Demography of aging

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Outline

- Introduction
- Demographic determinants of population aging
  - Stable population
  - Population projections
- Measures and methods
- Trajectories of population aging
- Theoretical issues
- Future research directions

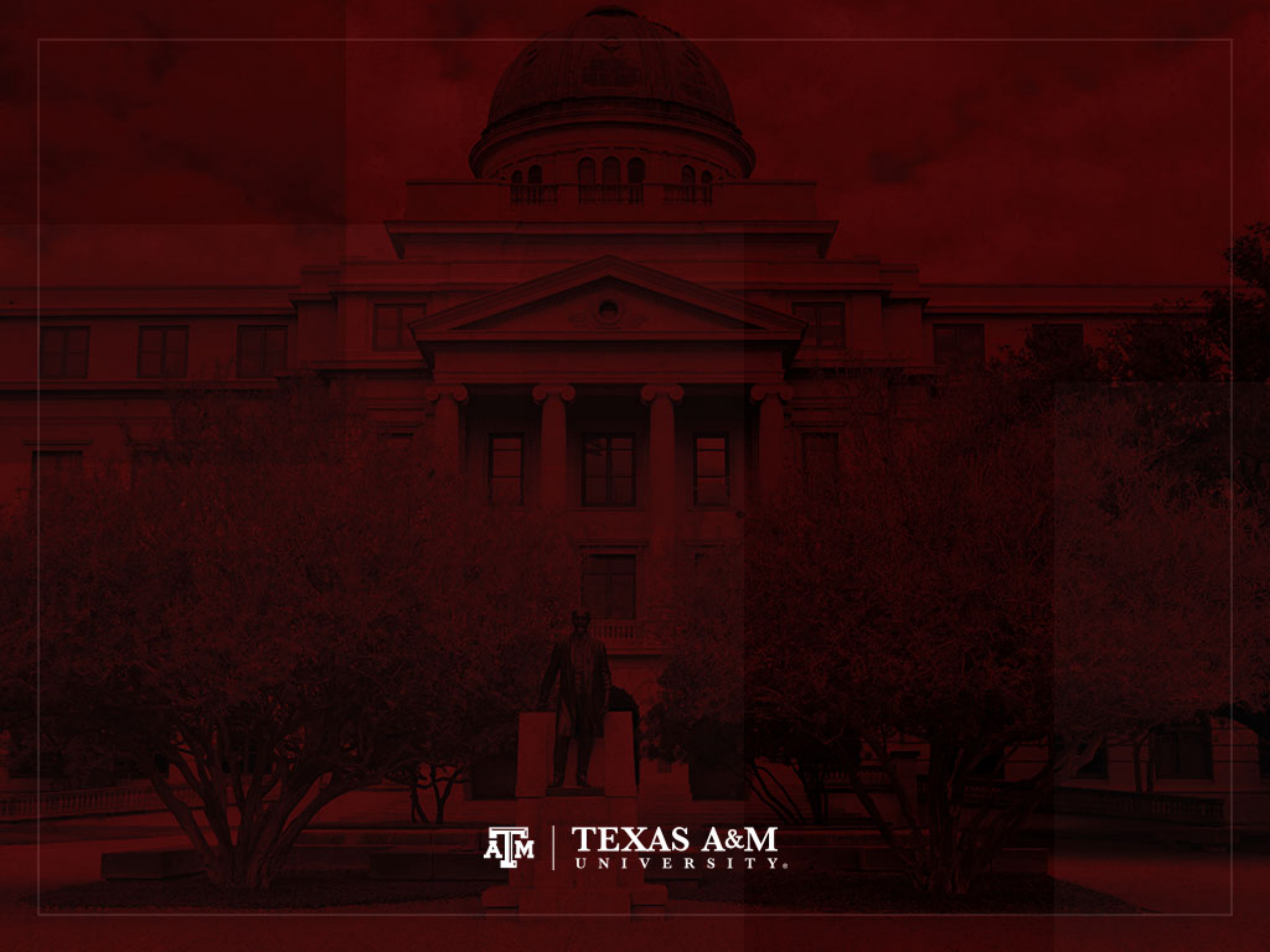
Introduction

- The global population of adults 60 years and older has been increasing (United Nations 2017a)
  - 382 million in 1980
  - 962 million in 2017
  - 2.1 billion by 2050

