Physical Demography

the physics of populations and human mortality

Charles Dermer, Ph.D. (theoretical physics, UCSD, 1984)

Day of the Dead Celebration - Nov 2nd - Blake Memorial Library

October 12, 2024

In memory of

Theodore Waldman (1925-2006)

Professor of Philosophy, Harvey Mudd College

Abstract

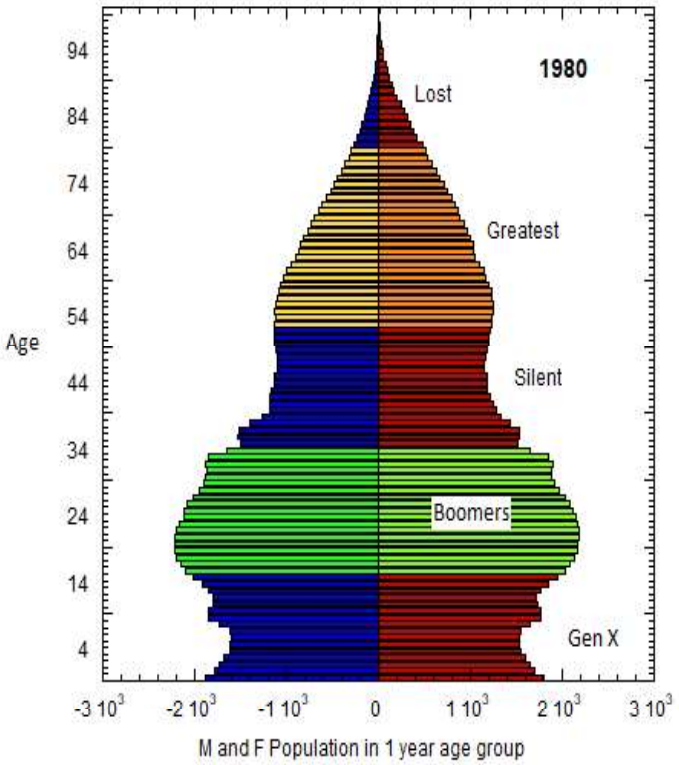
I propose a model for human mortality based on telomere loss and the statistical approach to cell senescence and organism death (Chpt. I). Physics at the cellular level is tested by mortality data at the population level. Population rates approach mortality rates in old (≥ 60 yo) age. The other component of the population rates, migration, can be important for the young. I argue (Chpt. II) that unusual spikes in the rates derived from 5-yr age ppn Hungarian population data are a long-term consequence of radioactive poisoning by the Chernobyl nuclear accident. Rates derived from WPP 1-yr data for Hungary indicate that the Hungarian population data in the ppn and WPP databases are corrupted.

Mortality rates rise exponentially in old age, irrespective of country. This permits a simple analytic and numerical actuarial study to calculate life expectancy, half-life, and 5-yr survival probability for our current and former presidents (Chpt. III). Population physics is formalized in Chpt. IV, where I show results of a numerical model for Ukrainian population evolution that uses a simplified fertility function for Ukrainian women. Even if the Russia-Ukraine war was to end today, Ukraine will suffer population decline to $\backsimeq 20\times10^6$ Ukrainians in 50 yrs should Ukrainian fertility rates in the last few decades persist. Chpt. V is a study of total and partial US age-stratified mortality rates in 2019 compared with rates from Covid-19 and alleged MRNA vaccine-related deaths. For ≈20-40 yo young adults, the harm from drug overdose and suicide has always been a much greater hazard than Covid, and there is no risk-reward benefit for persons $\lesssim$25 years of age to take MRNA vaccines.

In Chpt. VI, data for US population evolution are assembled, and the fertility function and age-stratified M and F mortality rates in the US back to 1950 are fit. For rates and profiles, I use the USCB 1-yr data found in the same WPP database cited by the ppn. I find $\backsimeq 3.8\times10^6$ more foreign born had entered the US from 2010-2020 and resided in the US in 2020 than the 12.6×10^6 reported, as well as an additional $\backsimeq 10^6$ babies born in the US to these migrants.

The data and rates are used in a simulation model (Chpt. VII) to project the US 2010 M and F profiles 50 years into the future assuming different rates of migrant entry into the US and different TFR (total fertility rate) scenarios for host and migrant populations.

The Great Replacement, declining TFRs around the world, the dream of a steady state with TFR $\backsimeq 2.1$, and the consequences of combatting declining fertility with immigration are discussed in §7.4. I conclude in Chpt. VIII with reflections on death, an outline of the algebra of genetic immortality, physics of life and death from the cell to the organism to the population, and final thoughts on life, death and immortality.



US M (left) and F (right) profile evolution, 1980-2023 (populations of 1-yr age groups in thousands). The generations of Americans are defined in Table VI.C1. Changes in the number of members of co-aging age groups give the sum of the migration and mortality rates for that age group. Population rates equal mortality rates in old age. Data from USCB/WPP.

TABLE OF CONTENTS

ABSTRACT IV

TABLE OF CONTENTS V

EXTENDED SUMMARY 1

PROLOGUE 4

0. INTRODUCTION TO PHYSICAL DEMOGRAPHY 8

I. TELOMERES AND THE STATISTICAL MECHANICS OF MORTALITY 16

Abstract *17*
1. INTRODUCTION 17
2. TELOMERE LOSS MODEL 18
3. COUNTRY POPULATION DATA 20
4. TELOMERE MODEL VS. MORTALITY DATA 22
5. DISCUSSION 24
6. SUMMARY AND CONCLUSION 24
Appendix A. Correction for the oldest age cohort *25*
Appendix B. Survival probability *25*
Appendix C. Importance of migration on rates derived from population data *27*

II. SPIKE IN HUNGARIAN POPULATION RATES FROM CHERNOBYL? 30

Abstract *31*
1. INTRODUCTION 31
2. DERIVATION OF MORTALITY RATES 31
3. SUICIDE 33
4. MIGRATION 33
5. DATA 34
7. EXCESS HUNGARIAN MORTALITY 35
8. THEORETICAL INTERPRETATION 35
6. CHERNOBYL 35
9. CONCLUSIONS 36
Appendix A: Animations *37*
Appendix B: Correspondence *38*

III. DON'T COUNT ON BOTH PRESIDENTS TRUMP AND BIDEN DYING BY NATURAL CAUSES IN THE NEXT 5 YEARS, THOUGH ONE PROBABLY WILL 41

Abstract *42*
1. INTRODUCTION 42
2. DATA AND THEORY 42
3. CALCULATIONS 44
4. DISCUSSION 46
5. CONCLUSIONS 47
Appendix A. Survival probability of the very old *48*
Appendix B. Analytic and semi-analytic solutions for $\tau_{1/2}$ and τ_{LE} *49*

Appendix C. US population and annual percentage growth rate, 1950-2030. ..... *50*

