longevity Dividend: Altering the Future Course of Health and Longevity

S. Jay Olshansky, Ph.D.
University of Illinois at Chicago
Summary

Message 1  Gompertz saw biology in the life table, and he was right – there is a law of mortality.

Message 2  Future trends in mortality and longevity will be driven by biology, not past trends. Linear thinking got us in trouble in the past, and it’s still getting us in trouble today.

Message 3  A life expectancy of 100 is highly unlikely, but the number of centenarians will rise dramatically.

Message 4  Life expectancy is likely to rise rapidly for some, and decline dramatically for others. Education is a longevity trump card.

Message 5  If the retirement age was indexed to longevity as originally intended, it would be much higher than it is today. However, raising the retirement age has dramatically different effects on population subgroups.

Message 6  Two forthcoming revolutions in medicine and aging science are about to permanently change the landscape of human longevity in the future.
Gompertz (1825) – summarized in Olshansky and Carnes (1997)
Ever Since Gompertz
The Bridge of Life

The Chances of Death by Karl Pearson (1897)
VI. A COMPARISON OF THE LAWS OF MORTALITY IN DROSOPHILA AND IN MAN

PROFESSOR RAYMOND PEARL

The American Naturalist (1922)

In the first study a rough, purely graphical comparison of the $l_x$ lines of the Drosophila and certain human life tables was instituted. This comparison, rough as it was, made apparent at once the fact that there was a fundamental similarity in laws of mortality in these two organisms.

It is my purpose in the present paper to make a more exact comparison of the values of the life table functions in the two cases. It will be seen that the similarity is even closer than was supposed from the rough comparison, and that in fact we are dealing here with qualitatively identical expressions of an obviously fundamental biological law.
VI. A Comparison of the Laws of Mortality in Drosophila and in Man

Professor Raymond Pearl

![Graph comparing the survivorship distributions of Drosophila and man (males in both cases) over the equivalent life spans.](image)
Solving the law of mortality required conditions that were difficult to overcome

- The ability to reliably measure Intrinsic Mortality
- Access to reliable intrinsic mortality rates for different species
- Scaling Time
Demonstration of consistency in the timing of death.
Source: Carnes and Olshansky, 2001
Source: Carnes and Olshansky, 2001
FIGURE 3  Comparison of cumulative survival curves for the mouse, beagle, and human populations plotted on the time scale for the B6CF1 mouse strain. Additional time axes are shown for the beagle and human to demonstrate the effect of scaling.
Why Do We Age and Live as Long as We Do?

Is There Biology in the Life Table?
"Nothing in biology makes sense except in the light of evolution."

Theodosius Dobzhansky
The American Biology Teacher, March 1973
BOTH Michelangelo and Darwin WERE RIGHT

The human body is a miraculous machine that works with near artistic perfection – for a while. Time reveals the “flaws” in a body design that was not intended for long-term use.
Alleles with detrimental affects are “pushed” by natural selection to either side of the reproductive window.

Genes that are harmful late in life are selected if they are favorable early in the lifespan.

In a world with limited physiological resources, selection favors investment in reproduction at the expense of immortality.
WHY DO WE LIVE AS LONG AS WE DO?
There is a remarkable consistency to the timing of death across species. Duration of life is calibrated to the onset and length of a species’ reproductive window.
77,000 days Bowhead Whale

55,000 days Sea Turtle

29,000 days Human

26,000 days Elephant

5,000 days Dog

1,000 days Mouse

77,000 d
55,000 d
29,000 d
26,000 d
5,000 d
1,000 d
Although there is no genetic program that limits how fast humans are capable of running, there are nevertheless biomechanical constraints on running speed.

Although there is no genetic program that limits the duration of life, there are nevertheless biomechanical constraints on the functioning of body parts that influence how long we live.
Can most live to 100?

Can we really add decades of life to people aged 70+ today faster than we added decades of life to children born in the early 20th century?
Does History Repeat Itself?

