Mortality

Ernesto F. L. Amaral

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Outline

- The health and mortality transition
  - Weeks 2015, Chapter 5, pp. 139–188
- Period mortality
  - Wachter 2014, Chapter 7, pp. 153–173
  - Weeks 2015, Chapter 5, pp. 170–180
  - Kintner 2003

Health and mortality transition

(Weeks 2015, Chapter 5, pp. 139–188)

- 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

Defining health and mortality transition

- 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

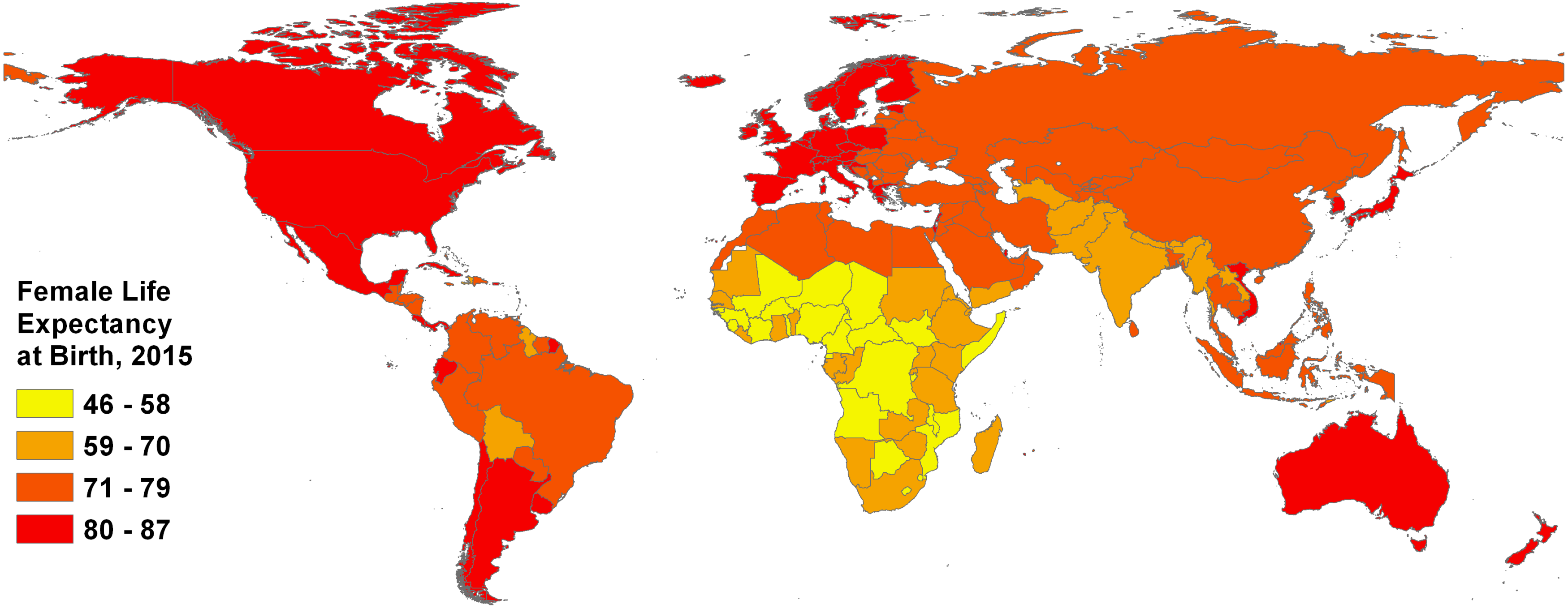
Death at older ages

- 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 variability by age in mortality is compressed, leading to an increased rectangularization of mortality
- Most people now survive to advanced ages and die pretty quickly
- The survival of more people to ever older ages is a key contribution to the demographic transition

Health and mortality 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



Meaning of 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 18th/early 19th	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 same disease that exists today
  - Don't really know why it was so fatal back then
  - 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
- Their immunity to the diseases they brought
  - Compared with the devastation the diseases wrought on indigenous populations
  - Is one explanation for relative ease with which Spain dominated Latin America after arriving around 1500