IV. THEORY OF POPULATION PROFILES AND THE UKRAINIAN DEATH SPIRAL **52**

Abstract *53*
1. INTRODUCTION 53
2. THEORY 54
3. NUMERICAL EXPERIMENT 56
4. RESULTS 57
5. UKRAINE DEMOGRAPHICS 59
(i) Mortality *59*
(ii) Fertility and Births *60*
(iii) Ukrainian 2023 Population Profile *63*
6. UKRAINE POPULATION PROJECTIONS 63
7. DISCUSSION 66
8. CONCLUSIONS 67
Appendix A: Profile evolution for different approximations *67*
Appendix B: Animations *69*
Appendix C: Check on results with 1-yr rates *70*

V. US MORTALITY RATES BY AGE GROUP IN 2019 VS. COVID-19 AND MRNA VACCINE MORTALITY RATES **72**

Abstract *73*
1. INTRODUCTION 73
2. MORTALITY RATES FROM POPULATION DATA 74
3. PARTIAL MORTALITIES: US, 2019 75
4. COMPARISON OF CANCER AND EXTERNAL MORTALITY RATES 78
5. COMPARISON OF CANCER, COVID-19, AND MRNA VACCINE MORTALITY RATES 80
6. COVID-19 INFECTION FATALITY RATE 83
7. TOTAL MORTALITY RATES IN US AND CHINA 84
8. SUMMARY AND DISCUSSION 85
9. CONCLUSIONS 86
Appendix A: Mortality-age profiles of the US in 2018 and 2019 ..... *88*
Appendix B: Immigration estimates from mortality and population data *89*
Appendix C: Evolving population rates in the US and China, 2000-2030 ..... *90*
Alternate short timeline of Covid-19 pandemic in the US *93*

VI. US POPULATION EVOLUTION: FERTILITY, MORTALITY AND MIGRATION **95**

Abstract *96*
1. INTRODUCTION 97
2. US POPULATION EVOLUTION: 1950-2024 101
3. US FERTILITY: 1950-2021 102
4. US MORTALITY: 1955-2022 106
5. US MIGRATION: 1950-2020 110
6. ANALYSIS OF POPULATION EQUATION WITH MIGRATION 111
7. CONFLICT IN US MIGRANT NUMBERS 114
8. EVOLVE 2010 US POPULATIONS TO 2020 USING 1-YR AGE COHORT DATA 116
(i) Early Census.gov 1-yr age cohort data *118*

(ii) Human Mortality Database 1-yr age cohort data *120*
(iii) US 5-yr mortality rates from HMD vs 5-yr rates from ppn data *121*
(iv) US 1-yr mortality rates from HMD 1-yr age cohort data *122*
(v) 1-yr data from UN Population Division (Rev. 2024) *124*
9. DISCUSSION 129
10. CONCLUSIONS 131
Appendix A: Evolution of a 2-sided Gaussian migrant population without mortality *133*
Appendix B: Evolution of a 2-sided Gaussian migrant population with mortality *134*
Appendix C: US population profiles in 2010 and 2020 ..... *135*
Appendix D: 1-yr vs. 5-yr age cohort data *137*
Appendix E: Fits to 2010-2020 US mortality and population data *138*
Appendix F: 1-yr USCB rates in the US during the Covid era *140*

VII. SIMULATIONS OF POPULATION EVOLUTION 144

Abstract *144*
1. INTRODUCTION 145
2. AVERAGE US MORTALITY RATES: 2010-2020 AND EXCESS CHILDREN 146
3. EVOLVING MIGRANT AGE PROFILE 149
4. THE CHILDREN OF MIGRANTS 152
(i) Migrant arrival age profiles and numbers: 2010-2020 ..... *153*
(ii) Calculation of children born to migrants entering 2010-2020 ..... *154*
(iii) GPLEX function for entering migrant age distributions *156*
5. EVOLVING PROFILES OF HOST, 1ST AND 2ND GENERATION MIGRANT POPULATIONS 157
6. SIMULATED FUTURE US POPULATION PROFILES 160
7. CODE RESULTS 164
8. DISCUSSION: TOTAL FERTILITY RATES AND THE GREAT REPLACEMENT 166
9. CONCLUSIONS 175
Appendix A: GPLEX function and normalization *180*
Appendix B: Physics with AI *180*
Appendix C: Migrant arrival fraction during Trump and Biden years *181*

VIII. DEATH AND DEMOGRAPHY 183

1. WHY DEATH? 183
2. FACES OF DEATH 184
i. Philosophy and Death *184*
ii. Religion and Death *185*
iii. Psychology of Death *186*
iv. Literature of Death *187*
3. BIOLOGY OF DEATH 189
4. DEATH PHYSICS 195
5. LIFE PHYSICS 199
6. LIFE, DEATH AND IMMORTALITY 200

APPENDIX. STATISTICAL PHYSICS AND THE GAUSSIAN FUNCTION 211

END NOTES 215

E1. PROBABILISTIC SOLUTION TO SOCIAL-SECURITY INCOME MAXIMIZATION 215

E2. READING A GRAPH: LINEAR, EXPONENTIAL AND POWER-LAW BEHAVIOR; DOUBLING TIME AND HALF-LIFE 217
E3. LESSONS LEARNED 221
E4. CHAPTER I ILLUSTRATION: WHAT DO I GET FOR A RIB? 222

INDEX 223

Illustrations

I. What do I get for a rib?

II. The Magyar nation

III. Crowd-fund life-lock alert bracelets for Trump and Biden

IV. Ukraine: the fights

V. Intrepid CIA agent finds China cafe

VI. Moses working on a passage in Deuteronomy

VII. Professor Feigenheimer makes a comment to his postdoc

Chpts. III-VII art and illustrations by SAAR

Select figures and animations

I.B1. Survival probability and half-life for persons of age τ with model mortality

II.1,2. Unusual spikes in Hungarian mortalities from ppn data demand explanation. Animations in II.A.

III. A1. Probability of survival for the old and very old (60-120 yo)

IV.B1, B2. Animations of Ukrainian mortalities (1980-2020) and Ukrainian population projections (2024-2072).

V.4. Comparison of total US 2019 mortalities vs. cancer, Covid-19, and estimated VAERS mortalities in 2020-2021

V.A1a, A1b. Mortality-age profiles for the US on linear and logarithmic scales, with names of age groups

VI.22. Loch Ness animation and plot of US 1-yr WPP with 5-yr ppn rates.

VII.16, 17, and 22. Animations of evolving US profiles for different migrant arrival fractions and TFR models

VIII.1. Pascal's Triangle. VIII.2. Model family tree.

App. A1-A9. Animations of particle distributions evolving statistically with time.

E.1. Plots of linear, exponential, and power-law functions on linear, log-linear and log-log scales

Tables

III.1 Coefficients for the range of mortalities for old M and F in the US in the last 20 years.

IV.1 Gaussian fertility coefficients for numerical experiments.

IV.2 Projections for Ukraine population.

VI.1 US fertility coefficients for the PLEX model.

VI.2 US fertility coefficients for 2-sided Gaussian model.

VI.3 US mortality coefficients with Band and exponential functions.

