

Mortality

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Outline

- Introduction
- Measurement of mortality
 - Standardization
 - Life table
- Short history of mortality in the world
- Mortality trends and causes of death
- Mortality and longevity in the United States
- Infant mortality
- Future course of mortality
- Coronavirus pandemic



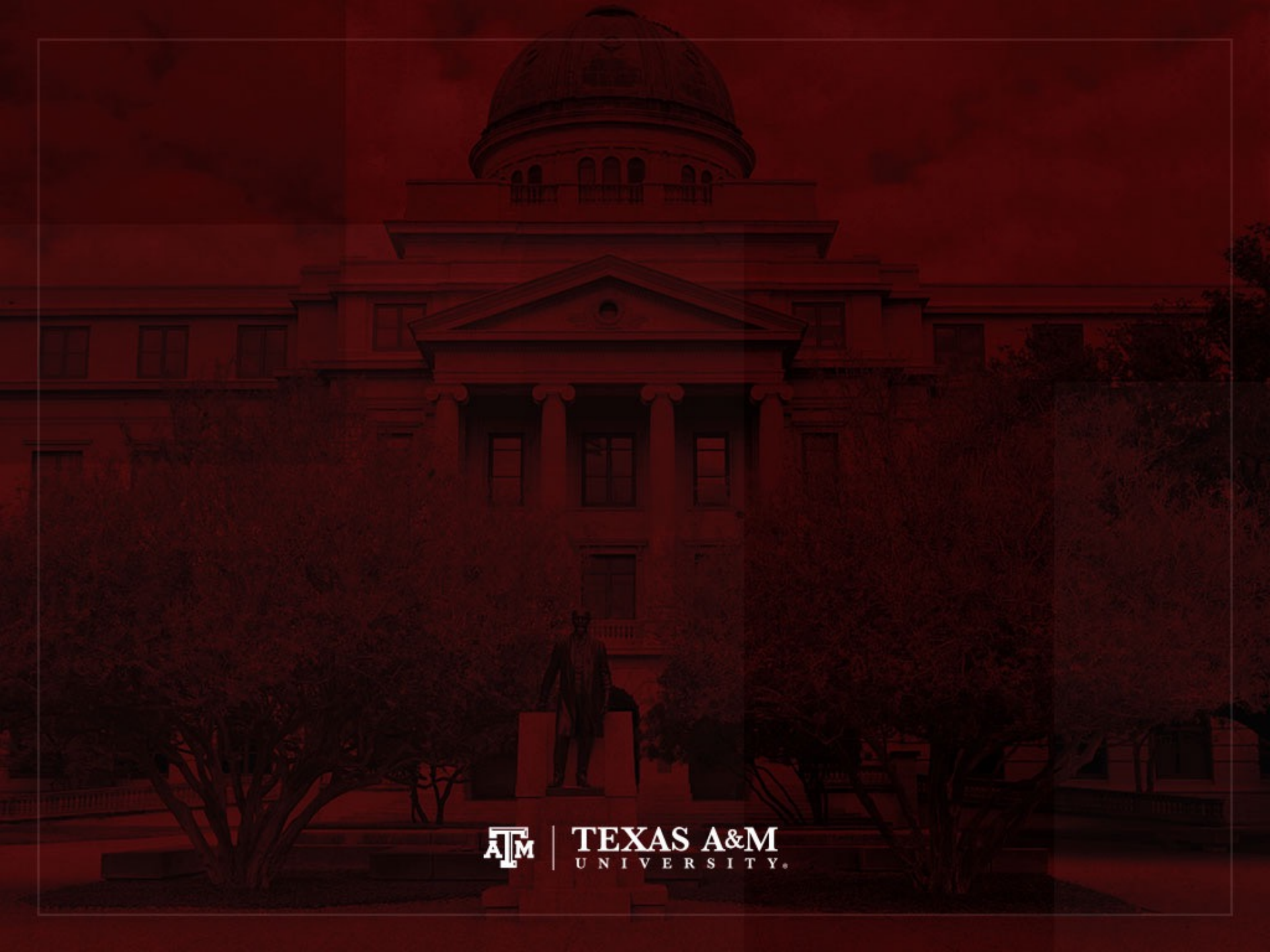
Introduction

- The impact of mortality varies significantly according to social and demographic characteristics
 - Age
 - Sex
 - Race/ethnicity
 - Social class
 - Marital status
 - Area of residence
- Levels of development, medical conditions, and a host of other factors influence life expectancy

Changes in causes of death

- There have been major changes over the historical record in the main causes of death
- People used to die mainly of infectious and parasitic diseases
- Today the major causes of death in developed countries are heart disease, cancer, and stroke
- Major causes of death are different in countries with high and low levels of life expectancy





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Measurement of mortality

- Quantification of mortality is central to demography
- Measurement of mortality dates back to John Graunt (1620–1674) and his analyses of the “Bills of Mortality”
- Mortality refers to the relative frequency of death in a population

Two concepts of mortality

- Life span
 - Numerical age limit of human life
 - Maximum recorded age at death
 - 122 years and 164 days, lived by the Frenchwoman Jeanne Louise Calment
- Life expectancy
 - Average expected number of years of life to be lived by a particular population at a given time

Crude death rate

- Crude death rate (*CDR*)

$$CDR = d / p * 1,000$$

- *d*: deaths in the year
- *p*: population at midyear

- Data for the United States for 2013

$$CDR = 2,596,993 / 316,497,531 * 1,000$$

$$CDR = 8.2$$

- World range of *CDR* in 2014

- United Arab Emirates (UAE) and Qatar = 1
- Lesotho = 21



CDR and age composition

- When *CDRs* are compared among countries, differences are sometimes due to differences in age composition
 - Previous examples mean that there are 8 times more deaths per 1,000 people in the US than in the UAE
 - Why is the *CDR* of the US eight times higher than of the UAE?
 - The main reason is that the UAE is much younger in average age than is the U.S.
 - Younger people have lower death rates



Young and old people

- Countries with
 - Large proportions of young people
 - Small proportions of old people
 - Usually have lower *CDRs*

- Countries with
 - Small proportions of young people
 - Large proportions of old people
 - Usually have higher *CDRs*



Changing age structure

- If age structure has changed over time
 - CDRs should not be used to compare the death experiences of the same population at different points in time
- US *CDR* did not change much in 54 years
 - $CDR_{1960} = 9.5$ per 1,000
 - $CDR_{2014} = 8.2$ per 1,000
- *CDR* is not capable of capturing the reduction in mortality when the population becomes older
 - The US became older between 1960 and 2014
 - Median age: 29 in 1960 and 37 in 2014



Crude rate

- *CDR* is a crude rate, because its denominator comprises the entire population
- However, population members are not equally at risk of experiencing death
- Risk of death varies by age, sex, race/ethnicity, socioeconomic status, and others
- Death rates vary considerably by age...



Age-specific death rates

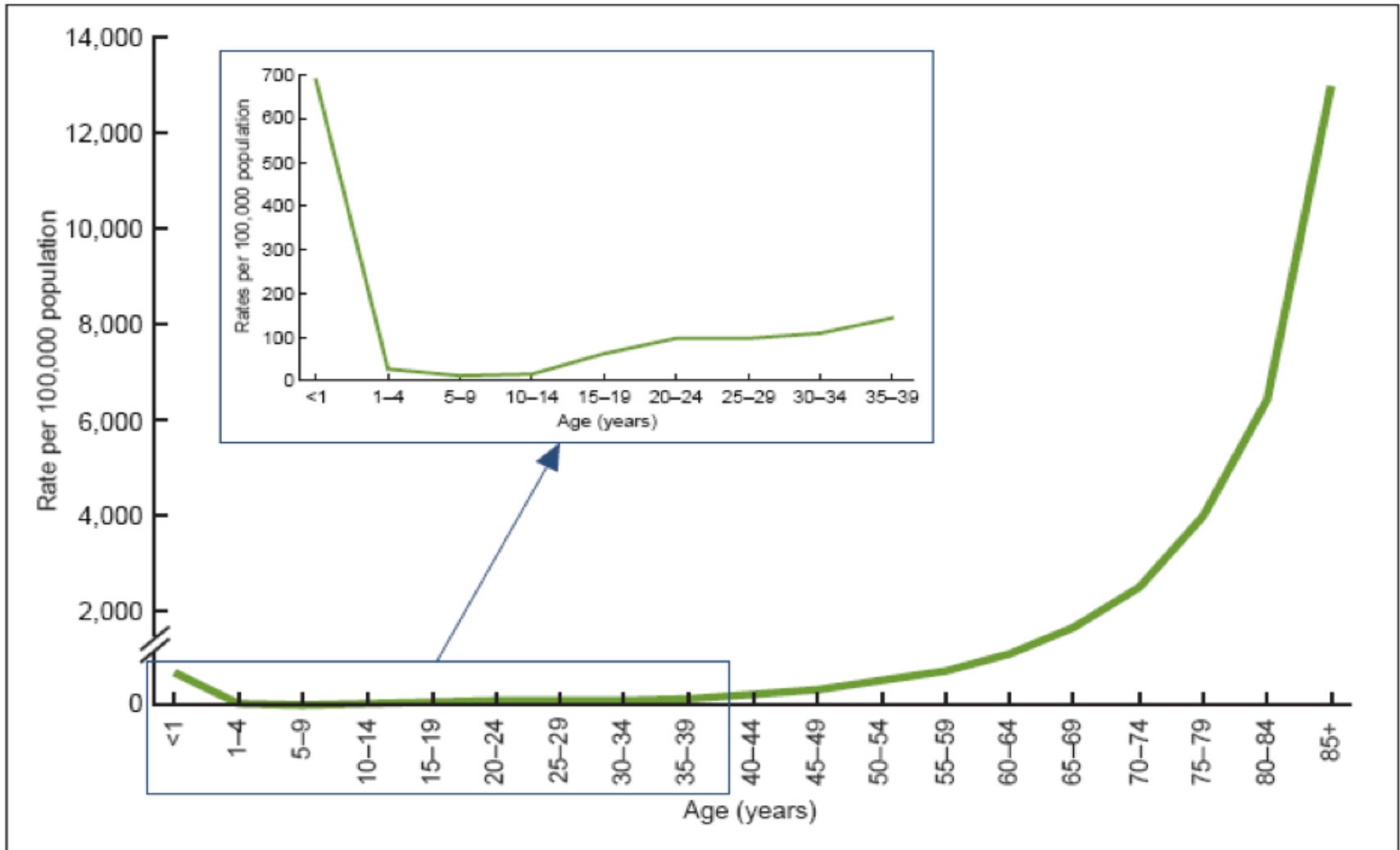
- Demographers use age-specific death rates as a more precise way to measure mortality
- Age-specific death rate (${}_nASDR_x$ or ${}_nM_x$)

$${}_nM_x = {}_nd_x / {}_np_x * 1,000$$

- ${}_nd_x$: deaths to persons aged x to $x+n$
- ${}_np_x$: persons in the population who are aged x to $x+n$
- n : width of the age group
- x : initial year of the age group
- For instance, *ASDR* for age group 15–19 is ${}_5M_{15}$

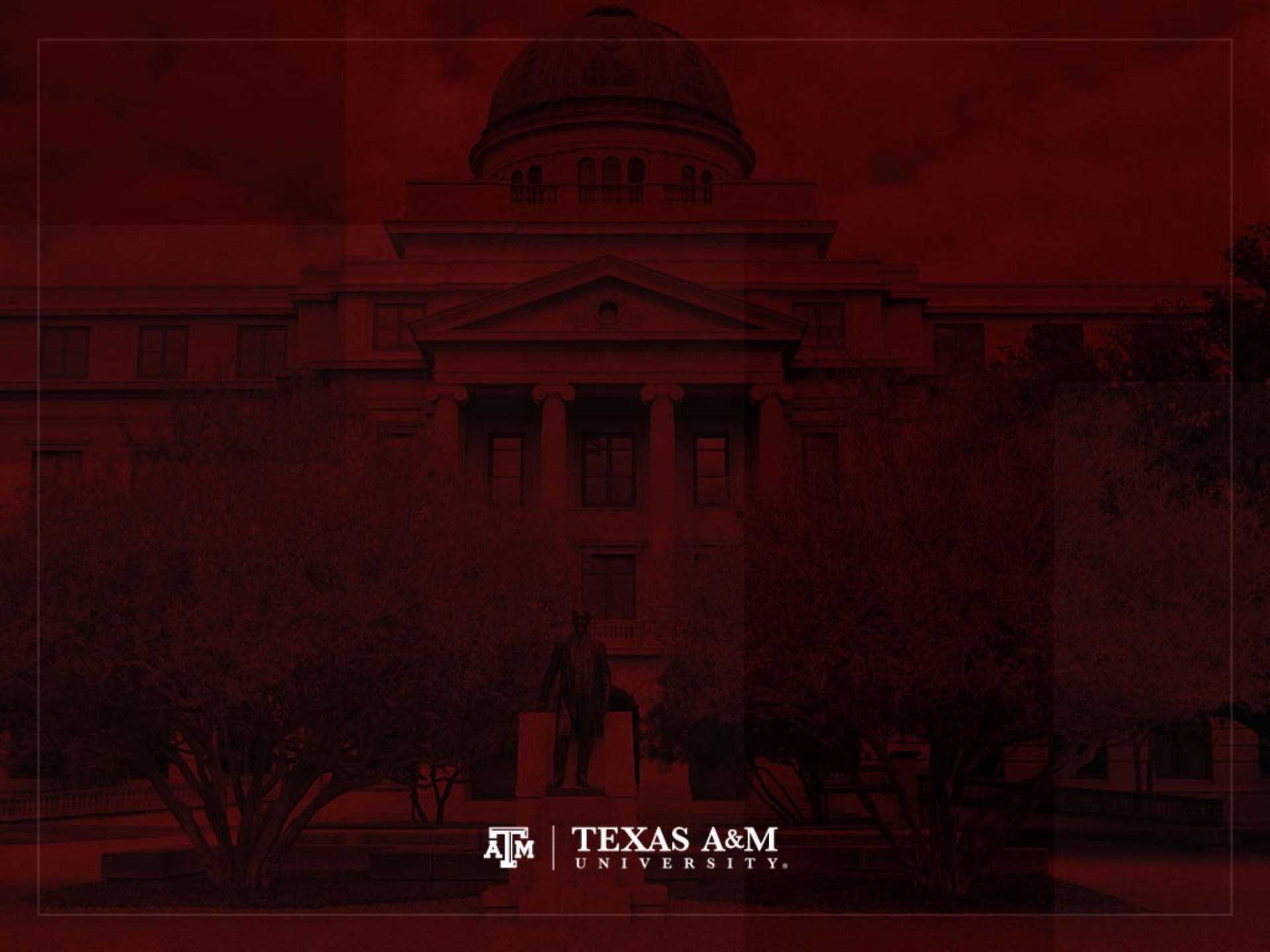


Age curve of mortality, US, 2007



Source: Minino, et al., 2009: 2.

Source: Poston, Bouvier 2017, p.169.



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Standardization

- ${}_nASDR_x$, and not *CDR*, should be used to compare the mortality experiences of countries with different age compositions
 - We use **standardization** to take into account age composition when we compare death rates among different countries
 - We can compare crude death rates for different countries or years
 - We need to adjust for differences in age structure
 - We estimate age-adjusted death rates and apply to a standard population



Mortality and fertility

- We cannot simply add up ${}_nASDR_x$ and multiply by the width of the age interval
 - People die just once
- This makes sense for age-specific fertility rates (${}_nASFR_x$) and total fertility rates (TFR)

$$TFR = \sum({}_nASFR_x * n)$$

- n : width of the age group
- Women can have more than one child



Age standardization

- Young populations tend to have low *CDRs*
- Old populations tend to have high *CDRs*
- We estimate a variation of *CDR* that allows us to account for age composition when comparing death rates among different countries

$$CDR = \sum {}_nASDR_x * ({}_nP_x / P) * 1,000$$

- P : total population
- ${}_nP_x$: population in age group x
- ${}_nASDR_x$: *ASDR* for people aged x to $x+n$



United States, 2006

| Age group | Population | Prop. population | Deaths | Age-specific death rate (ASDR) |
|--------------|--------------------|------------------|------------------|--------------------------------|
| 0-1 | 4,147,760 | 0.0139 | 27,126 | 0.00654 |
| 1-4 | 16,352,320 | 0.0548 | 4,742 | 0.00029 |
| 5-9 | 20,142,000 | 0.0675 | 2,820 | 0.00014 |
| 10-14 | 21,454,960 | 0.0719 | 3,862 | 0.00018 |
| 15-19 | 21,604,160 | 0.0724 | 13,827 | 0.00064 |
| 20-24 | 20,947,680 | 0.0702 | 19,062 | 0.00091 |
| 25-29 | 20,022,640 | 0.0671 | 18,020 | 0.00090 |
| 30-34 | 20,261,360 | 0.0679 | 21,477 | 0.00106 |
| 35-39 | 21,067,040 | 0.0706 | 32,233 | 0.00153 |
| 40-44 | 22,857,440 | 0.0766 | 52,801 | 0.00231 |
| 45-49 | 22,588,880 | 0.0757 | 77,028 | 0.00341 |
| 50-54 | 20,142,000 | 0.0675 | 99,300 | 0.00493 |
| 55-59 | 17,158,000 | 0.0575 | 127,312 | 0.00742 |
| 60-64 | 13,040,080 | 0.0437 | 149,961 | 0.01150 |
| 65-69 | 10,115,760 | 0.0339 | 180,061 | 0.01780 |
| 70-74 | 8,474,560 | 0.0284 | 234,830 | 0.02771 |
| 75-79 | 7,400,320 | 0.0248 | 321,914 | 0.04350 |
| 80-84 | 5,580,080 | 0.0187 | 388,262 | 0.06958 |
| 85-89 | 3,192,880 | 0.0107 | 353,005 | 0.11056 |
| 90-94 | 1,342,800 | 0.0045 | 234,681 | 0.17477 |
| 95-99 | 387,920 | 0.0013 | 107,283 | 0.27656 |
| 100+ | 89,520 | 0.0003 | 39,292 | 0.43892 |
| Total | 298,400,000 | 0.9999 | 2,508,899 | 1.20116 |

CDR per 1,000

8.41



Venezuela, 2006

| Age group | Population | Prop. population | Deaths | Age-specific death rate (ASDR) |
|--------------|-------------------|------------------|----------------|--------------------------------|
| 0-1 | 487,056 | 0.0219 | 7,905 | 0.01623 |
| 1-4 | 1,779,200 | 0.0800 | 1,139 | 0.00064 |
| 5-9 | 2,308,512 | 0.1038 | 739 | 0.00032 |
| 10-14 | 2,275,152 | 0.1023 | 933 | 0.00041 |
| 15-19 | 2,250,688 | 0.1012 | 3,286 | 0.00146 |
| 20-24 | 2,057,200 | 0.0925 | 4,896 | 0.00238 |
| 25-29 | 1,872,608 | 0.0842 | 4,138 | 0.00221 |
| 30-34 | 1,614,624 | 0.0726 | 3,278 | 0.00203 |
| 35-39 | 1,530,112 | 0.0688 | 3,290 | 0.00215 |
| 40-44 | 1,401,120 | 0.0630 | 4,049 | 0.00289 |
| 45-49 | 1,145,360 | 0.0515 | 4,707 | 0.00411 |
| 50-54 | 971,888 | 0.0437 | 5,520 | 0.00568 |
| 55-59 | 769,504 | 0.0346 | 5,964 | 0.00775 |
| 60-64 | 558,224 | 0.0251 | 6,548 | 0.01173 |
| 65-69 | 400,320 | 0.0180 | 7,514 | 0.01877 |
| 70-74 | 302,464 | 0.0136 | 8,584 | 0.02838 |
| 75-79 | 215,728 | 0.0097 | 9,212 | 0.04270 |
| 80-84 | 117,872 | 0.0053 | 8,877 | 0.07531 |
| 85-89 | 53,376 | 0.0024 | 6,816 | 0.12769 |
| 90-94 | 15,568 | 0.0007 | 3,241 | 0.20820 |
| 95-99 | 2,224 | 0.0001 | 724 | 0.32576 |
| 100+ | 2,224 | 0.0001 | 1,089 | 0.48975 |
| Total | 22,240,000 | 0.9951 | 102,449 | 1.37655 |

CDR per 1,000

4.61



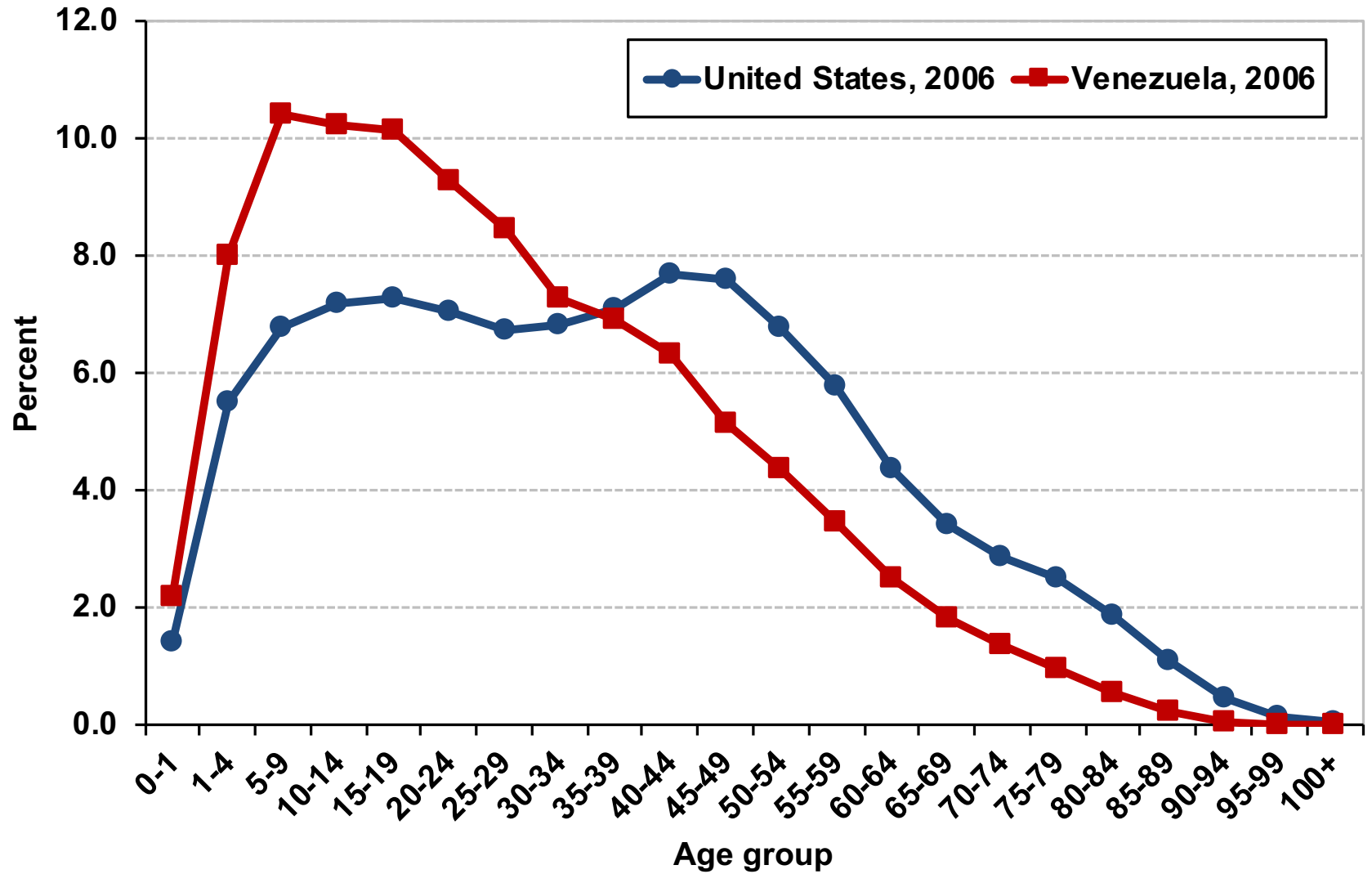
Population distribution by country

| Age group | United States (%) | Venezuela (%) | Ratio United States / Venezuela |
|--------------|-------------------|---------------|------------------------------------|
| 0-1 | 1.39 | 2.19 | 0.63 |
| 1-4 | 5.48 | 8.00 | 0.69 |
| 5-9 | 6.75 | 10.38 | 0.65 |
| 10-14 | 7.19 | 10.23 | 0.70 |
| 15-19 | 7.24 | 10.12 | 0.72 |
| 20-24 | 7.02 | 9.25 | 0.76 |
| 25-29 | 6.71 | 8.42 | 0.80 |
| 30-34 | 6.79 | 7.26 | 0.94 |
| 35-39 | 7.06 | 6.88 | 1.03 |
| 40-44 | 7.66 | 6.30 | 1.22 |
| 45-49 | 7.57 | 5.15 | 1.47 |
| 50-54 | 6.75 | 4.37 | 1.54 |
| 55-59 | 5.75 | 3.46 | 1.66 |
| 60-64 | 4.37 | 2.51 | 1.74 |
| 65-69 | 3.39 | 1.80 | 1.88 |
| 70-74 | 2.84 | 1.36 | 2.09 |
| 75-79 | 2.48 | 0.97 | 2.56 |
| 80-84 | 1.87 | 0.53 | 3.53 |
| 85-89 | 1.07 | 0.24 | 4.46 |
| 90-94 | 0.45 | 0.07 | 6.43 |
| 95-99 | 0.13 | 0.01 | 13.00 |
| 100+ | 0.03 | 0.01 | 3.00 |
| Total | 99.99 | 99.51 | 1.00 |

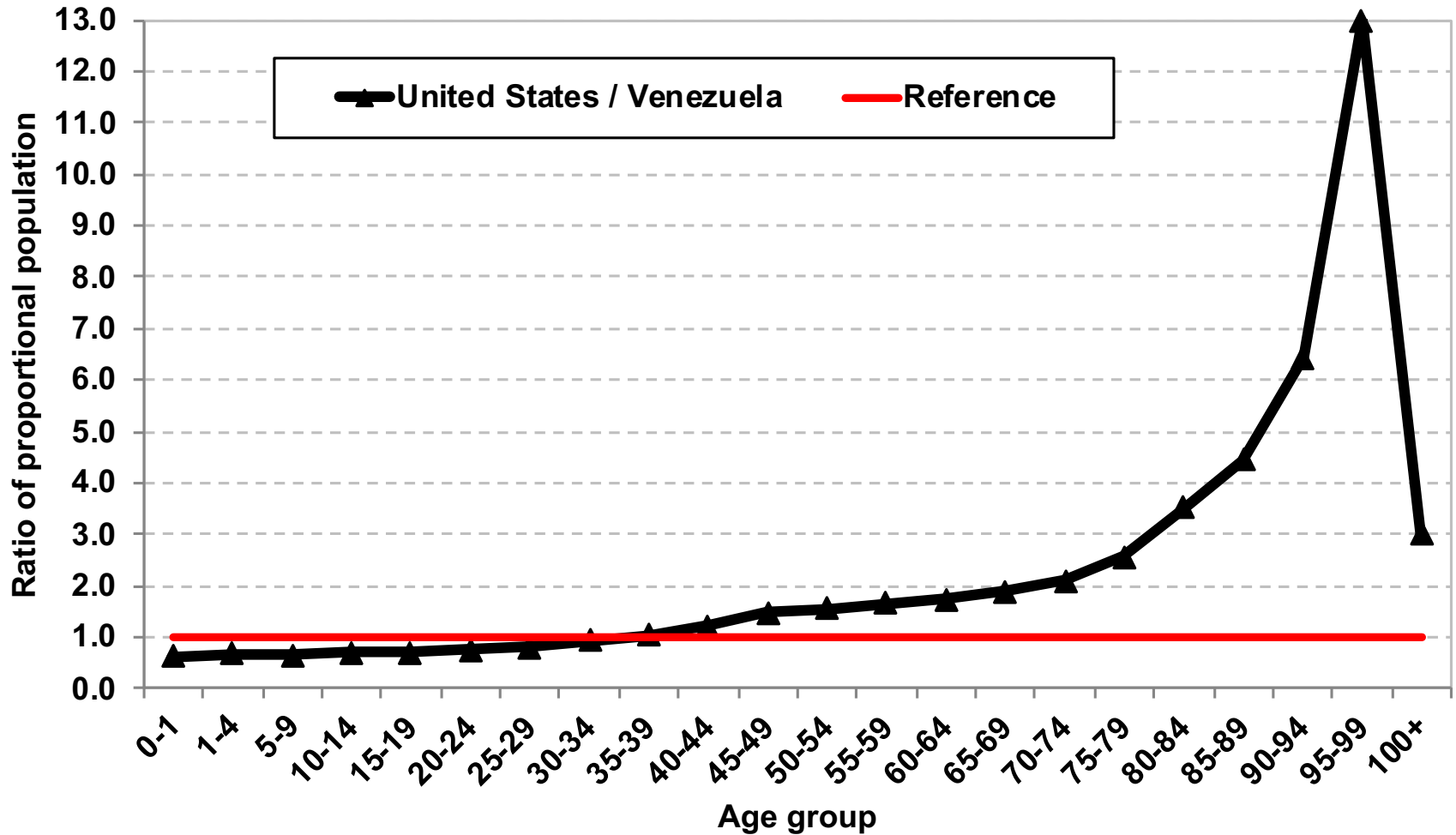
- The U.S. has an older population than Venezuela
- This is causing $CDR_{US} > CDR_{VE}$