- The pace of aging has been faster is less developed countries than in developed countries (He et al. 2016)

Policies for an aging population

- Larger share of older adults requires that governments design policies aimed at public services to benefit an aging population
  - Social welfare
  - Health care services
  - Labor markets
  - Retirement
  - Technology
  - Housing
  - Transportation
  - Intergenerational relationships



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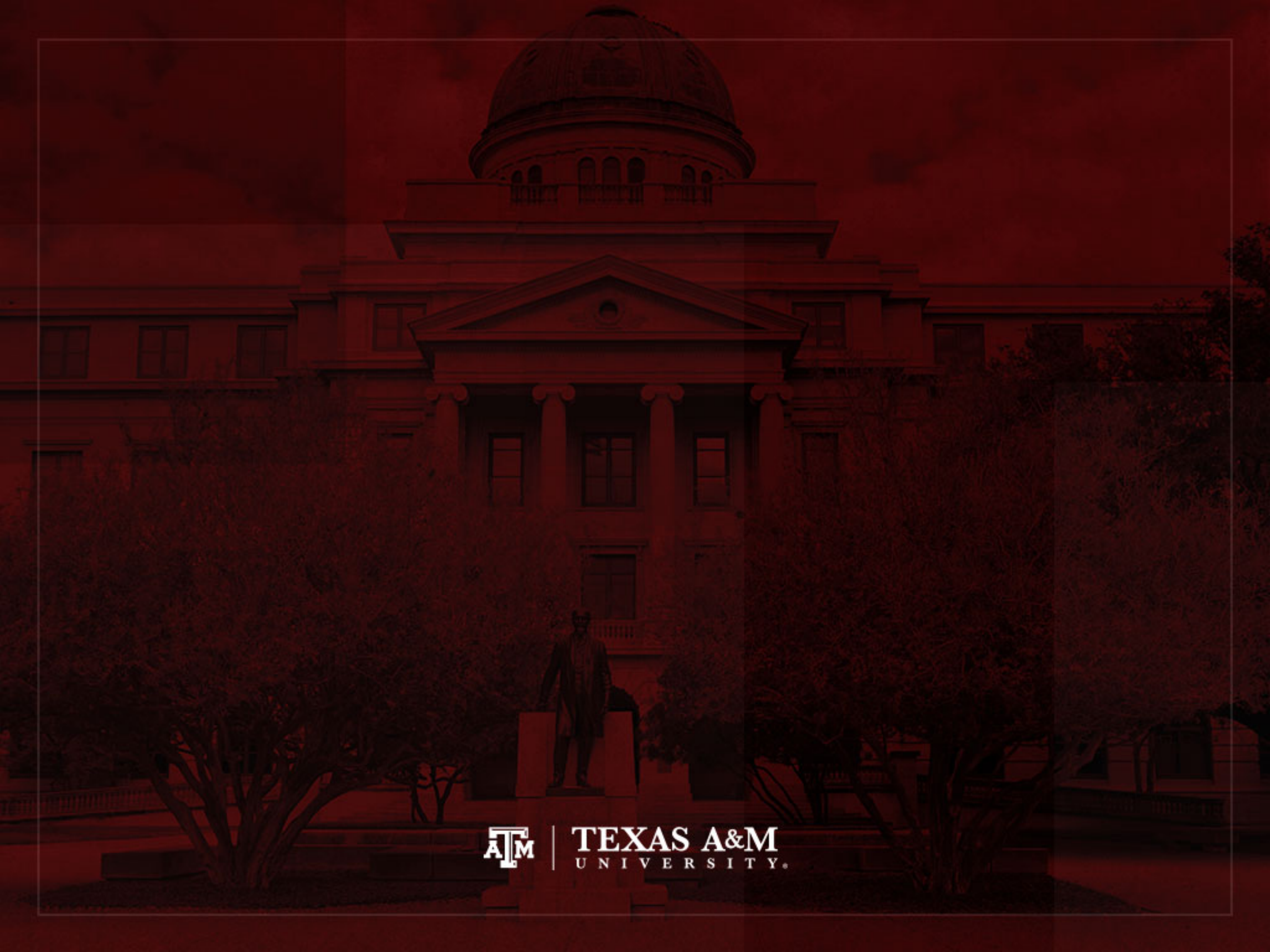
Demographic determinants