VI.C1 The generations of Americans, and their date- and age-ranges in 2024.

VI.C2 Dates of birth, ages (as of July 1, 2024) and generations of currently living presidents.

VII.1 TFRs of selected countries in 2022

Extended Summary

I explore the physical connection between human mortality at the cellular level and at the population level. Combined mortality and migration rates are derived from the changes in the numbers of males (M) and females (F) in co-aging age groups. I used the 5-yr age-cohort populationpyramid.net (ppn) data for initial studies, until anomalies forced me to find a useful 1-yr data set, which for the US was the United States Census Bureau (USCB) data found at the World Population Projects UN data base (WPP). This database gives the number of M and F in 1-yr age groups from 0 to >100 yo in countries of the world going back as far back as 1950. The ppn data give the same, but for 5-yr age cohorts. The ppn and USCB rates agree for the old (>60 yo), but there can be significant discrepancies in rates for the young (<60 yo).

A statistical model for human mortality based on telomere shortening is used to model old-age mortality rates. The model predictions are tested against the 5-yr ppn rates for the old, assumed equal to the mortality rates (this assumption is fully justified in App. I.C). The model predicts a gently curving age-dependent mortality rate in contrast to observed exponential behavior. Besides not being in complete agreement with the old-age rates, a model assumption about the relationship between cell death and human death is unwarranted. This opens some questions that are revisited in Chpt. VIII.

In the 5 countries—USA, Iceland, Hungary, Japan, and China—chosen for model comparison during the fiducial epoch 2010-2015, I found very odd evolving spikes for young Hungarians aged ≈20-30 in the 5-yr ppn rates around 2010. After ruling out suicide and migration, and barring a data issue, I interpreted them as mortality spikes due to aftereffects of the Chernobyl disaster (Chpt. II). After looking at the WPP data for Hungary, it is likely a data issue as the rates implied by the data appear badly processed. The 1-yr rates, if believed, would make the Hungarian mortality even more extreme.

Chapter III is a foray into actuarial science, where I calculate the life expectancy, half-life, and 5-yr survival probabilities of US M with the same age as President Biden and former President Trump (as of 1/2024). Supposing that low US M mortalities rates from the ppn data apply to these men, I find that both Trump and Biden have better than even odds that they will live more than 5 years. The joint probability that they both live for 5 more years is under 50%. The rates from the 1-yr USCB data give the same survival probabilities.

I build a simple population model in Chpt. IV to follow the evolution of the Ukrainian population profile after 2023. Besides using nonevolving mortality rates derived from 2008-2013 Ukraine ppn data, the major simplification is to use a fertility δ-function, where the number of children born each year is directly proportional to the number of women aged 30 in the Ukrainian population. The 1-yr M and F 2023 Ukrainian profile,[a] in full agreement with the ppn 5-yr 2023 Ukrainian data, was used as the initial condition to evolve the Ukraine 2023 M and F population profile into the future. The forecast is that the

[a] I used the 2023 profile; it has since been replaced by 2024, which is rather odd, since I am still in 2024.

population of Ukraine, which peaked at 51.8×10^6 Ukrainians in 1992, will fall to $\approx20\times10^6$ in 50 years from a pre-war (2021) population of 43.53×10^6. A very optimistic projection for Ukraine finds $\approx30\times10^6$ in 50 years. The Ukraine-Russia War is a catastrophe for Ukraine.

In Chapter V, I assemble US age-stratified mortality rates for homicide, suicide, drug overdose deaths, motor vehicular fatalities (MVF) and cancer in 2019, just preceding the Covid-19 pandemic, and compare them with age-stratified rates from Covid-19 deaths and sudden deaths alleged to be caused by the MRNA vaccines and reported in VAERS data during the US Covid-19 pandemic years (by convention, 2020-2023.5). During the peak years 2020-2022, Covid-19 deaths were relatively equally fatal, ~10-20%, at all ages $\gtrsim35$, compared to the total mortality rates at that age. Sudden deaths were at the 10% level compared to reported Covid deaths at these ages. For young adults, the real pandemic is suicide and drug overdose death, the so-called "deaths of despair." Taking an MRNA "vaccine" by persons $\lesssim$25-30 yo is ill-advised given the negative risk-reward tradeoff, even in the best case that they are truly "safe and effective."

With the age-stratified populations and mortality rates in hand, the evolving entering migrant age distributions follow. The 5-yr ppn rates gave peculiar results (Apps. V.B, V.C, and Figs. C3 and C4 animations), forcing me to find reliable 1-yr data. After studying some early USCB 1-yr data for the US in 2010 and 2020, and deriving unusable rates from data in for the US in the Human Mortality Database (HMD; see Fig. VI.19 animation), I finally arrived back at the WPP database (§VI.8).

In Chpt. VI, I fit the US F fertility function and the age-stratified US M and F mortality rates going back to about 1950. The fits are generally based on 5-yr age cohort rate data. I made a population model using these rates, evolving the 2010 US population profile to 2020 and then subtracting the resulting profile from the reported 2020 US profile. I determine quite unambiguously that the number of foreign born entering the US from 2010-2020, as implied by the USCB data, was $\backeqsim(12.3 + 3.8)\times10^6 \backeqsim 16.1\times10^6$, with the 12.3×10^6 number given in a separate USCB report on foreign-born arrivals giving arrival migrant populations stratified in sex, age, and time of entry into the US (Fig. VI.8). In addition, there were $\backsimeq10^6$ babies born to foreign born entering the country in this decade. This number is less certain because it depends sensitively on the fertility function of the US host population in the differencing method.

In Chpt. VII, the previous chapter's fits to US fertility and mortality rates are used to simulate US population evolution into the future. The age-stratified migrant arrival distribution is modeled by a GPLEX function—a Gaussian below a peak age of 19 (M) or 20 (F), and a power law times exponential (PLEX) function at ages greater than the peak age. It is fit to the Chpt. VI differencing results.

In the projections of US population profiles, I initially assumed an entering migrant (both legal and illegal) fraction $f_m = 0.3$, that is, the entering foreign-born (called migrant) population is 0.3% of the total US (host) population at that date. I also assume a declining fertility function, namely TFR model (a) in Fig. VII.20. The result is the Fig. VII.16 animation. Fig. VII.17 is an animation of the evolving host and migrant age profiles with $f_m = 0.1$, 0.3 and 1.0, assuming a middle TFR model (b) for both the host and migrant populations. The Fig. VII.32 animation shows a hypothetical scenario where the entering migrants and their children have a larger TFR (TFR model (c) in Fig. VII. 20) than the host and the host's children, who are assumed to follow TFR model (b). Inverted pyramids form for the host youth, and

growing pyramids form for the migrant youth and their children (who are US citizens) because of the younger profile of the entering migrants compared to the host population.

I discuss the results in the context of Renaud Camus's use of the phrase "Great Replacement" to describe our current historical epoch. Importation of unskilled immigrants into technically advanced countries is one way to counter declining fertility in that country. I argue that values of $f_m \gtrsim 0.4$ over a decade or two is a recipe for social unrest and division, and that $f_m \lesssim 0.3$ for both legal and illegal entry into the US is the optimal value.