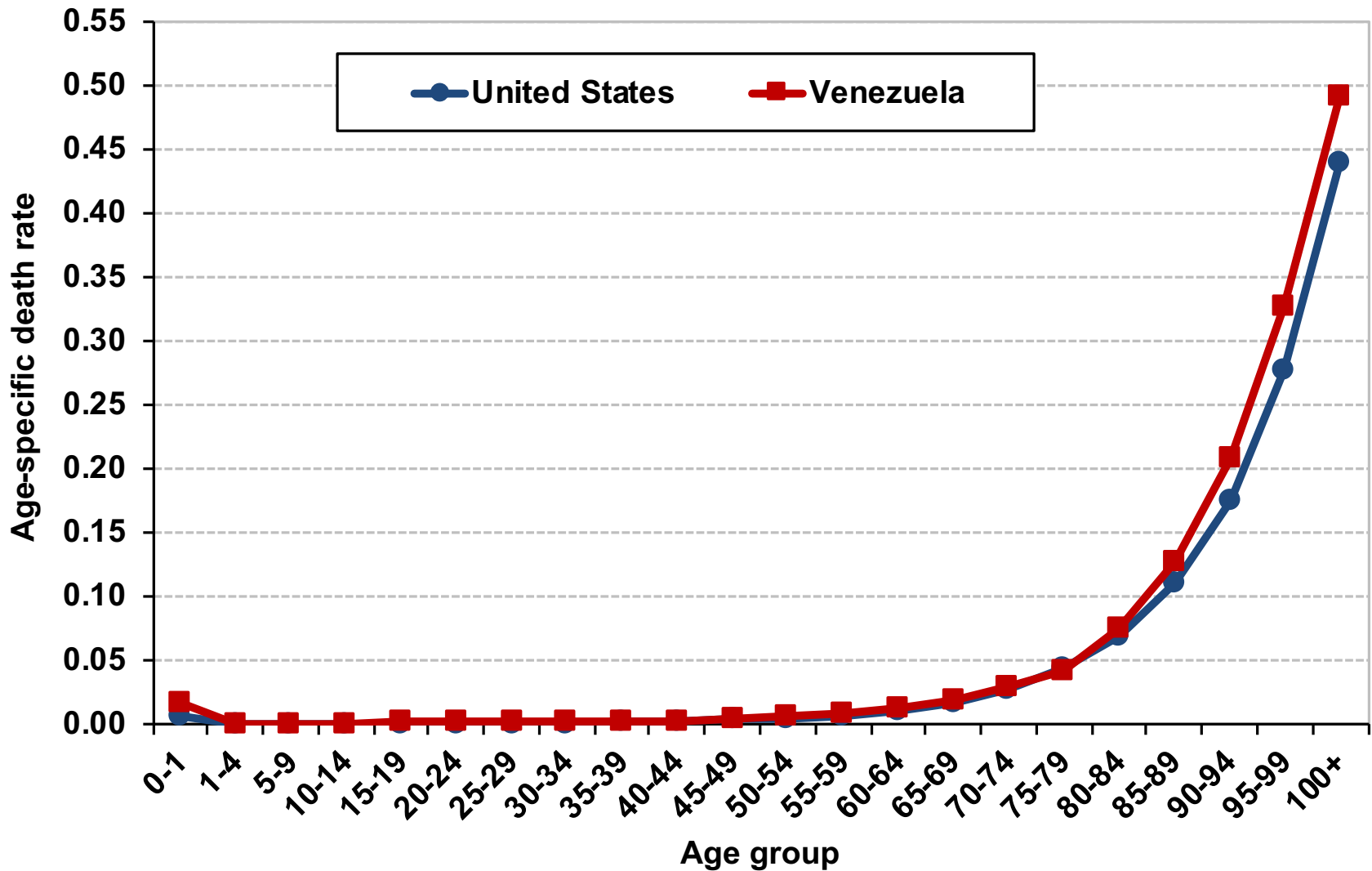
Age structure



The U.S. has an older population than Venezuela



Age-specific death rates, 2006



Standardize Venezuela's *CDR*

| Standardization Age group | Venezuela (observed rates) | United States (standard prop. population) | Venezuela's rates times U.S. prop. population |
|------------------------------|-------------------------------|--|--|
| 0-1 | 0.01623 | 0.0139 | 0.0002 |
| 1-4 | 0.00064 | 0.0548 | 0.0000 |
| 5-9 | 0.00032 | 0.0675 | 0.0000 |
| 10-14 | 0.00041 | 0.0719 | 0.0000 |
| 15-19 | 0.00146 | 0.0724 | 0.0001 |
| 20-24 | 0.00238 | 0.0702 | 0.0002 |
| 25-29 | 0.00221 | 0.0671 | 0.0001 |
| 30-34 | 0.00203 | 0.0679 | 0.0001 |
| 35-39 | 0.00215 | 0.0706 | 0.0002 |
| 40-44 | 0.00289 | 0.0766 | 0.0002 |
| 45-49 | 0.00411 | 0.0757 | 0.0003 |
| 50-54 | 0.00568 | 0.0675 | 0.0004 |
| 55-59 | 0.00775 | 0.0575 | 0.0004 |
| 60-64 | 0.01173 | 0.0437 | 0.0005 |
| 65-69 | 0.01877 | 0.0339 | 0.0006 |
| 70-74 | 0.02838 | 0.0284 | 0.0008 |
| 75-79 | 0.04270 | 0.0248 | 0.0011 |
| 80-84 | 0.07531 | 0.0187 | 0.0014 |
| 85-89 | 0.12769 | 0.0107 | 0.0014 |
| 90-94 | 0.20820 | 0.0045 | 0.0009 |
| 95-99 | 0.32576 | 0.0013 | 0.0004 |
| 100+ | 0.48975 | 0.0003 | 0.0001 |
| Total | | 0.9999 | 0.0097 |

CDR per 1,000

9.68



Another way... same results...

| Standardization Age group | United States (standard population) | Venezuela (observed rates) | Venezuela (standardized deaths) |
|--------------------------------------|--|---------------------------------------|--|
| 0-1 | 4,148,175 | 0.0162 | 67,325 |
| 1-4 | 16,353,955 | 0.0006 | 10,467 |
| 5-9 | 20,144,014 | 0.0003 | 6,446 |
| 10-14 | 21,457,106 | 0.0004 | 8,797 |
| 15-19 | 21,606,321 | 0.0015 | 31,545 |
| 20-24 | 20,949,775 | 0.0024 | 49,860 |
| 25-29 | 20,024,642 | 0.0022 | 44,254 |
| 30-34 | 20,263,386 | 0.0020 | 41,135 |
| 35-39 | 21,069,147 | 0.0022 | 45,299 |
| 40-44 | 22,859,726 | 0.0029 | 66,065 |
| 45-49 | 22,591,139 | 0.0041 | 92,850 |
| 50-54 | 20,144,014 | 0.0057 | 114,418 |
| 55-59 | 17,159,716 | 0.0078 | 132,988 |
| 60-64 | 13,041,384 | 0.0117 | 152,975 |
| 65-69 | 10,116,772 | 0.0188 | 189,892 |
| 70-74 | 8,475,408 | 0.0284 | 240,532 |
| 75-79 | 7,401,060 | 0.0427 | 316,025 |
| 80-84 | 5,580,638 | 0.0753 | 420,278 |
| 85-89 | 3,193,199 | 0.1277 | 407,740 |
| 90-94 | 1,342,934 | 0.2082 | 279,599 |
| 95-99 | 387,959 | 0.3258 | 126,381 |
| 100+ | 89,529 | 0.4898 | 43,847 |
| Total | 298,400,000 | | 2,888,718 |

CDR per 1,000

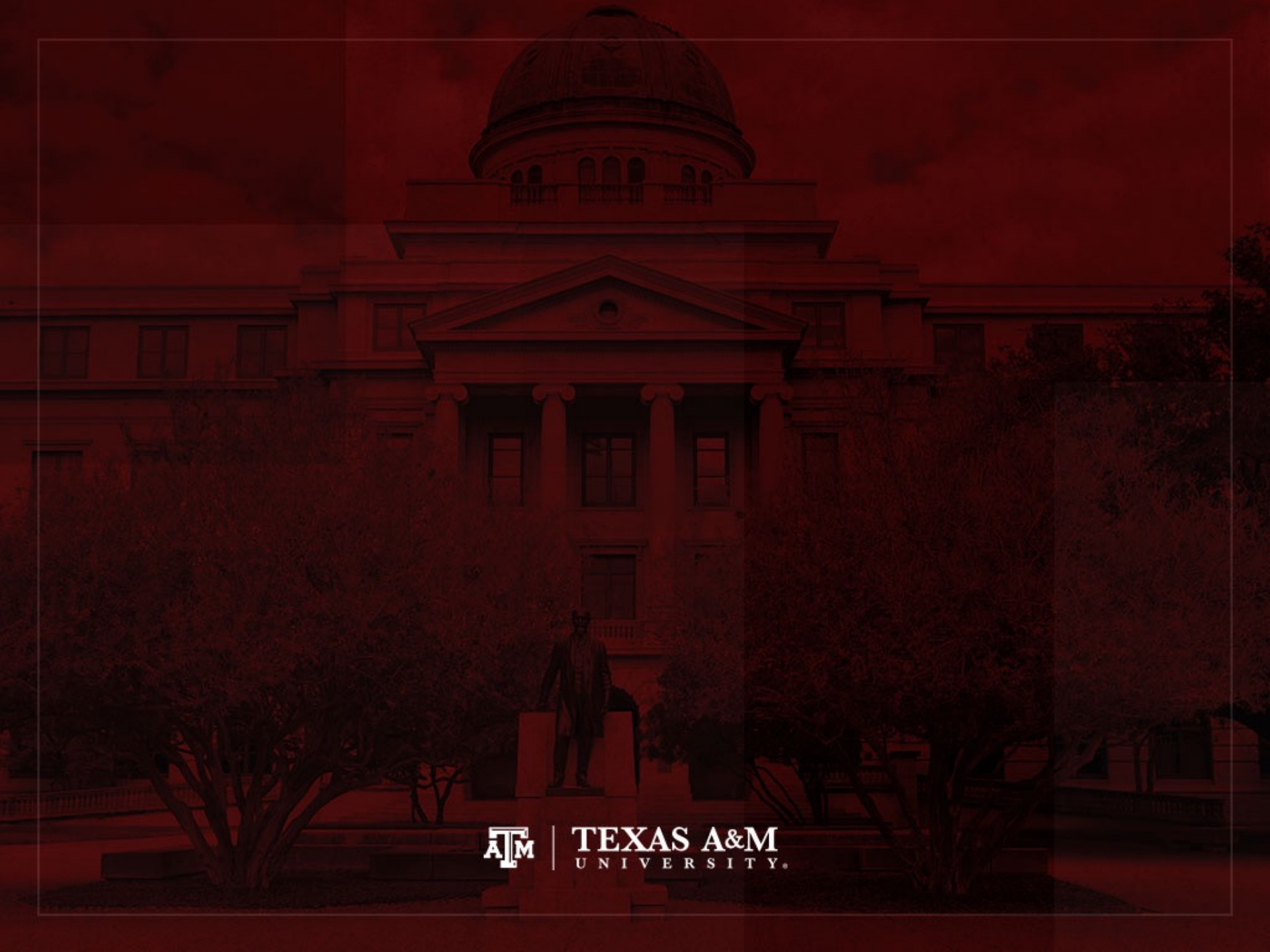
9.68



Comparing crude death rates

- $CDR_{\text{United States original}}$
= 8.41 deaths per 1,000
- $CDR_{\text{Venezuela original}}$
= 4.61 deaths per 1,000
- $CDR_{\text{Venezuela standardized}}$
= 9.68 deaths per 1,000





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Life table

- One of the most important and elegant measures of the mortality experiences of a population is the life table
- It dates back to John Graunt (1620–1674) and his “Bills of Mortality”
- Demographers use the life table to determine life expectancy, not only at birth but at any age



Important information from life table

- Like the total fertility rate (*TFR*), the life table is a synthetic or hypothetical measure
- It tells us how many years of life, on average, may a person expect to live if the person during his or her lifetime is subjected to the age-specific probabilities of dying of a particular country or population at a given time

Example: United States, 2010

- Let's say that the population of the U.S. in 2010 had a life expectancy of birth of 78.7 years
- This means that if a cohort of persons, throughout the years of their life, were subjected to the *ASDRs* (${}_nM_x$) of the total population in the U.S. in 2010
 - They would live, on average, 78.7 years



Examples of Life expectancy

- Life expectancy at birth is a primary indicator of quality of life

| 2013 | Life expectancy | |
|---|-----------------|--------|
| | Male | Female |
| World | 69 | 73 |
| More developed countries | 75 | 82 |
| Less developed countries (except China) | 65 | 69 |
| Japan | 80 | 86 |
| Lesotho | 42 | 45 |
| Sierra Leone | 45 | 46 |



Limitations of e_0

- We need to be aware of the fact that when considering life expectancy at birth (e_0), infant mortality plays a very important role
- When e_0 is low, a major reason is their very high infant mortality rate
- When comparing values of life expectancy at birth across countries, we should not think of e_0 as a modal age at death

Abridged life table

- An abridged life table is calculated for age groups
- Usually for five-year age groups
- Rather than for single-year age groups

Radix and mortality probabilities

- A life table starts with a population (a radix) of 100,000 persons born alive at age 0
 - This number is arbitrary, but conventional
 - It can also be 1,000 or 1
- From each age to the next, the population is decremented according to age-specific mortality probabilities until all members have died
 - The mortality schedule is fixed and does not change over the life of the population



Life table for U.S. population, 2010

| Life Table for the Total Population, United States, 2010 | | | | | | |
|--|-----------|---------|-----------|-----------|-----------|-------|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Age range | ${}_nq_x$ | l_x | ${}_nd_x$ | ${}_nL_x$ | T_x | e_x |
| <1 | 0.006123 | 100,000 | 612 | 99,465 | 7,866,027 | 78.7 |
| 1-4 | 0.001071 | 99,388 | 106 | 397,294 | 7,766,561 | 78.1 |
| 5-9 | 0.000573 | 99,281 | 57 | 496,250 | 7,369,267 | 74.2 |
| 10-14 | 0.000708 | 99,224 | 70 | 495,989 | 6,873,017 | 69.3 |
| 15-19 | 0.002463 | 99,154 | 244 | 495,240 | 6,377,028 | 64.3 |
| 20-24 | 0.004317 | 98,910 | 427 | 493,529 | 5,881,789 | 59.5 |
| 25-29 | 0.004791 | 98,483 | 472 | 491,249 | 5,388,260 | 54.7 |
| 30-34 | 0.005497 | 98,011 | 539 | 488,744 | 4,897,011 | 50.0 |
| 35-39 | 0.006913 | 97,472 | 674 | 485,753 | 4,408,267 | 45.2 |
| 40-44 | 0.009979 | 96,798 | 966 | 481,758 | 3,922,514 | 40.5 |
| 45-49 | 0.016044 | 95,833 | 1,538 | 475,584 | 3,440,756 | 35.9 |
| 50-54 | 0.024343 | 94,295 | 2,295 | 466,066 | 2,965,173 | 31.4 |
| 55-59 | 0.035106 | 92,000 | 3,230 | 452,347 | 2,499,106 | 27.2 |
| 60-64 | 0.049847 | 88,770 | 4,425 | 433,348 | 2,046,759 | 23.1 |
| 65-69 | 0.074406 | 84,345 | 6,276 | 406,912 | 1,613,411 | 19.1 |
| 70-74 | 0.112315 | 78,069 | 8,768 | 369,612 | 1,206,499 | 15.5 |
| 75-79 | 0.174782 | 69,301 | 12,113 | 317,694 | 836,886 | 12.1 |
| 80-84 | 0.274384 | 57,188 | 15,692 | 248,038 | 519,193 | 9.1 |
| 85-89 | 0.430820 | 41,497 | 17,878 | 162,723 | 271,155 | 6.5 |
| 90-94 | 0.615282 | 23,619 | 14,532 | 79,720 | 108,432 | 4.6 |
| 95-99 | 0.783397 | 9,087 | 7,119 | 24,670 | 29,212 | 3.2 |
| 100+ | 1.00000 | 1,968 | 1,968 | 4,542 | 4,542 | 2.3 |

Source: Arias (2014: 62).



Basic life table columns

1. Age intervals of each group
2. ${}_nq_x$: probability of dying between age x and age $x+n$
3. l_x : number of survivors at each age x
4. ${}_nd_x$: number of deaths between age x and age $x+n$
5. ${}_nL_x$: number of years lived by all persons who enter the age interval while in the age interval
6. T_x : number of years lived by the population in the age interval and in all subsequent intervals
7. e_x : remaining life expectancy at each age



1. Age intervals of each group

- Age groups refer to the range of years between two birthdays
- The age group 5–9 refers to the five-year interval between the fifth and the tenth birthdays



2. Probabilities of dying (${}_nq_x$)

- The most basic column of the life time shows probabilities of dying for each age group (${}_nq_x$)
 - These are probabilities that persons alive at the beginning of an age interval will die during the interval, before they reach the start of the next age interval

$${}_nq_x = {}_nd_x / l_x$$

- For last age group, ${}_nq_x=1.0$ because everybody dies



Rates and probabilities

- Difference between mortality rates (${}_nM_x$) and mortality probabilities (${}_nq_x$) is the denominator
- ${}_nM_x$: denominator is midyear population
- ${}_nq_x$: denominator is population alive at the beginning of the age interval

3. Number of survivors (l_x)

- Number of people alive at the beginning of the age interval (l_x)
 - Known as “the little I column”
- It is calculated by subtracting the number of people dying (${}_n d_x$) from the l_x value in the age interval immediately preceding the one being calculated
- Example of U.S. life table in 2010
 - Of the 99,224 people alive at the beginning of the age interval 10–14 (l_{10})
 - 70 of them die during the age interval (${}_5 d_{10}$)
 - Thus, the value of l_{15} is $99,154 = 99,224 - 70$



4. Number of deaths (${}_n d_x$)

- Number of people who die during a particular age interval (${}_n d_x$)

$${}_n d_x = l_x * {}_n q_x$$

- For the number of people who die during the age interval of 40–44

$${}_5 d_{40} = {}_5 q_{40} * l_{40}$$

$${}_5 d_{40} = 0.009979 * 96,798$$

$${}_5 d_{40} = 966$$



5. Years lived in age interval (${}_nL_x$)

- Total number of years lived by all persons who enter that age interval while in the age interval (${}_nL_x$)
 - Known as “the big L column”
- Example of U.S. life table in 2010
 - 98,011 persons are alive at the beginning of age interval 30–34 (l_{30})
 - If none of them died during the age interval, they would have lived 490,055 years (98,011 times 5)
 - But 539 of them died (${}_5d_{30}$)



Different formulas for ${}_nL_x$

- Demographers assume that deaths are roughly distributed during the five-year period for many of the age intervals
- This assumption does not apply to the first few age intervals
 - There are several formulas to produce the nL_x value for the first few age groups
- At the other age extreme, 100+ in the life table, another formula is used



6. Years lived in current and subsequent age intervals (T_x)

- Total number of years lived by the population in the age interval and in all subsequent age intervals (T_x)
 - We sum ${}_nL_x$ from the oldest age backwards to get T_x

$$T_x = \sum_{i=x}^w L_i$$

- L_i : entry i in the ${}_nL_x$ column
- $\sum_{i=x}^w$: sum of the ${}_nL_x$ column starting at entry x through the last ${}_nL_x$ entry (w)



Example of T_x

- Example of U.S. life table in 2010

$$T_{95} = {}_5L_{95} + {}_{\infty}L_{100}$$

$$T_{95} = 24,670 + 4,542$$

$$T_{95} = 29,212$$



7. Remaining life expectancy (e_x)

- Average number of years of life remaining at the beginning of the age interval (e_x)
- It provides life expectancy at any age

$$e_x = T_x / l_x$$

- Example of U.S. life table in 2010

$$e_0 = T_0 / l_0 = 7,866,027 / 100,000 = 78.7$$

$$e_{25} = T_{25} / l_{25} = 5,388,260 / 98,483 = 54.7$$

- Persons aged 25–29 can expect to live an additional 54.7 years

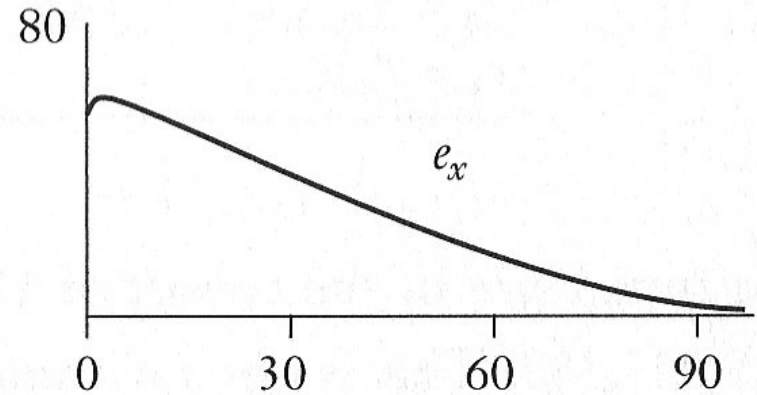
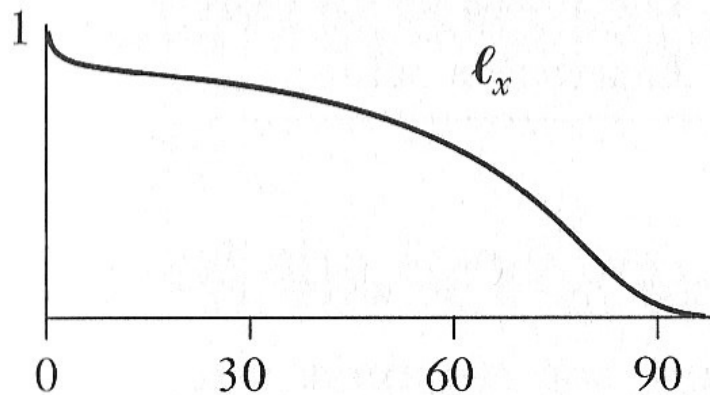
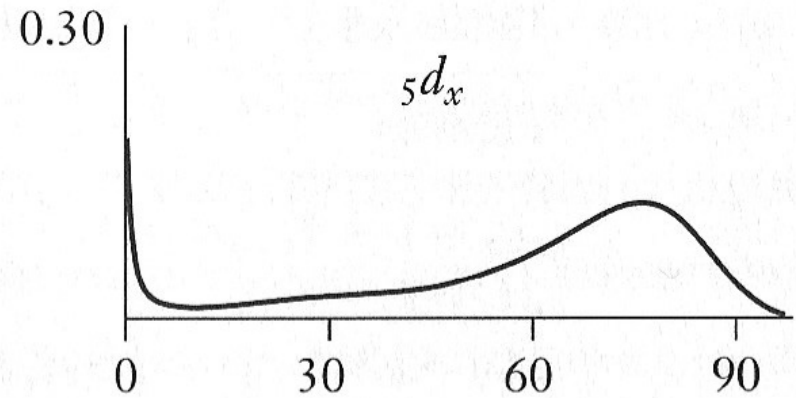
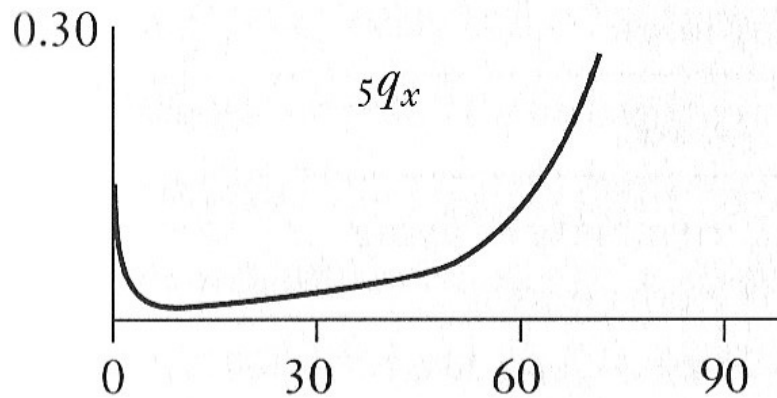


Average age at death ($x + e_x$)

- e_x is the expectation of future life beyond age x
 - It is not an average age at death
- We add x and e_x to obtain the average age at death for cohort members who survive to age x
 - Not all lifetables include $x + e_x$
 - The $x + e_x$ column always go up
- e_x does not always go down
 - It often goes up after the first few years of life, because babies who survive infancy are no longer subject to the high risks of infancy



Typical shapes of lifetable functions



Stable population

- Alfred Lotka (1880–1949) used life tables in the development of his stable population theory
- If a population that is closed to migration experiences constant schedules of age-specific fertility and mortality rates
 - It will develop a constant age distribution
 - It will grow at a constant rate, irrespective of its initial age distribution

Stable population theory

- It considers a closed population
 - A population in which migration does not occur
- If a population experiences constant age-specific fertility and mortality rates for a long time
 - It develops a constant age distribution and grows at a constant rate, irrespective of its initial age distribution
 - Demographers sometimes indicate that stable populations forget their past
- Age distribution of a stable population depends on
 - The underlying age-specific mortality rates
 - The rate of growth



Stationary population

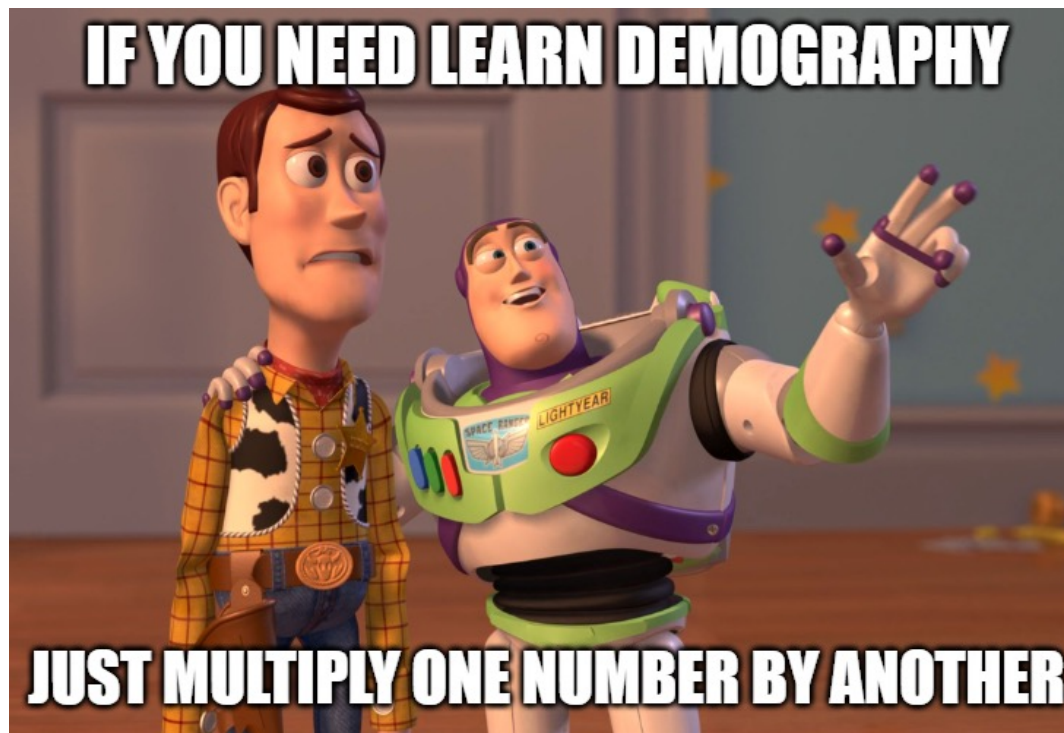
- Stationary population is a stable population in which the birth rate equals the death rate
- This results in no change in the size of the population
- It is also considered in the absence of migration

Births * Life expectancy at birth

 **Elon Musk**  @elonmusk · Jan 18

UN projections are utter nonsense. Just multiply last year's births by life expectancy. Given downward trend in birth rate, that is best case unless reversed.

[Show this thread](#)

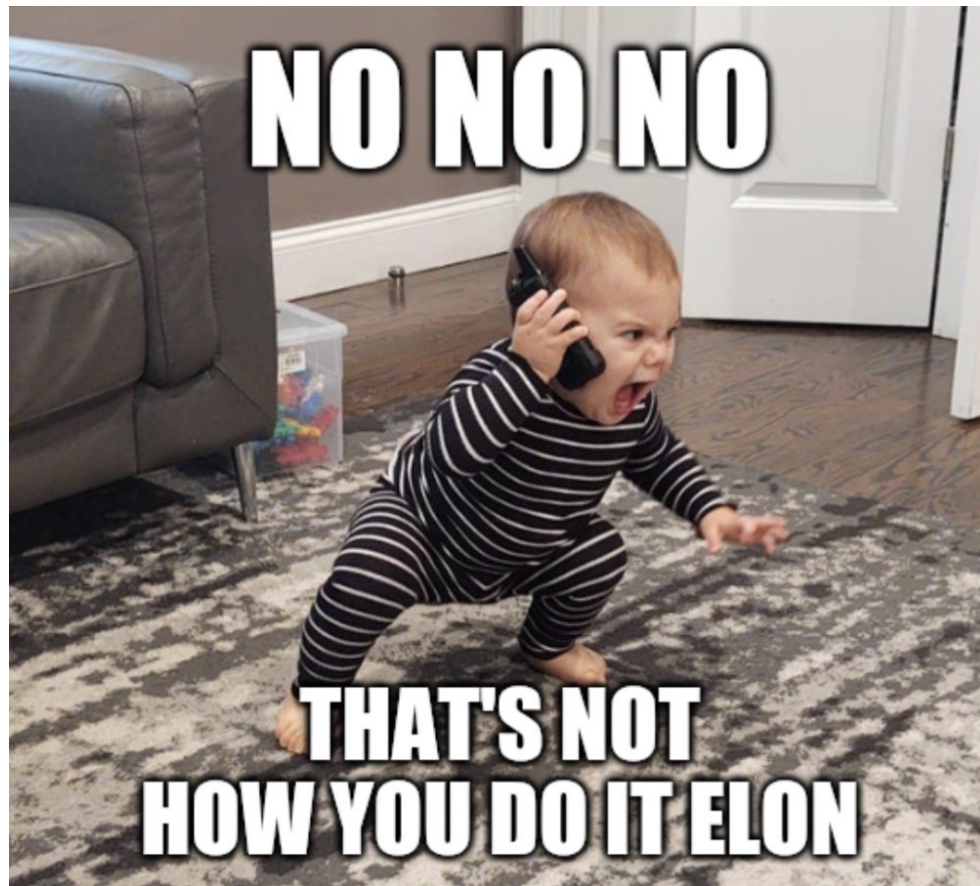


Births * Life expectancy at birth

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Births * Life expectancy at birth

Elon Musk @elonmusk · Jan 18

UN projections are utter nonsense. Just multiply last year's births by life expectancy. Given downward trend in birth rate, that is best case unless reversed.

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Ilya Kashnitsky
@ikashnitsky

If there is just one take-home message from this thread let it be

✓ Life expectancy is a snapshot of the *current* mortality

✗ It's not a projection/forecast of the actual experience of the newborn cohorts

11/

9:14 AM · Mar 5, 2021 · Typefully



Jonas Schöley
@jschoeley

Replying to @ikashnitsky @elonmusk and @HMDatabase

It's true IF we look at world population (0 migration) AND it's stationary (birth rates = death rates since generations) AND mortality remains constant whereas fertility is allowed to decline. Then we reached peak population which can be estimated by $B \cdot e^0$. Bullshit assumptions.