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

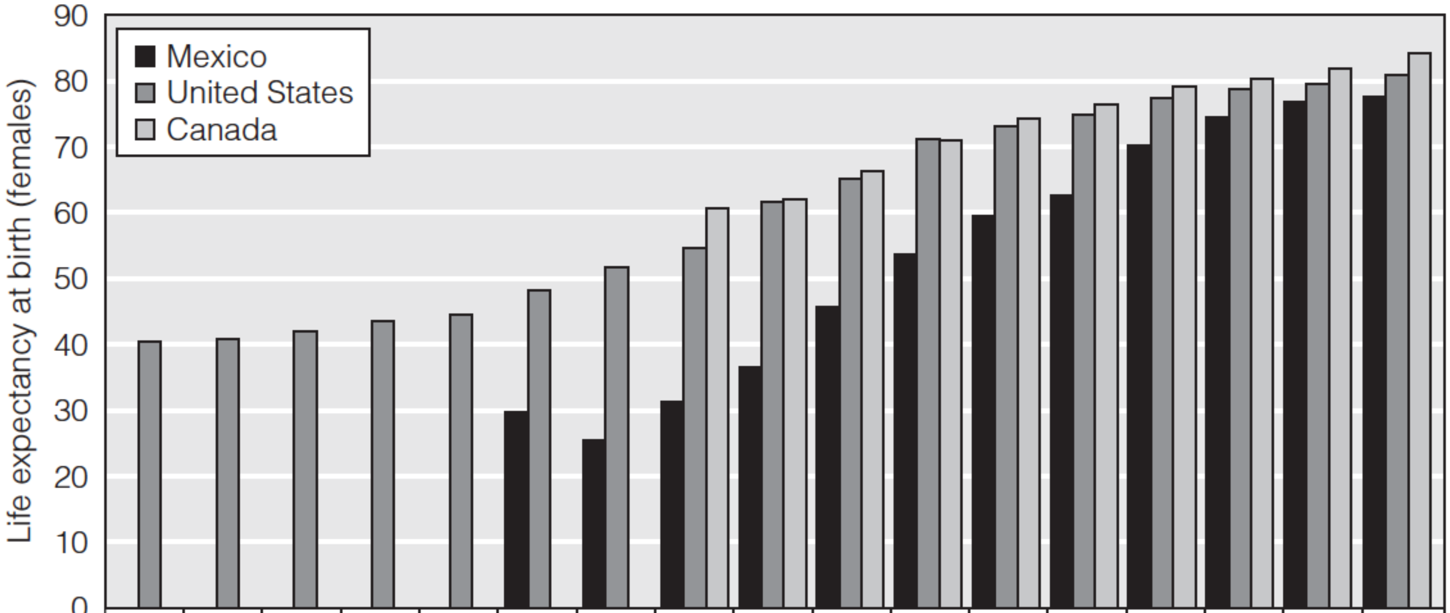
19th century

- 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

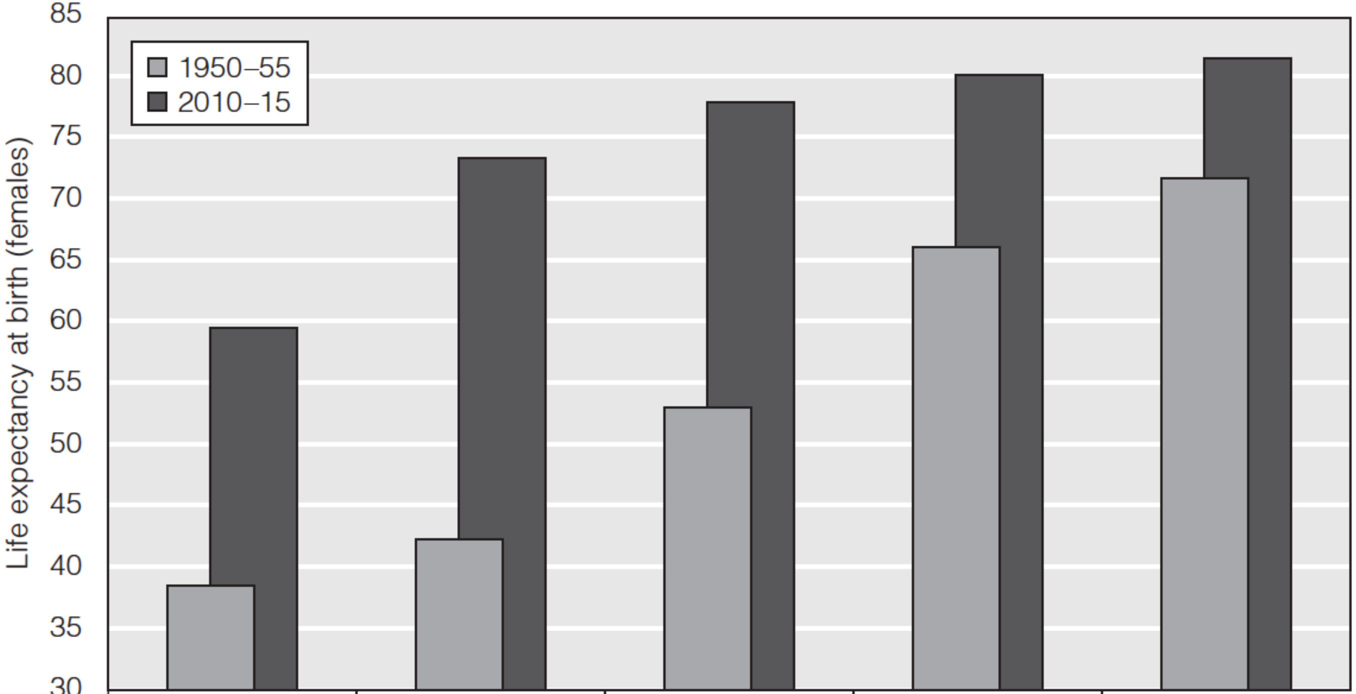
- Health as a social movement
  - Leading to government-organized universal health care systems in all rich countries except the U.S.
- Antibiotics emerging around WWII
- More vaccinations
- Oral rehydration therapy for infants and adults
- Advanced diagnoses, drugs, and other treatments for degenerative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



	Africa	Asia	Latin America	Europe	North America
1950–55	38.6	42.4	53.1	66.1	71.7
2010–15	59.6	73.4	77.9	80.1	81.5

Postponing death

- Two ways to postpone death to the oldest possible ages
- Prevent diseases from occurring or from spreading when they do occur
  – 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 be fat
  - 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