The right level is ultimately a value question. I tabulate rates for authorized entry at the border and though the H1B, EB1 and EB4 programs in . I find that the migrant arrival fraction during the Trump years from 10/1/2018 - 9/30/2020 was $f_m^{Trump} \geq 0.23$, and that the fraction for the first 3 years of the Biden-Harris administration was $f_m^{Biden} \geq 0.50$ (§VII.8 and App. VII.C). These are lower limits as they do not count foreign born who illegally enter the US undetected (i.e., illegal aliens), or those brought in under Temporary Protected Status (TPS).

The outcome of the 2024 US presidential election may well hinge on whether the American people prefer immigration at rates taking place during the Trump administration or the Biden-Harris administration. Given the net negatives to the host population of the large-scale importation of the unskilled and uneducated, and the high TFRs of African countries, US should prioritize relations with Africa and disengage from Ukraine now that the West has led Ukraine down the "primrose path" (J. Mearsheimer) to ruin. Better that the West loses face than we lose everything in a thermonuclear war with Russia over a European nation Ukraine, the least of which can be said without fear of contradiction is that it nowhere borders the north Atlantic.

The desire for eternal youth, and the longing for longevity and a parallel longing for a steady-state population with TFR $\cong$ 2.1, whether in a given country or throughout the world, invites questions of death and immortality. I review in §VIII.2 some faces of death seen in philosophy, the Christian religion, psychology and literature. I visit the biology of death from a popular source, Wikipedia, and then outline an algebra of immortality parallel to some ideas in Dawkins's book, "*The Selfish Gene*." The telomere-loss model is revisited, including the connection between cell death and human death. I suggest an easy correction to "fix" the model by relating the death of the organism to a certain fraction of cells that have reached senescence through cell division and telomere loss. The timing counter for a cell to divide and lose telomeres would be distributed around some mean value.

Parallel questions in life physics are briefly mentioned in §VIII.5, and I set the stage for such an investigation. I conclude in Chpt. VIII that the recompense for death is the genetic immortality of the family, band, tribe, …, citizens and humanity.[b] But there is a proviso. Genetic immortality is achieved only if the lineage does not go extinct. This intense competition to avoid death and extinction is at the heart of Darwin's theory of natural selection, which inheres in the cell's genome, the organism sustained by the cells, and the concept of mind that we intuit, which includes fear of death and desire for life.

[b] As Bret Weinstein might say, "You'll be safe if you call it a clade."

Prologue

On May 25, 2023, at about 5 pm according to my iPhone metadata, my wife, my big sister and I were returning from a jeep tour to see mountain sights near Durango, Colorado where my sister lives. On the return trip, we passed an unusually large property, more like a hacienda. My sister pointed out that this was the property of Matthew McConaughey. Though never having watched more than half of a McConaughey movie, I blurted out, "What's he done to be so rich?" My sister replied, "He won an Academy Award, have you?" "I've written lots of science papers, has he?" "So have lots of people."[c]

She was right again. All the same, it started me thinking how a quasi-Gaussian distribution in household wealth or personal income (the supposedly halcyon '50s) could evolve with time to form a power law, like the Pareto 80/20 distribution where most of the wealth is owned, or work is done by only a few people (see Endnote 2). Power-law particle energy distributions are made by shocks formed by sudden energy releases, and shocks have been well studied in fluid physics and astrophysics, and studied to death in bomb physics. Could a power law form in the absence of something corresponding to a shock, e.g., a revolution or war, in a peacetime economy?

I thought that this was a nice statistical problem to explore, even if it's been done before.[d] The idea was that interactions between particles are defined by their size, or cardinality. In each step, there is a random probability for one particle to interact with another particle, and if one particle's size exceeds that of the other particle, it would gain value on a statistical basis in proportion to the difference in size of the two particles, with the smaller particle losing that value. Would a power law form that way? I still don't know, but if it does, the press release would say, "Mr. Big gets the money."

I made the Appendix animations of particle distributions evolving with time, some in the presence of reflecting and absorbing boundaries, and some with continuous injection. In the meantime, I ran into numerical issues and was diverted to mortality and population studies.

Since about 2020 or 2021, while walking the dog, I had been listening to the Dark Horse Podcast hosted by evolutionary biologists Heather Heying and Bret Weinstein. Bret can be hyperbolic at times, but they are both extremely intelligent and offered a different, more nuanced view of Covid origins, vaccines and treatments than provided by the New York Times, the Washington Post and the New Yorker (my wife subscribes, not me). While studying my first animation, Fig. A1, of the evolution of the simplest right, left, and difference distributions of particles with 60% probability of stepping to the right in each step, I

[c] I'm certain this was the conversation. My sister has no recollection of it, and thought the tour driver night have said "Louis Lamour," who has a hotel in Durango. My wife remembers that the name Matthew McConaughey came up. There is no online record of McConaughey having a Durango residence. In the fog of memory, the first casualties are brain cells at senescence.

[d] I've been retired for 9.0 years now, but by year ≈7 I had more or less achieved my retirement goal of understanding the mystery of music, at least Western music up to the year 1913 (see Endnote 2). The Maxwell equation (there's only one) for music is $2^{7/12} = 1.4983 \ldots \cong 3/2$, the perfect fifth. From this follows the 12-note chromatic scale, the difference between 12-tone equal temperament (TET) tuning and Pythagorean tunings, the cycle of fourths and circle of fifths, I-IV-V, 7-note diatonic and 5-note pentatonic scales, intervals and chords, etc.

recalled an interview that Bret did with his brother Eric Weinstein on the latter's Portal[e] podcast about the shortening of telomeres, the Hayflick limit, and cellular senescence. Though I didn't understand all the particulars, and still don't, deriving the remaining area of an evolving Gaussian as it moves through a boundary, which is what the telomere-shortening to senescence process sounds like, should be perfectly analytic. And so it was (Chpt. I).

I've always been the type of physicist that likes to fit models to data (no string theory for me). I have been perusing populationpyramid.net (ppn) for the past few decades. One can find population-pyramid (I prefer the generic term "profile") data for just about every country on Earth yearly from 1950 to the present. They even have future projections, though I could not find documentation to the model underlying their projections at the ppn website (there is one at WPP). The conveniently formatted excel data files are given for 5-yr M and F age cohorts, the youngest group being 0-4 yo infants and young children.

A country's history is revealed by the moving silhouette of its evolving population profile. The gashes and valleys bear witness to national tragedies (e.g., WWII in Russia, Holodomor in Ukraine, Cultural Revolution in China, WWI, etc.). The profiles show population explosion or decline. They also reflect different social attitudes (for example, I think it is safe to say that the UAE is a patriarchal society). A modern history course interpreting changing profile behavior in light of the country's history might have some pedagogical value.