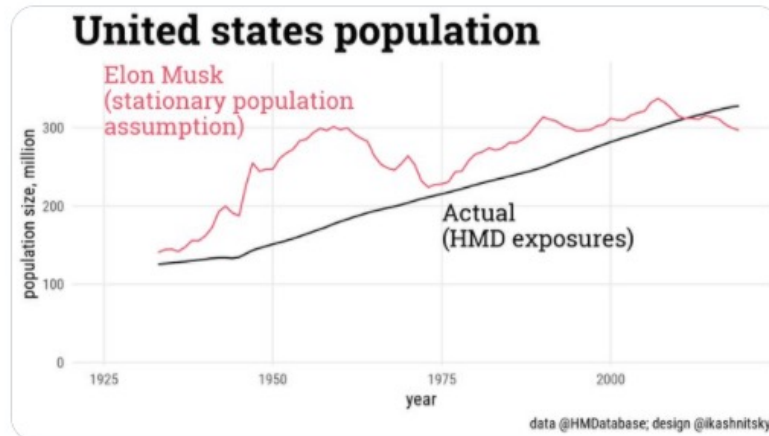
5:41 AM · Jan 19, 2022 · Twitter Web App



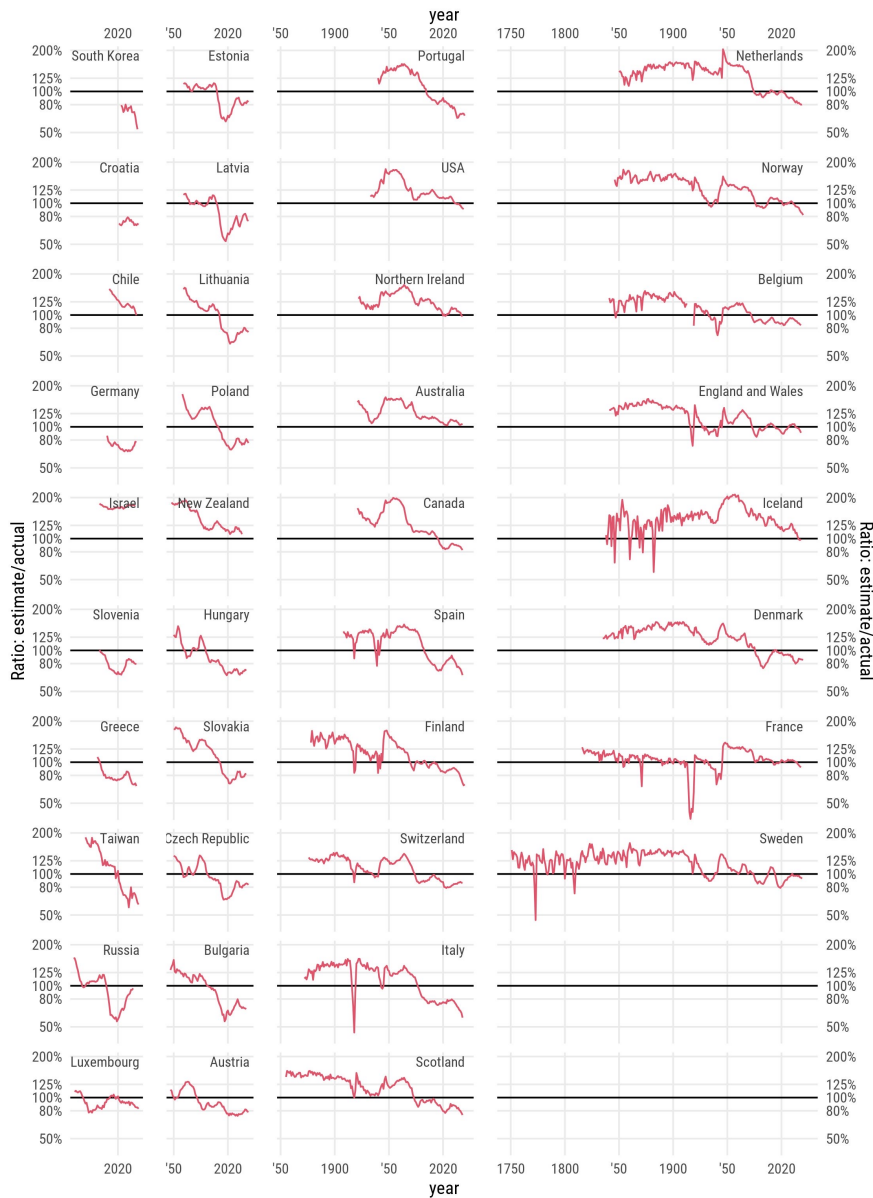
Ilya Kashnitsky @ikashnitsky · Jan 19

Okay. Maybe this is a bit overkill but let's illustrate how this projection method of @elonmusk (in fact, a stationary population assumption) worked with past data using @HMDatabase

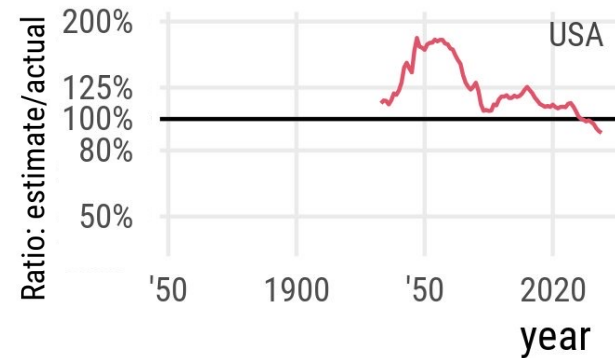
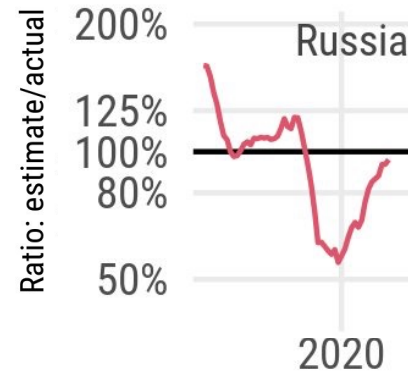
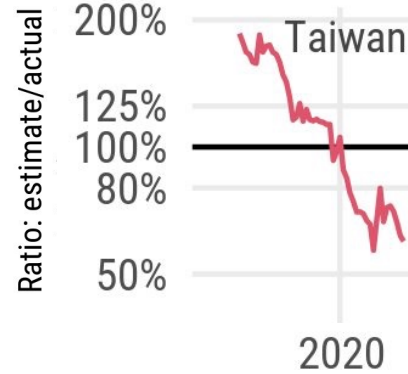
Here is just the US 🇺🇸

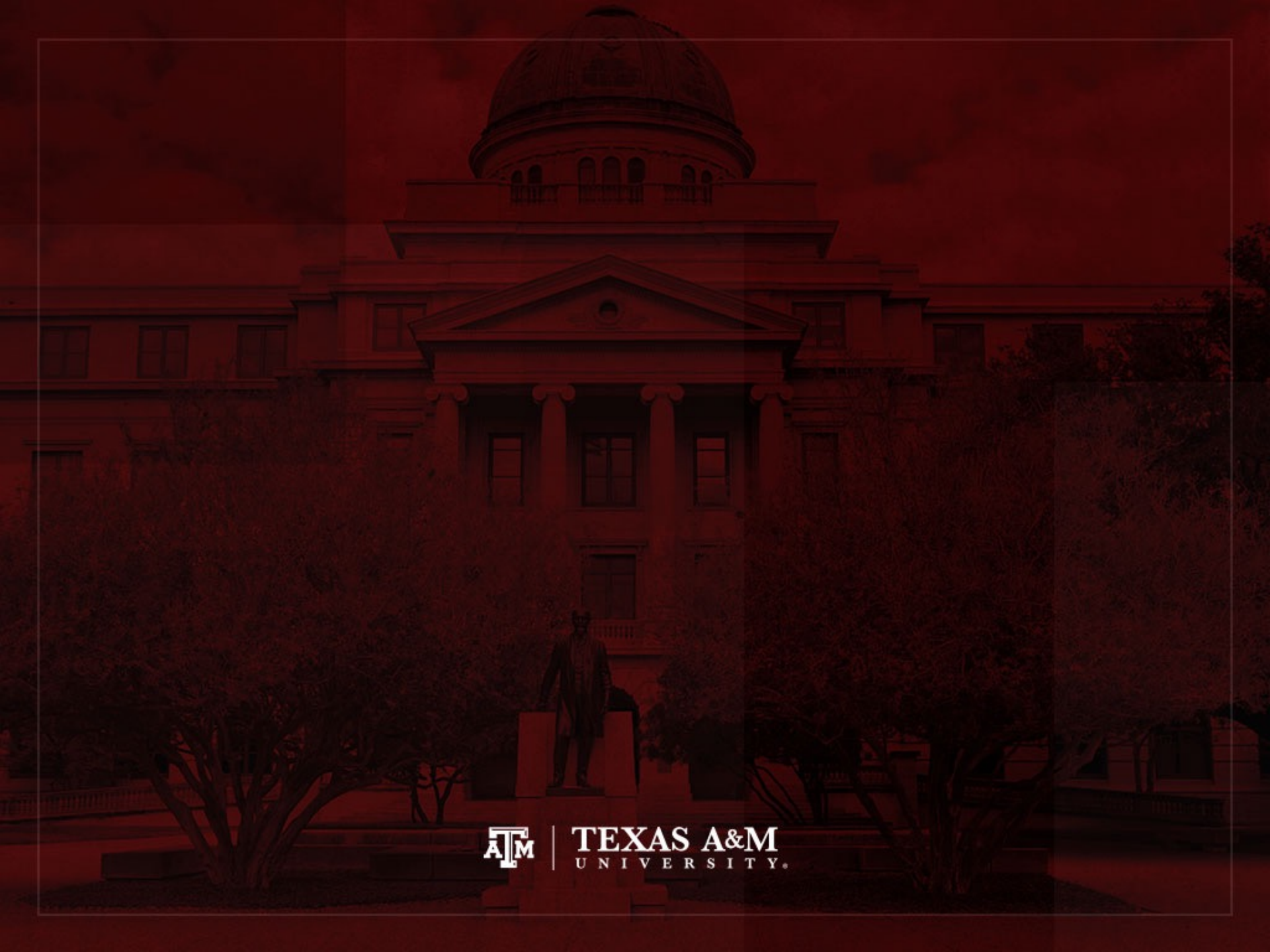


Population size under the stationary assumption relative to the actual dynamics



data @HMDatabase; design @ikashnitsky





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Life table (extra)

- Estimate overall mortality of population
 - **Assumption**: age-specific rates for the period continue unchanged into the future
 - **Synthetic cohort**: imaginary cohort of new born babies would experience a life table from a specific period
 - **Life expectancy**: average age at death for a hypothetical cohort born in a particular year and being subjected to the risks of death experienced by people of all ages in that year

Life table, U.S. women, 2010

| Age interval | Number of females in the population | Number of deaths in the population | Age-specific death rates in the interval | Of 100,000 hypothetical people born alive: | | | Number of years lived | | Expectation of life |
|----------------|-------------------------------------|------------------------------------|--|---|---------------------------------------|----------------------------------|-----------------------|--|--|
| | | | | Probabilities of death (proportion of persons alive at beginning who die during interval) | Number alive at beginning of interval | Number dying during age interval | In the age interval | In this and all subsequent age intervals | Average number of years of live remaining at beginning of age interval |
| x to $x + n$ | ${}_n P_x$ | ${}_n D_x$ | ${}_n M_x$ | ${}_n q_x$ | l_x | ${}_n d_x$ | ${}_n L_x$ | T_x | e_x |
| Under 1 | 1,976,387 | 11,503 | 0.00582 | 0.005791 | 100,000 | 579 | 99,508 | 8,098,622 | 81.0 |
| 1-4 | 7,905,548 | 1,976 | 0.00025 | 0.000999 | 99,421 | 99 | 397,445 | 7,999,114 | 80.5 |
| 5-9 | 9,959,019 | 1,095 | 0.00011 | 0.000550 | 99,322 | 55 | 496,471 | 7,601,670 | 76.5 |
| 10-14 | 10,097,332 | 1,313 | 0.00013 | 0.000650 | 99,267 | 65 | 496,173 | 7,105,199 | 71.6 |
| 15-19 | 10,736,677 | 3,436 | 0.00032 | 0.001599 | 99,202 | 159 | 495,615 | 6,609,025 | 66.6 |
| 20-24 | 10,571,823 | 4,757 | 0.00045 | 0.002247 | 99,044 | 223 | 494,662 | 6,113,410 | 61.7 |
| 25-29 | 10,466,258 | 5,652 | 0.00054 | 0.002696 | 98,821 | 266 | 493,440 | 5,618,747 | 56.9 |
| 30-34 | 9,965,599 | 6,876 | 0.00069 | 0.003444 | 98,555 | 339 | 491,925 | 5,125,308 | 52.0 |
| 35-39 | 10,137,620 | 10,138 | 0.00100 | 0.004988 | 98,215 | 490 | 489,852 | 4,633,382 | 47.2 |
| 40-44 | 10,496,987 | 17,005 | 0.00162 | 0.008067 | 97,725 | 788 | 486,656 | 4,143,531 | 42.4 |
| 45-49 | 11,499,506 | 29,094 | 0.00253 | 0.012570 | 96,937 | 1,219 | 481,639 | 3,656,874 | 37.7 |
| 90-94 | 1,023,979 | 165,495 | 0.16162 | 0.575549 | 29,621 | 17,048 | 105,484 | 148,164 | 5.0 |
| 95-99 | 288,981 | 78,398 | 0.27129 | 0.808265 | 12,573 | 10,162 | 37,458 | 42,680 | 3.4 |
| 100+ | 44,202 | 20,403 | 0.46159 | 1.000000 | 2,411 | 2,411 | 5,222 | 5,222 | 2.2 |



Probability of dying (${}_nq_x$)

- Need to convert age-specific death rates (${}_nM_x$) to probabilities of dying (${}_nq_x$)
- Probability of death relates the number of deaths during any given number of years to the number of people who started out being alive and at risk of dying

$${}_nq_x = (n)({}_nM_x) / 1 + (a)(n)({}_nM_x)$$

- $(a)(n)$: average years lived per person by people dying in the interval. $a=0.5$ implies that deaths are distributed evenly over an age interval. For 0–1 age, $a=0.85$. For 1–4 age, $a=0.60$.
- For last group, $q=1.0$.



Number of deaths (${}_n d_x$) and alive (l_x)

- The life table assumes an initial population of 100,000 births (radix), which is subjected to the mortality schedule
 - Radix can also be 1
- Number of people dying during age interval (${}_n d_x$) equals probability of death times number alive at beginning (l_x)

$${}_n d_x = ({}_n q_x)(l_x)$$

- Subtracting those who died in the previous age interval gives the number of people still alive at the beginning of next age interval

$$l_{x+n} = l_x - {}_n d_x$$

Number of years lived (${}_nL_x$)

- Number of years lived (${}_nL_x$) has to consider that some people die before the end of the age interval
- The lower the death rates, more people will survive through an entire age interval

$${}_nL_x = n(l_x - a_n d_x)$$

- a : usually 0.5, which implies that deaths are distributed evenly over an age interval. For 0–1 age, $a=0.85$. For 1–4 age, $a=0.60$
- ${}_nL_x$ for the oldest, open-age interval

$$L_{100+} = I_{100} / M_{100}$$

- I_{100} : number of survivors to oldest age
- M_{100} : death rate at the oldest age



Cumulative number of years lived (T_x)

- Number of years lived are added up, cumulating from the oldest to the youngest ages
- Total number of years lived in a given age interval and all older age intervals (T_x)

$$T_x = T_{x+n} + {}_nL_x$$

- At the oldest age, T_x equals ${}_nL_x$

Life expectancy (e_x)

- Expectation of life is the average remaining lifetime
- It is the total years remaining to be lived at exact age x
- Division of total number of years lived (T_x) by number of people alive at that exact age (l_x)

$$e_x = T_x / l_x$$

- This index summarizes the level of mortality prevailing in a given population at a particular time

Probability of surviving (p_x)

- Probability of surviving from birth to age x is designated p_x

$$p_x = l_x / l_0$$

- We can also estimate the probability of surviving from one particular age group to the subsequent age group

Crude death and birth rates

- Crude death rate (CDR) equals total number of deaths (I_0) divided by total population (T_0)
- Crude birth rate (CBR) equals total number of births (I_0) divided by total population (T_0)

$$\text{CDR} = \text{CBR} = I_0 / T_0 = 1 / (T_0 / I_0) = 1 / e_0$$



Alternative interpretations

- **Synthetic cohort** (history of a hypothetical cohort)
 - Lifetime mortality experience of a single cohort of newborn babies, who are subject to specific age-specific mortality rates
 - Used in public health/mortality studies, calculation of survival rates for estimating population, fertility, net migration...
- **Stationary population**
 - Results from unchanging schedule of age-specific mortality rates and a constant annual number of births/deaths (radix)
 - Used in the comparative measurement of mortality and in studies of population structure



Same interpretation

- **x to $x+n$**
 - Period of life between two exact ages
 - For instance, 20–25 means the 5-year interval between the 20th and 25th birthdays
- **${}_nq_x$**
 - Proportion of persons in the cohort alive at the beginning of an indicated age interval (x) who will die before reaching the end of that age interval ($x+n$)
 - Probability that a person at his/her x^{th} birthday will die before reaching his/her $x+n^{\text{th}}$ birthday
- **e_x (life expectancy)**
 - Average remaining lifetime (in years) for a person who survives to the beginning of the indicated age interval

l_x

- **Synthetic cohort**

- Number of persons living at the beginning of the indicated age interval (x) out of the total number of births assumed as the radix of the table

- **Stationary population**

- Number of persons who reach the beginning of the age interval each year

$${}_n d_x$$

- **Synthetic cohort**

- Number of persons who would die within the indicated age interval (x to x+n) out of the total number of births assumed in the table

- **Stationary population**

- Number of persons that die each year within the indicated age interval

$$nL_x$$

- **Synthetic cohort**

- Number of person-years that would be lived within the indicated age interval (x to $x+n$) by the cohort of 100,000 births assumed

- **Stationary population**

- Number of persons in the population who at any moment are living within the indicated age interval

$$T_x$$

- **Synthetic cohort**

- Total number of person-years that would be lived after the beginning of the indicated age interval by the cohort of 100,000 births assumed

- **Stationary population**

- Number of persons in the population who at any moment are living within the indicated age interval and all higher age intervals

Interpretation as stationary population

ABRIDGED LIFE TABLE FOR THE FEMALE POPULATION OF THE UNITED STATES: 2007

| Age group | Width n | Population nPx | Deaths nDx | Of 100,000 born alive | | | | Stationary population | | Average remaining lifetime ex |
|-----------|---------|----------------|------------|------------------------------|----------------------|--------------------------------------|-----------------------------|-------------------------|-------------------------------|-------------------------------|
| | | | | Age-specific death rates nMx | Proportion dying nqx | # living at beginning of interval lx | # dying during interval ndx | In the age interval nLx | In this and following ages Tx | |
| 0 | 1 | 1,998,761 | 12,845 | 0.0064 | 0.0064 | 100,000 | 641 | 99,684 | 8,103,588 | 81.0 |
| 1-4 | 4 | 8,109,371 | 2,069 | 0.0003 | 0.0010 | 99,359 | 101 | 397,248 | 8,003,904 | 80.6 |
| 5-9 | 5 | 9,720,587 | 1,192 | 0.0001 | 0.0006 | 99,258 | 61 | 496,150 | 7,606,656 | 76.6 |
| 10-14 | 5 | 9,918,543 | 1,370 | 0.0001 | 0.0007 | 99,197 | 68 | 495,828 | 7,110,506 | 71.7 |
| 15-19 | 5 | 10,617,178 | 3,741 | 0.0004 | 0.0018 | 99,129 | 175 | 495,242 | 6,614,678 | 66.7 |
| 20-24 | 5 | 10,073,754 | 4,925 | 0.0005 | 0.0024 | 98,954 | 242 | 494,215 | 6,119,436 | 61.8 |
| 25-29 | 5 | 10,122,681 | 5,824 | 0.0006 | 0.0029 | 98,713 | 284 | 492,910 | 5,625,222 | 57.0 |
| 30-34 | 5 | 9,469,789 | 6,956 | 0.0007 | 0.0037 | 98,429 | 361 | 491,314 | 5,132,312 | 52.1 |
| 35-39 | 5 | 10,666,827 | 11,126 | 0.0010 | 0.0052 | 98,068 | 510 | 489,165 | 4,640,998 | 47.3 |
| 40-44 | 5 | 11,155,652 | 18,375 | 0.0016 | 0.0082 | 97,558 | 800 | 485,944 | 4,151,834 | 42.6 |
| 45-49 | 5 | 11,572,428 | 29,834 | 0.0026 | 0.0128 | 96,757 | 1,240 | 480,926 | 3,665,890 | 37.9 |
| 50-54 | 5 | 10,709,011 | 40,396 | 0.0038 | 0.0187 | 95,518 | 1,786 | 473,463 | 3,184,963 | 33.3 |
| 55-59 | 5 | 9,339,919 | 50,868 | 0.0054 | 0.0269 | 93,732 | 2,521 | 462,827 | 2,711,501 | 28.9 |
| 60-64 | 5 | 7,636,068 | 62,624 | 0.0082 | 0.0402 | 91,211 | 3,670 | 447,543 | 2,248,674 | 24.7 |
| 65-69 | 5 | 5,725,079 | 74,499 | 0.0130 | 0.0631 | 87,541 | 5,528 | 424,827 | 1,801,131 | 20.6 |
| 70-74 | 5 | 4,738,379 | 96,395 | 0.0203 | 0.0971 | 82,012 | 7,962 | 391,395 | 1,376,304 | 16.8 |
| 75-79 | 5 | 4,314,403 | 139,360 | 0.0323 | 0.1500 | 74,050 | 11,109 | 343,929 | 984,910 | 13.3 |
| 80-84 | 5 | 3,582,388 | 192,519 | 0.0537 | 0.2378 | 62,941 | 14,970 | 278,566 | 640,981 | 10.2 |
| 85+ | --- | 3,511,395 | 464,781 | 0.1324 | 1.0000 | 47,971 | 47,971 | 362,415 | 362,415 | 7.6 |

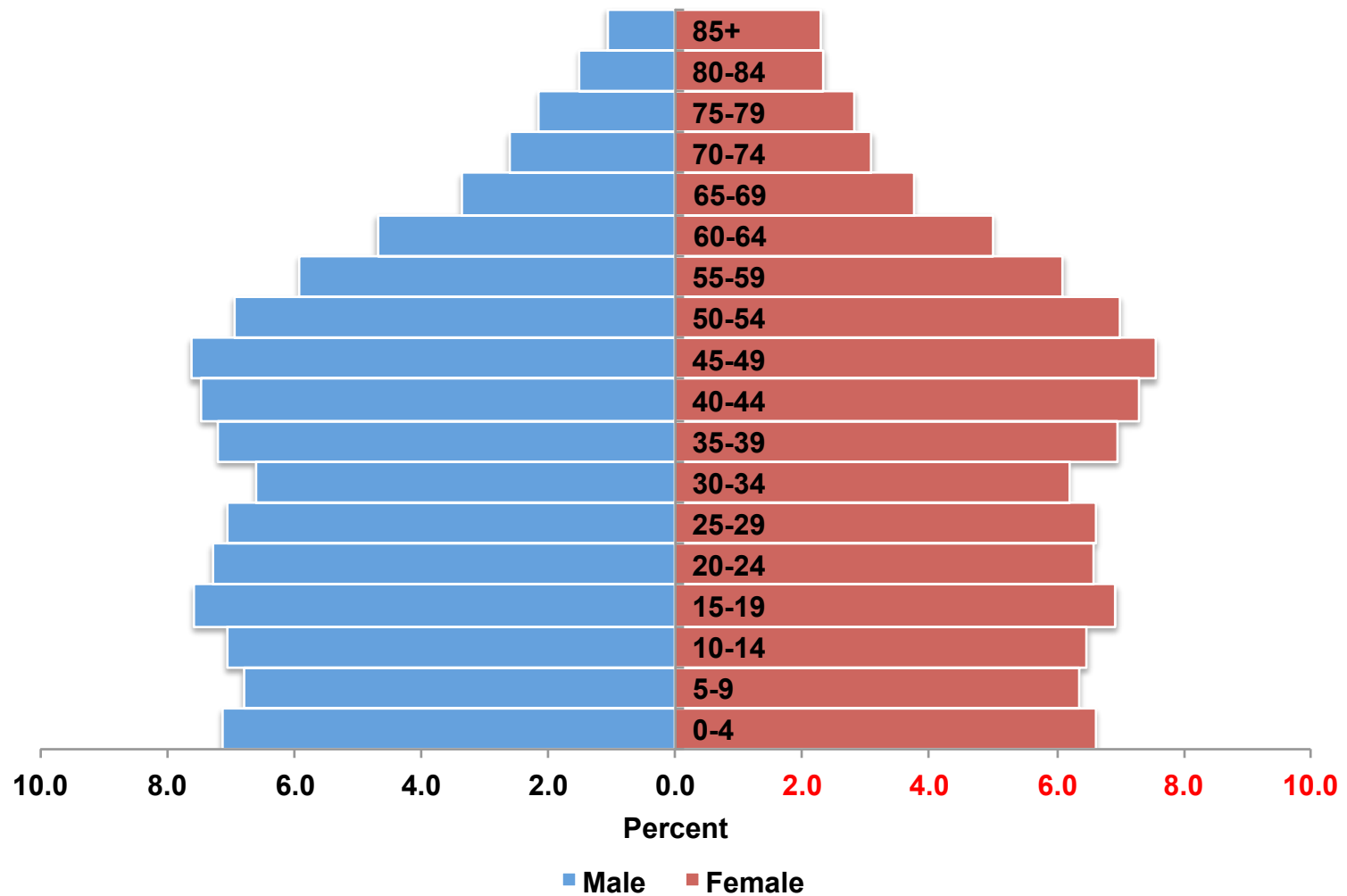
ABRIDGED LIFE TABLE FOR THE MALE POPULATION OF THE UNITED STATES: 2007

| Age group | Width n | Population nPx | Deaths nDx | Of 100,000 born alive | | | | Stationary population | | Average remaining lifetime ex |
|-----------|---------|----------------|------------|------------------------------|----------------------|--------------------------------------|-----------------------------|-------------------------|-------------------------------|-------------------------------|
| | | | | Age-specific death rates nMx | Proportion dying nqx | # living at beginning of interval lx | # dying during interval ndx | In the age interval nLx | In this and following ages Tx | |
| 0 | 1 | 2,079,846 | 16,293 | 0.0078 | 0.0078 | 100,000 | 780 | 99,615 | 7,582,342 | 75.8 |
| 1-4 | 4 | 8,507,893 | 2,634 | 0.0003 | 0.0012 | 99,220 | 123 | 396,648 | 7,482,726 | 75.4 |
| 5-9 | 5 | 10,095,353 | 1,519 | 0.0002 | 0.0008 | 99,097 | 75 | 495,313 | 7,086,078 | 71.5 |
| 10-14 | 5 | 10,484,813 | 2,066 | 0.0002 | 0.0010 | 99,022 | 98 | 494,887 | 6,590,765 | 66.6 |
| 15-19 | 5 | 11,252,863 | 9,558 | 0.0008 | 0.0042 | 98,925 | 419 | 493,658 | 6,095,878 | 61.6 |
| 20-24 | 5 | 10,828,130 | 15,758 | 0.0015 | 0.0073 | 98,505 | 714 | 490,881 | 5,602,220 | 56.9 |
| 25-29 | 5 | 10,489,470 | 15,107 | 0.0014 | 0.0072 | 97,791 | 702 | 487,338 | 5,111,340 | 52.3 |
| 30-34 | 5 | 9,802,132 | 14,685 | 0.0015 | 0.0075 | 97,089 | 725 | 483,776 | 4,624,002 | 47.6 |
| 35-39 | 5 | 10,684,227 | 19,755 | 0.0018 | 0.0092 | 96,364 | 887 | 479,777 | 4,140,226 | 43.0 |
| 40-44 | 5 | 11,085,591 | 30,350 | 0.0027 | 0.0136 | 95,477 | 1,299 | 474,390 | 3,660,450 | 38.3 |
| 45-49 | 5 | 11,318,167 | 47,904 | 0.0042 | 0.0210 | 94,179 | 1,974 | 466,332 | 3,186,060 | 33.8 |
| 50-54 | 5 | 10,313,298 | 66,552 | 0.0065 | 0.0318 | 92,205 | 2,931 | 454,237 | 2,719,728 | 29.5 |
| 55-59 | 5 | 8,790,943 | 81,590 | 0.0093 | 0.0454 | 89,274 | 4,055 | 436,954 | 2,265,491 | 25.4 |
| 60-64 | 5 | 6,979,426 | 92,028 | 0.0132 | 0.0640 | 85,218 | 5,451 | 413,393 | 1,828,537 | 21.5 |
| 65-69 | 5 | 5,003,042 | 100,492 | 0.0201 | 0.0959 | 79,677 | 7,651 | 380,904 | 1,415,144 | 17.7 |
| 70-74 | 5 | 3,889,104 | 117,852 | 0.0303 | 0.1414 | 72,116 | 10,196 | 336,467 | 1,034,240 | 14.3 |
| 75-79 | 5 | 3,192,676 | 149,669 | 0.0469 | 0.2107 | 61,920 | 13,046 | 278,295 | 697,773 | 11.3 |
| 80-84 | 5 | 2,235,826 | 171,134 | 0.0765 | 0.3220 | 48,874 | 15,739 | 205,629 | 419,478 | 8.6 |
| 85+ | --- | 1,606,146 | 248,866 | 0.1549 | 1.0000 | 33,135 | 33,135 | 213,850 | 213,850 | 6.5 |

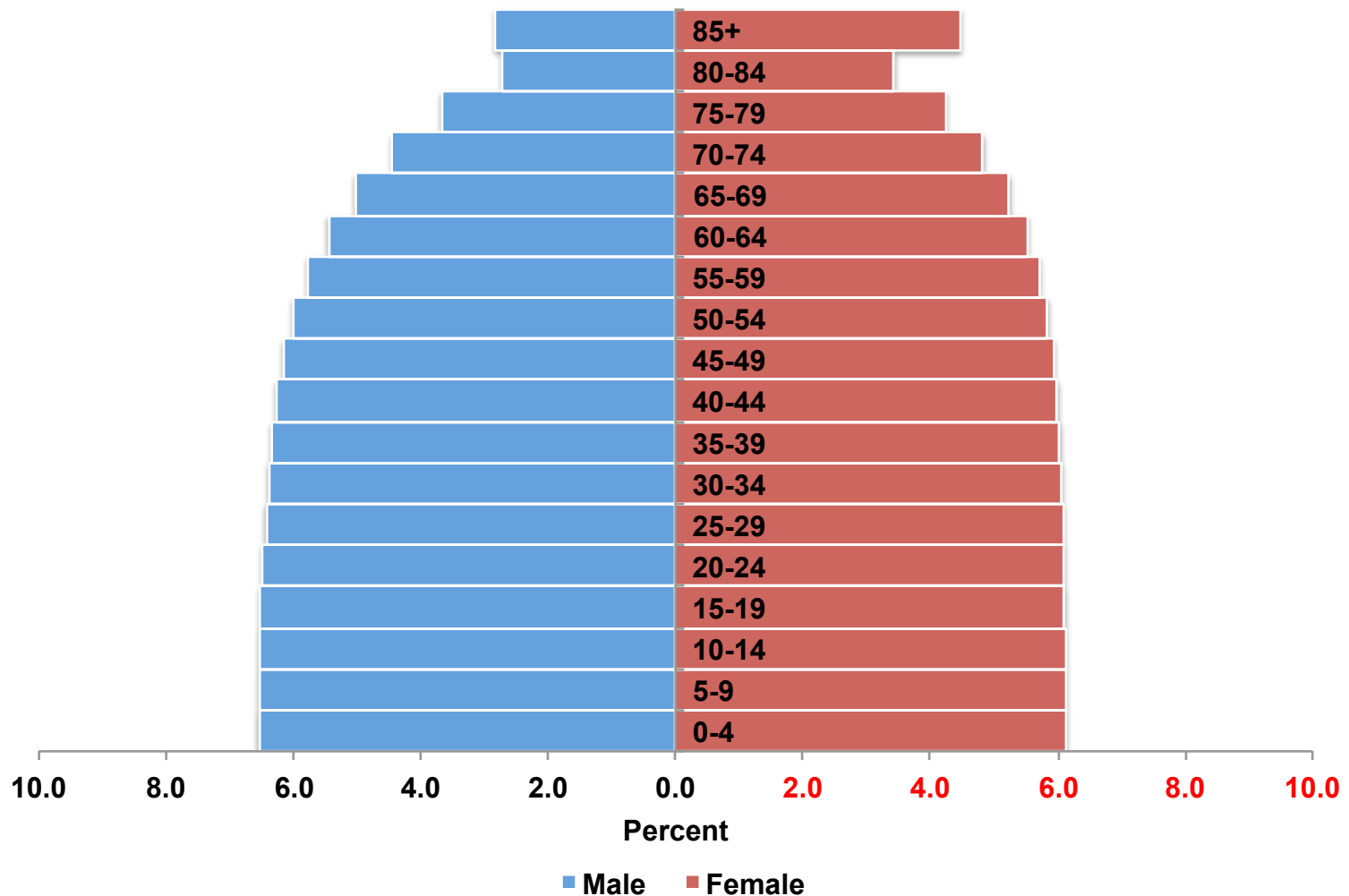
Source: Formulas from Kintner (2003); Population data from 2007 ACS; Death data from CDC (http://www.cdc.gov/nchs/data/dvs/mortfinal2007_worktable310.pdf).