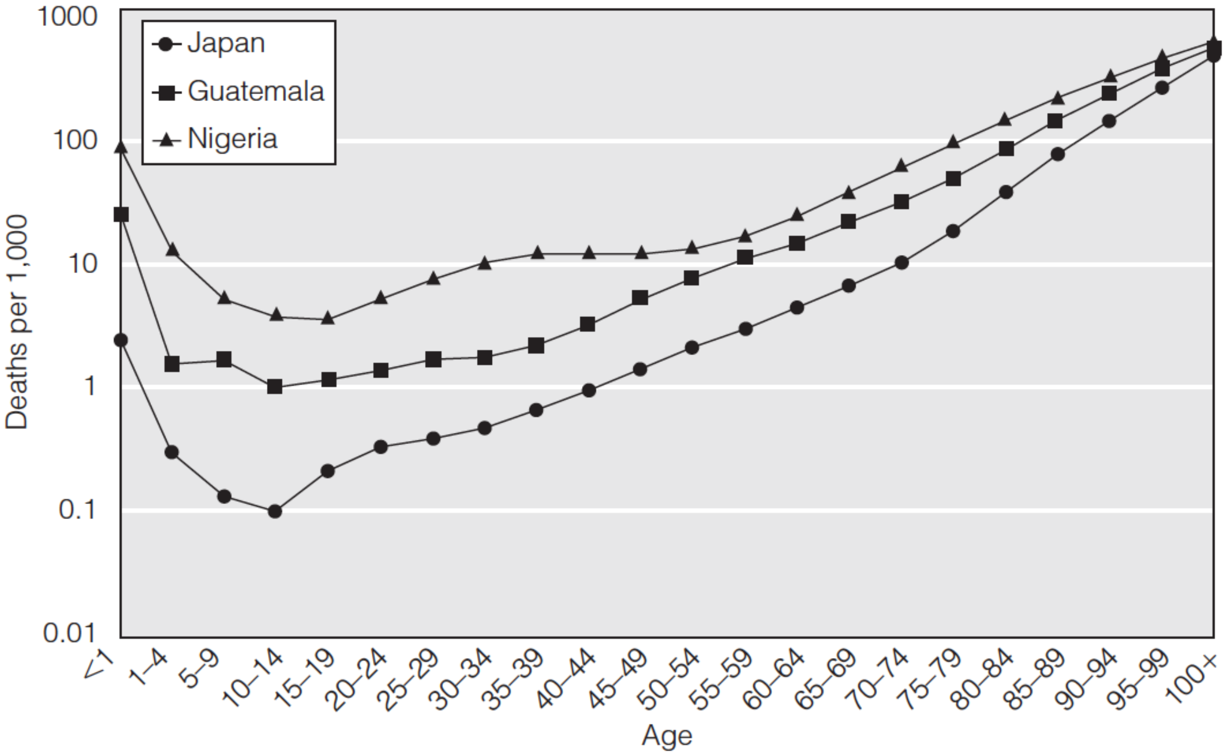
Life span and longevity

- Life span: oldest age to which human beings can survive
  - 122?
  - 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

Age differentials in mortality

- 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
- After the initial year of life, lasting at least until middle age
  - Corresponds to reproductive ages
  - Risks of death are relatively low
- Beyond middle age
  - Mortality increases
  - Although at a decelerating rate

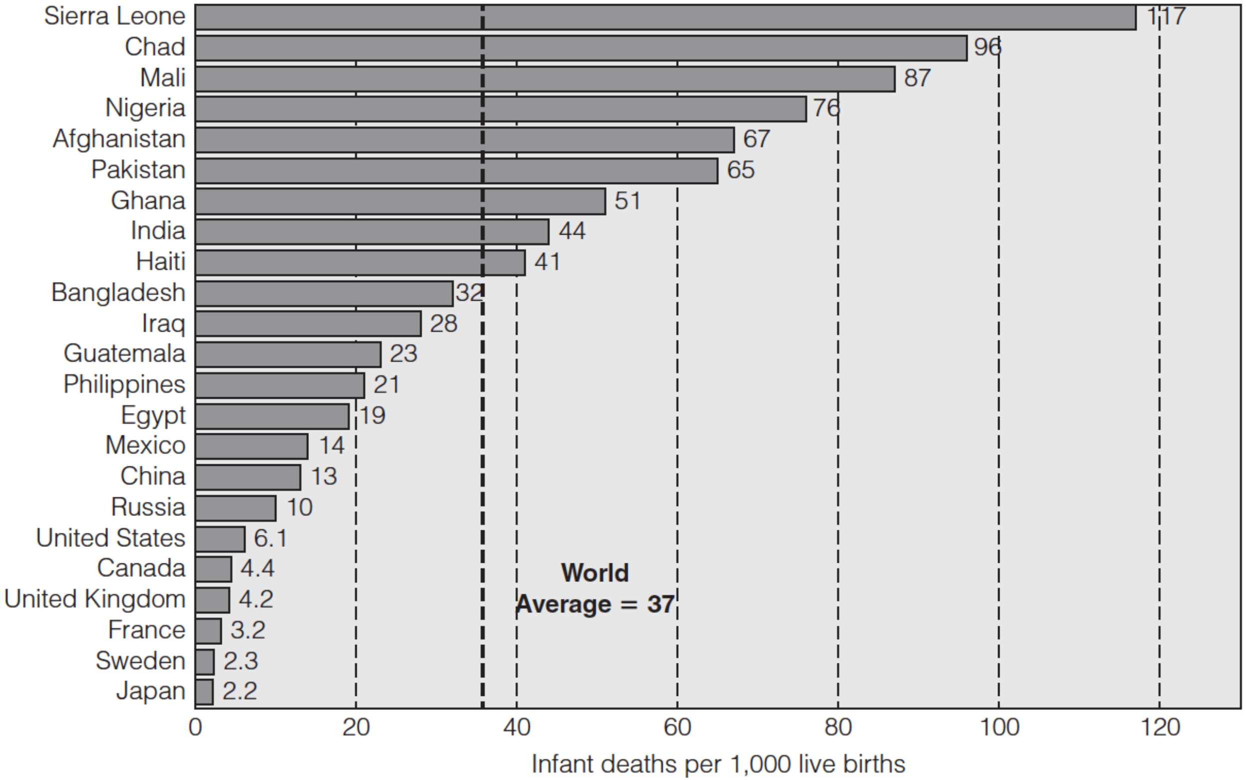
Highest death rates, 2011: very young and the old