It occurred to me, and I make no claims to originality other than having thought of the idea myself, that the change in the numbers of M or F in a 5-yr age cohort as they age 5 years (the co-aging cohort) would represent the loss of members of that age cohort due to mortality. It's not quite that simple, because migration also changes the age-cohort numbers. But for the old, those of us ≥ 60 years of age, migration is less important and mortality more important, and the population rates become equal to the mortality rates.

That was the data set I was looking for! I derived population rates for 5 countries, and fit the telomere-loss model to the old-age population/mortality rates. It's not a perfect fit, but the model opens up some interesting questions about the relationship between cell death and human death. Most fascinating for me was testing a theoretical model based on physics at the cellular level with data gathered at the population level.

One of the countries, Hungary, had unusual features in its population rates which I interpreted as mortality spikes resulting from Chernobyl (Chpt. II). I always entertained the possibility that it could have been a data issue, starting with the question mark in the title (I've heard it said that if there is one, the answer is almost certainly no). I posted the paper on Facebook, got a few responses and a detailed message from an anonymous Hungarian demographer that in no way solved the puzzle. My reply was not so diplomatic, either. I received no further response. I post her message in Hungarian, the google-translate English version and my reply in App. II.B.

[e] The Portal # 19, The Prediction and the DISC (Jan. 18, 2020). >40:30 for biology and >54:00 for telomeres.

Issues with the ppn data in Chpt. V (Fig. V.B1b and the Figs. V.C3 and V.C4 animations in particular) were completely resolved for the US migration studies in Chpts. VI and VII when using the 1-yr US data from the WPP. I supposed that the spikes in the Hungarian rates would disappear when using the 1-yr Hungarian WPP data. They didn't. If anything, the spikes are more pronounced than those given by the ppn data, but the rates also show hallmarks of severe data processing (Fig. II.2).

The Hungarian demographer directed me to the KSH Hungarian population website. Thanks, but no thanks. I will not do the work of figuring out why the Hungarian population data supplied to the WPP and ppn are garbage, if they are. Until Hungarian demographers do their job and confirm or refute my claim, the hypothesis remains unfalsified but not unfalsifiable that excess mortality implied by Hungarian population data was due to aftereffects of the Chernobyl disaster.

To continue, I wouldn't say that solving differential equations was my bread and butter—that would be high-energy astrophysics—but for perhaps 10 years now I've wanted to recast the population equation for profile evolution using the same formalism I developed in my high-energy radiation research. I found a few analytic, purely academic solutions some 5 years ago. Now I had the mortality rates in hand—simple exponentials for the old!—which was the first essential input to a population simulation (the others being birth and migration).

First I did an actuarial study in Chpt. III to calculate life expectancy, half-life (a more interesting half-life than the radioactive decay half-life, because it depends on a person's age),[f] and the 5-yr survival probability. I obtained these values for US men with the current age as former President Trump and President Biden. In actuarial studies, we really are just numbers.

Then I made a first simple population code and evolved the 2023 Ukrainian M and F 1-yr age cohort profiles that I found online into the future (Chpt. IV). I used a very simple Ukrainian fertility function, with births in proportion to the number of Ukrainian women aged 30. Even with a more accurate fertility function, the fertility of Ukraine as measured by its TFR in the past few decades foretells a future of declining population, arguably to as low as $\cong 20\times10^6$ Ukrainians in 50 years from a 1992 high of 51.78×10^6.

I had 4 papers in hand now, and got virtually no response (actually one; see App. II.B) after posting them on Facebook and Substack. Submitting them to a peer-reviewed journal would be folly, starting with the unseemly vanity-publishing arrangement ("page charges") and the corruption of peer-reviewed journals (for instance, the Proximal Origins paper in *Nature Medicine* has still not been retracted) and the peer-review process itself (I've seen it from both the inside and outside).

I took a 30-day road trip to El Salvador last February to clear my head, and gave a talk at Mexico's INAOE in Puebla, Mexico, which was warmly received. It reminded me that the academic world is not completely awful. But I was consumed with this problem. What do I do with it? With animations and

[f] To 1st order, the life expectancy ≈ ½ × half-life. The half-life is the important number, not the life expectancy, which is the time when the age cohort has used up half its remaining years (because it still has the other half to live).

weblinks, it's unsuitable as a book, so it has to be an e-book. I emailed a publisher (twice) and an academic I know who is well versed in scientific publishing but didn't get so much as the courtesy of a reply.

All right, I have a deadline (70th birthday), I have a problem that I can do on my own that's both topical (another reason to avoid publishing in scientific journals is getting sandbagged by the reviewers) and, I hope, lasting. We are in a new era of publishing. Since returning from El Salvador, I've decided to self-publish.

In Chpt. V, I study US Covid-19 mortalities within the context of death from other causes, for example, homicide, suicide, drug overdose death and cancer. Fits to US mortality rates and fertility functions going back as far as 1950 are made in Chpt. VI. I struggle in §VI.8 to find good 1-yr data, finally returning to the WPP from which the ppn data were sourced. Somehow anomalies or artefacts were introduced when converting the 1-yr WPP/USCB data to 5-yr ppn data (even worse for the 1-yr HMD), which became undeniable from the animations of the yearly age-stratified migrant entry rate (Figs. V.C3, V.C4.

The fits to the age-stratified mortality rates and fertility function for the US are used as inputs in Chpt. VI to evolve (= aging + birth + migration) the WPP 2010 US M and F population profile through 2020 and 2023, where they are benchmarked against the 2020 and 2023 USCB 1-yr M and F profiles, with the difference giving the M and F migrant age distributions and numbers entering the US since 2010. I calculate that $\cong 16.1\times10^6$ foreign born entered the US from 2010-2020 by evolving the USCB 2010 M and F age profiles to 2020, and subtracting the evolved profiles from the USCB 2020 M and F profiles. In addition, there would be about a million babies born to the foreign born who entered during that decade. This is $>3.8\times10^6$ more foreign born entering the US from 2010-2020 than reported.

Neither the provenance of these people nor another anomaly that arose when interpreting US migration data (§VI.7) need to be understood in order to use the population code to project into the future. Chpt. VII shows the results of the code by animating future US profile evolution for different migrant arrival rates and different fertilities of the host and migrant populations.

I then discuss the Great Replacement taking place in the West, the optimal rate of migrants into the US, and the import of different TFRs and declining fertilities around the world. The optimal rate of migrants into the US is ultimately a value question, but can be informed by such studies as this. I argue for a rate of migrant numbers, both legal and illegal, of no more than $\cong$0.3% of the US population in that year. I also delve into policy issues in §VII.8, and believe that the USA has a blind spot regarding Africa.

Putting a hard number, 0.3%, on the recommended migrant-entry fraction moves the discussion from binary thinking—open borders vs. closed borders—to realistic policy prescriptions. Binary thinking has invaded much of our discourse, and I lament its use in §VII.9, except in the one place where binary thinking is essential—the sexual M and F (gender identity is different).