Population, U.S., 2007



nL_x from previous life tables, U.S., 2007

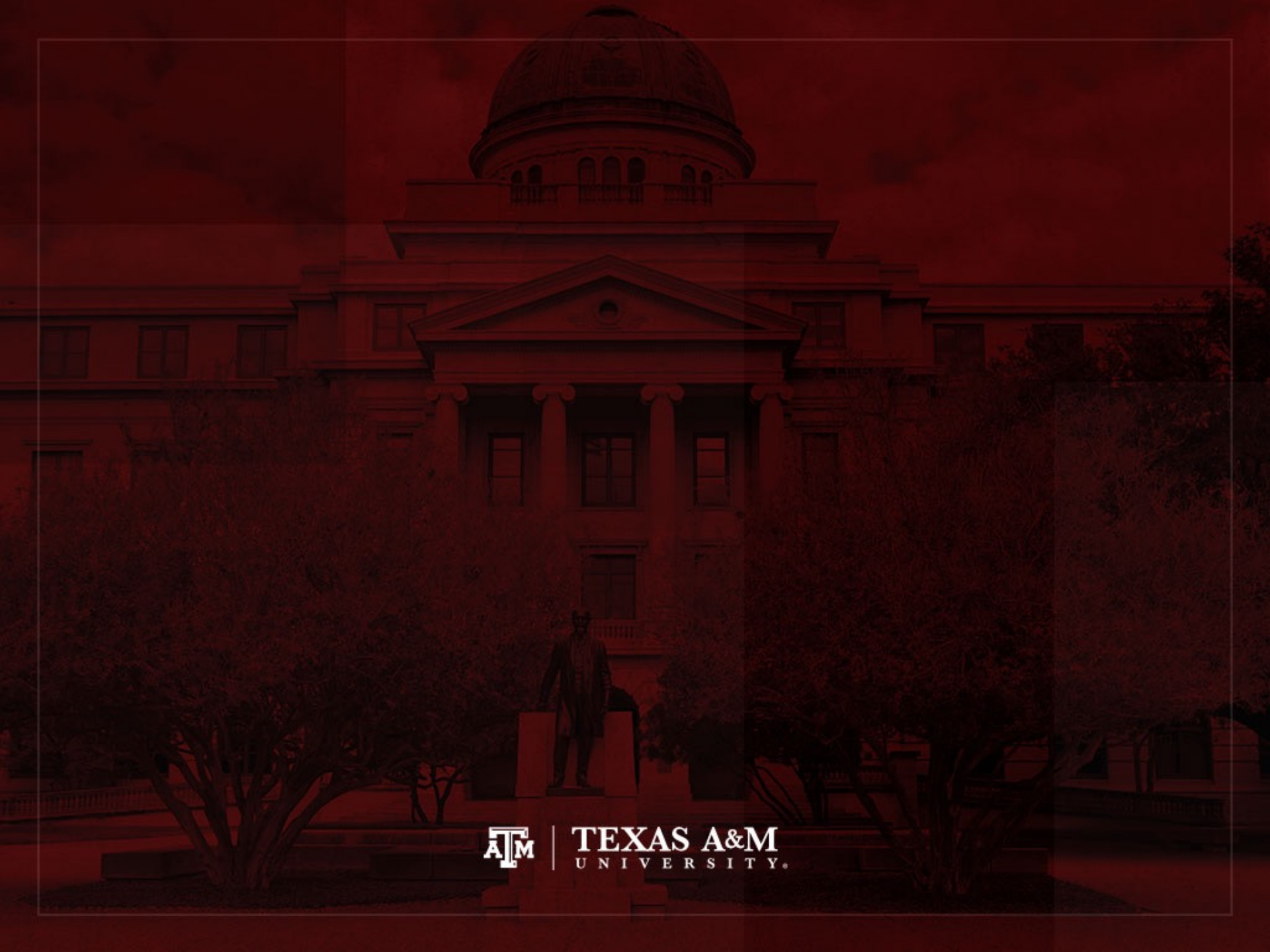


Problems with life tables

- We saw life tables based on complete empirical data
- We might experience some issues
 - Have partial information to build our life table
 - Have data for only some age groups
 - Information for some ages may be more reliable than for other ages
 - Have ideas about mortality level, but not a full life table to make projections
- We can use model life tables to solve these issues

Model life tables

- A life table constructed from mathematical formulas is called a model life table
 - Use mathematical formulas to fill in missing parts
 - Have a whole life table from partial information
 - Identify suspicious and poor quality data with model expectations
 - Supply standard assumptions for projections
 - Find regularities for the invention of indirect measures
 - Reconstruct rates from historical counts of births and deaths (inverse projection)



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Short history of mortality in the world

- Defining the health and mortality transition
- Health and mortality changes over time
- Life span and longevity
- Disease and death over the life cycle
- Causes of poor health and death
- Health and mortality inequalities



Morbidity and mortality

- Health, death: two sides of morbidity, mortality
 - Morbidity: prevalence of disease in a population
 - Mortality: pattern of death

- Health and mortality transition
 - Epidemiologic transition (Omran 1971)
 - Shift from prevailing poor health (high morbidity) and high death rates (high mortality) primarily from communicable diseases, occurring especially among the young...
 - To prevailing good health and low deaths rates from infectious diseases, with most people dying at older ages from degenerative diseases

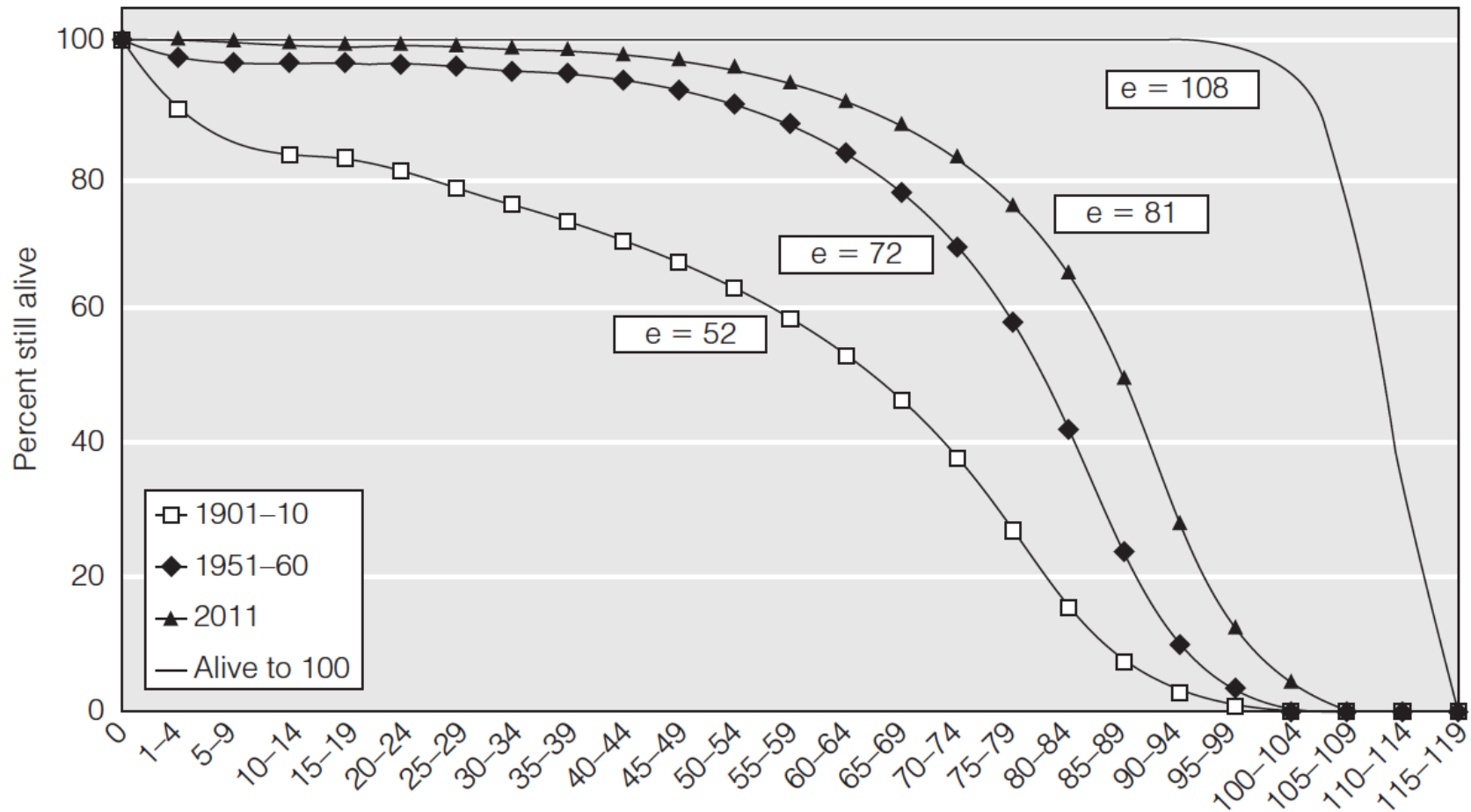


Death at older ages

- For virtually all of human history, early death was commonplace
- Beginning about 200 years ago, we have been steadily pushing death to older ages
- The survival of more people to ever older ages is a key contribution to the demographic transition
- Most people now survive to advanced ages and die pretty quickly
- The variability by age in mortality is compressed, leading to an increased rectangularization of mortality...



Rectangularization of mortality, United States

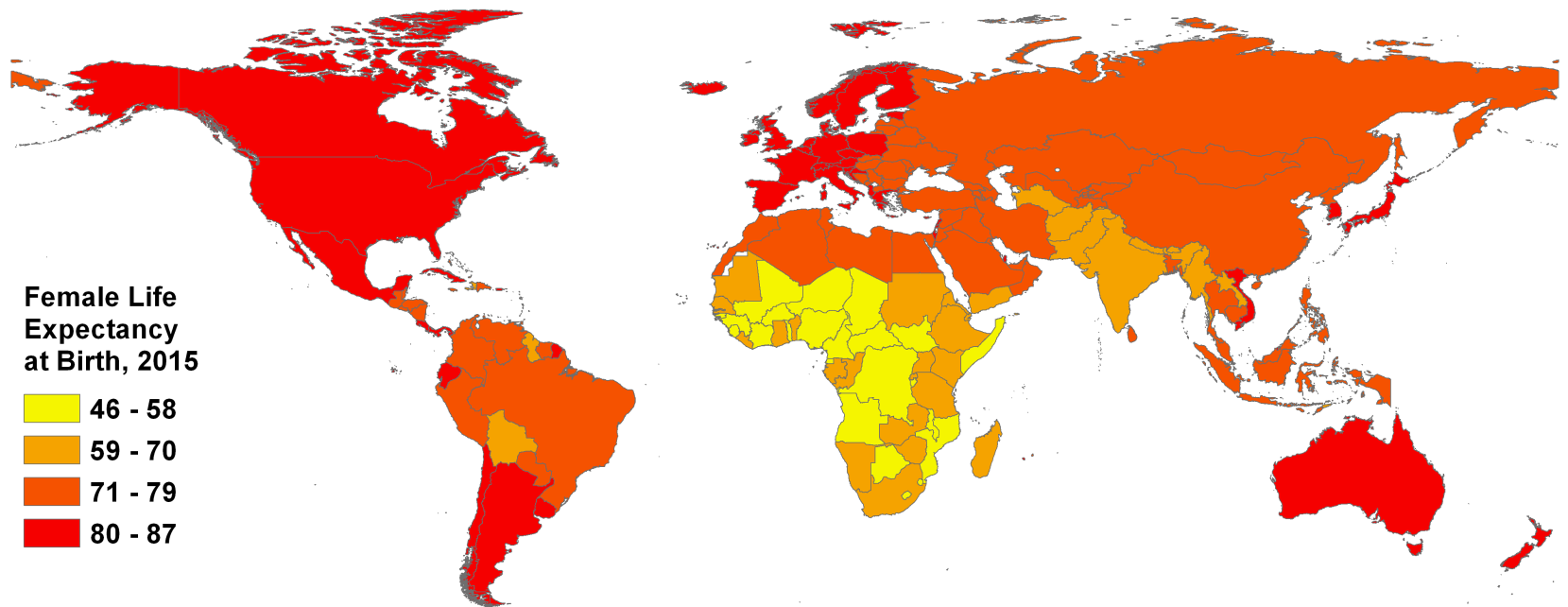


Changes over time

- For most of history, life expectancy fluctuated between 20 and 30 years
- About 2/3 of babies survived to their first birthday, and about 1/2 were still alive at age five
 - Now it's 99%
- Around 10% of people made it to age 65 in a pre-modern society
 - Now it's 90%



Female life expectancy at birth



Health improvements

| Period and regions | Life expectancy (females) | % surviving to age | | | | Births required for ZPG |
|--|---------------------------|--------------------|----|----|----|-------------------------|
| | | 1 | 5 | 25 | 65 | |
| Premodern | 20 | 63 | 47 | 34 | 8 | 6.1 |
| | 30 | 74 | 61 | 50 | 17 | 4.2 |
| US/Europe, late 18 th /early 19 th | 40 | 82 | 73 | 63 | 29 | 3.3 |
| Lowest Sub-Saharan | 46 | 89 | 82 | 75 | 34 | 2.7 |
| World average circa 2015 | 73 | 98 | 98 | 97 | 77 | 2.1 |
| Mexico | 78 | 99 | 99 | 98 | 84 | 2.1 |
| United States | 81 | 99 | 99 | 99 | 88 | 2.1 |
| Canada | 84 | 99 | 99 | 99 | 91 | 2.1 |
| Japan (highest in the world) | 86 | 99 | 99 | 99 | 93 | 2.1 |



The Roman era

- Life expectancy in the Roman era is estimated to have been 22 years
- People who reached adulthood were not too likely to reach a very advanced age, although of course some did



The Middle Ages

- The plague (black death) hit Europe in the 14th century, having spread west from Asia
 - An estimated 1/3 of the population of Europe may have perished from the disease between 1346 and 1350
- It appears to be the same disease that exists today
 - Not really known why it was so fatal in the past
 - Probably due to generally poor health and few resources to battle the disease



The Columbian exchange

- Columbus and other European explorers took diseases, horses, and guns to the Americas
 - Brought back new foods and few new diseases
- One explanation for relative ease with which Spain dominated Latin America after arriving around 1500
 - Explorers had immunity to the diseases they brought
 - Compared to the devastation the diseases affected indigenous populations



Industrial Revolution, 1760–1840

- Plague and Little Ice Age had receded
- Income improved nutrition, housing, and sanitation
- Life expectancy in Europe and the U.S.: ≈ 40 years
 - Was population growth a cause or effect of rising living standards?
- There were as many deaths to children under 5 as there were at 65 and over
 - Infectious diseases were still the dominant reasons for death, but their ability to kill was diminishing



19th century

- Key elements in postponing death
 - Belief in the power of human intervention (Western science)
 - Improved nutrition: occurred first in Western Europe
 - Clean water, toilets, bathing facilities
 - Sewerage in cities: sanitation studies in Liverpool
 - Small pox vaccinations: Edward Jenner in England
- Validation of germ theory
 - Ignaz Semmelweis in Vienna: pioneer of antiseptic procedures
 - Joseph Lister in Glasgow: cleanliness principals in surgery
 - Louis Pasteur in Paris: formal experiments about germs, diseases

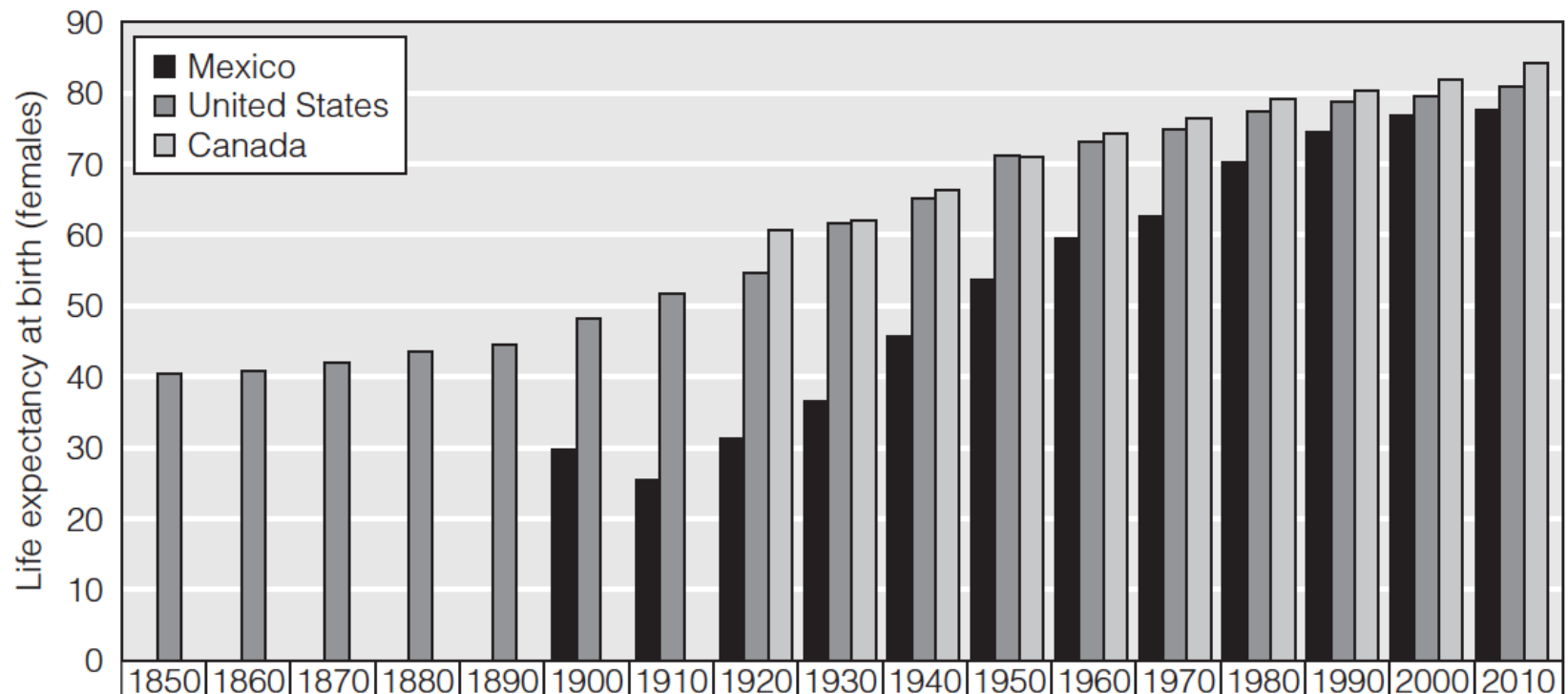


20th century

- Health as a social movement
 - Leading to government-organized universal health care systems in all rich countries except the U.S.
- Antibiotics emerging around WWII
- More vaccinations
- Oral rehydration therapy for infants and adults
- Advanced diagnoses, drugs, and other treatments for degenerative diseases to keep older people alive longer



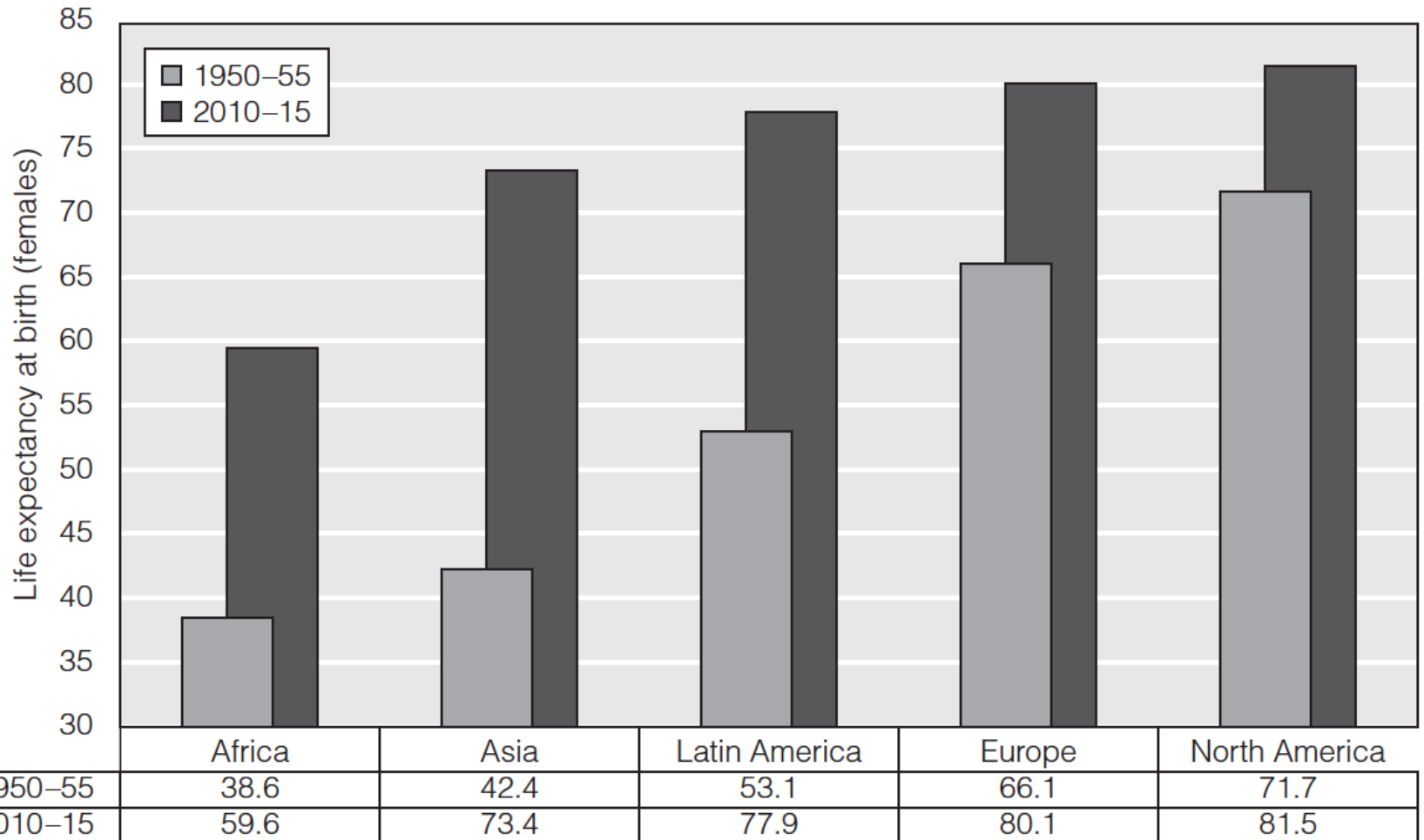
Improvements in life expectancy



| | | | | | | | | | | | | | | | | | |
|---------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 1850 | 1860 | 1870 | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 |
| Mexico | | | | | | 29.8 | 25.4 | 31.5 | 36.7 | 45.7 | 53.7 | 59.5 | 62.7 | 70.3 | 74.5 | 76.9 | 77.7 |
| United States | 40.5 | 40.9 | 42 | 43.5 | 44.5 | 48.3 | 51.8 | 54.6 | 61.6 | 65.2 | 71.1 | 73.1 | 74.8 | 77.4 | 78.8 | 79.6 | 80.9 |
| Canada | | | | | | | | 60.6 | 62.1 | 66.3 | 70.9 | 74.3 | 76.5 | 79.1 | 80.4 | 81.9 | 83.5 |



World War II: a turning point



Postponing death

- Two ways to postpone death to the oldest possible ages
- Prevent diseases from occurring or spreading when they do occur (prevention)
 - Vaccinations, clean water, sanitation, good nutrition
 - No physicians needed
- Curing people of disease when they are sick
 - Diagnostic technology, drugs, skilled physicians



Nutrition transition and obesity

- Poor were skinny because only the rich could afford to access enough quantities of food
 - Not any more
- Nutrition transition is a worldwide shift toward
 - Diet high in fat and processed foods
 - Diet low in fiber
 - Less exercise
 - Increases in degenerative diseases



Life span and longevity

- Life span: oldest age to which human beings can survive
 - 122 years and 164 days (by 2016)
 - It is almost entirely a biological phenomenon
- Longevity/life expectancy: age at which we actually die
 - Expected number of years to be lived, on average, by a particular population at a particular time
 - Currently about 71 for all humans
 - It has biological and social components
- Populations with high mortality tend to have high morbidity
 - This is not a one-to-one relationship
 - We may live longer even though not being very healthy

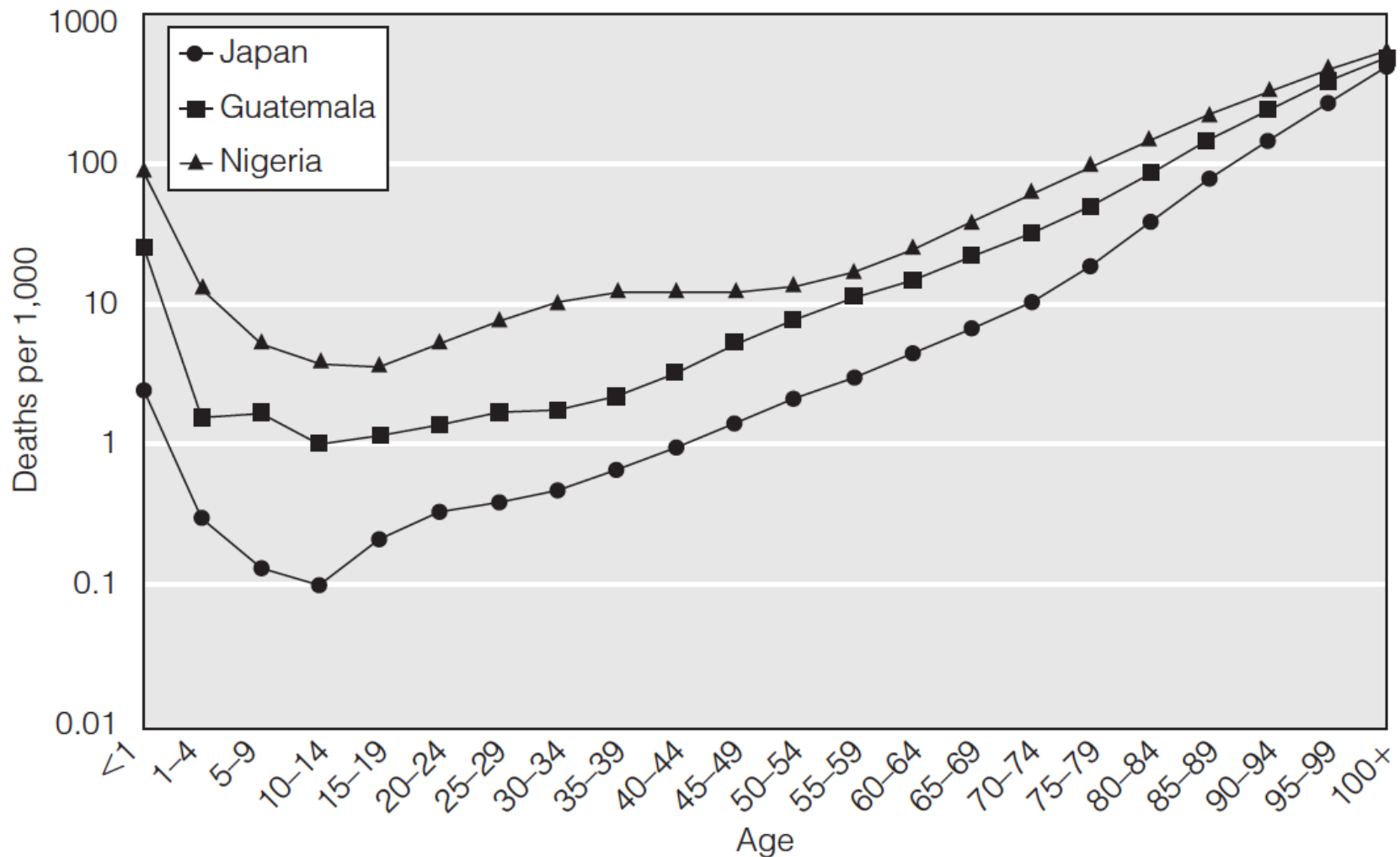


Mortality by age

- Humans are like most other animals with respect to the general pattern of death by age
 - The very young and the old are most vulnerable
 - Young adults are least likely to die
- Risks of death are relatively low
 - After the initial year of life, lasting at least until middle age
 - Corresponds to reproductive ages
- Beyond middle age
 - Mortality increases
 - Although at a decelerating rate