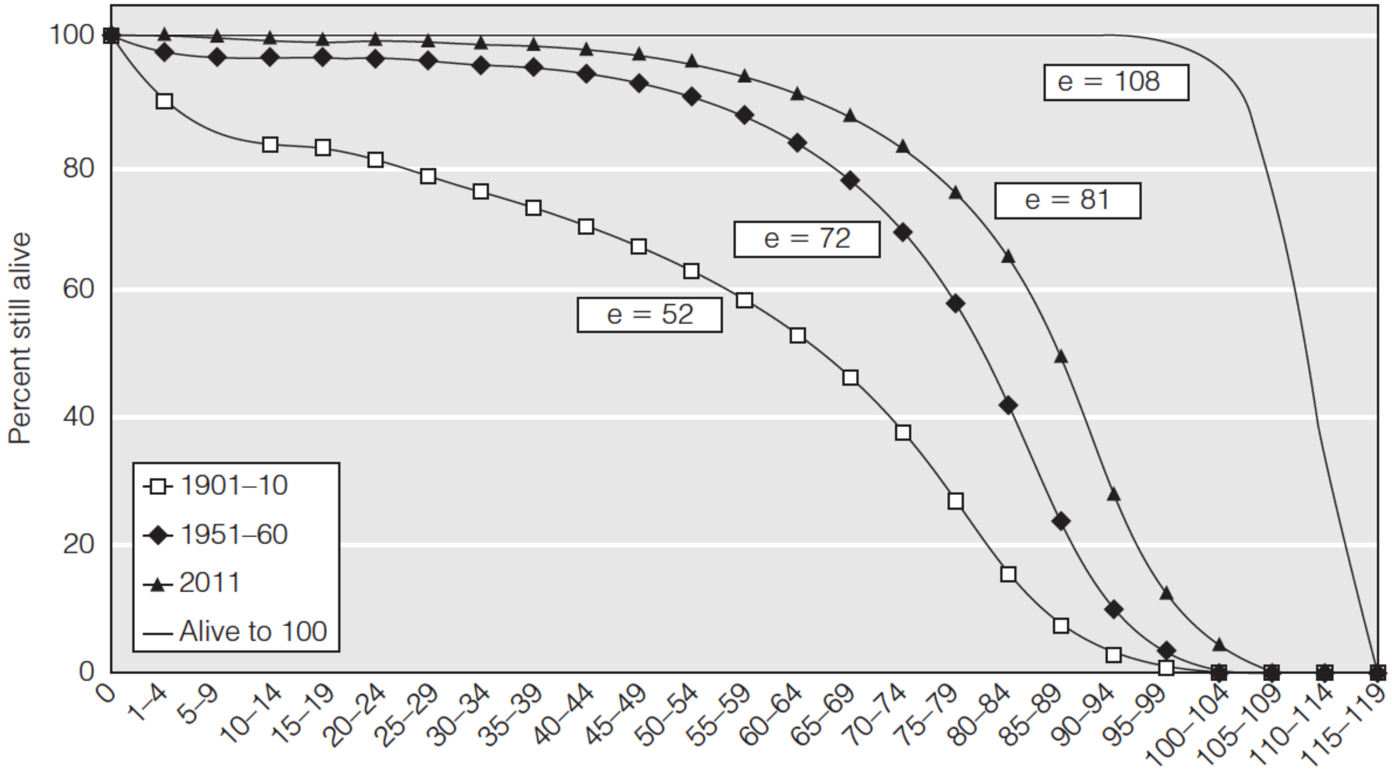
Infant mortality

- 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 around the world, 2015



Rectangularization of mortality, United States



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...

Causes of poor health and death

- The World Health Organization categorizes deaths into
  - 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
COPD	Non-Com.	3.0	32	45	51	
Diarheal diseases	Com.	1.9			47	69
HIV/AIDS	Com.	1.6			24	70
Tranchea 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

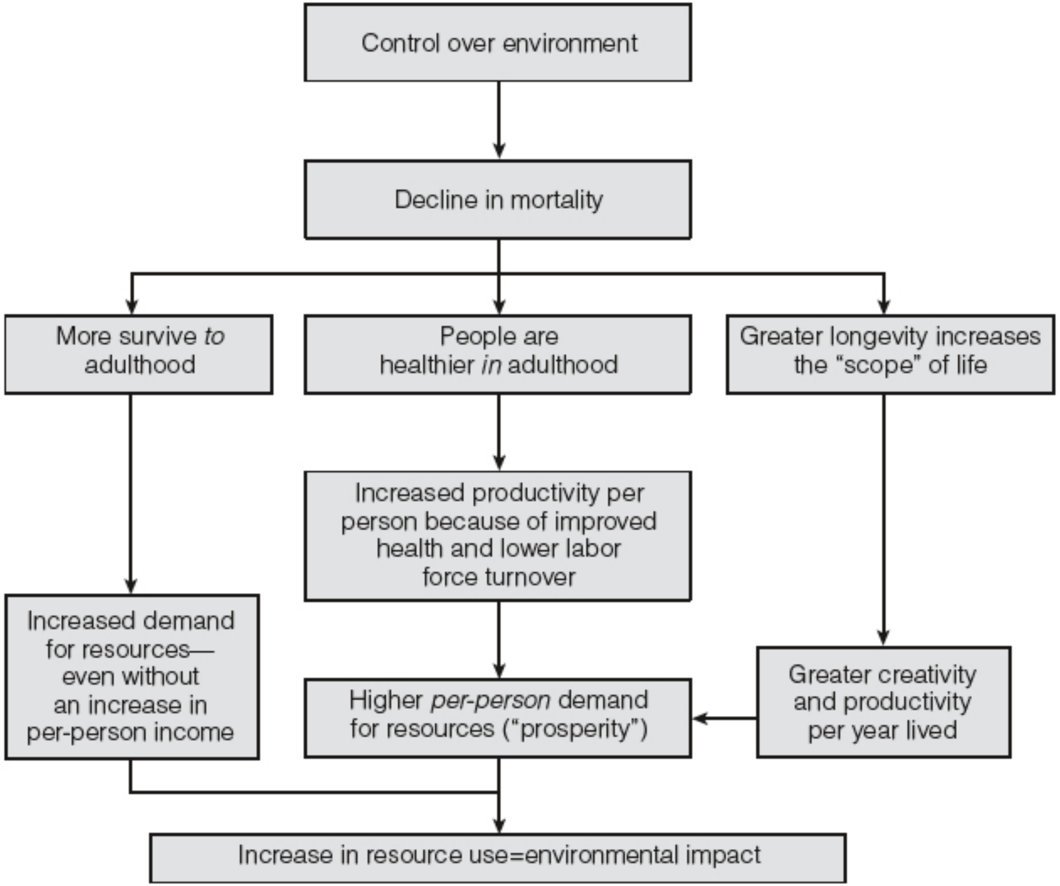
"Real causes" of death in low-mortality societies