Looming over this study is the shadow of death. I've tried to leaven the depressing nature of the subject with some humor. I conclude in Chpt. VIII by delving into ways we face death through philosophy, religion, psychology, and literature. The biology of death is revisited in §VIII.3, if only to compare

Pascal's triangle with a family tree and outline the algebra of genetic immortality. I take a final look at death physics and critique the telomere-loss model in §VIII.4. I penultimately end on a happier note by taking the briefest look at the physics of fertility. Questions of immortality, life and death occupy §VIII.6 before I conclude, or concede, that death is the price we pay for being alive.

0. Introduction to Physical Demography

The physics of the evolution of the age-stratified population $N_i(\tau;t) = dN_i(\tau; t)/d\tau$ is a simple differential equation of two variables, age τ and time (or date) t, given by

$$\frac{\partial N_i(\tau;t)}{\partial t} = -\frac{\partial N_i(\tau;t)}{\partial \tau} + B_i(t)\delta(\tau) + \dot{M}_i(\tau;t) - \nu_i(\tau,t)N_i(\tau;t)\,. \quad (1)$$

The index *i* refers to country and sex. This equation is easily enough solved numerically, if the birth rate $B_i(t)$, the age- and time-dependent mortality rate $\nu_i(\tau,t)$, and the age-stratified migration rate $\dot{M}_i(\tau;t)$ into and out of the country are specified. These terms conceal multiple layers of complexity. Some simple analytic solutions are found for eq. (1), one of particular importance (eq. [I.B1], with a simplified, constant mortality law only). Numerical solutions to eq. (1) are also explored. The population theory itself is not encountered until Chapter IV (all undergraduate physics).

The physics at the population level depends fundamentally on the physics at the cellular level, where questions of birth and death are settled. There being a general understanding of the two-body interactions leading to birth (involving male gametes reaching their targets, the ova), the focus of this study is instead on a more somber topic, human mortality.

A thought experiment is conducted in Chapter I to explain the rather uniform behavior of the *age-stratified mortality rates* (sometimes referred to here simply as "mortalities") for the old (≥ 60 years of age, yo) in different countries. Their similarity suggests that an underlying process encoded in our genes at the cellular and molecular level is responsible for the behavior of old-age mortality. One thing to notice about the abrupt cutoff of population numbers in old age, which is much faster than an exponential, is that it appears more like a smoothed Heaviside (step) function. This same behavior manifests in the error function and the hyperbolic tangent function, which might be a clue to the physics of mortality.

While developing a numerical statistical model (App. A), I noticed that the remaining fractional area of a Gaussian as it passes through a boundary would also show such an abruptly changing profile (see Appendix). In the meantime, I had become aware of some ideas relating telomere shortening to cell senescence. With each cell division, the telomere length shortens. After some 40-50 divisions, the cell stops dividing and reaches senescence and cell death.[g] If the dividing cells shed their telomeres statistically as they divide and reach senescence, then the mortality rate can be related to the fraction of

[g] The actual biological complexity of this topic is both well and poorly understood, as a search on *cellular senescence* makes clear.

cells reaching senescence. In the telomere-loss model, I posit that the fraction of the humans that die mirrors the fraction of cells that have reached senescence.

Chapter I opens with a meditation on death, where I pay homage to the wisdom of the ancients. I show how mortality rates can be derived analytically from the statistical telomere-shortening model. The essential data sets used in this chapter and throughout the book are the yearly UN population data for a given country from 1950 through the present and projected into the future. The data sets, online in excel format at populationpyramid.net (ppn), give the number of males (M) and females (F) in 5-year age cohorts from infancy to >100 yo in that country. Differences between the numbers of 5-yr age cohort populations as the populations age for 5 years give mortality rates averaged over 5 years. Mortalities calculated in this way are completely insensitive to variations in the country's birth rate. A correction for migration must, however, be made when there are significant numbers of migrants, which is most important for the young (< 60 yo). Comparison of the gently curving mortalities with age predicted by the telomere loss-model with the measured power-law mortalities of the old indicates that the model as presented in Chapter I is incomplete or wrong.

In Chapter I, I also plot the mortalities of 7 different countries in the 2010-2015 epoch. Among the countries examined were some with low migration, namely Iceland, Japan and Hungary. I found an extraordinary rate spike for 20-30 yo Hungarians, which I interpret as mortality spikes. This made me take a closer look at the Hungarian rates over time (Chpt. II). From epochs 2006-2011 through epoch 2010-2016, these spikes, if interpreted as due to mortality, mean that the mortality rates of M and F Hungarians between ≈20 and 30 yo exceeded 0.01 yr^{-1}, and that members of those age groups were literally centimated each year over a period of ≈4 years.

After showing that suicide and migration can't explain the spikes (but could it be a data issue?), the only plausible explanation I could defend implicates radiation effects on babies in utero, infants and young children from the 1986 Chernobyl meltdown, when radioactive dust from the explosion was carried westward and rained down on Hungary, causing the very young in the 1980s to prematurely die in the 2010s. This argument is made in Chapter II. If correct, more than 50,000 Hungarians met premature deaths due to radiation poisoning from Chernobyl. If correct, it argues against nuclear power as a panacea to the energy problem. If correct, it is hard to be an ardent supporter of nuclear power.

Since writing the previous paragraph, I've looked at the rates derived from Hungarian data in the 1-yr WPP database. The spikes are still there,… but the data look highly processed. Hungarian demographers will have to clarify and explain if or why the Hungarian data in these two databases, ultimately from the United Nations Department of Economic and Social Affairs, UN Population Division, are bad. Until then, I'll defend the Chernobyl hypothesis.

I also suggest how the behavior can be explained with the telomere-loss model if telomeres are shortened by ionizing radiation. Detailed modeling will follow independent confirmation of the result. Who knows what puzzles lie in the population data of other countries?

Chapter III strikes a lighter note, where I calculate the probabilities that President Biden and former President Trump survive the next 5 years. The 50% probabilities for the expected number of years that

Biden and Trump have yet to live are also calculated. This assumes that the mortality rates of Biden, Trump, and RFK, Jr. too, follow the mortality rates of the population of US males with similar ages. Although the calculations were made for the 5 years following January 2024, they can easily be reevaluated for the current date. Indeed, the actuarial knowledge gained in this chapter enables one to probabilistically determine the best age to maximize Social Security income. This calculation is made for some test cases in Endnote E1.

The tragedy of the ongoing Russia-Ukraine war is examined through the lens of physical demography in Chapter IV. Population eq. (1) is derived, and numerical solutions are computed for the case of negligible migration. Having a grasp of old-age mortality from the earlier chapters, and a rough approximation for mortality in general, I turn my attention to the female fertility function, namely the birth rate by age group for women of a given country. Gaussians at peak female fertility age $\tau_{pk} \approx$ 25-35 yo turn out to be adequate approximations for the fertility function, as shown in Chapter VI for US women, and are useful in Chapter IV for conducting numerical experiments and testing approximations.