- Forecasters have a long history of both underestimating and overestimating longevity. Today a new set of errors are being made because they are relying almost exclusively on the extrapolation of past trends into the future. There is definitive evidence that some cohorts in some countries will live shorter lives and others will live longer lives than anticipated from actuarial models.

Source: Olshansky, 1988

Source: Olshansky et al., 2005
World Record for the 1-Mile Run (Males)


1 minute at 2420
0 minutes at 2580
Can Human Biology Allow Most of Us to Become Centenarians?

B.A. Carnes,1 S.J. Olshansky,2 and L. Hayflick3

1Reynolds Department of Geriatric Medicine, College of Medicine, The University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma.
2Division of Epidemiology and Biostatistics, School of Public Health, University of Illinois at Chicago, Illinois.
3Department of Anatomy, University of California, San Francisco.

Address correspondence to Bruce A. Carnes, PhD, Reynolds Department of Geriatric Medicine, The University of Oklahoma Health Science, 921 NE 13th Street (11G), Oklahoma City, Oklahoma 72104. E-mail: Bruce-Carnes@ouhsc.edu.

Life span is a topic of great interest in science, medicine and among the general public. How long people live has a profound impact on medical costs, intergenerational interactions, and the solvency of age-based entitlement programs around the world. These challenges are already occurring and the magnitude of their impact is, in part, proportional to the fraction of a population that lives the longest. Some demographic forecasts suggest that most babies born since the year 2000 will survive to their 100th birthday. If these forecasts are correct, then there is reason to fear that the financial solvency of even the most prosperous countries are in jeopardy. We argue here that human biology will preclude survival to age 100 for most people.
YOUNG VERSUS OLD BRAIN

Loss of hippocampus
axons
gyri

Healthy
25-year-old

80-year-old with cognitive losses

% with disease

Age (yrs)

Nerve conducting velocity
Maximum heart rate
Kidney blood flow
Maximum IQ

Level

115
100

74
81
88

Arthritis
Diabetes
Cancer
Heart disease

Mortality

Age
Period and Cohort Life Expectancy at Birth (US, 1900 and 2000)

Source: US Social Security Administration and Christensen et al., 2009
Olshansky et al., 1990. *Science.*

**Fig. 2.** Percentage of reduction in the conditional probability of death for the United States (from 1985 levels) required to produce a life expectancy at birth from 80 to 120 years.

- Mortality reductions restricted to age 50+
- Life expectancy at birth with the elimination of:
  - Cancer
  - Ischemic heart disease
  - Cancer and ischemic heart disease
  - All cardiovascular diseases, diabetes, and cancer

Reduction in mortality (%)

Life expectancy at birth

70 75 80 85 90 95 100 105 110 115 120

Males

Females

71.2 78.3 74.35 74.7 81.28 81.45 85.3 86.42 94.1
Maximum Lifespan Potential = 122

Maximum Observed Age at Death = 105, 113 *

Period Life Expectancy at Birth = 49, 80 *

Modal Age at Death = 73, 88 *

U.S. FEMALES

1900

200 0
Observed Distribution of Life Table Deaths for Females in the United States, 1900 and 1985