- Tobacco
- Diet and activity patterns
- Alcohol misuse
- Infectious diseases
- Toxic agents
- Motor vehicles
- Guns
- Sex
- Drugs

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

Long-term impact of mortality transition



RAND
CORPORATION

Period mortality

(Wachter 2014, Chapter 7, pp. 153–173)
(Weeks 2015, Chapter 5, pp. 170–180)
(Kintner 2003)

- Measuring period mortality
- Standardization
- Period life tables
- Model life tables

Measuring period mortality

- Crude death rate (*CDR*) is the total number of deaths in a year divided by the average total population

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

- Age/sex-specific death rate (*nMx* or *ASDR*)

$${}_{n}M_{x} = {}_{n}d_{x} / {}_{n}p_{x} * 100,000$$

Standardization

- Compare crude death rates for different years or regions
- Need to adjust for differences in age structure
- Estimate age-adjusted death rates (*AADR*) and apply to a standard population

$$ADDR = \Sigma\ {}_{n}ws_{x} * {}_{n}M_{x}$$

  - ${}_{n}ws_{x}$: standard weight representing this age group's proportion in the total population
  - ${}_{n}M_{x}$: age-specific death rate

Example of standardization (1/4)

Deaths		
Age group	PE	RS
0–4	3,777	2,342
5–9	244	206
10–14	324	297
15–19	1,292	846
20–24	1,784	1,258
25–29	1,723	1,256
30–34	1,572	1,351
35–39	1,649	1,802
40–44	2,056	2,418
45–49	2,172	3,331
50–54	2,663	4,136
55–59	3,037	4,907
60–64	3,402	5,631
65–69	4,325	7,055
70–74	4,651	8,065
75–79	5,308	8,661
80+	12,219	17,621
Total	**52,198**	**71,183**

Population		
Age group	PE	RS
0–4	847,364	913,339
5–9	850,579	945,206
10–14	916,926	970,575
15–19	934,602	1,029,218
20–24	819,853	914,423
25–29	685,373	820,035
30–34	616,696	837,181
35–39	557,721	867,514
40–44	461,225	781,380
45–49	384,029	667,259
50–54	331,372	548,390
55–59	263,131	424,619
60–64	231,472	351,702
65–69	171,950	285,196
70–74	139,544	216,227
75–79	96,984	137,857
80+	104,780	134,881
Total	**8,413,601**	**10,845,002**

Age-specific death rate		
Age group	PE	RS
0–4	0.0045	0.0026
5–9	0.0003	0.0002
10–14	0.0004	0.0003
15–19	0.0014	0.0008
20–24	0.0022	0.0014
25–29	0.0025	0.0015
30–34	0.0025	0.0016
35–39	0.0030	0.0021
40–44	0.0045	0.0031
45–49	0.0057	0.0050
50–54	0.0080	0.0075
55–59	0.0115	0.0116
60–64	0.0147	0.0160
65–69	0.0252	0.0247
70–74	0.0333	0.0373
75–79	0.0547	0.0628
80+	0.1166	0.1306
CDR (‰)	**6.20**	**6.56**

Source: Brazilian Health Ministry (DATASUS). Data for the states of Pernambuco (PE) and Rio Grande do Sul (RS), 2005.