The fertility factor *f* is essentially the number of female babies made by each woman, with an equal number of M babies if the sex ratio at birth is unity. Population pyramids form when $f > 1$, and populations collapse over decades into ice-cream-cone-like old-age-heavy profiles when $f < 1$. It is closely related to the Total Fertility Rate (TFR), and f = TFR/2 for the purposes of Chpt. IV.

The demographics of Ukraine are surveyed and the fertility of females is approximated by the ratio of the number of girls in the 0-4 yo age range to the number of women in different 5-yr age cohorts, with a comparable number of boys for a sex ratio of unity. For Ukraine, this translates into a value of $f<1$ since 1990, and $f<0.75$ from 1990-2010. f rises to ≈0.75 from 2000-2005 before falling to $f \leq 0.7$ in 2020 (Fig. V.6).

Besides population collapse, Ukraine suffers the calamity of the war. Using UN 1-year age-cohort data for Ukraine in 2023 as the starting condition for the population equation, I evolve the population profile forward in time assuming fertility factors $f \leq 1$. The results are not good. They imply that even if the war were to stop this month (4/2024), the number of Ukrainians will shrink to ≈20 million in 70 years, from a high of more than 50 million in 1992. UN projections give ≈ 30 million in 70 years by making unwarrantedly optimistic assumptions. It is a catastrophe, most of all for the victims of this tragedy.

Chapter V turns to the topic of Covid-19, the disease caused by the SARS-CoV-2 coronavirus. I survey and compare Covid-19 mortalities with the age-stratified US mortality rates by sex due to suicide, homicide, drug overdose, motor vehicle fatalities and cancer in 2019 and the years shortly before the pandemic. A useful distinction is made between *external* mortalities, which involve external insults to the body that cause death, and *somatic* mortalities from illness and disease. I derive infection fatality rates for the first 2 years of the pandemic, 2020-2021, that are in good agreement with studies in 2020 and 2022 (Fig. V.5). Estimated mortalities from analyses of controversial VAERS data indicate that the reward/risk ratio is unfavorable for persons $\lesssim$25 yo (Fig. V.4). If the mRNA vaccines are indeed "safe and effective," it may have made some sense in the early years of the pandemic for the middle-aged and old to take the

vaccine, though Covid-19 mortalities were always $\lesssim$40% and usually $\lesssim$20% of total mortalities in all age groups.

Whether it was due to the emergence of mild variants, vaccine effectiveness, reaching community ("herd") protection through natural immunity, the most vulnerable having died, or something else, the Covid-19 pandemic effectively ended 3.5 years after it began. Looking back now, what have we learned? The lessons I draw are mostly negative (§V.9 conclusions). But from a policy perspective, it is vitally important to regulate gain-of-function research.

Fertility, mortality and migration in the US since about 1950 are the subjects of Chapter VI. Fertility functions for US females between 1950 and 2020 are well described by power-law times exponential (PLEX) functions and 2-sided Gaussian functions. Total M and F mortality rates for the US between 1955 and 2020 are fit to a Band function (two smoothly connected power laws) for external mortalities, and by an exponential mortality rate for somatic mortalities, with doubling timescale ≈ 8 yr.

Analytic and numerical solutions for the evolution of migrant populations are obtained by approximating the migration term $\dot{M}_i(\tau; t)$ in eq. (1), which is the rate of migrant arrivals by age group, by a 2-sided Gaussian. Analytic and semi-analytic solutions to eq. (1) are obtained for the age-stratified foreign-born population in the US in the case that the age-stratified injection rate of migrants is described by 1- or 2-sided Gaussian functions. Solutions are obtained without mortality (App. VI.A) and with a simplified mortality law (App. VI.B).

Numerical evolution of 1-yr age cohort data from the US Census Bureau and the Human Mortality Database are used as initial conditions for the M and F US populations. The code replenishes the numbers by birth and immigration, and depletes the numbers by death and emigration. The data are used to benchmark the numerical simulation model (§VI.8) by evolving 2010 population data to 2020, subtracting from the 2020 population data, and comparing the result with data for the foreign-born population entering between 2010 and 2020.

Three data sets are considered: (a) early USCB 1-yr data for the US in 2010 and 2020, (b) HMD data, and (c) USCB data (Rev. 4, 2024) for the US. Set (a), as warned, was filled with major artefacts, namely age heapings and anomalies at the Boomer/Silent divide. These data sets are presented in the traditional population pyramid style in App. VI.C. The generations of Americans and ages and generations of currently living US presidents (as of 8/2024) are also discussed there.

Set (b) initially looked promising, as mortality rates derived from the 5-yr ppn data, when consistently compared with 5-yr rates from the HMD, were in general agreement, though with some anomalies. The rates derived from the HMD 1-yr data ranged, however, from wildly scattered to suspiciously well-behaved (Fig. VI.19 animation), rendering them of little use for migration studies. I confirmed the HMD red-letter warning that the USCB data "for years 2010-2021 are preliminary as the US Census Bureau has yet to revise its inter-censal (2010-2019) and post-censal (2020-2021) population estimates."

The rates derived from population data can go negative because of migration. The rates become very large for the old because of its exponential behavior. To display negative values and large positive values on the same graph, I stacked the log part on top of the linear part. The shape reminds me of the Loch Ness monster, so I call them Loch Ness plots—see, e.g., Fig. VI.16 and the Fig. VI.17 animation.

Data set (c), the master UN population WPP database from the USCB (Rev. 2024), gave rates that were well-behaved. It became clear that detailed population modeling requires both 1-yr total mortality rates and 1-yr population rates to derive the age-stratified foreign-born population accurately. But whether using the 5-yr total mortality rates from Chpt. V, or making adjustments to smoothly connect the mortality rates for the young with the mortality rates for the old given by the old-age population rates, the subtraction of the evolved 2010 population from the 2020 population gave large disparities for the number of young, $\tau \lesssim 35$ yo foreign born entering the US during 2010-2020. I calculate that there were $\cong 3.8\times10^6$ more foreign born in the US in 2020 who entered the US from 2010-2020 than the 12.28×10^6 foreign born residing in the US in 2020 who entered the US from 2010-2020, according to this USCB report (Table 5)

The 16.1×10^6 foreign born in the US in 2020 who entered the US from 2010-2020 will have $\approx10^6$ babies during this decade, though the number is quite uncertain because of year-to-year variability in the US female fertility function that is not captured by the fits to 5-yr fertility data. But this uncertainty is of little concern for projections into the future, since such projections depend on unknown future US TFRs and fertility functions.

Having developed a framework to compute population evolution, I simulate the evolution of the US population for the next 50 years (Chpt. VII). The starting conditions are the initial M and F population profiles from the USCB 2010 1-yr age cohort data in the WPP, which are evolved to 2020 and 2023 and checked against the USCB 2020 and 2023 data to benchmark the code, and then into the future. The migrant population is assumed to enter at a rate $f_m\%$ × the US population of that year, with an age profile matching the difference profile between the USCB 2020 profile and the USCB 2010 profile evolved to 2020. *Host* refers to the 2010 US population and their children and their children's children, etc. *Migrant* refers to all foreign born entering the US since 2010 and their children and grandchildren, etc. Results for population evolution are examined and animated after finding suitable mortality rates, fertility functions, and migrant arrival age distributions and rates consistent with the USCB 2020 and 2023 data.