- Demographic changes in fertility, mortality, and migration have profound effects on the age-structure of societies

- Age distribution is determined by
  - Size and history of its birth cohorts
  - Age-specific mortality rates
  - Migration rates

Demographic components

- The demographic processes contribute to population aging
  - Declines in **fertility** have been the primary engine behind the growth of older populations in many regions of the world (He et al. 2016)
  - Global aging can also be attributed to the low levels of **mortality** which have fueled population aging in many countries
  - Age patterns of **immigration** and **emigration** also have influence on population aging to a lesser degree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Stable population

- Stable population is any population produced by age-specific rates of fertility and mortality constant over a long period of time
  - Its age pyramid is determined uniquely by its lifetable and its long-term growth rate
  - Proportions in each age group in a stable population do not change over time
  - Numbers in each age group may change over time
    - Population may be growing or declining in size
    - It depends on what the growth rate happens to be

Source: Wachter, 2014.

Stable ≠ Stationary

- Stable population
  - Rates stay the same
  - Population size may change
- Stationary population
  - Rates and population size remain the same
  - Growth rate is zero
  - It is a special case of a stable population
  - It satisfies the extra condition of having zero population growth (ZPG)

Source: Wachter, 2014.

Little more on stationary

- We can imagine complicated cases in which age-specific rates are changing in ways that cancel each other out
  - So that population size remains the same
  - Sometimes such a population is called stationary

- But we reserve the word stationary for cases with
  - Unchanging rates
  - Unchanging size

Source: Wachter, 2014.

Stable population model

- Stable population theory is a central tenet of modern demography that is used to examine the structure and growth of population aging
- It is the mathematical analysis of stable age pyramids
  – It is a theory that goes back to the work of Leonhard Euler in 1760
- It was extensively developed by
  – Alfred Lotka in the early 1900s
  – Nathan Keyfitz and Ansley Coale in the last half-century

Source: Wachter, 2014.

Theory to deal with age structure

- There is theory to deal with age structure
  - It accounts for the relative numbers of young and old men and women in a population

- Basic idea is to obtain formulas for how a population will be theoretically distributed by age
  - If population has been closed to migration
  - If its birth and death rates have been unchanging for a long time

Source: Wachter, 2014.

Actual ≠ Theoretical

- The actual age distribution of the population naturally differs from the theoretical age distribution

- Deviations are explained by
  - Events of migration
  - Changes in fertility and mortality rates in the prior history of the population

Source: Wachter, 2014.

General and special features

- The age distribution of each population has general and special features
- General features
  - Similar to those of populations with same vital rates
- Special features
  - Specific and derived from its own particular history

Source: Wachter, 2014.

Graphical diagrams

- Age pyramid, age distribution, age structure
  - They represent the distribution of the population by age and sex
  - They are made up of a pair of bar graphs, one for men and one for women, turned on their sides and joined
- The vertical axis corresponds to age
  - The young are toward the bottom, the elderly toward the top
  - The open-ended age group at the very top is sometimes drawn with a triangle instead of bars
- For each age group
  - The bar coming off the axis to the right represents the number of women in that age group
  - The bar to the left represents the number of men

Source: Wachter, 2014.

Idealized age pyramids

- Examples of idealized stable pyramids that occur in closed populations with unchanging vital rates
- Tall and slender
  - It is a case for a long-lived population with near zero growth
- Quite pyramidal in shape
  - It is a case for a population with heavy mortality and rapid growth

Source: Wachter, 2014.