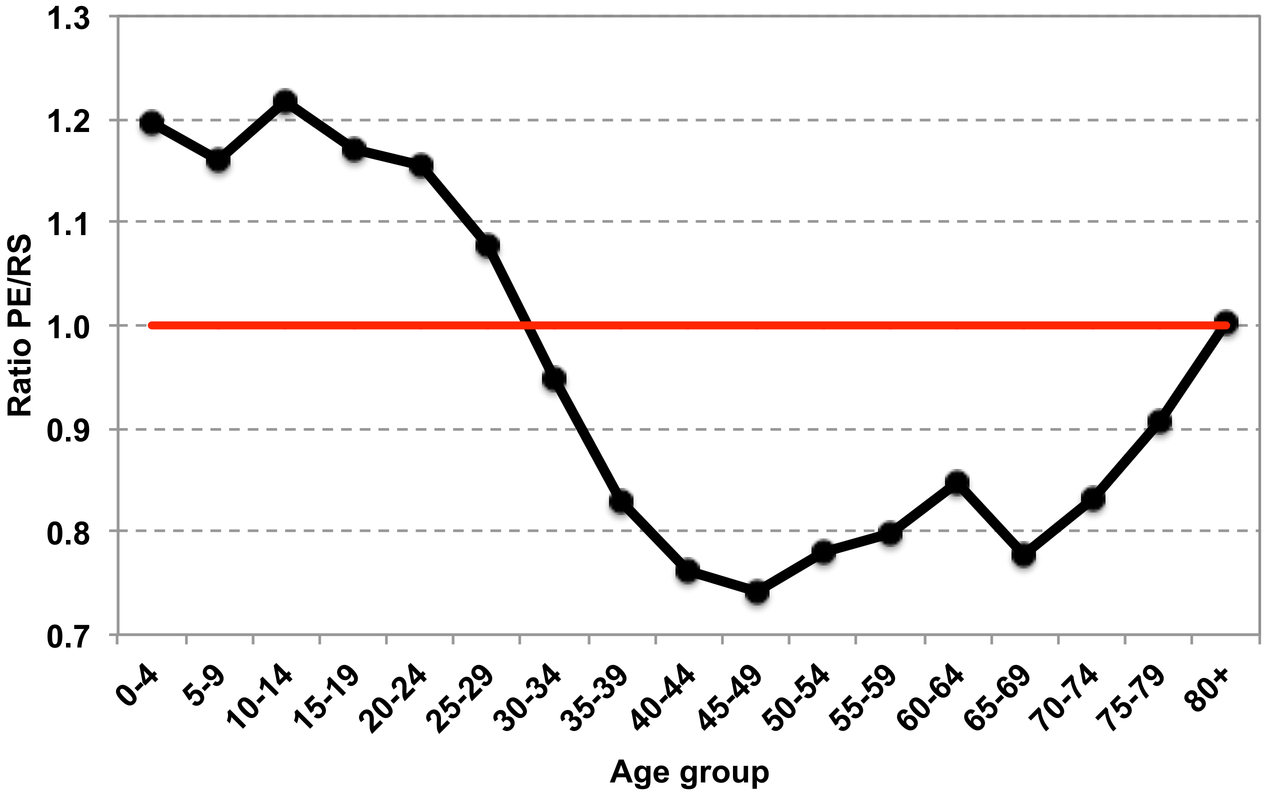
Example of standardization (2/4)

Age group	PE population (%)	RS population (%)	Ratio PE / RS
0–4	10.07	8.42	1.20
5–9	10.11	8.72	1.16
10–14	10.90	8.95	1.22
15–19	11.11	9.49	1.17
20–24	9.74	8.43	1.16
25–29	8.15	7.56	1.08
30–34	7.33	7.72	0.95
35–39	6.63	8.00	0.83
40–44	5.48	7.20	0.76
45–49	4.56	6.15	0.74
50–54	3.94	5.06	0.78
55–59	3.13	3.92	0.80
60–64	2.75	3.24	0.85
65–69	2.04	2.63	0.78
70–74	1.66	1.99	0.83
75–79	1.15	1.27	0.91
80+	1.25	1.24	1.00
Total	**100.00**	**100.00**	**1.00**

- PE has a younger population than RS
- This is causing $CDR_{PE} < CDR_{RS}$

Source: Brazilian Health Ministry (DATASUS). Data for the states of Pernambuco (PE) and Rio Grande do Sul (RS), 2005.

Example of standardization (3/4)



- PE has a younger population than RS
- This is causing $CDR_{PE} < CDR_{RS}$

Source: Brazilian Health Ministry (DATASUS). Data for the states of Pernambuco (PE) and Rio Grande do Sul (RS), 2005.

Example of standardization (4/4)

Age group	PE (standard population)	RS (observed rates)	RS (standardized deaths)
0–4	847,364	0.0026	2,173
5–9	850,579	0.0002	185
10–14	916,926	0.0003	281
15–19	934,602	0.0008	768
20–24	819,853	0.0014	1,128
25–29	685,373	0.0015	1,050
30–34	616,696	0.0016	995
35–39	557,721	0.0021	1,158
40–44	461,225	0.0031	1,427
45–49	384,029	0.0050	1,917
50–54	331,372	0.0075	2,499
55–59	263,131	0.0116	3,041
60–64	231,472	0.0160	3,706
65–69	171,950	0.0247	4,254
70–74	139,544	0.0373	5,205
75–79	96,984	0.0628	6,093
80+	104,780	0.1306	13,689
Total	**8,413,601**		**49,569**

- $CDR_{PE\ original}$
= 6.20 deaths per 1,000

- $CDR_{RS\ original}$
= 6.56 deaths per 1,000

- $CDR_{RS\ standardized}$
= 49,569 / 8,413,601
= 5.89 deaths per 1,000

Source: Brazilian Health Ministry (DATASUS). Data for the states of Pernambuco (PE) and Rio Grande do Sul (RS), 2005.

Period life tables

- 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 for females, U.S., 2010

					Of 100,000 hypothetical people born alive:		Number of years lived		Expectation of life
Age interval	Number of females in the population	Number of deaths in the population	Age-specific death rates in the interval	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 $x + n$	${}_nP_x$	${}_nD_x$	${}_nM_x$	${}_nq_x$	l_x	${}_nd_x$	${}_nL_x$	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 ($_nd_x$) 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 ($_nd_x$) equals probability of death times number alive at beginning (l_x)

$$_nd_x = (_nq_x)(l_x)$$

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

$$l_{x+n} = l_x - {_nd_x}$$

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

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

  - l_{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 (l_0) divided by total population (T_0)
- Crude birth rate (CBR) equals total number of births (l_0) divided by total population (T_0)

$$CDR = CBR = l_0 / T_0 = 1 / (T_0 / l_0) = 1 / e_0$$

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 20^{th} and 25^{th} 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 $x+n^{th}$ 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