Deaths

Age

50 55 60 65 70 75 80 85 90 95 100 105 110 115 120

Low Disability Moderate Disability High Disability

Heart Disease, Stroke, Cancer

Alzheimers, Arthritis, Osteoporosis, Vision & Hearing Impairment

1900 1985
There is no demographic, actuarial, or biological justification for concluding that most (or even half of the population) can live to 100
Education
The Longevity Trump Card
Conditional Probability of Death \[ q(x) \] for Females in the U.S. (U.S. Non-Hispanic White, Insured with $1 Million+ Policies, and Whites with College Education (2005)
Conditional Probability of Death [q(x)] for Males in the U.S. (U.S. Non-Hispanic White, Insured with $1 Million+ Policies, and Whites with College Education (2005))
The average duration of life will be only 2 months greater, but the distribution of death by age will be dramatically different.
The diagonal line represents an exact match between estimated life span with accelerated aging and observed or expected life span. Presidents who appear above the line lived longer than their estimated life span while those who appear below the line died before their estimated life span. Expected life spans of living presidents are based on their current ages. Presidents who did not die of natural causes (Lincoln, Garfield, McKinley, and Kennedy, indicated by shading) and living presidents (Carter, G. H. Bush, Clinton, G. W. Bush, and Obama, indicated by bold) were included in estimates of mean age at inauguration and estimated mean life span at age of inauguration with accelerated aging. These presidents were excluded from analyses involving observed survival because they are either still alive or did not die from natural causes.

Source: Olshansky, SJ. 2012. Longevity of CEOs of MetLife.
A Possible Decline in Life Expectancy in the United States in the 21st Century?

S. Jay Olshansky, Ph.D.
University of Illinois at Chicago

Douglas J. Passaro, M.D.
University of Illinois at Chicago

Ronald C. Hershow, M.D.
University of Illinois at Chicago

Jennifer Layden, MPH
University of Illinois at Chicago

Bruce A. Carnes, Ph.D.
University of Oklahoma

Jacob Brody, M.D.
University of Illinois at Chicago

Leonard Hayflick, Ph.D.
University of California at San Francisco

Robert N. Butler, M.D.
International Longevity Center

David B. Allison, Ph.D.
University of Alabama at Birmingham

David S. Ludwig, M.D., Ph.D.
Children’s Hospital, Boston

Funding: NIH/NIA; NIDDK; IGPA

New England Journal of Medicine
Obesity Trends* Among U.S. Adults

1985

(*BMI ≥ 30, or ~ 30 lbs overweight for 5’ 4” person)

<table>
<thead>
<tr>
<th>No Data</th>
<th>&lt;10%</th>
<th>10%–14%</th>
<th>15%–19%</th>
<th>20%–24%</th>
<th>≥25%</th>
</tr>
</thead>
</table>

Source: CDC
Obesity Trends Among U.S. Adults

1990
Obesity Trends Among U.S. Adults

1995

- No Data
- <10%
- 10%–14%
- 15%–19%
- 20%–24%
- ≥25%
Obesity Trends Among U.S. Adults

2000

Legend:
- No Data
- <10%
- 10%–14%
- 15%–19%
- 20%–24%
- ≥25%
Obesity Trends Among U.S. Adults

2004
Obesity is a global pandemic
OBESITY: A Weighty Issue for Children

Fat for Life?
Six Million Kids Are Seriously Overweight. What Families Can Do.

By Geoffrey Cowley & Sharon Begley

www.StrangeConclusions.com
By Eric N. Reither, S. Jay Olshansky, and Yang Yang

New Forecasting Methodology Indicates More Disease And Earlier Mortality Ahead For Today’s Younger Americans

**ABSTRACT** Traditional methods of projecting population health statistics, such as estimating future death rates, can give inaccurate results and lead to inferior or even poor policy decisions. A new “three-dimensional” method of forecasting vital health statistics is more accurate because it takes into account the delayed effects of the health risks being accumulated by today’s younger generations. Applying this forecasting technique to the US obesity epidemic suggests that future death rates and health care expenditures could be far worse than currently anticipated. We suggest that public policy makers adopt this more robust forecasting tool and redouble efforts to develop and implement effective obesity-related prevention programs and interventions.

DOI: 10.1377/hlthaff.2011.0092
HEALTH AFFAIRS 30, NO. 8 (2011): ©2011 Project HOPES. The People-to-People Health Foundation, Inc.

Eric N. Reither (eric.reither@usu.edu) is an associate professor in the Department of Sociology at Utah State University, in Logan.