Highest death rates, 2011: very young and the old



Mortality by sex (gender)

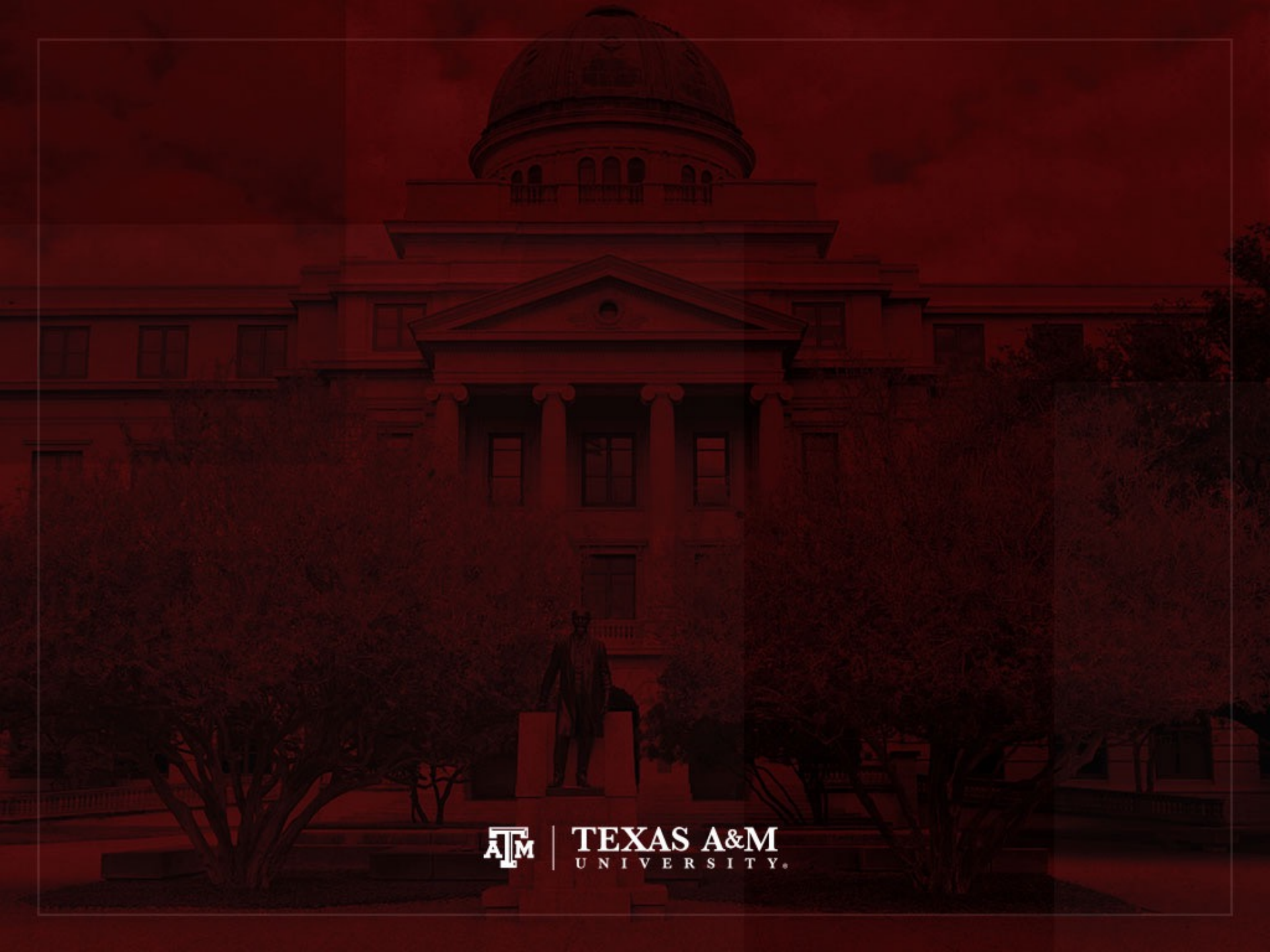
- Women (sex)
 - Have a lower probability of death at every age from the moment of conception'
- Women (gender)
 - Unless society intervenes with a lower status for women that gives them less food, less access to health care, less education, lower earnings...



Other mortality differentials

- Urban and rural differentials
 - Urban now better than rural
- Neighborhood inequalities
 - Slums are bad for your health
- Educational differentials
 - Better educated live longer
- Social status differentials
 - The rich live longer
- Race and ethnicity differentials
 - Being different will be used against you
- Marital status
 - Being married is good for your health





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Mortality trends and causes of death

- Categories of diseases according to the World Health Organization
 - Communicable diseases
 - Noncommunicable diseases
 - Injuries

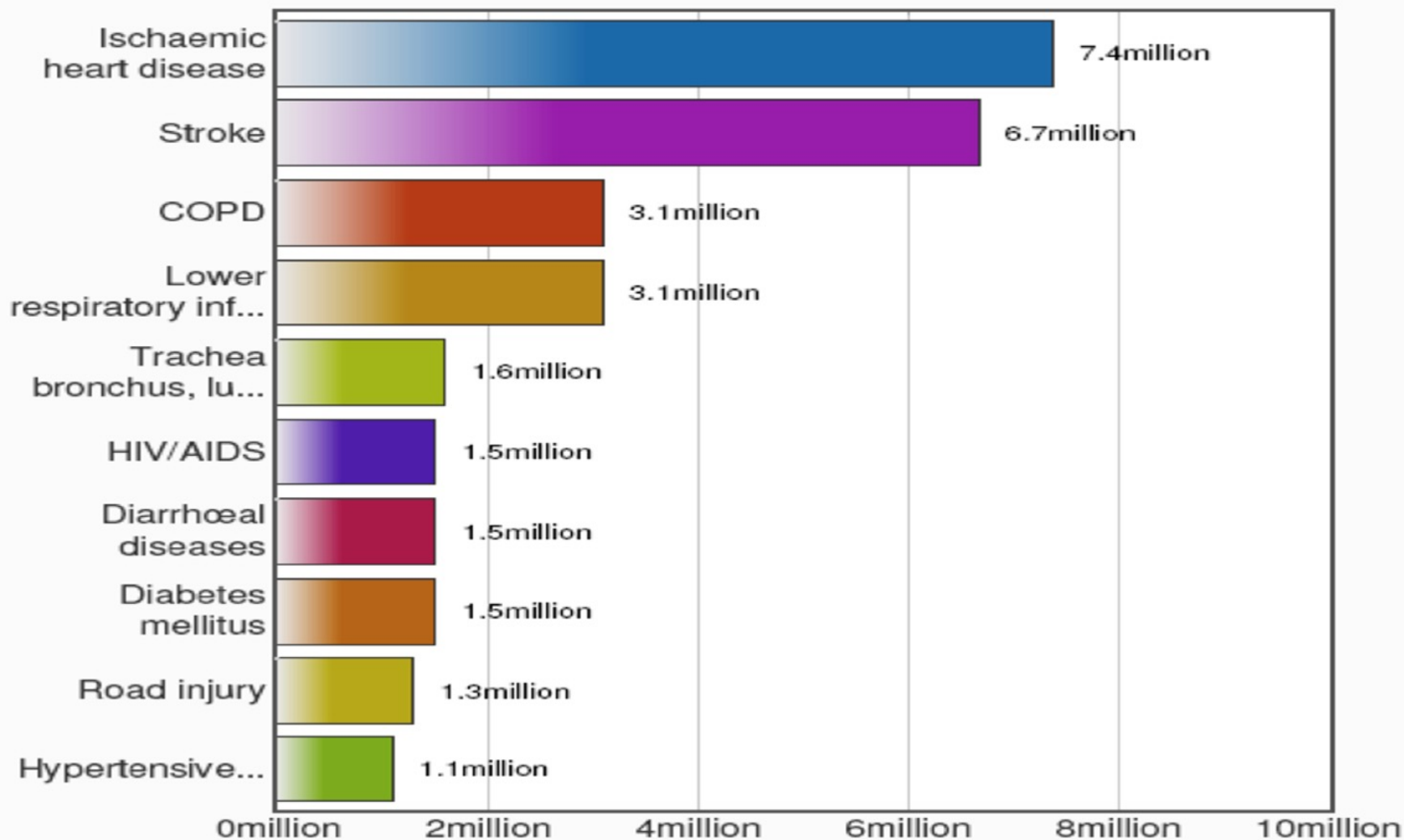
Communicable diseases

- Bacterial (e.g., tuberculosis)
- Viral (e.g., measles)
- Protozoan (e.g., malaria)
- Maternal conditions
 - Lack of prenatal care
 - Delivering somewhere besides a hospital
 - Seeking an unsafe abortion
- Perinatal conditions
 - “Surrounding birth” — just before and just after birth
- Nutritional deficiencies



| Cause of death | Broad category of cause | Number of deaths in world 2011 (millions) | Top ten death rates (per 100,000 population), 2011 | | | |
|--|-------------------------|---|--|-------------------------------|-------------------------------|----------------------|
| | | | High income countries | Upper middle income countries | Lower middle income countries | Low income countries |
| Ischemic heart disease | Non-Com. | 7.0 | 119 | 120 | 93 | 47 |
| Stroke | Non-Com. | 6.2 | 69 | 126 | 75 | 56 |
| Lower respiratory infection | Com. | 3.2 | 32 | 22 | 60 | 98 |
| Chronic obstructive pulmonary disease (COPD) | Non-Com. | 3.0 | 32 | 45 | 51 | |
| Diarheal diseases | Com. | 1.9 | | | 47 | 69 |
| HIV/AIDS | Com. | 1.6 | | | 24 | 70 |
| Trachea bronchus, lung cancers | Non-Com. | 1.5 | 51 | 28 | | |
| Diabetes mellitus | Non-Com. | 1.4 | 21 | 20 | 20 | |
| Road injury | Injury | 1.3 | | 21 | 19 | |
| Prematurity | Com. | 1.2 | | | 27 | 43 |
| Alzheimer's disease and other dementias | Non-Com. | | 48 | | | |
| Colon rectal cancers | Non-Com. | | 27 | | | |
| Hypertensive heart disease | Non-Com. | | 20 | 18 | | |
| Breast cancer | Non-Com. | | 16 | | | |
| Malaria | Com. | | | | | 38 |
| Tuberculosis | Com. | | | | 22 | 32 |
| Protein-energy malnutrition | Com. | | | | | 32 |
| Birth asphyxia and birth trauma | Com. | | | | | 30 |
| Liver cancer | Non-Com. | | | 19 | | |
| Stomach cancer | Non-Com. | | | 18 | | |
| Life expectancy at birth (both sexes) | | | 80 | 74 | 66 | 60 |

The 10 leading causes of death in the world 2012



Source: World Health Organization. Available at:
<http://www.who.int/mediacentre/factsheets/fs310/en/> (accessed April 29, 2016)

Adults and children estimated to be living with HIV, 2013

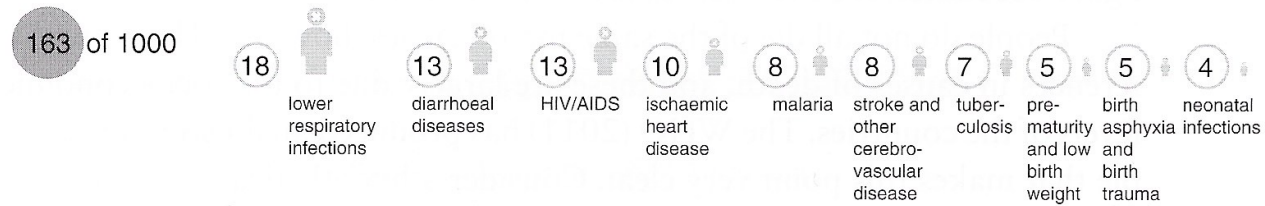


Total: 35.0 million

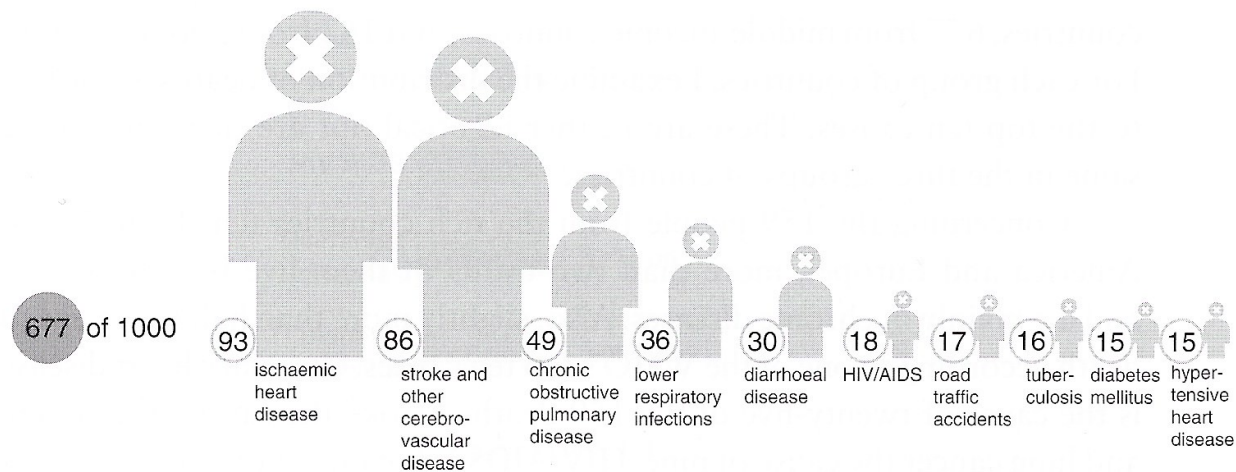
95% confidence interval: [33.2 million – 37.2 million]

Top ten causes of death, 2008

Low-income countries



Middle-income countries



High-income countries

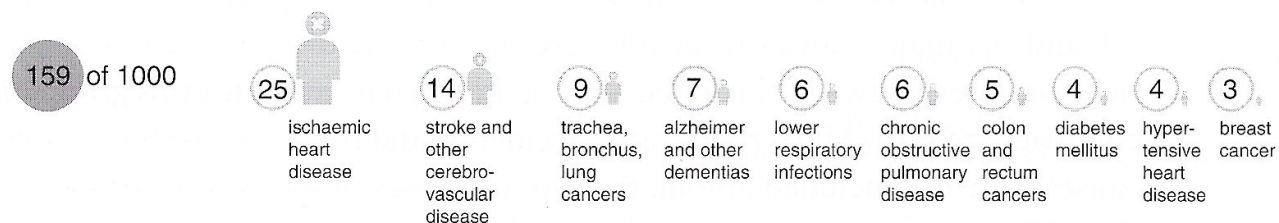
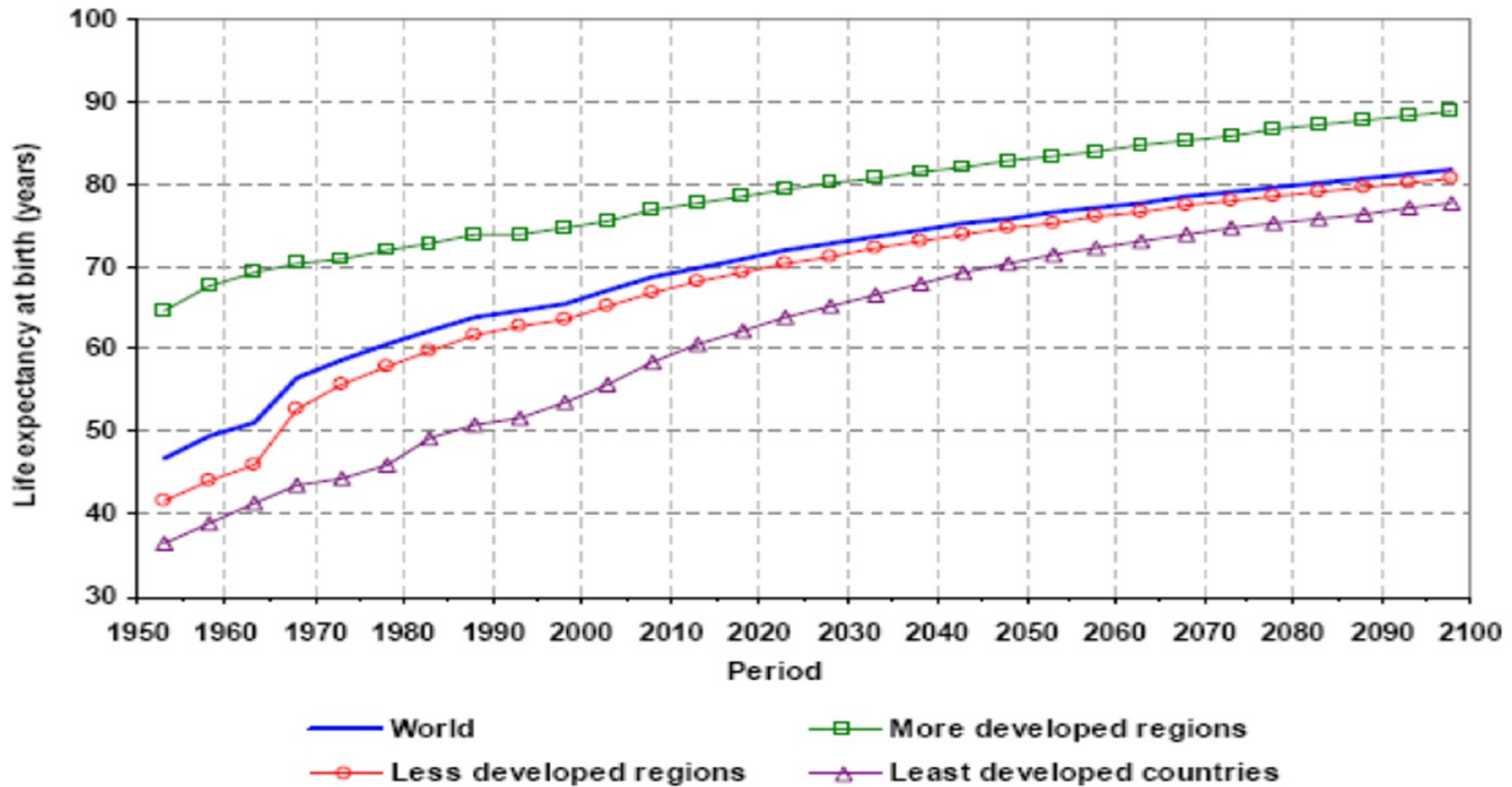
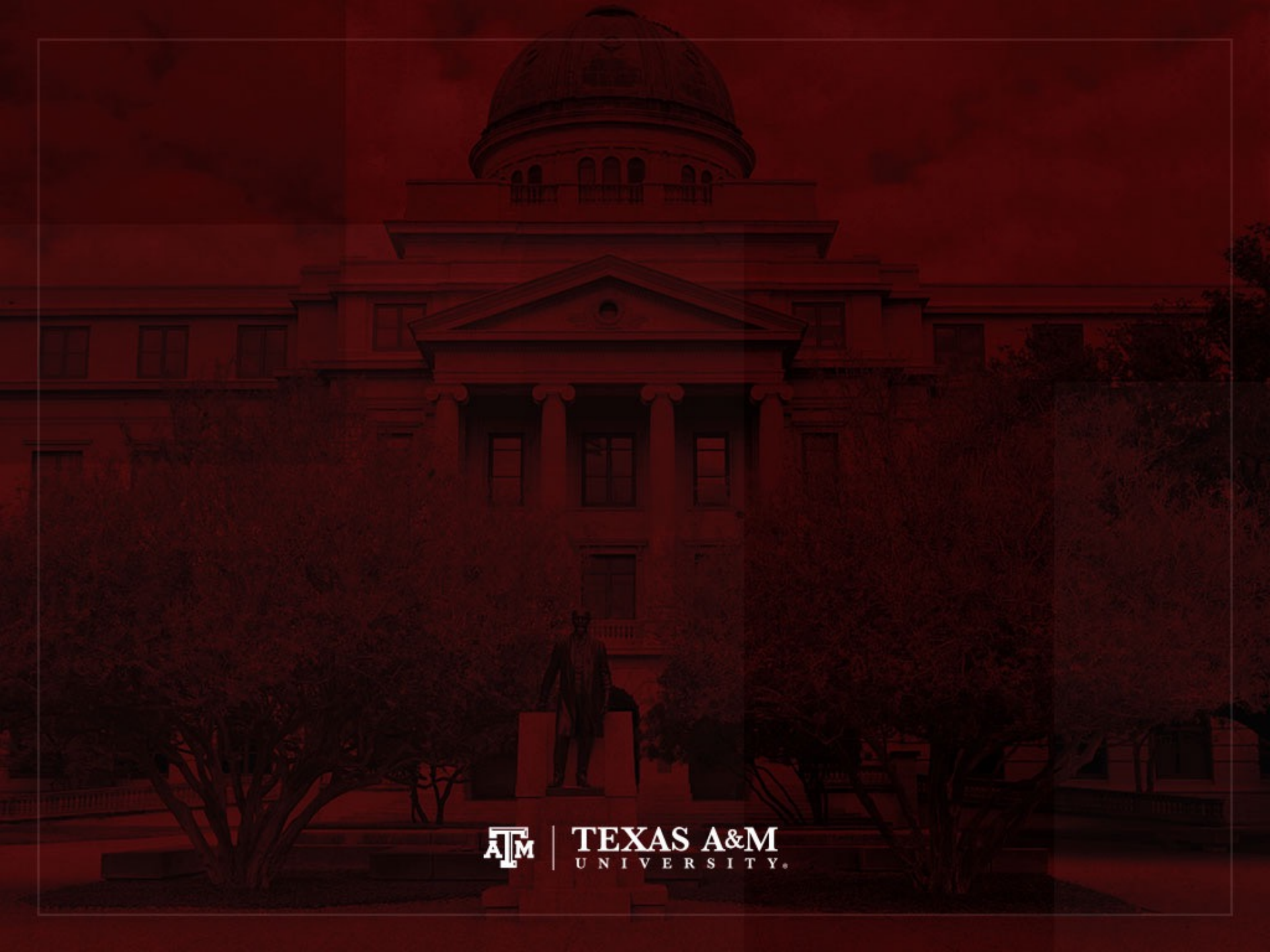


Figure 7.6. Life Expectancy at Birth: World and More developed, Less developed, and Least developed regions, 1950 to 2100



Source: United Nations, 2013d: 16. |



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Mortality and longevity in the U.S.

- Mortality started dropping gradually
 - In response to changes in the socioeconomic conditions and the environment of modernization
 - Much of the mortality reduction started to happen before the initiations of any appreciable public health measures
- Life expectancy increased
 - 46 for males and 48 for females in 1900
 - 76 for males and 81 for females in 2013



Mortality in the United States

- Most improvements happened from 1900 to 1950
 - Germ theory: control of infectious and parasitic diseases
 - Boiling bottles and milk, washing hands, protecting food from flies, isolating sick children, ventilating rooms, improving water supply, sewage disposal
- Since 1950s, life expectancy improvements is due to prevention and control of chronic diseases
 - Heart disease, stroke...

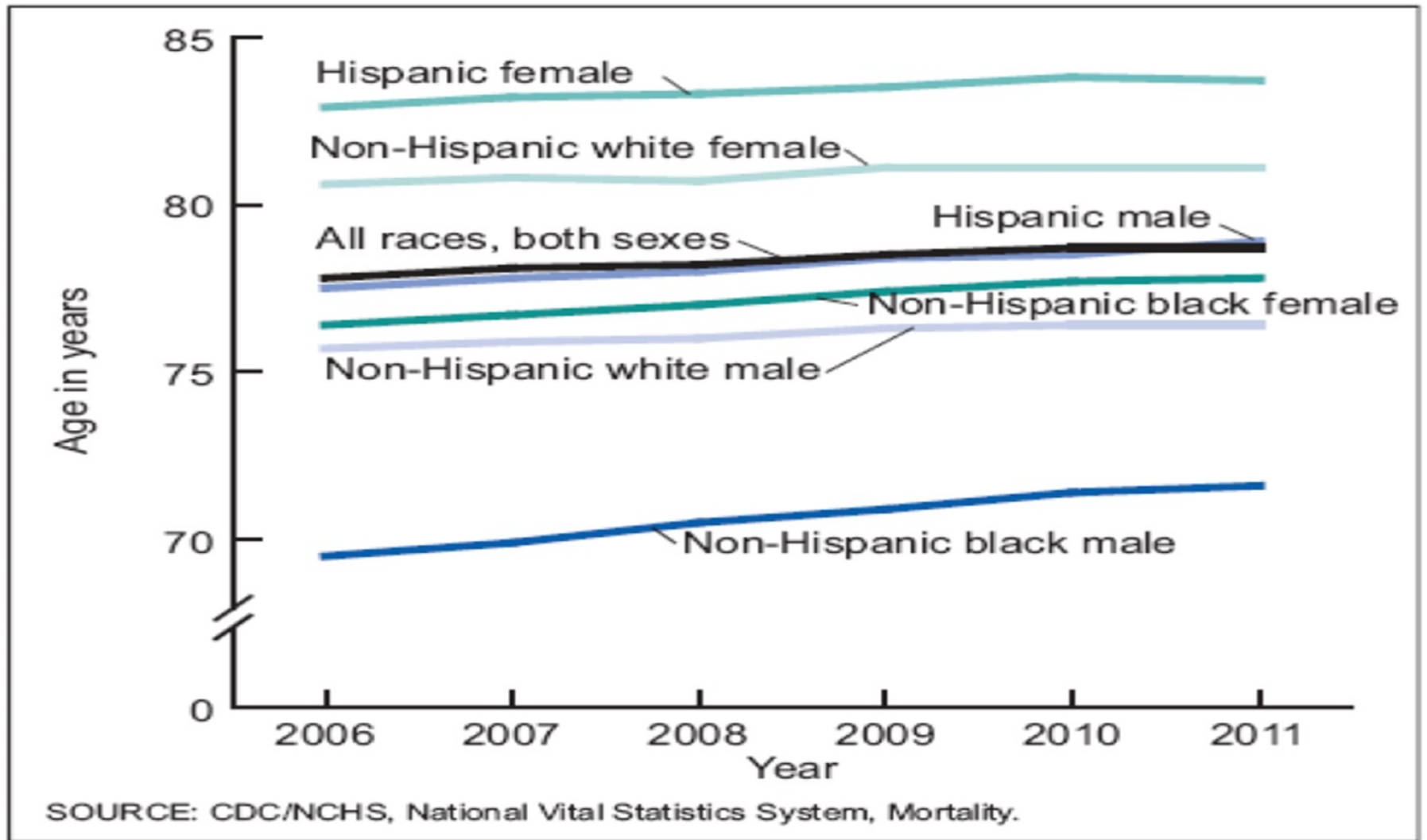


Hispanic paradox

- The Hispanic epidemiological paradox is the empirical finding that Hispanics have death rates of about the same magnitude as, and sometimes lower than, whites
- Also known as the Latino mortality paradox
- These findings are more evident for those of Mexican origin



Life expectancy at birth by race/ethnicity: U.S., 2006–2011



Explaining the Hispanic paradox

- Data artifacts
 - **Underreporting** of Hispanic-origin identification on death certificates
 - **Misstatement of age**, perhaps overstatement, at the older ages
- Migration effects
 - **Healthy migrant effect**: self-selection of immigrants in better physical and mental health
 - **Salmon bias**: Mexican Americans in poor health return to Mexico at old ages (return migrant effect)
- Cultural effects
 - **Better dietary** practices of Latinos and **stronger family** obligations and relationships



Racial crossover

- Life expectancy at birth is the lowest for blacks compared with Hispanics and whites
- For most of their lives, blacks have higher death rates than Hispanics and whites
- The situation changes at the very oldest ages
- By late life, death rates for blacks become lower than those for whites, and in some cases lower than those for Hispanics



Life expectancy at ages 70, 80, 90, and 100 by race/ethnicity and sex: United States, 2010