${}_{n}L_{x}$

- **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

${}_{n}T_{x}$

- **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

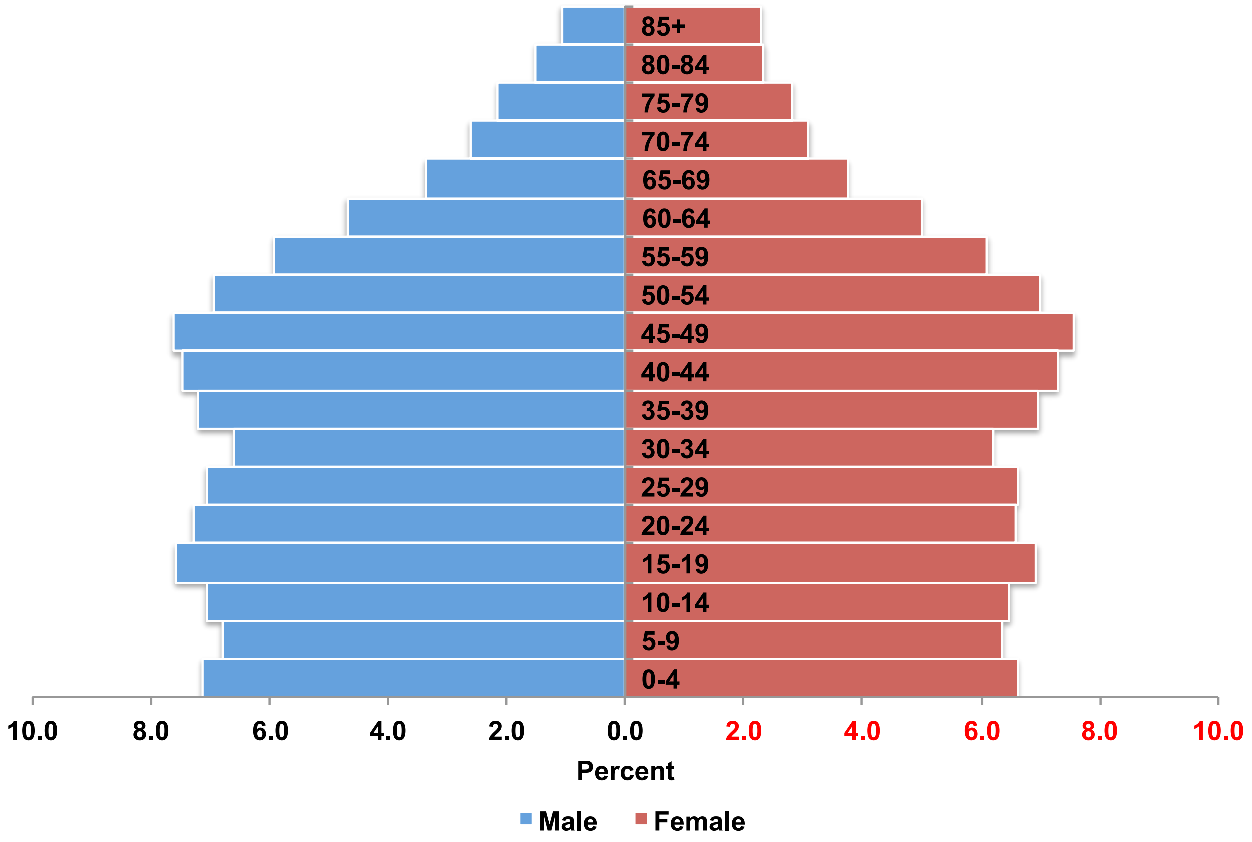
						Of 100,000 born alive		Stationary population		
Age group	**Width**	**Population**	**Deaths**	**Age-specific death rates**	**Proportion dying**	**# living at beginning of interval**	**# dying during interval**	**In the age interval**	**In this and following ages**	**Average remaining lifetime**
	n	**nPx**	**nDx**	**nMx**	**nqx**	**lx**	**ndx**	**nLx**	**Tx**	**ex**
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