S. Jay Olshansky is a professor in the School of Public Health at the University of Illinois, in Chicago.

Yang Yang is an associate professor in the Department of Sociology and the Lineberger Comprehensive Cancer Center at the University of North Carolina, in Chapel Hill.
Differences in Life Expectancy Due to Race and Educational Differences Are Widening, and Many May Not Catch Up

Life expectancy at birth for white males and females in the U.S. with less than 12 years of education (1990-2008)

Resetting Social Security: What is Fair?

Olshansky et al., 2014
MacArthur Research Network on an Aging Society [in preparation]
“When it is realized that too large a proportion of the population would probably be left idle with a retirement age of 65, the general feeling will undoubtedly be that a constant retirement age should be banished, or that it should be left as a balancing item” (p.8)  
Williamson and Myers, 1937

“we can therefore expect a considerable shift in the retirement age. Advancing it five years would make a lot of difference. There may be times when it could be reduced” (p.8)  
Williamson and Myers, 1937

“Similarly, in the future when there are a great many persons over 65, most of the able-bodied individuals will and should continue working to age 70 or 75 if their services seem needed” (p.18)  
Myers, 1938

Table 1. Life expectancy at birth \([e_0]\), age 65 \([e_{65}]\), and conditional survival from age 25 to age 65 \([S_{25-65}]\), by sex (U.S., 1935, 1983, 2010)

<table>
<thead>
<tr>
<th></th>
<th>(e_0)</th>
<th>(e_{65})</th>
<th>(S_{25-65})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M(F,T)</td>
<td>M(F,T)</td>
<td>M(F,T)</td>
</tr>
<tr>
<td>1935</td>
<td>59.0 (63.0, 60.9)</td>
<td>12.0 (13.4, 12.7)</td>
<td>59.8 (67.7, 63.5)</td>
</tr>
<tr>
<td>1983</td>
<td>71.0 (78.1, 74.7)</td>
<td>14.4 (18.6, 16.7)</td>
<td>74.8 (85.5, 80.9)</td>
</tr>
<tr>
<td>2010</td>
<td>76.4 (81.2, 78.9)</td>
<td>17.9 (20.5, 19.4)</td>
<td>82.3 (89.1, 85.7)</td>
</tr>
</tbody>
</table>


Figure 1. Observed and hypothetical full retirement ages indexed to life expectancy at age 65 (U.S., 1935, 1983, 2010)

Figure 2. Hypothetical full retirement ages indexed to life expectancy at age 65 for White Females by Level of Completed Education, 2010

What the Full Retirement Age Should be If Indexed to Life Expectancy at Age 65

Subgroup by Level of Completed Education

WF<16 WF-16+

69.2 73.3

Full Retirement Age
The Next Health and Longevity Revolution is Forthcoming
Redesign / Replace Body Parts Already in Existence

BRAIN TRANSPLANT
ONE ORGAN WE WILL HAVE A DIFFICULT TIME “FIXING”
Sex and trait selection

Germ line modification

Therapeutic cloning

Genetic engineering to treat or eliminate diseases
Exciting Advances in Biomedical Technology

Personalized Medicine
Person 1: 5.5 mg. of medicine X
Person 2: 6.2 mg. of medicine X
Reducing the risk of fatal diseases by treating them as if they are independent of each other may extend the period of old age.
I imagine an intervention, such as a pill, that could significantly reduce your risk of cancer. Imagine an intervention that could reduce your risk of stroke, or dementia, or arthritis. Now, imagine an intervention that does all those things, and at the same time reduce your risk of everything else undesirable about growing older— including heart disease, diabetes, Alzheimer’s and Parkinson’s disease, hip fractures, osteoporosis, sensory impairments, and sexual dysfunction. Such a pill may sound like fiction, but aging interventions already fit this general model. And many scientists believe that such interventions are scientifically achievable and for people. People already place a high value on both quality and length of life, which is why children are immunized against infectious diseases. In the same way, we suggest that a concerted effort to slow aging begins immediately—because it will save and extend lives, improve health, and create wealth.
New model of health promotion and disease prevention for the 21st century