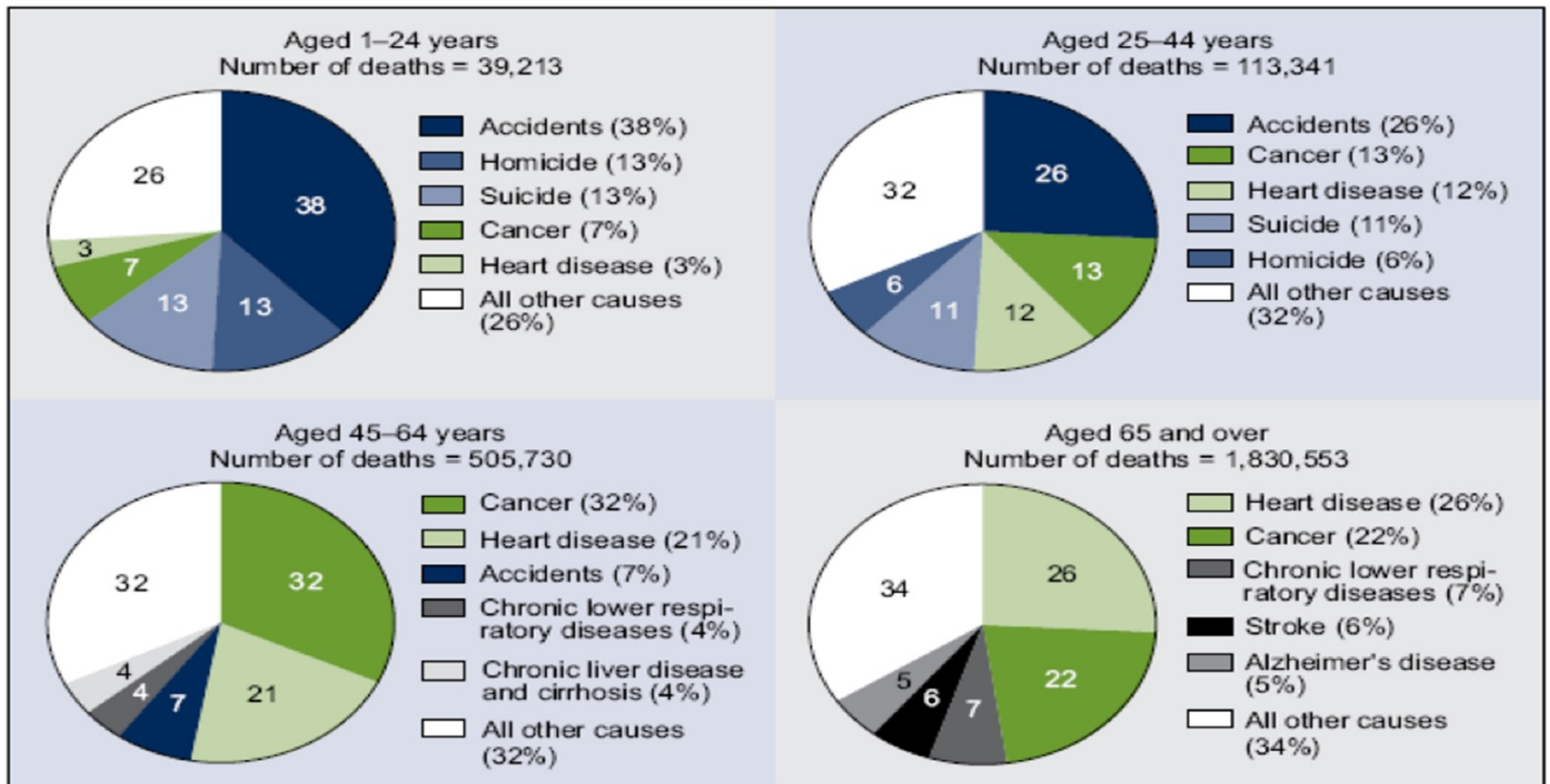
| Age | Hispanics | | NH-Whites | | NH-Blacks | |
|-----|-----------|---------|-----------|---------|-----------|---------|
| | Males | Females | Males | Females | Males | Females |
| 70 | 15.4 | 18.0 | 14.2 | 16.4 | 12.8 | 15.7 |
| 80 | 9.0 | 10.8 | 8.1 | 9.6 | 7.8 | 9.6 |
| 90 | 4.5 | 5.4 | 4.0 | 4.8 | 4.4 | 5.2 |
| 100 | 2.3 | 2.6 | 2.0 | 2.3 | 2.5 | 2.8 |

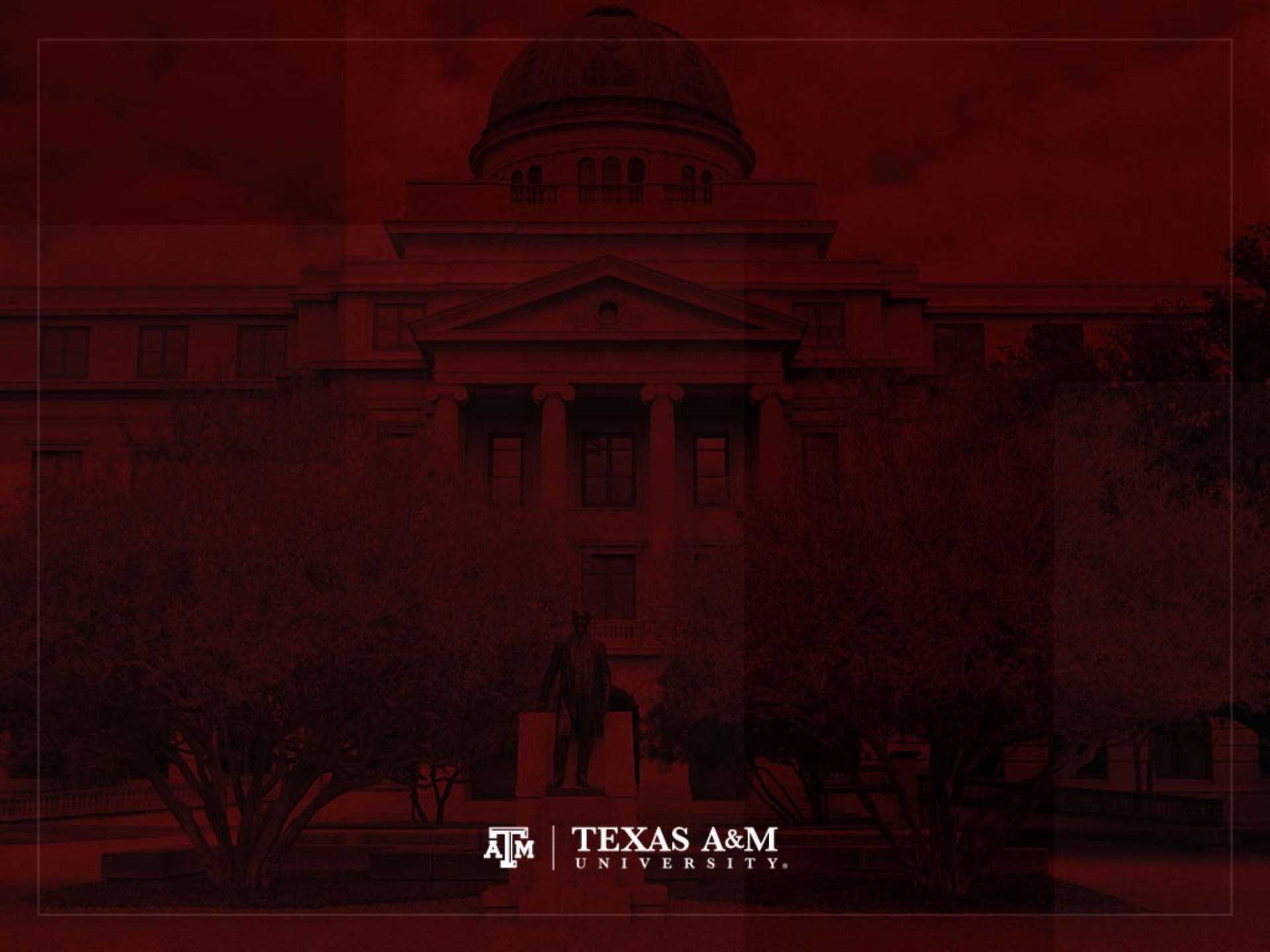
Explaining the racial crossover

- Age misreporting on death certificates
 - Overstatement of age
 - But this would only postpone crossover to later ages, not eliminating it
- Population heterogeneity in frailty
 - The surviving elderly black population is a more robust group of disadvantaged individuals
 - The more frail blacks die before the age of 80 or 90
 - This produces a more robust group of blacks that live longer than the majority



Percent distribution of five leading causes of death by age group: United States, 2011





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Infant mortality

- The infant mortality rate (IMR) is the most common measure of infant death
 - It is the number of deaths in a year to children under age 1 per 1,000 babies born in the year
- Declining infant mortality is key to population growth
- Reduction attributable especially to the development of oral rehydration therapy (ORT)
 - A solution of salts and sugars taken orally
 - Treats diarrhea: A major cause of death in young children
 - Developed in labs, tested in the field, especially Bangladesh
 - One of its founders still holds a teaching position at Harvard School of Public Health (Dr. Richard Cash)



Infant mortality, 2015

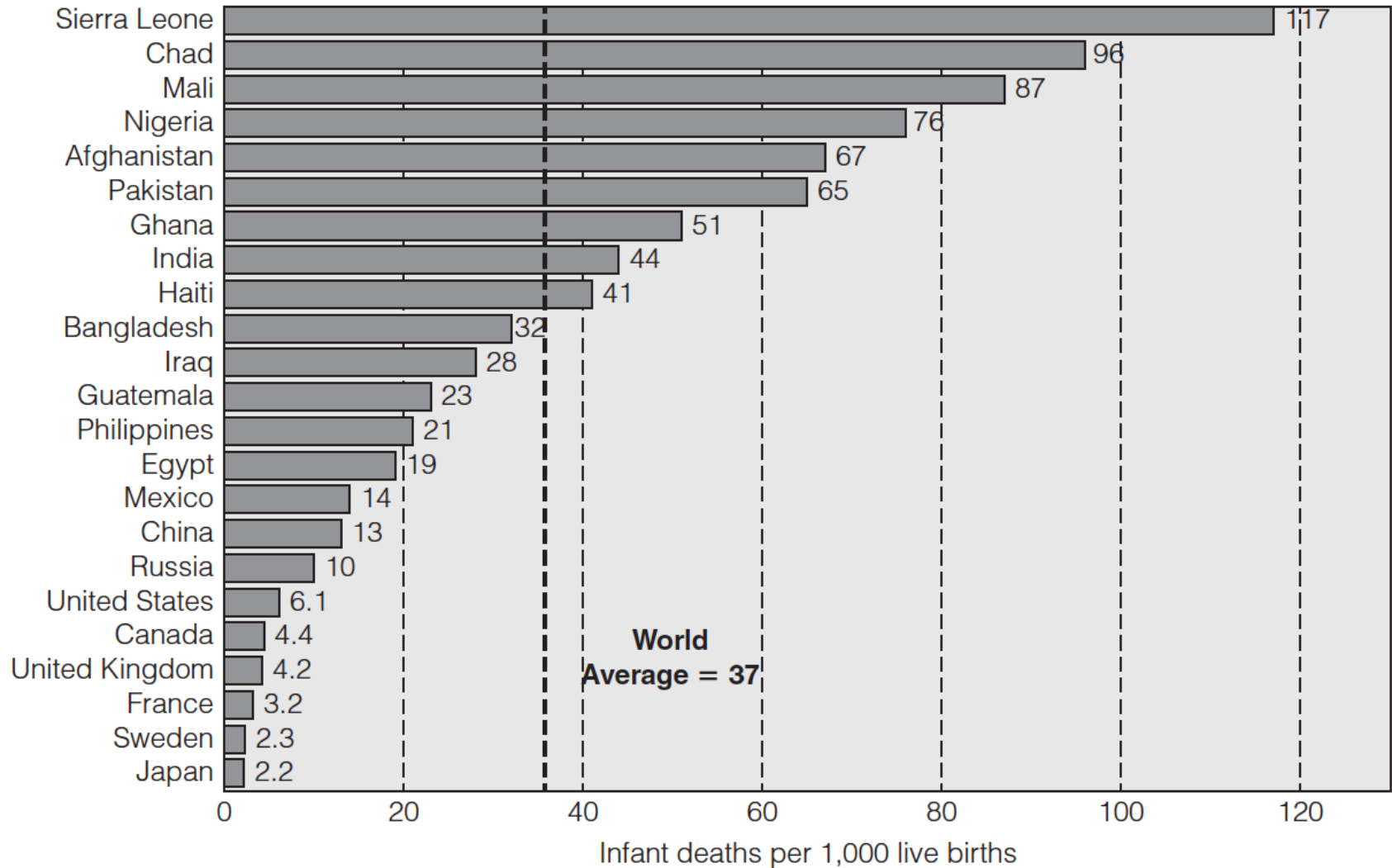
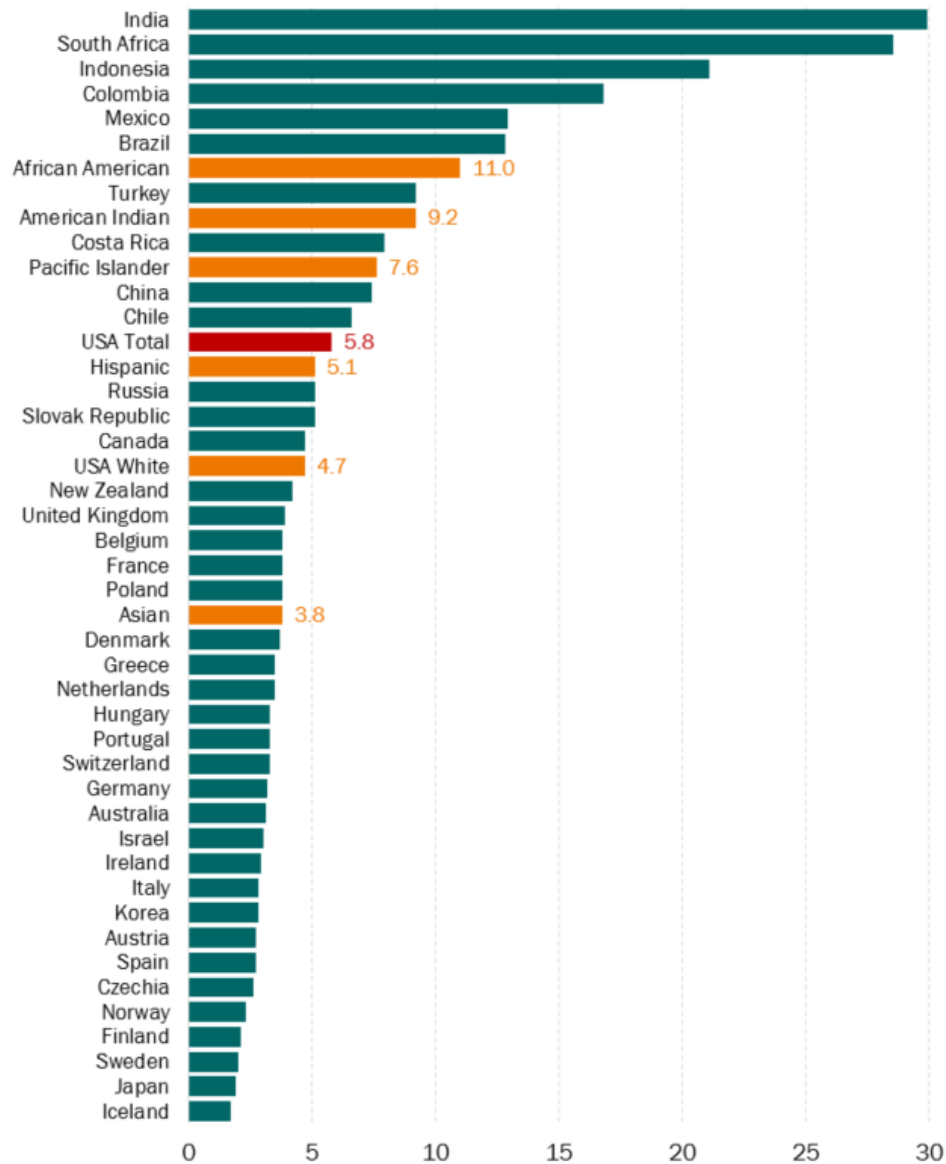


Table 7.4. Countries with the Highest and the Lowest Infant Mortality Rates in the World, 2013

| Highest infant mortality rates | | Lowest infant mortality rates | |
|--------------------------------|-----|-------------------------------|-----|
| Central African Republic | 116 | Iceland | 1.8 |
| Congo, Dem. Rep. | 109 | Finland | 1.8 |
| Chad | 96 | Japan | 1.9 |
| Angola | 96 | Singapore | 2.0 |
| Guinea-Bissau | 94 | Estonia | 2.1 |
| Sierra Leone | 92 | Sweden | 2.3 |

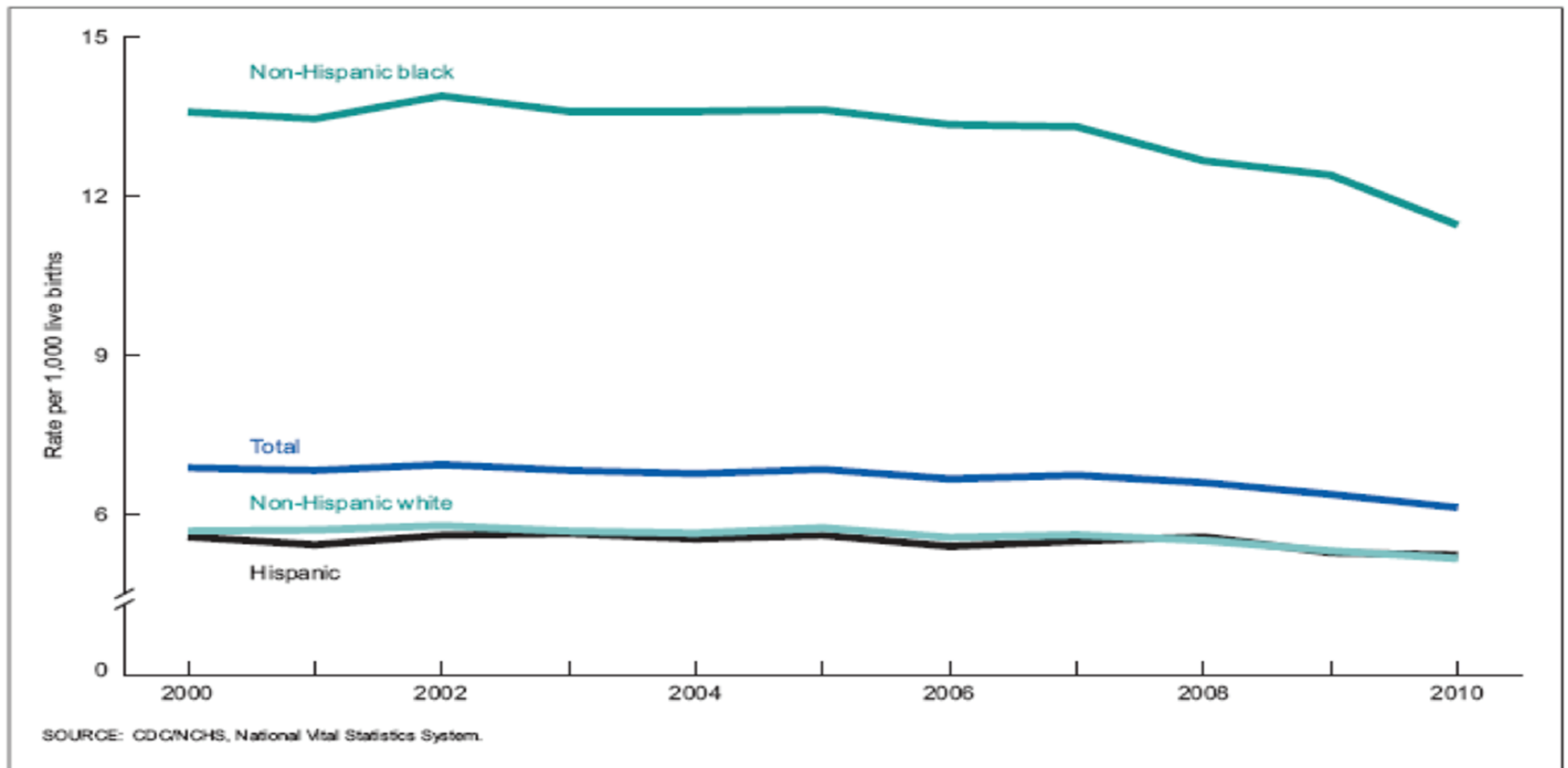
Source: Population Reference Bureau, 2014.

Infant mortality rate in select countries and US race-ethnic groups



Deaths per 1,000 live births. Data for 2018 or 2019 for countries, 2017 for US race-ethnic groups. Except Hispanic, race-ethnic groups are non-Hispanic. PN Cohen chart from OECD and NCHS data.

Infant mortality rates by mother's race/ethnicity: United States, 2000–2010



Neonatal and postneonatal mortality rates

- The infant mortality rate (IMR) may be thought of as the sum of two rates
- Neonatal mortality rate (NMR)
 - Deaths of babies aged 28 days or less per 1,000 live births
- Postneonatal mortality rate (PMR)
 - Deaths of babies aged between 29 days and 1 year per 1,000 live births



Neonatal mortality rates and number of neonatal deaths

| Region | Neonatal mortality rate (deaths per 1,000 live births) | | | Number of neonatal deaths (thousands) | |
|--|---|-----------|-----------------------------------|--|--------------|
| | 1990 | 2013 | Decline (percent) 1990–2013 | 1990 | 2013 |
| Developed regions | 8 | 3 | 55 | 118 | 48 |
| Developing regions | 36 | 22 | 40 | 4,554 | 2,714 |
| Northern Africa | 30 | 13 | 56 | 109 | 53 |
| Sub-Saharan Africa | 46 | 31 | 32 | 977 | 1,066 |
| Latin America and the Caribbean | 22 | 9 | 58 | 255 | 101 |
| Caucasus and Central Asia | 26 | 15 | 42 | 51 | 26 |
| Eastern Asia | 25 | 8 | 69 | 784 | 150 |
| Excluding China | 12 | 8 | 35 | 11 | 7 |
| Southern Asia | 51 | 30 | 42 | 1,940 | 1,086 |
| Excluding India | 49 | 30 | 39 | 578 | 338 |
| South-eastern Asia | 27 | 14 | 47 | 321 | 160 |
| Western Asia | 28 | 14 | 50 | 111 | 67 |
| Oceania | 26 | 21 | 19 | 5 | 6 |
| World | 33 | 20 | 40 | 4,672 | 2,763 |

Endogenous and exogenous

- **Endogenous cause of death** in an infant can occur because of genetic issues or conditions associated with fetal development or the birth process
- **Exogenous cause of death** is due mainly to environmental or external factors, such as infections or accidents



Causes of neonatal deaths

- The main causes of neonatal deaths are **endogenous conditions**
- Congenital malformations, chromosomal abnormalities, complications of delivery, low birthweight, genetic disorders...
- However, endogenous causes dominate infant mortality mainly in the early days of life, and not for the entire first month of life



Causes of postneonatal deaths

- Postneonatal mortality rate was 18 per 1,000 live births for the world in 2013
 - Rate was 2 in developed countries
- Deaths in postneonatal period and in first few years of life are mainly due to **exogenous causes**
 - Infectious disease, accidents, injury
- Improved living standards, better healthcare, and public health programs have greater effects on exogenous causes than on endogenous causes



Stillbirth rate (SBR)

- Stillbirths (miscarriages, fetal deaths)
 - A stillbirth is a fetus not born alive and is not registered as a death
 - SBR: stillbirths per 1,000 live births plus stillbirths in the year
 - Stillbirths are often identified in hospital reports dealing with obstetric procedures
- WHO: interventions can be planned if we know at what point before birth the fetus died
 - 2.6 million stillbirths in the world in 2009
 - 18.9 stillbirths per 1,000 live births plus stillbirths



Perinatal mortality rate (PeMR)

- PeMR relates to stillbirths and deaths of babies who lived for only seven days or less per 1,000 live births plus stillbirths in the year
- **Endogenous** causes of mortality in the 1st week after birth are similar to the causes of stillbirths
- PeMR in 2010
 - World (47)
 - Developed world (10); less developed world (50)
 - Czech Republic and Singapore (4); Mauritania (111)
- U.S.: 6.5 in 2006; 6.3 in 2011



Maternal mortality ratio (MMR)

- MMR measures the extent to which mothers die immediately before, during, or after giving birth because of problems associated with the pregnancy or childbirth
 - **Numerator:** number of deaths in a year of women dying as a result of complications of pregnancy, childbirth, and the puerperium (condition of the woman immediately following childbirth)
 - **Denominator:** live births occurring in the year
 - Multiplied by 100,000, because it is increasingly rare in developed countries



Examples of maternal deaths

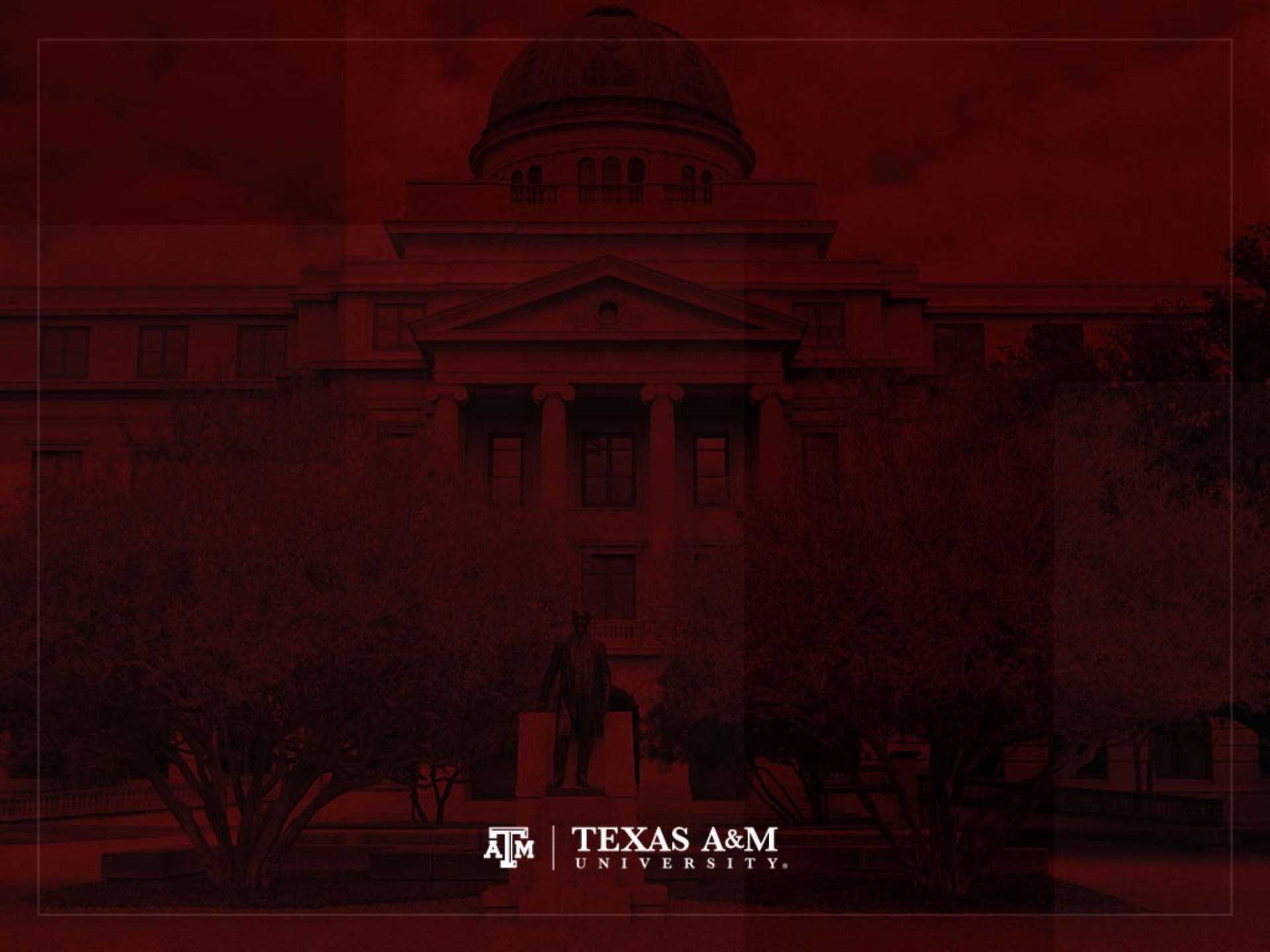
- World
 - 529,000 maternal deaths in 2000
 - 313,000 maternal deaths in 2015
- Developing regions in 2015
 - 99% of all maternal deaths
 - 66% in sub-Saharan Africa
 - 21% in southern Asia
- MMR in 2015
 - World: 216 per 100,000 live births
 - Sierra Leone: 1,360
 - Sub-Saharan Africa: 546
 - U.S., Iran, Hungary: 21
 - Greece, Singapore (3); Estonia (2)



Factors associated with MMR

- Maternal deaths are mostly due to age, parity (number of children), birth spacing
 - Younger and older women are more likely, compared to women in their 20s and 30s
 - High-parity women are at high risk
 - Women with short birth intervals are also at high risk
- Other factors
 - Chronic disease and malnutrition, poverty, unwanted pregnancies, inadequate prenatal and obstetric care, lack of access to a hospital





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Future course of mortality

- Is it likely that mortality rates will continue to fall resulting in even higher levels of life expectancy than those attained by developed countries?
- There are two positions
 - One argues for a limit
 - The other argues against one
- Poston argues against a fixed biological maximum life expectancy (more optimistic view)



Mortality reversals

- Modern medical and public health techniques will surely bring about further reductions in mortality from the major causes
- However, there is evidence since the early 1980s of mortality reversals
 - First in Eastern Europe
 - Later in sub-Saharan Africa



Eastern Europe

- What is causing mortality reversals in Eastern Europe?
- Possible factors include
 - Lack of preventative health programs
 - Inadequate quality of medical services
 - Smoking and alcohol abuse
 - General neglect of individual health
- These were caused by
 - Lack of life choices under the former communist regimes
 - Unemployment, relative deprivation, and inability to cope with economic challenges of the capitalist regime



Sub-Saharan Africa

- The AIDS epidemic has halted or reversed gains in life expectancy in many of the sub-Saharan African countries

Degenerative diseases

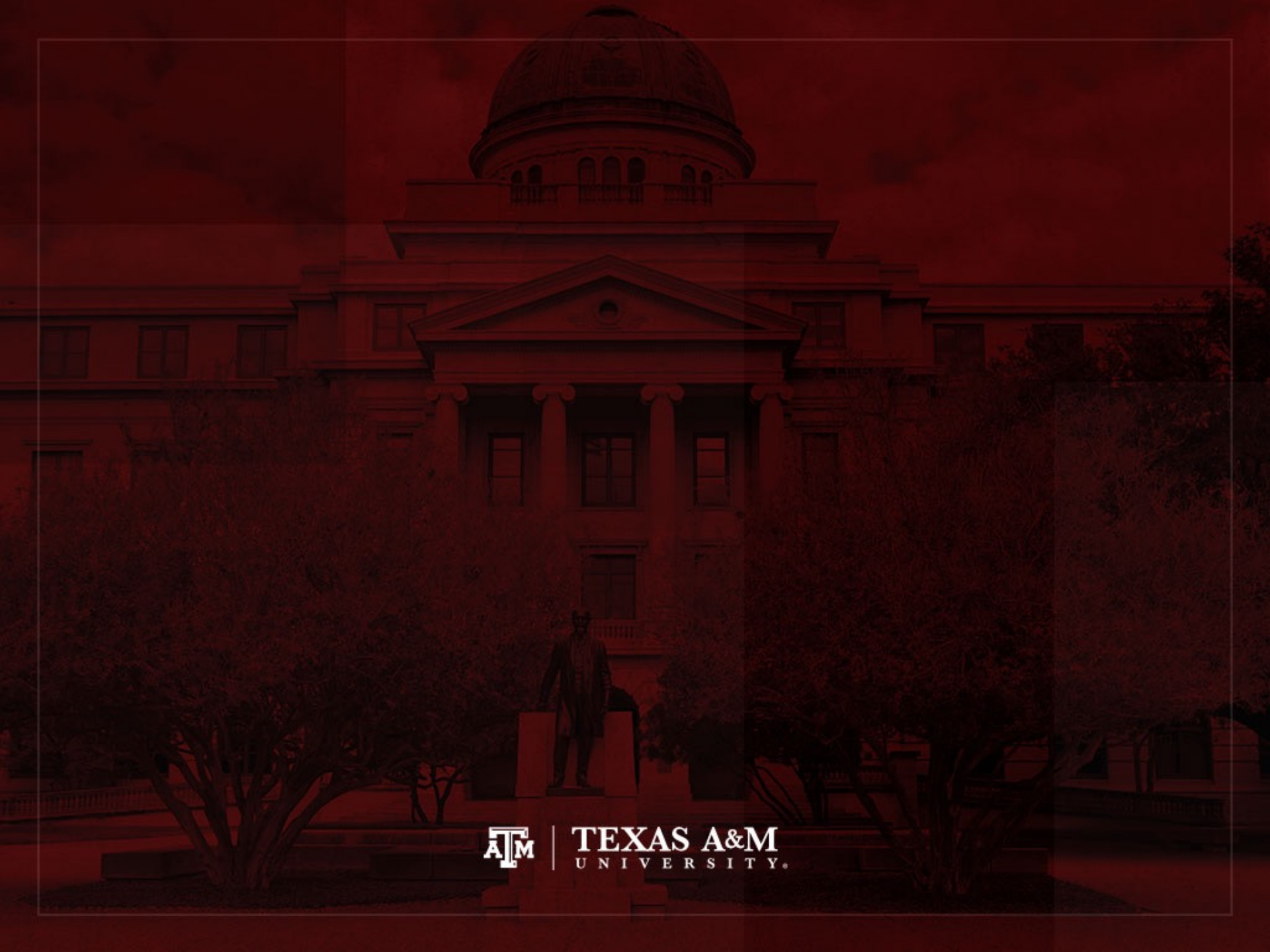
- Degenerative diseases are the major causes of death in the developed world
- Future improvements in the treatment of these diseases is likely
 - However, eliminating a specific degenerative disease would result in small increases to life expectancy because these diseases occur to older individuals
 - Eliminating heart disease would raise life expectancy in the U.S. by 5 years, and eliminating cancer would raise it by 3 years



Important question

- The important question is not “will life expectancy increase?”
- The important question is “by how much will life expectancy increase?”