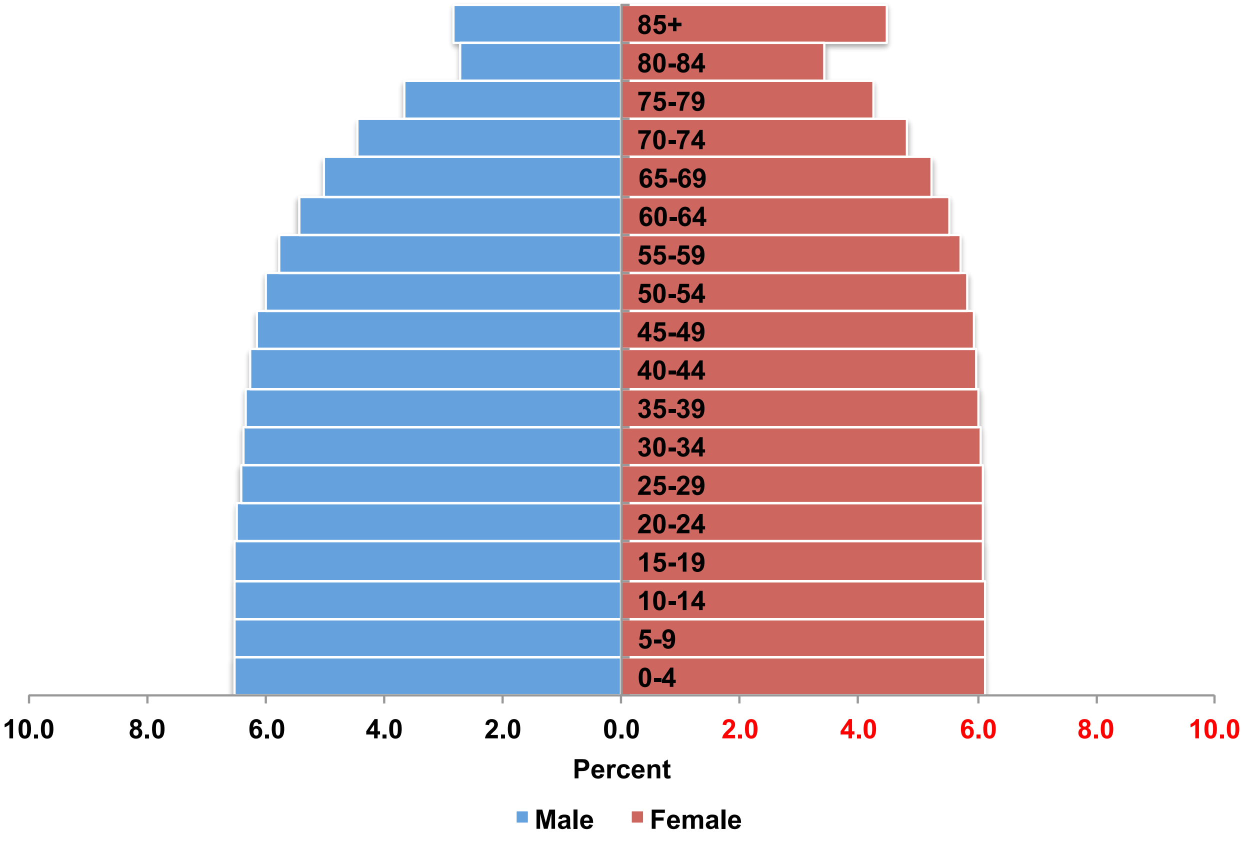
						Of 100,000 born alive		Stationary population		
Age group	**Width**	**Population**	**Deaths**	**Age-specific death rates**	**Proportion dying**	**# living at beginning of interval**	**# dying during interval**	**In the age interval**	**In this and following ages**	**Average remaining lifetime**
	n	**nPx**	**nDx**	**nMx**	**nqx**	**lx**	**ndx**	**nLx**	**Tx**	**ex**
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	79,767	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).

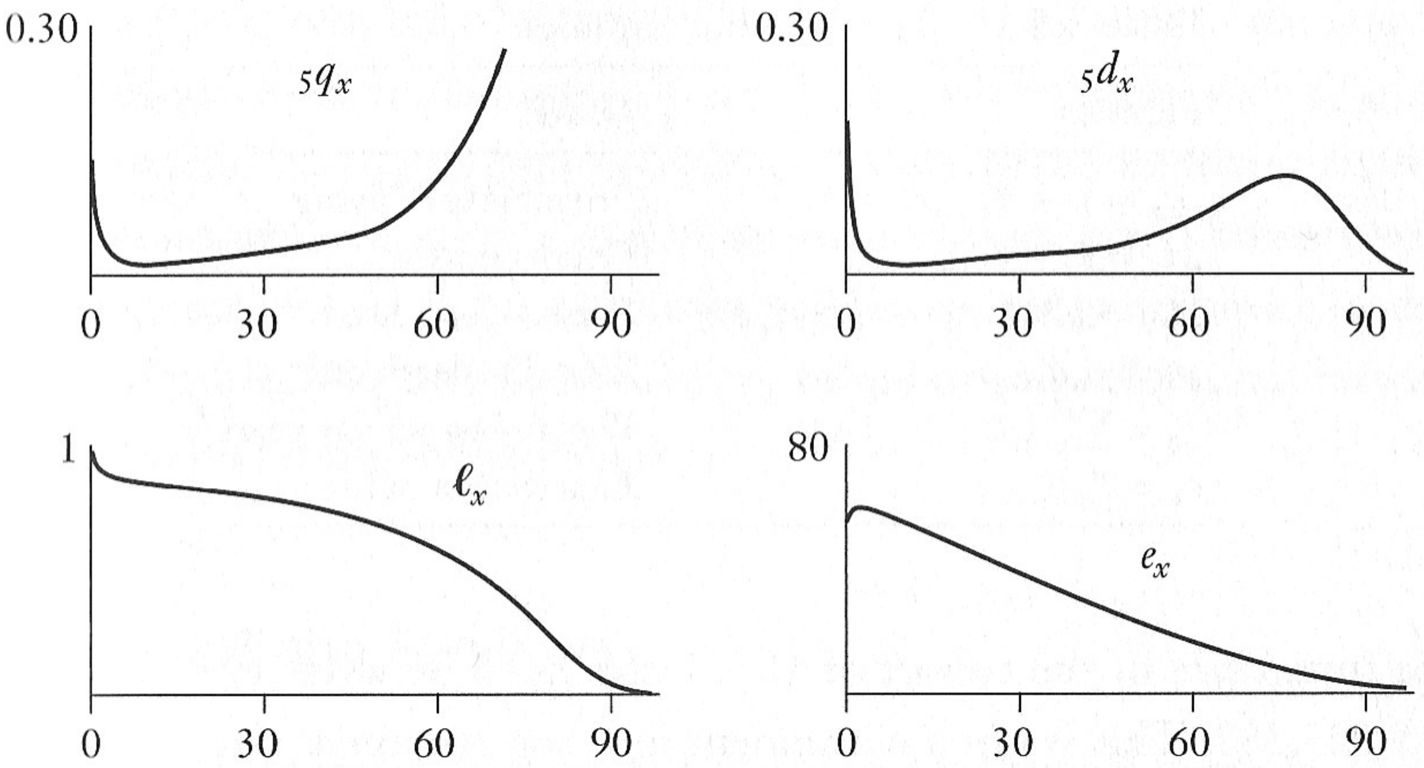
Population, U.S., 2007



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



Typical shapes of lifetable functions



Source: Wachter 2014, p. 61.

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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