Fig. VI.16 shows a simulation with $f_m = 0.3$, close to the historical US average, with a declining TFR for both the host and migrant populations to a value of TFR=1.44 in 2040 and later. Fig.VI.17 animates profile evolution for f_m=0.1, 0.3, and 1.0, with both host and migrant TFR=1.75 after 2020. In both simulations, host and migrant populations display inverted pyramids, but the migrant profile grows relative to the host profile, especially for the young. Fig. VI.17 projects the US profile into the future for a fictitious scenario where the migrants' TFR=2.5 after 2040, while the host's TFR = 1.75.

Several issues are discussed. For example, for how many generations should the descendants of migrants be classified with the migrants and not the host?; 2. what is the optimal value of f_m for the US?

I argue that $f_m \lesssim 0.3$, about equal to the historical average since 1950 (Fig. VI.1b) , is defensible in terms of social stability and economic costs. 3. Can declining fertility be reversed, and if not, what are the best long-term immigration policy goals for the US? I recommend improving soft power in Africa, and engaging more with our own hemisphere, but not through CIA coups.

The best number for f_m is ultimately a value question. What is not a value is the Great Replacement, as described by French philosopher Renaud Camus,[1] that is, mass importation of foreign born into numerous Western nations (e.g., Germany, France, Italy, UK, US, Ireland, Spain; Camus's focus is France). Leaving aside whether it is a fact, however one should define a fact, the Great Replacement is a description of population changes in the West that have been taking place over the last few decades.

What is the best path forward for the US? Perhaps Japan and South Korea show the way to a future of managed decline, but the situation is quite different and, I think, more hopeful in the US. I argue that a migrant arrival fraction $f_m \cong 0.3$, consisting mainly of skilled and educated (though not brought in to simply abuse the H1B program), would nourish the US population with new ideas and new talent. The US should disengage from its proxy war with Russia, and focus on Africa and the Western Hemisphere.

This is not the place for policy prescriptions, though they are unavoidable in a study such as this. The focus here is instead the physics, specifically, the physics (and metaphysics) from cell death to human death to population mortality. I summarize this 17-month physics journey in Chpt. VIII, concluding with thoughts on life, death and immortality.

About me and my writing style:

I am a retired (since 2015 at the age of 60) PhD research physicist. I've authored hundreds of conference papers and journal articles, nearly 100 of which I was the first author. My main research specialty was high-energy radiation from black holes. I wrote a book[2] on this subject with Professor Govind Menon of Troy University in Troy, AL that summarizes much of my research on the topic.

Seventeen months ago, in May 2023, I became consumed with a problem in statistical physics, stumbled into the question of mortality (which is, in any case, of increasing concern) and then found, quite by accident, the Hungarian rate spikes while looking at the Hungarian population data (besides Hungary having low migration, the first chapter of the book is dedicated to an esteemed professor from Hungary).

The early chapters in this document were originally written to be submitted independently to peer-reviewed journals, so the chapters are self-contained. This comes at the cost of some repetition. The thematic similarity of the papers, and their unsuitability to most scientific journals because of historical and literary references, suggested to me that this research might better be published as a book, and then primarily as an electronic book or research document because of the weblinks and animations.

Each chapter, save the Introductory (0) and Summary (VIII) chapters, retain the original format of a science paper, not only because of my training, but because this format is a time saver for the reader.

Science papers are designed to be speed read: abstract, intro, figures and captions, scan the equations, discussion and certainly conclusions.[h] If more detail is needed, *then* the body of the paper is read.

Some technical notes: The differential age-stratified population $dN_i(\tau;t)/d\tau$ is denoted by $N_i(\tau;t)$ (with a semicolon)—and sometimes simply by $N_i(\tau)$, with units of N/τ, in this case, [#/yr]. Here t acts as a parameter and τ is the independent variable. By comparison, a quantity such as the mortality rate $\nu(\tau,t)$ (units of [yr^{-1}], with a comma separator) depends on 2 parameters, age τ and time t.

The Dirac delta function $\delta(x)$ has its usual meaning: $\delta(x)=0$ for all $x\neq 0$ and $\delta(x=0)\to\infty$ such that $\int_{x_1}^{x_2} dx\,\delta(x)=1$ for all $x_1<0<x_2$. The delta function is the derivative of the Heaviside step function H(x) defined by H(x) = 0 for x < 0 and H(x) = 1 for x ≥ 1.[i] The δ-function allows one to make an estimate of the value of an integral by replacing one of the terms in the integrand by its average y-value at the value of x where y is largest. The δ-function in eq. (1) says that all humans are born at age 0.

Incidentally, I use the Gregorian calendar sans date suffixes, so that the current year is 2024. To be precise, the date, an integer, is 2024 and the time, a double, is 2024.5455 UT (afternoon of July 17, 2024, or so, when I write this). Where unclear, units of [yr] are used for time and age and [yr^{-1}] for rates. Thus, if the mortality rate is $\nu = 0.001\ yr^{-1}$, the chance of a person dying that year is ≅ 0.1%. *If* that rate were to remain constant with age, such a person would live on average another ≅ 700 years (the population is reduced by a factor of 2 in $\ln 2/\nu_0$ ≅ 700 yr (Endnote 2). The average life expectancy would be less; see Chpt. III and Endnote 1). The reality is that the average human mortality rate rises exponentially with age for $\tau \gtrsim 60$ yo (years old, or years of age) with a doubling time of ≈ 7-8 yrs. The survival rate goes inversely as the exponential of the mortality rate times age. This double exponential of death extinguishes any hope of longevity or immortality, or even living beyond the age of ≅110.

A cited equation lacking a chapter suffix in the equation number, e.g., eq. (2) in Chapter IV, is local to the chapter in which it resides. If an equation is referenced outside that chapter, then it is written as a global, in this case, eq. (IV.2). Similarly for figures, appendices and variables, though τ (age), t (time) are globals, and ν [yr^{-1}] always refers to a rate.

Regarding the research and references, I left government and the academy 9 years ago and therefore lack access to a technical library. All links are to open-source data (many technical articles are public). Indeed, the UN population division and the US public health services provide mountains of data. Much of what I cover has surely been treated by professional demographers, but a self-contained first-principles approach merging physics and demography applied to topics of current interest might provide some new insights.

[1] Camus, R. 2023. *Enemy of the Disaster*, tr. L. Betty and E. Rundell (Vauban Books: Blowing Rock, NC)
[2] Dermer, C. D., and Menon, G. 2009. *High Energy Radiation from Black Holes* (Princeton Univ. Press: Princeton)

[h] The deflection and confusion sections, as my colleague L. T. would say.
[i] In my mind's ear, I hear my math colleagues groaning. And they would be right. Here, math is a tool, not an obsession.