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Coronavirus pandemic, August 24, 2020

| # | Country, Other | Total Cases | New Cases | Total Deaths | New Deaths | Total Recovered | Active Cases | Serious, Critical | Tot Cases/ 1M pop | Deaths/ 1M pop | Total Tests | Tests/ 1M pop | Population |
|----|------------------------------|-------------|-----------|--------------|------------|-----------------|--------------|-------------------|-------------------|----------------|-------------|---------------|---------------|
| | World | 23,809,061 | +6,189 | 817,005 | +431 | 16,358,235 | 6,633,821 | 61,715 | 3,054 | 104.8 | | | |
| 1 | USA | 5,915,630 | | 181,114 | | 3,217,981 | 2,516,535 | 16,483 | 17,856 | 547 | 76,883,479 | 232,071 | 331,293,410 |
| 2 | Brazil | 3,627,217 | | 115,451 | | 2,778,709 | 733,057 | 8,318 | 17,046 | 543 | 14,144,344 | 66,473 | 212,784,888 |
| 3 | Mexico | 563,705 | +3,541 | 60,800 | +320 | 389,124 | 113,781 | 3,346 | 4,365 | 471 | 1,263,835 | 9,787 | 129,132,739 |
| 4 | India | 3,164,881 | | 58,546 | | 2,403,101 | 703,234 | 8,944 | 2,290 | 42 | 35,902,137 | 25,978 | 1,382,011,722 |
| 5 | UK | 326,614 | | 41,433 | | N/A | N/A | 72 | 4,807 | 610 | 15,177,265 | 223,394 | 67,939,531 |
| 6 | Italy | 260,298 | | 35,441 | | 205,662 | 19,195 | 65 | 4,306 | 586 | 8,053,551 | 133,231 | 60,448,212 |
| 7 | France | 244,854 | | 30,528 | | 85,199 | 129,127 | 399 | 3,750 | 468 | 6,000,000 | 91,890 | 65,295,389 |
| 8 | Spain | 420,809 | | 28,872 | | N/A | N/A | 658 | 9,000 | 617 | 8,517,446 | 182,162 | 46,757,536 |
| 9 | Peru | 600,438 | | 27,813 | | 407,301 | 165,324 | 1,525 | 18,174 | 842 | 3,006,993 | 91,014 | 33,038,913 |
| 10 | Iran | 361,150 | | 20,776 | | 311,365 | 29,009 | 3,848 | 4,292 | 247 | 3,062,422 | 36,392 | 84,150,494 |
| 11 | Colombia | 551,696 | | 17,612 | | 384,171 | 149,913 | 1,493 | 10,825 | 346 | 2,508,972 | 49,231 | 50,962,919 |
| 12 | Russia | 961,493 | | 16,448 | | 773,095 | 171,950 | 2,300 | 6,588 | 113 | 34,600,000 | 237,077 | 145,943,991 |
| 13 | South Africa | 611,450 | | 13,159 | | 516,494 | 81,797 | 539 | 10,291 | 221 | 3,564,065 | 59,983 | 59,418,339 |
| 14 | Chile | 399,568 | | 10,916 | | 372,464 | 16,188 | 1,014 | 20,875 | 570 | 2,231,463 | 116,583 | 19,140,575 |
| 15 | Belgium | 82,092 | +156 | 9,996 | +4 | 18,242 | 53,854 | 89 | 7,079 | 862 | 2,144,563 | 184,921 | 11,597,214 |
| 16 | Germany | 236,117 | | 9,336 | | 209,600 | 17,181 | 245 | 2,817 | 111 | 10,197,366 | 121,652 | 83,824,401 |
| 17 | Canada | 125,647 | | 9,083 | | 111,694 | 4,870 | 62 | 3,325 | 240 | 5,169,166 | 136,782 | 37,791,278 |
| 18 | Argentina | 350,867 | | 7,366 | | 256,789 | 86,712 | 1,960 | 7,753 | 163 | 1,105,878 | 24,435 | 45,257,261 |
| 19 | Indonesia | 155,412 | | 6,759 | | 111,060 | 37,593 | | 567 | 25 | 2,056,166 | 7,506 | 273,950,524 |
| 20 | Iraq | 207,985 | | 6,519 | | 150,389 | 51,077 | 661 | 5,154 | 162 | 1,457,665 | 36,125 | 40,350,522 |

Source: <https://www.worldometers.info/coronavirus/>.

Coronavirus pandemic, January 19, 2021

| # | Country, Other | Total Cases | New Cases | Total Deaths | New Deaths | Total Recovered | Active Cases | Serious, Critical | Tot Cases/ 1M pop | Deaths/ 1M pop | Total Tests | Tests/ 1M pop | Population |
|----|------------------------------|-------------|-----------|--------------|------------|-----------------|--------------|-------------------|-------------------|----------------|-------------|---------------|---------------|
| | World | 96,237,790 | +232,850 | 2,055,893 | +6,897 | 68,851,713 | 25,330,184 | 111,938 | 12,346 | 263.8 | | | |
| 1 | USA | 24,644,355 | +17,914 | 408,858 | +235 | 14,557,408 | 9,678,089 | 28,543 | 74,214 | 1,231 | 287,821,421 | 866,745 | 332,071,530 |
| 2 | Brazil | 8,523,635 | +11,397 | 210,404 | +76 | 7,452,047 | 861,184 | 8,318 | 39,944 | 986 | 28,600,000 | 134,026 | 213,390,822 |
| 3 | India | 10,596,107 | +13,460 | 152,743 | +150 | 10,244,677 | 198,687 | 8,944 | 7,637 | 110 | 187,802,827 | 135,358 | 1,387,456,647 |
| 4 | Mexico | 1,649,502 | +8,074 | 141,248 | +544 | 1,237,321 | 270,933 | 5,359 | 12,720 | 1,089 | 4,139,021 | 31,918 | 129,676,467 |
| 5 | UK | 3,466,849 | +33,355 | 91,470 | +1,610 | 1,546,575 | 1,828,804 | 3,916 | 50,921 | 1,344 | 65,263,737 | 958,598 | 68,082,466 |
| 6 | Italy | 2,400,598 | +10,497 | 83,157 | +603 | 1,781,917 | 535,524 | 2,487 | 39,737 | 1,376 | 29,619,436 | 490,285 | 60,412,645 |
| 7 | France | 2,914,725 | | 70,686 | | 210,200 | 2,633,839 | 2,813 | 44,600 | 1,082 | 40,217,159 | 615,381 | 65,353,232 |
| 8 | Russia | 3,612,800 | +21,734 | 66,623 | +586 | 3,002,026 | 544,151 | 2,300 | 24,750 | 456 | 97,300,000 | 666,580 | 145,969,038 |
| 9 | Iran | 1,342,134 | +5,917 | 56,973 | +87 | 1,131,883 | 153,278 | 4,272 | 15,868 | 674 | 8,634,553 | 102,085 | 84,582,271 |
| 10 | Spain | 2,336,451 | | 53,769 | | N/A | N/A | 3,287 | 49,962 | 1,150 | 30,165,217 | 645,041 | 46,764,785 |
| 11 | Colombia | 1,923,132 | | 49,004 | | 1,754,222 | 119,906 | 3,482 | 37,575 | 957 | 9,188,440 | 179,530 | 51,180,617 |
| 12 | Germany | 2,062,450 | +3,136 | 48,505 | +400 | 1,716,200 | 297,745 | 5,074 | 24,573 | 578 | 36,353,196 | 433,128 | 83,931,720 |
| 13 | Argentina | 1,807,428 | | 45,832 | | 1,594,768 | 166,828 | 3,564 | 39,790 | 1,009 | 5,592,646 | 123,122 | 45,423,669 |
| 14 | Peru | 1,068,802 | | 38,931 | | 984,726 | 45,145 | 1,670 | 32,170 | 1,172 | 5,901,809 | 177,640 | 33,223,435 |
| 15 | South Africa | 1,346,936 | | 37,449 | | 1,117,452 | 192,035 | 546 | 22,555 | 627 | 7,653,371 | 128,157 | 59,718,648 |
| 16 | Poland | 1,443,804 | +4,835 | 33,698 | +291 | 1,197,034 | 213,072 | 1,582 | 38,172 | 891 | 8,143,530 | 215,302 | 37,823,686 |
| 17 | Indonesia | 927,380 | +10,365 | 26,590 | +308 | 753,948 | 146,842 | | 3,371 | 97 | 8,433,961 | 30,657 | 275,111,495 |
| 18 | Turkey | 2,392,963 | | 24,161 | | 2,270,769 | 98,033 | 2,183 | 28,207 | 285 | 27,523,423 | 324,426 | 84,837,235 |
| 19 | Ukraine | 1,167,655 | +3,939 | 21,046 | +177 | 886,248 | 260,361 | 177 | 26,788 | 483 | 5,983,122 | 137,265 | 43,588,032 |
| 20 | Belgium | 679,771 | +932 | 20,472 | +37 | 46,959 | 612,340 | 352 | 58,513 | 1,762 | 7,620,430 | 655,948 | 11,617,426 |

Coronavirus pandemic, August 31, 2021

| # | Country, Other | Total Cases | New Cases | Total Deaths | New Deaths | Total Recovered | New Recovered | Active Cases | Serious, Critical | Tot Cases/ 1M pop | Deaths/ 1M pop | Total Tests | Tests/ 1M pop | Population |
|----|------------------------------|-------------|-----------|--------------|------------|-----------------|---------------|--------------|-------------------|-------------------|----------------|-------------|---------------|---------------|
| | World | 218,171,757 | +278,500 | 4,527,970 | +4,700 | 195,040,717 | +304,214 | 18,603,070 | 113,811 | 27,989 | 580.9 | | | |
| 1 | USA | 39,953,651 | +6,943 | 656,482 | +89 | 30,945,115 | +650 | 8,352,054 | 25,541 | 119,888 | 1,970 | 582,550,800 | 1,748,051 | 333,257,237 |
| 2 | Brazil | 20,752,281 | | 579,643 | | 19,692,898 | | 479,740 | 8,318 | 96,831 | 2,705 | 56,897,224 | 265,485 | 214,314,149 |
| 3 | India | 32,808,018 | +40,198 | 438,962 | +370 | 31,982,180 | +29,967 | 386,876 | 8,944 | 23,506 | 314 | 521,541,098 | 373,663 | 1,395,753,675 |
| 4 | Mexico | 3,341,264 | +5,564 | 258,491 | +326 | 2,686,568 | +16,627 | 396,205 | 4,798 | 25,603 | 1,981 | 9,723,416 | 74,506 | 130,505,007 |
| 5 | Peru | 2,149,591 | | 198,263 | | N/A | N/A | N/A | 1,333 | 64,158 | 5,917 | 16,733,426 | 499,437 | 33,504,611 |
| 6 | Russia | 6,918,965 | +17,813 | 183,224 | +795 | 6,181,054 | +18,624 | 554,687 | 2,300 | 47,388 | 1,255 | 178,700,000 | 1,223,912 | 146,007,206 |
| 7 | Indonesia | 4,089,801 | +10,534 | 133,023 | +532 | 3,760,497 | +16,781 | 196,281 | | 14,771 | 480 | 32,216,075 | 116,354 | 276,880,593 |
| 8 | UK | 6,757,650 | | 132,485 | | 5,427,062 | | 1,198,103 | 982 | 98,940 | 1,940 | 266,714,771 | 3,905,032 | 68,300,272 |
| 9 | Italy | 4,534,499 | | 129,146 | | 4,263,960 | | 141,393 | 548 | 75,126 | 2,140 | 83,728,076 | 1,387,181 | 60,358,447 |
| 10 | Colombia | 4,907,264 | | 124,883 | | 4,737,467 | | 44,914 | 8,155 | 95,264 | 2,424 | 24,121,717 | 468,271 | 51,512,348 |
| 11 | France | 6,746,283 | | 114,308 | | 6,225,201 | | 406,774 | 2,270 | 103,089 | 1,747 | 124,769,146 | 1,906,579 | 65,441,374 |
| 12 | Argentina | 5,178,889 | | 111,607 | | 4,869,104 | | 198,178 | 2,713 | 113,380 | 2,443 | 22,017,526 | 482,024 | 45,677,243 |
| 13 | Iran | 4,992,063 | +31,319 | 107,794 | +643 | 4,205,927 | +30,522 | 678,342 | 7,879 | 58,565 | 1,265 | 28,213,229 | 330,985 | 85,240,218 |
| 14 | Germany | 3,950,247 | +3,231 | 92,682 | +11 | 3,738,000 | +6,100 | 119,565 | 1,096 | 46,973 | 1,102 | 68,329,706 | 812,527 | 84,095,254 |
| 15 | Spain | 4,847,298 | | 84,146 | | 4,338,145 | | 425,007 | 1,685 | 103,628 | 1,799 | 60,618,810 | 1,295,943 | 46,775,830 |
| 16 | South Africa | 2,770,575 | | 81,830 | | 2,533,956 | | 154,789 | 546 | 46,041 | 1,360 | 16,426,011 | 272,965 | 60,176,262 |
| 17 | Poland | 2,888,670 | +285 | 75,345 | +5 | 2,657,084 | +30 | 156,241 | 60 | 76,423 | 1,993 | 19,778,356 | 523,259 | 37,798,415 |
| 18 | Turkey | 6,366,438 | | 56,458 | | 5,823,111 | | 486,869 | 633 | 74,555 | 661 | 76,140,298 | 891,652 | 85,392,352 |
| 19 | Ukraine | 2,286,296 | +1,356 | 53,789 | +51 | 2,207,940 | +1,257 | 24,567 | 177 | 52,646 | 1,239 | 11,980,323 | 275,866 | 43,428,075 |
| 20 | Chile | 1,638,675 | +345 | 36,937 | +14 | 1,595,747 | +577 | 5,991 | 687 | 84,876 | 1,913 | 20,276,691 | 1,050,240 | 19,306,720 |

Source: <https://www.worldometers.info/coronavirus/>.

Coronavirus pandemic, January 17, 2022

| # | Country, Other | Total Cases | New Cases | Total Deaths | New Deaths | Total Recovered | New Recovered | Active Cases | Serious, Critical | Tot Cases/ 1M pop | Deaths/ 1M pop | Total Tests | Tests/ 1M pop | Population |
|----|------------------------------|-------------|-----------|--------------|------------|-----------------|---------------|--------------|-------------------|-------------------|----------------|-------------|---------------|---------------|
| | World | 331,459,057 | +138,304 | 5,563,652 | +219 | 269,090,164 | +64,428 | 56,805,241 | 97,247 | 42,523 | 713.8 | | | |
| 1 | USA | 67,631,191 | | 874,321 | | 43,165,667 | | 23,591,203 | 25,869 | 202,490 | 2,618 | 862,458,737 | 2,582,225 | 333,998,303 |
| 2 | Brazil | 23,083,297 | | 621,261 | | 21,710,831 | | 751,205 | 8,318 | 107,419 | 2,891 | 63,776,166 | 296,783 | 214,891,229 |
| 3 | India | 37,618,271 | | 486,784 | | 35,394,882 | | 1,736,605 | 8,944 | 26,852 | 347 | 705,411,425 | 503,527 | 1,400,939,318 |
| 4 | Russia | 10,834,260 | | 321,990 | | 9,878,371 | | 633,899 | 2,300 | 74,191 | 2,205 | 246,800,000 | 1,690,051 | 146,031,061 |
| 5 | Mexico | 4,385,415 | +17,101 | 301,469 | +59 | 3,478,130 | +34,246 | 605,816 | 4,798 | 33,471 | 2,301 | 13,163,932 | 100,471 | 131,022,844 |
| 6 | Peru | 2,606,126 | | 203,464 | | N/A | N/A | N/A | 1,038 | 77,378 | 6,041 | 23,289,858 | 691,497 | 33,680,346 |
| 7 | UK | 15,305,410 | | 152,075 | | 11,497,602 | | 3,655,733 | 746 | 223,644 | 2,222 | 434,073,111 | 6,342,723 | 68,436,401 |
| 8 | Indonesia | 4,272,421 | | 144,174 | | 4,119,472 | | 8,775 | | 15,369 | 519 | 67,715,434 | 243,593 | 277,986,279 |
| 9 | Italy | 8,790,302 | | 141,391 | | 6,093,633 | | 2,555,278 | 1,717 | 145,717 | 2,344 | 156,338,495 | 2,591,622 | 60,324,574 |
| 10 | Iran | 6,224,196 | | 132,095 | | 6,066,819 | | 25,282 | 1,313 | 72,669 | 1,542 | 42,908,102 | 500,962 | 85,651,435 |
| 11 | Colombia | 5,568,068 | | 131,130 | | 5,258,204 | | 178,734 | 342 | 107,659 | 2,535 | 31,171,683 | 602,704 | 51,719,680 |
| 12 | France | 14,274,528 | | 127,263 | | 9,198,995 | | 4,948,270 | 3,895 | 217,943 | 1,943 | 211,520,605 | 3,229,497 | 65,496,464 |
| 13 | Argentina | 7,197,323 | | 118,231 | | 6,193,473 | | 885,619 | 2,099 | 157,024 | 2,579 | 30,753,911 | 670,959 | 45,835,727 |
| 14 | Germany | 8,045,348 | | 116,411 | | 7,000,000 | | 928,937 | 3,212 | 95,553 | 1,383 | 89,622,218 | 1,064,429 | 84,197,463 |
| 15 | Poland | 4,323,482 | | 102,309 | | 3,800,051 | | 421,122 | 1,519 | 114,430 | 2,708 | 28,591,765 | 756,744 | 37,782,620 |
| 16 | Ukraine | 3,759,530 | | 98,361 | | 3,556,162 | | 105,007 | 177 | 86,769 | 2,270 | 17,182,817 | 396,574 | 43,328,102 |
| 17 | South Africa | 3,560,921 | | 93,451 | | 3,375,859 | | 91,611 | 546 | 58,895 | 1,546 | 21,815,463 | 360,811 | 60,462,270 |
| 18 | Spain | 8,424,503 | | 90,993 | | 5,331,175 | | 3,002,335 | 2,251 | 180,077 | 1,945 | 66,213,858 | 1,415,348 | 46,782,734 |
| 19 | Turkey | 10,522,099 | | 84,920 | | 9,737,610 | | 699,569 | 1,128 | 122,722 | 990 | 125,433,490 | 1,462,964 | 85,739,301 |
| 20 | Romania | 1,911,546 | | 59,257 | | 1,776,122 | | 76,167 | 485 | 100,399 | 3,112 | 17,974,573 | 944,065 | 19,039,551 |

Coronavirus pandemic, March 29, 2022

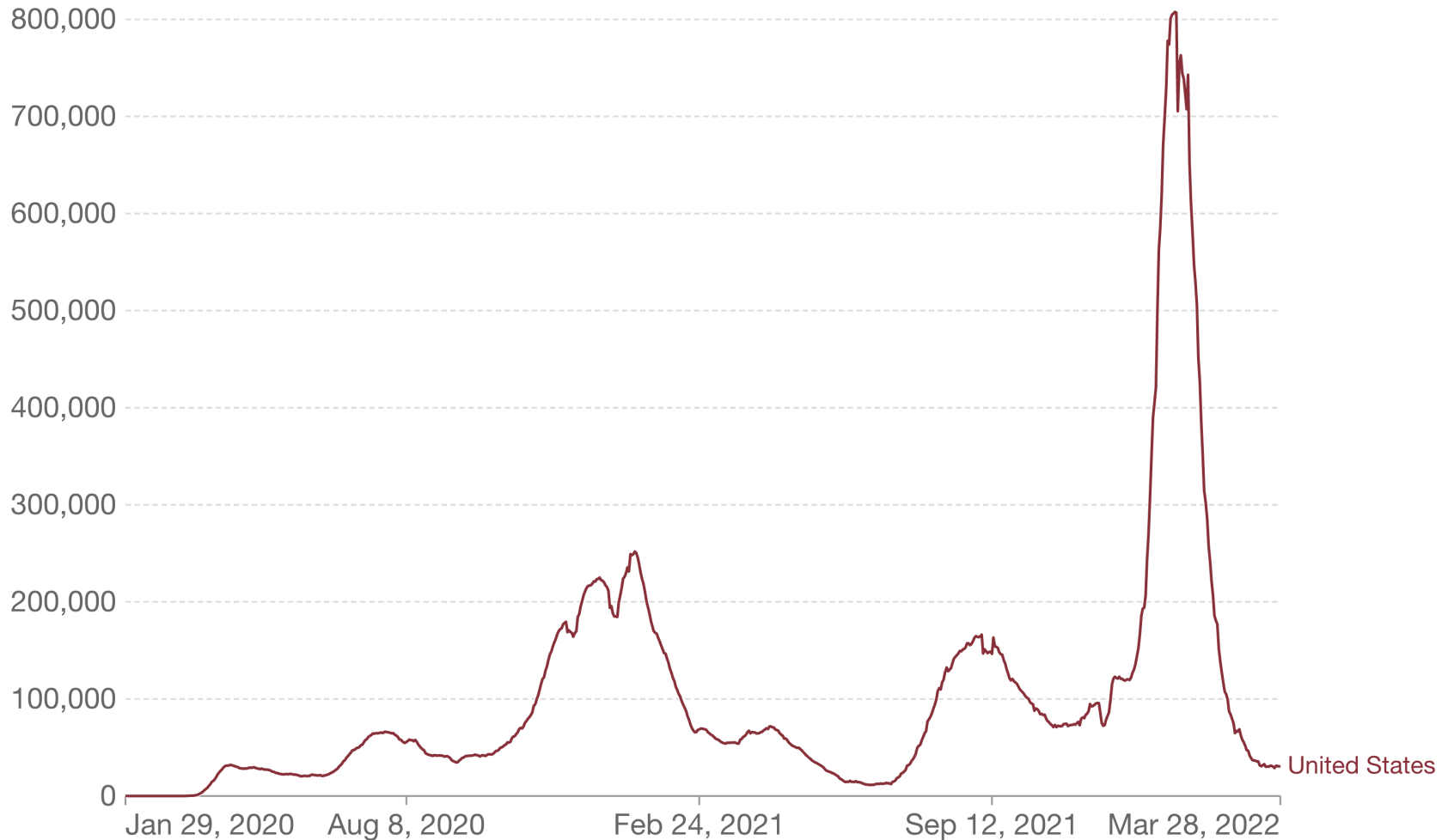
| # | Country, Other | Total Cases | New Cases | Total Deaths | New Deaths | Total Recovered | New Recovered | Active Cases | Serious, Critical | Tot Cases/ 1M pop | Deaths/ 1M pop | Total Tests | Tests/ 1M pop | Population |
|----|------------------------------|-------------|-----------|--------------|------------|-----------------|---------------|--------------|-------------------|-------------------|----------------|-------------|---------------|---------------|
| | World | 484,149,715 | +825,872 | 6,153,482 | +1,827 | 418,238,579 | +562,422 | 59,757,654 | 58,264 | 62,112 | 789.4 | | | |
| 1 | USA | 81,658,973 | | 1,004,244 | | 64,683,169 | | 15,971,560 | 2,270 | 244,218 | 3,003 | 979,700,827 | 2,930,000 | 334,368,837 |
| 2 | Brazil | 29,852,341 | | 659,012 | | 28,550,311 | | 643,018 | 8,318 | 138,732 | 3,063 | 63,776,166 | 296,386 | 215,179,769 |
| 3 | India | 43,021,982 | | 521,098 | | 42,485,534 | | 15,350 | 8,944 | 30,653 | 371 | 787,355,354 | 560,981 | 1,403,532,139 |
| 4 | Russia | 17,803,503 | +19,660 | 368,025 | +339 | 16,737,206 | +47,229 | 698,272 | 2,300 | 121,906 | 2,520 | 273,400,000 | 1,872,052 | 146,042,988 |
| 5 | Mexico | 5,651,553 | +657 | 322,761 | +11 | 4,950,686 | +1,775 | 378,106 | 4,798 | 43,049 | 2,459 | 15,527,815 | 118,279 | 131,281,762 |
| 6 | Peru | 3,545,628 | | 212,157 | | N/A | N/A | N/A | 492 | 104,999 | 6,283 | 28,614,628 | 847,384 | 33,768,214 |
| 7 | UK | 20,905,515 | | 164,671 | | 18,903,733 | | 1,837,111 | 302 | 305,170 | 2,404 | 500,714,605 | 7,309,226 | 68,504,466 |
| 8 | Italy | 14,396,283 | | 158,877 | | 12,983,350 | | 1,254,056 | 487 | 238,714 | 2,634 | 199,235,675 | 3,303,656 | 60,307,637 |
| 9 | Indonesia | 6,005,646 | +3,895 | 154,882 | +108 | 5,735,055 | +10,092 | 115,709 | 2,771 | 21,561 | 556 | 91,760,483 | 329,435 | 278,539,122 |
| 10 | France | 25,059,028 | | 141,821 | | 23,023,051 | | 1,894,156 | 1,486 | 382,440 | 2,164 | 254,106,036 | 3,878,060 | 65,524,008 |
| 11 | Iran | 7,156,746 | +2,743 | 140,109 | +46 | 6,863,298 | +4,526 | 153,339 | 1,477 | 83,357 | 1,632 | 48,991,010 | 570,611 | 85,857,043 |
| 12 | Colombia | 6,083,939 | | 139,585 | | 5,917,027 | | 27,327 | 342 | 117,398 | 2,693 | 33,853,193 | 653,242 | 51,823,346 |
| 13 | Germany | 20,634,572 | +169,500 | 129,360 | +254 | 16,092,900 | +219,500 | 4,412,312 | 2,494 | 244,925 | 1,535 | 104,701,826 | 1,242,773 | 84,248,567 |
| 14 | Argentina | 9,028,730 | | 127,943 | | 8,852,314 | | 48,473 | 550 | 196,640 | 2,787 | 35,298,948 | 768,790 | 45,914,969 |
| 15 | Poland | 5,952,200 | +6,608 | 114,939 | +110 | 5,304,270 | +10,772 | 532,991 | 336 | 157,571 | 3,043 | 35,534,904 | 940,706 | 37,774,722 |
| 16 | Ukraine | 4,959,082 | | 107,861 | | N/A | N/A | N/A | 177 | 114,586 | 2,492 | 19,521,252 | 451,065 | 43,278,115 |
| 17 | Spain | 11,451,676 | | 102,392 | | 10,755,608 | | 593,676 | 510 | 244,766 | 2,189 | 471,036,328 | 10,067,851 | 46,786,186 |
| 18 | South Africa | 3,713,833 | | 99,970 | | 3,600,227 | | 13,636 | 546 | 61,279 | 1,650 | 23,757,304 | 392,001 | 60,605,275 |
| 19 | Turkey | 14,815,041 | | 97,861 | | 14,475,383 | | 241,797 | 975 | 172,443 | 1,139 | 152,938,450 | 1,780,160 | 85,912,775 |
| 20 | Romania | 2,847,015 | +4,276 | 64,958 | +44 | 2,606,660 | | 175,397 | 398 | 149,724 | 3,416 | 22,028,806 | 1,158,488 | 19,015,141 |

New cases (linear), United States, 03/29/2022

Daily new confirmed COVID-19 cases



7-day rolling average. Due to limited testing, the number of confirmed cases is lower than the true number of infections.



Source: Johns Hopkins University CSSE COVID-19 Data

CC BY

New deaths (linear), United States, 03/29/2022

Daily new confirmed COVID-19 deaths

Due to varying protocols and challenges in the attribution of the cause of death, the number of confirmed deaths may not accurately represent the true number of deaths caused by COVID-19.



Source: Johns Hopkins University CSSE COVID-19 Data

CC BY

United States, 03/29/2022

Daily new confirmed COVID-19 cases & deaths per million people

7-day rolling average. Limited testing and challenges in the attribution of cause of death means the cases and deaths counts may not be accurate.