Our susceptibility to disease increases as we grow older. **Robert Butler and colleagues** argue that interventions to slow down ageing could therefore have much greater benefit than those targeted at individual disease.
The Private Sector

The New York Times

Tech Titans Form Biotechnology Company

BY CLAIRE CAIN MILLER AND ANDREW POLLACK
SEPTEMBER 16, 2013

Silicon Valley has an obsession with immortality, and not just as science fiction. Many people here say they believe that the day when technology makes it possible to live forever is just around the corner.

On Wednesday, some of the tech world’s most formidable players announced an effort to get closer to that point, with a new biotechnology company to fight the aging process and the diseases that accompany it.

The company, Calico, was conceived and backed by Google, whose co-founder and chief executive, Larry Page, portrayed it as one of the company’s long-shot projects, like self-driving cars. Arthur D. Levinson, 63, the former chief executive of Genentech and the chairman of Apple, agreed to be the chief executive and is also an investor.

Larry Page, Google’s co-founder and chief executive, and Arthur D. Levinson, a former chief executive of Genentech and the chairman of Apple. (Left: John G. Mabanglo/European Pressphoto Agency; Right: Roche)

is Calico’s only employee for now, would not say when, or even if, Calico hoped to develop a drug to fight aging.

Dr. Levinson said that at first Calico would be “more of an institute certainly than a pharmaceutical company,” focusing on basic research aimed at picking apart the biological mechanisms behind aging.

An anti-aging drug has been a long-sought goal, both by some consumers and by companies, as well as by various hucksters. Rather than treat each particular disease, retarding aging could potentially pre-

Aging is the single biggest risk factor for virtually every significant human disease...

Our goal is to extend and enhance the healthy, high-performance lifespan and change the face of aging. For the first time, the power of human genomics, informatics, next generation DNA sequencing technologies, and stem cell advances are being harnessed in one company, Human Longevity Inc., with the leading pioneers in these fields. Our goal is to solve the diseases of aging by changing the way medicine is practiced.

It's not just a long life we're striving for, but one which is worth living.

Human Longevity Inc. (HLI) Launched to Promote Healthy Aging Using Advances in Genomics and Stem Cell Therapies

@JCVenter on CBS Morning Show [http://rt.co/9PnhQpGm](http://rt.co/9PnhQpGm) #genomics

[2 days ago]
AGING BIOLOGY IS AT THE CORE OF CHRONIC DISEASES

AGING

Frailty Resilience

Frailty/Sarcopenia
CKD
Diabetes
Neurodegenerative
Menopause
HIV/AIDS
Blindness
Arthritis/Osteoporosis
COPD/ Pulmonary Fibrosis
CVD
Cancer
Stroke

AGING BIOLOGY IS AT THE CORE OF CHRONIC DISEASES

Frailty/Sarcopenia
CKD
Diabetes
Neurodegenerative
Menopause
HIV/AIDS
Blindness
Arthritis/Osteoporosis
COPD/ Pulmonary Fibrosis
CVD
Cancer
Stroke
Do We Need to Know in Advance Which Scientific Pathways to the Longevity Dividend Will Work?

Genetics of long-lived people

Caloric restriction

Compounds with properties that appear to slow aging
### LDI Primary Goals

1. Accelerate research on aging

1. Accelerate translation of research into therapeutic interventions

- **Extend healthy life**
- **Reduce health care costs**
- **Reduce the burden of disease**
- **Reduce gap between life expectancy and healthy life expectancy**
REMEMBER THE TWENTY EXTRA YEARS YOU ADDED TO YOUR LIFE THROUGH CLEAN, HEALTHY LIVING? — WELL, THESE ARE THEM.
300 Word Video