United States

New cases (per 1M)



New deaths (per 1M)



Source: Johns Hopkins University CSSE COVID-19 Data

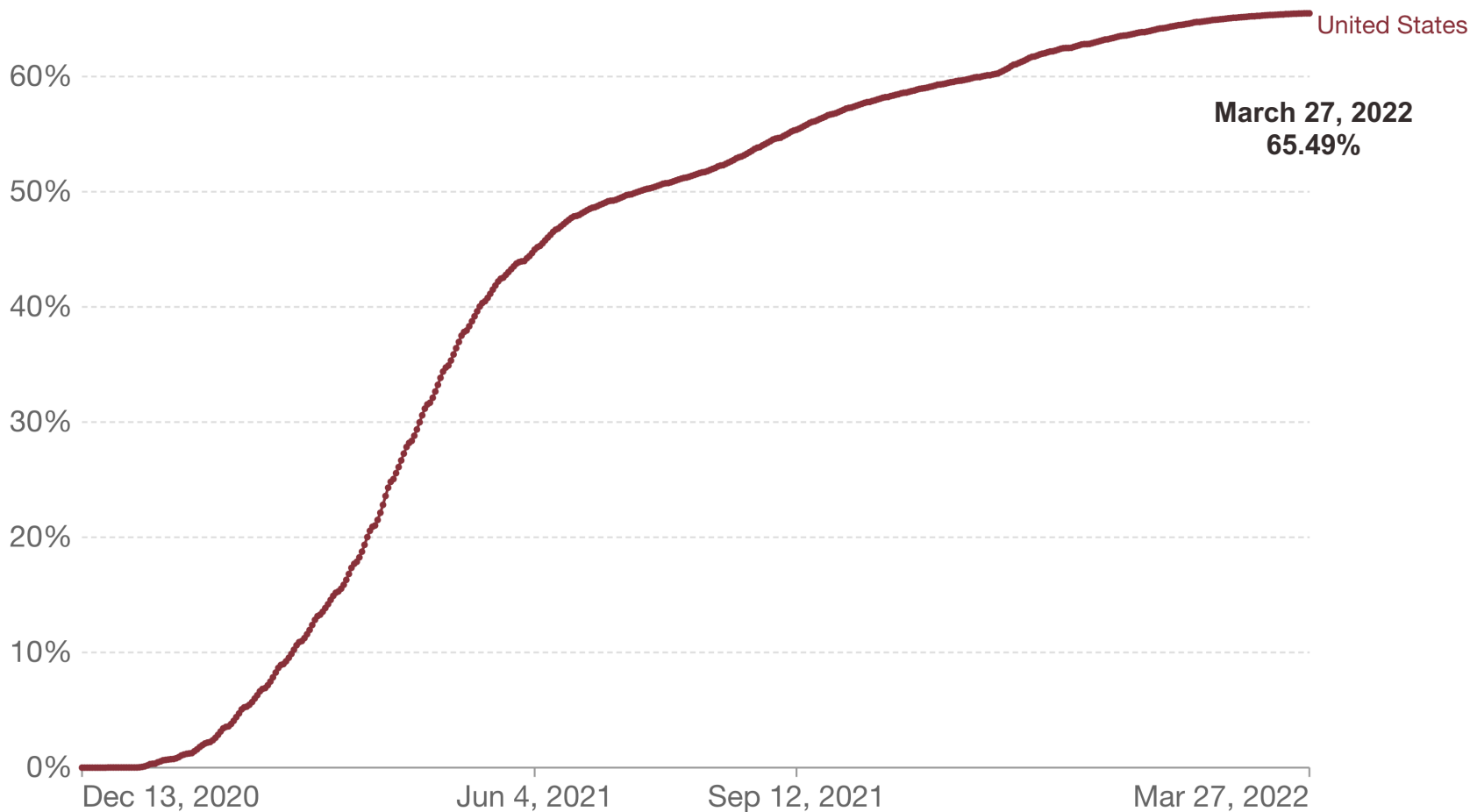
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Fully vaccinated, United States, 03/29/2022

Share of people who completed the initial COVID-19 vaccination protocol

Total number of people who received all doses prescribed by the initial vaccination protocol, divided by the total population of the country.

Our World
in Data



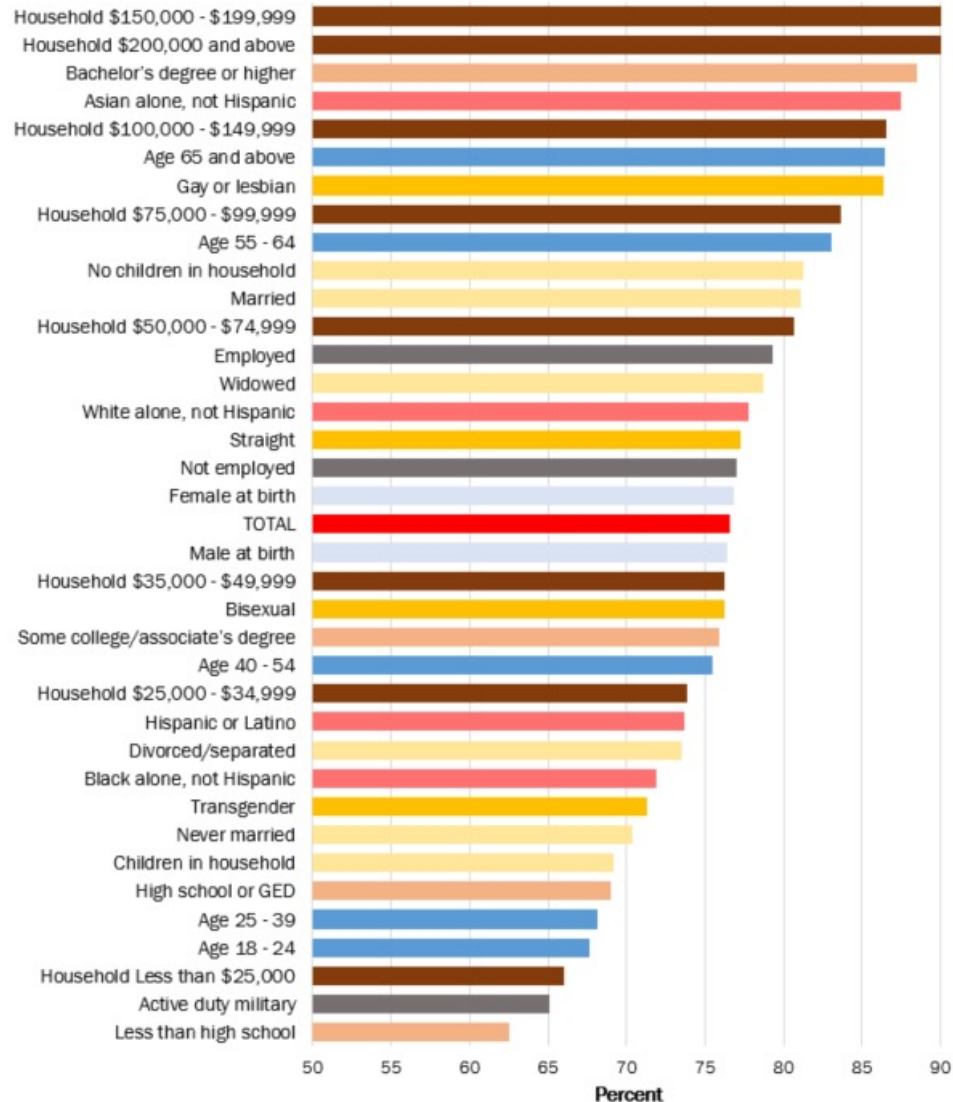
Source: Official data collated by Our World in Data

Note: Alternative definitions of a full vaccination, e.g. having been infected with SARS-CoV-2 and having 1 dose of a 2-dose protocol, are ignored to maximize comparability between countries.

CC BY

United States

Percent fully vaccinated, by demographic characteristics, September 1-13



PN Cohen figure from US Census Bureau Household Pulse Survey data, Sep 1-13, 2021 (Week 37)



Understanding Coronavirus in America

USC
Dornsife
Center for Economic
and Social Research

Likelihood of getting COVID-19 vaccine, by education

College degree



No college degree

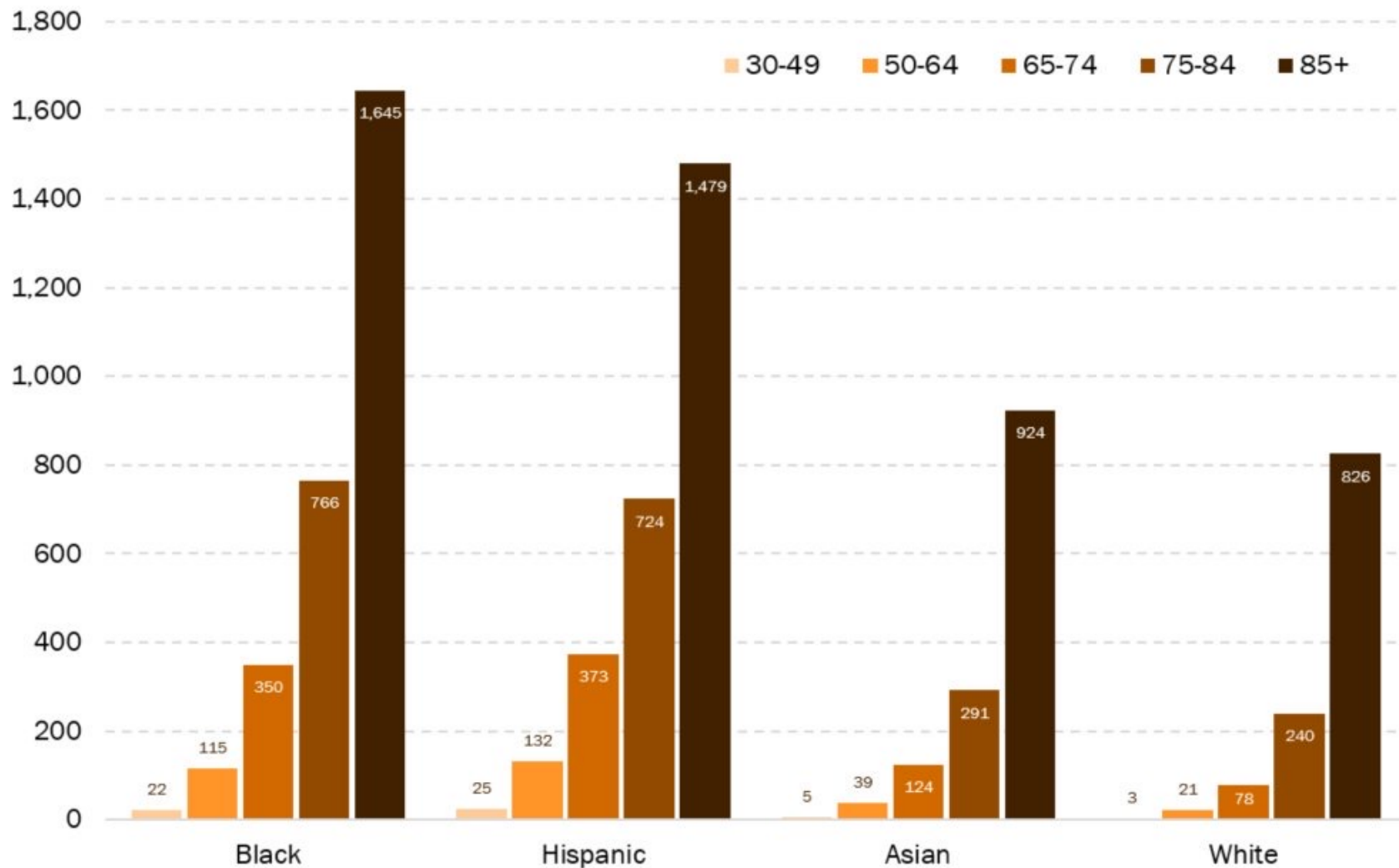


 Vaccinated  Likely  Unlikely  Unsure

Findings are based on 6,231 participants who responded between January 20, 2021 and February 16, 2021. Margin of sampling error is +/-1 percentage point for all U.S. residents, and +/- 2 percentage points for educational attainment subgroups. "College degree" includes bachelor's degree or higher. More information at covid19pulse.usc.edu

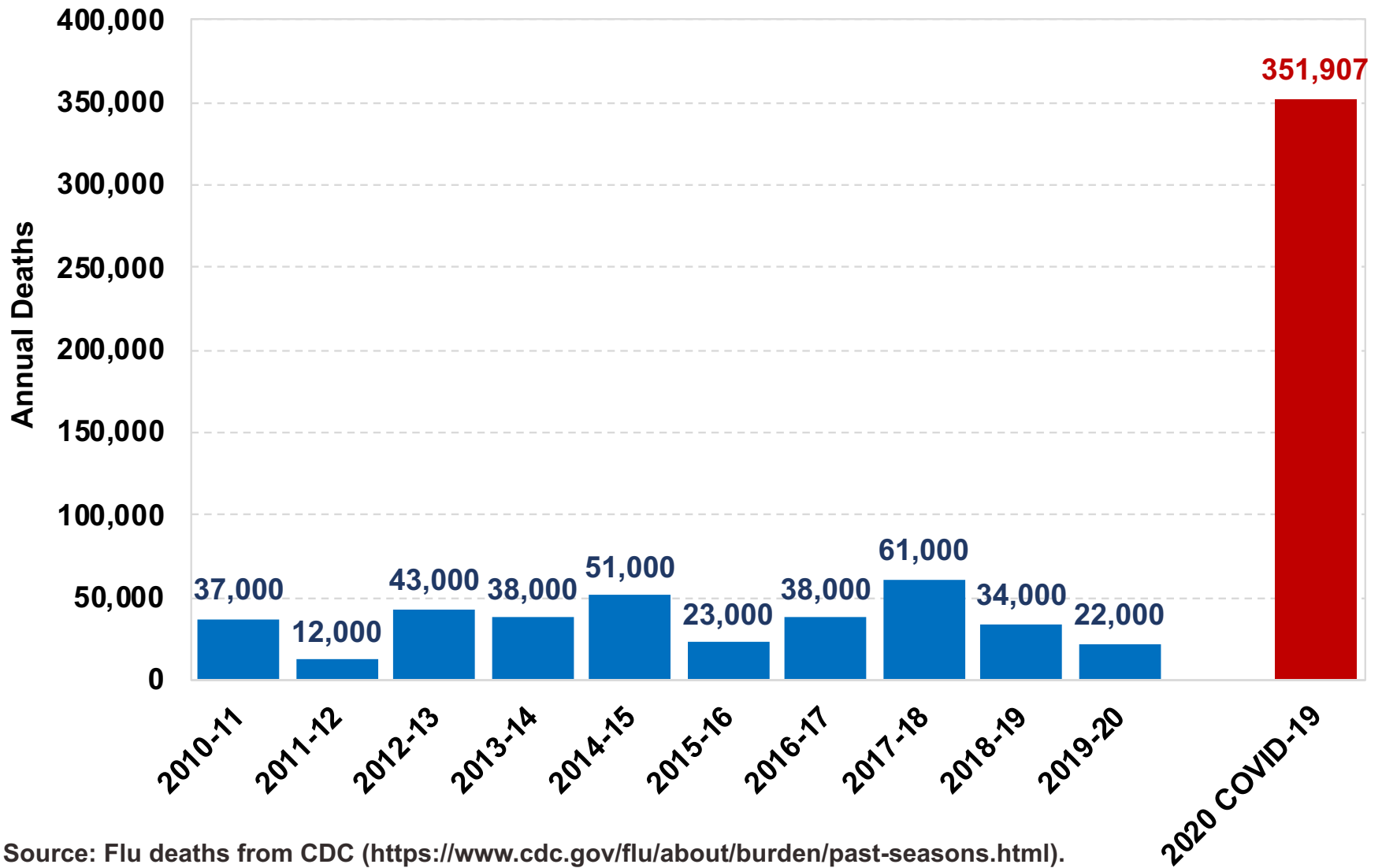


COVID-19 deaths per 100,000 population, by race/ethnicity and age, U.S.



Deaths from CDC data as of September 30. Black, Asian, and White are non-Hispanic. Population denominators from the 2018 ACS via IPUMS.org. White denominators are for single-race respondents; others include multiple-race. PN Cohen analysis.

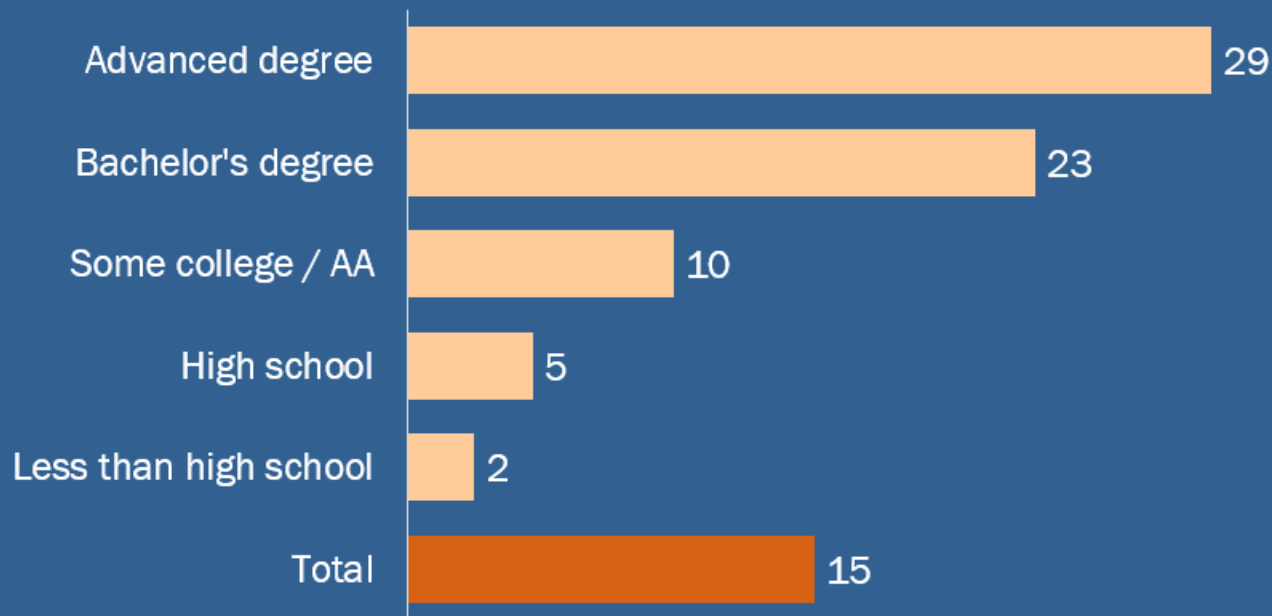
Annual flu deaths (2010–2020) and COVID-19 deaths (2020), United States



Source: Flu deaths from CDC (<https://www.cdc.gov/flu/about/burden/past-seasons.html>). COVID-19 deaths from Our World in Data (<https://ourworldindata.org>).

United States

Percent teleworking in August 2021 because of the coronavirus pandemic

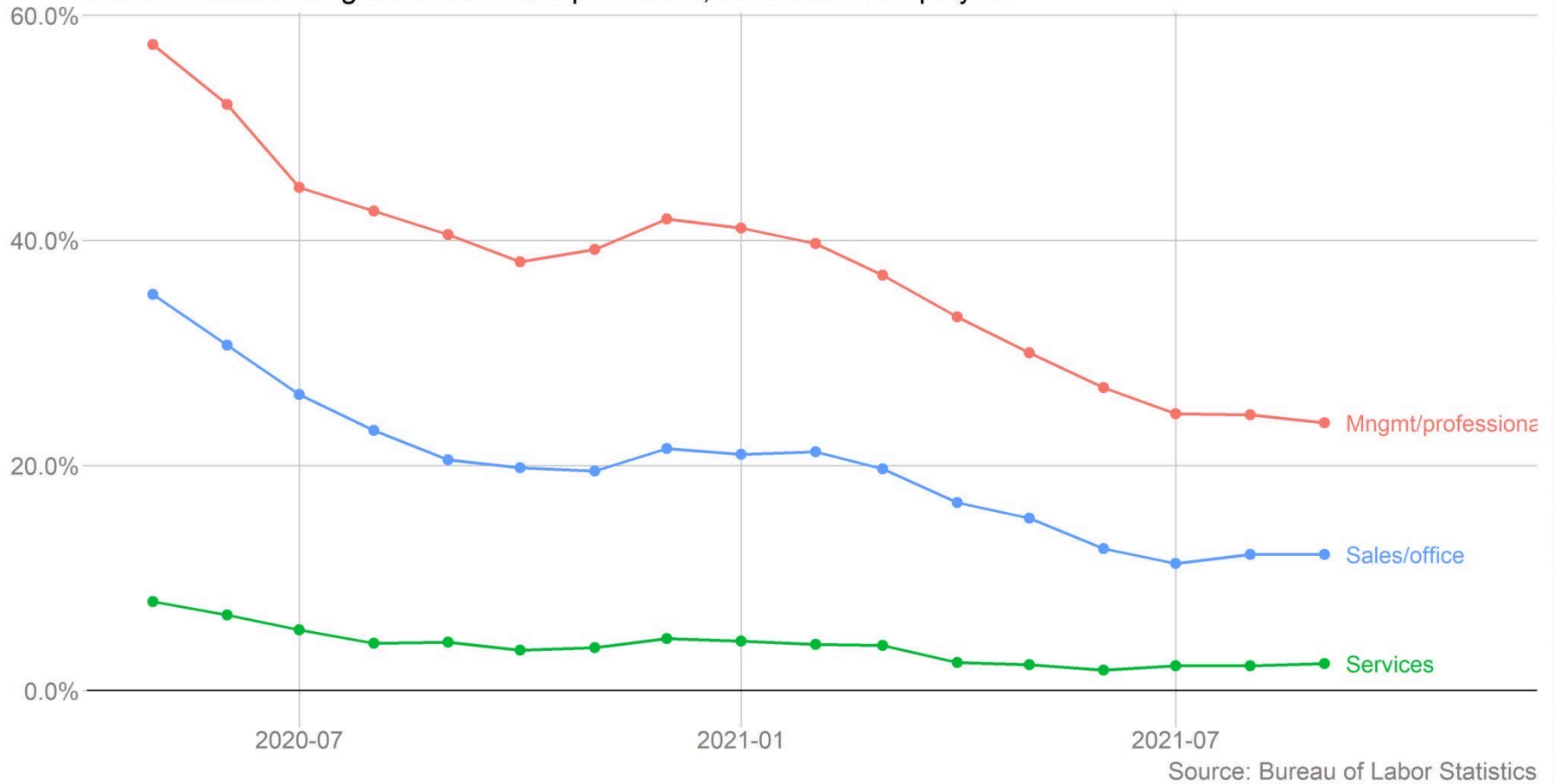


PN Cohen figure from data at:
<https://www.bls.gov/cps/effects-of-the-coronavirus-covid-19-pandemic.htm>

United States

Remote Work in the Pandemic, by Occupation

Persons teleworking because of the pandemic, as share of employed



United States

Percent of workers in occupations suitable for telework
By industry average hourly wage



Linear fit weighted by industry size. PN Cohen figure from 2019 Bureau of Labor Statistics data.

Coronavirus pandemic data

- **Coronavirus COVID-19 Global Cases**

Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)

<https://coronavirus.jhu.edu/map.html>

- **COVID-19 Coronavirus Pandemic**

Worldometer

<https://www.worldometers.info/coronavirus/>

- **Coronavirus Pandemic (COVID-19)**

Our World in Data

<https://ourworldindata.org/coronavirus>

- **COVID Community Vulnerability Map**

Jvion – Prescriptive Analytics for Preventable Harm

<https://covid19.jvion.com/>

- **Coronavirus Deaths by U.S. State and Country Over Time: Daily Tracking**

Josh Katz, Margot Sanger-Katz

<https://www.nytimes.com/interactive/2020/03/21/upshot/coronavirus-deaths-by-country.html?action=click&auth=login-email&login=email&module=Top%20Stories&pgtype=Homepage>



Coronavirus and demography

- **Resources about demography and COVID-19**

Population Europe

<https://population-europe.eu/news/demography-coronavirus>

- **A demographer's view of the coronavirus pandemic**

Isaac Chotiner

March 13, 2020

<https://www.newyorker.com/news/q-and-a/a-demographers-view-of-the-coronavirus-pandemic>

- **Coronavirus: Why it's so deadly in Italy**

Andreas Backhaus

March 13, 2020

<https://medium.com/@andreasbackhausab/coronavirus-why-its-so-deadly-in-italy-c4200a15a7bf>

- **Demographic science aids in understanding the spread and fatality rates of COVID-19**

Jennifer Beam Dowd, Valentina Rotondi, Liliana Andriano, David M. Brazel, Per Block, Xuejie Ding, Yan Liu, Melinda C. Mills

March 14, 2020

https://osf.io/fd4rh/?view_only=c2f00dfe3677493faa421fc2ea38e295&fbclid=IwAR15NPHaq_Ha9yK3uDDN0FhdAZmnfMLfdqgrHaL7qllf3jBYu8CA_9qcEq

- **Students could be undercounted in the census as coronavirus closes colleges – here's why that matters**

Dudley L. Poston, Jr.

March 23, 2020

<https://theconversation.com/students-could-be-undercounted-in-the-census-as-coronavirus-closes-colleges-heres-why-that-matters-13388>



Coronavirus and sex

- **Sex, gender and COVID-19**

Global Health 5050

<http://globalhealth5050.org/covid19/>

- **Sex, gender and COVID-19: Disaggregated data and health disparities**

BMJ Global Health Blogs

March 24, 2020

<https://blogs.bmj.com/bmjgh/2020/03/24/sex-gender-and-covid-19-disaggregated-data-and-health-disparities/>

- **Here's why the coronavirus may be killing more men than women. The US should take note**

Katie Polglase, Gianluca Mezzofiore, Max Foster

March 24, 2020

<https://www.cnn.com/2020/03/24/health/coronavirus-gender-mortality-intl/index.html>



Coronavirus and politics

- **The Real Pandemic Danger Is Social Collapse**

Branko Milanovic

March 19, 2020

https://www.foreignaffairs.com/articles/2020-03-19/real-pandemic-danger-social-collapse?utm_medium=social&utm_source=twitter_cta&utm_campaign=cta_share_buttons

- **Coronavirus Could Overwhelm U.S. Without Urgent Action, Estimates Say**

James Glanz, Lauren Leatherby, Matthew Bloch, Mitch Smith, Larry Buchanan, Jin Wu, Nicholas Bogel-Burroughs

March 20, 2020

<https://www.nytimes.com/interactive/2020/03/20/us/coronavirus-model-us-outbreak.html?action=click&module=Spotlight&pgtype=Homepage>

- **Before Virus Outbreak, a Cascade of Warnings Went Unheeded**

David E. Sanger, Eric Lipton, Eileen Sullivan, Michael Crowley

March 22, 2020

<https://www.nytimes.com/2020/03/19/us/politics/trump-coronavirus-outbreak.html>

- **Sisi and Erdogan Are Accomplices of the Coronavirus**

Steven A. Cook

March 17, 2020

<https://foreignpolicy.com/2020/03/17/sisi-and-erdogan-are-partners-with-the-coronavirus/>

- **How South Korea Flattened the Curve**

Max Fisher, Choe Sang-Hun

March 23, 2020

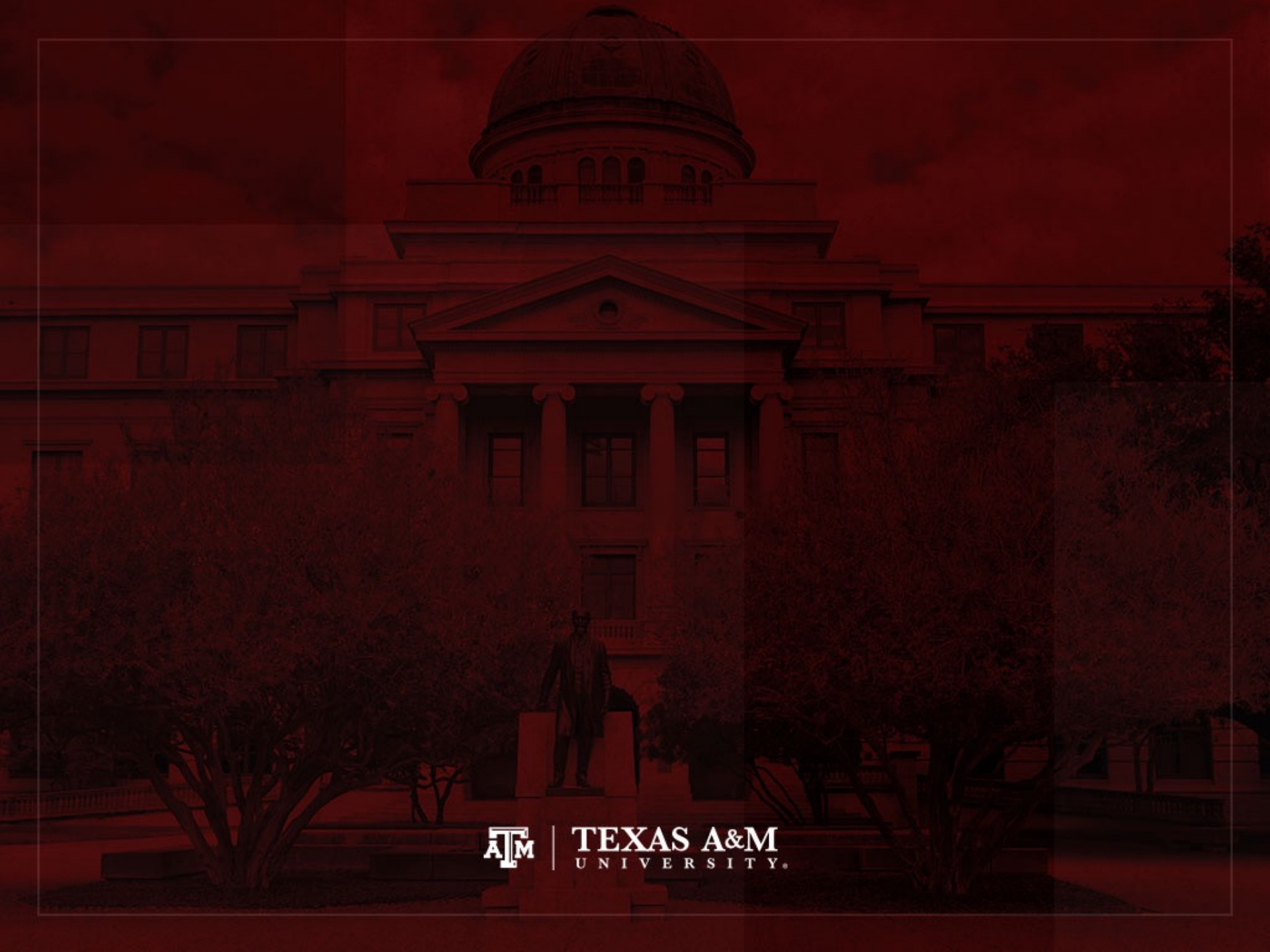
<https://www.nytimes.com/2020/03/23/world/asia/coronavirus-south-korea-flatten-curve.html?action=click&module=Top%20Stories&pgtype=Homepage>



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