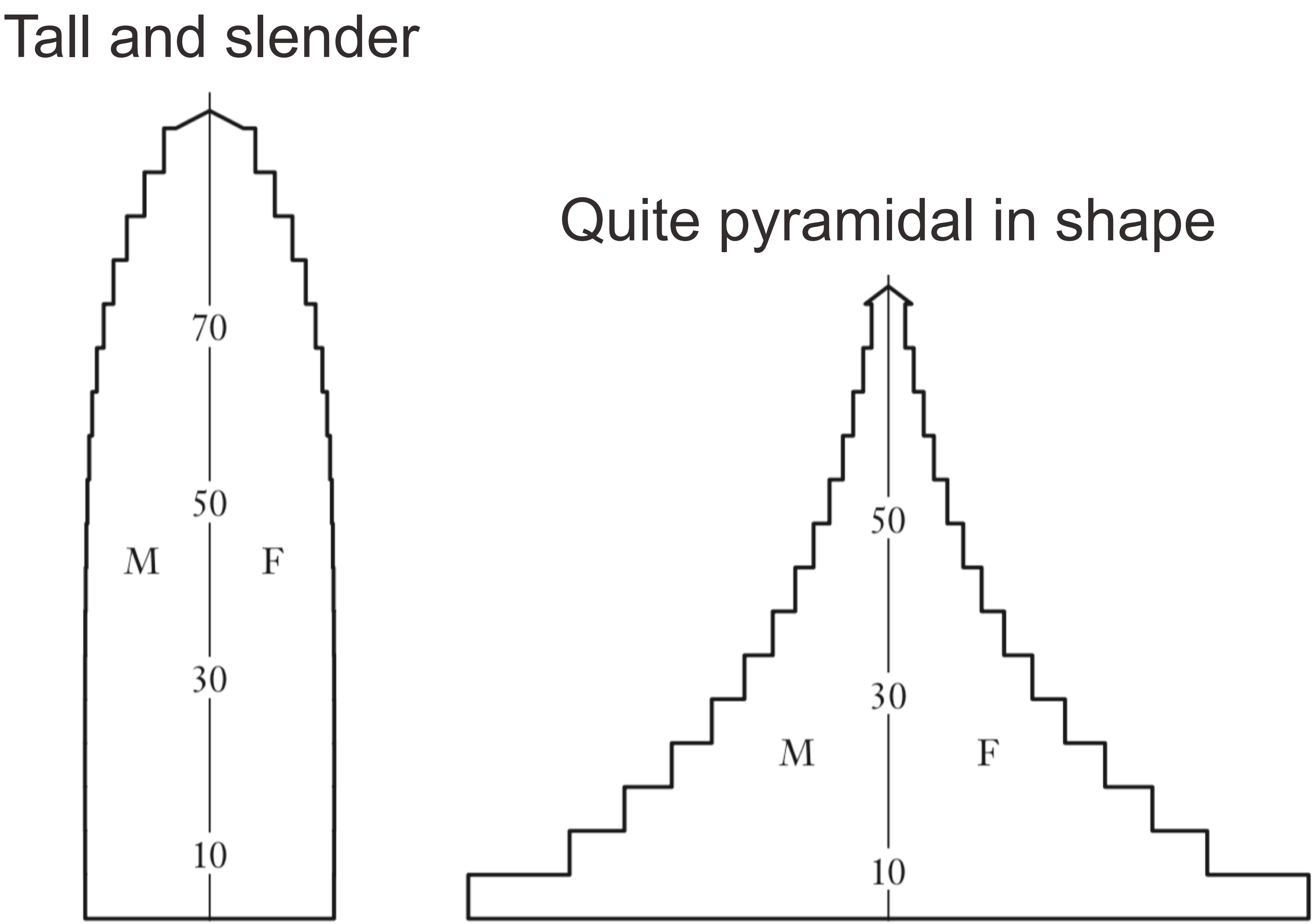


Figure 10.1 Examples of stable age pyramids

Source: Wachter, 2014.

Observed age pyramids

- Examples of observed age pyramids
- France in 1960
  - It shares overall shape with the low-growth sable case
  - But notches among 20 and 40 years of age due to low births during World Wars I and II
- Mauritius in 1963
  - It shares overall shape with high-growth stable case
  - But indentations at working ages hint at changes around 1945 from increasing growth
    - Gains against infant mortality

Source: Wachter, 2014.

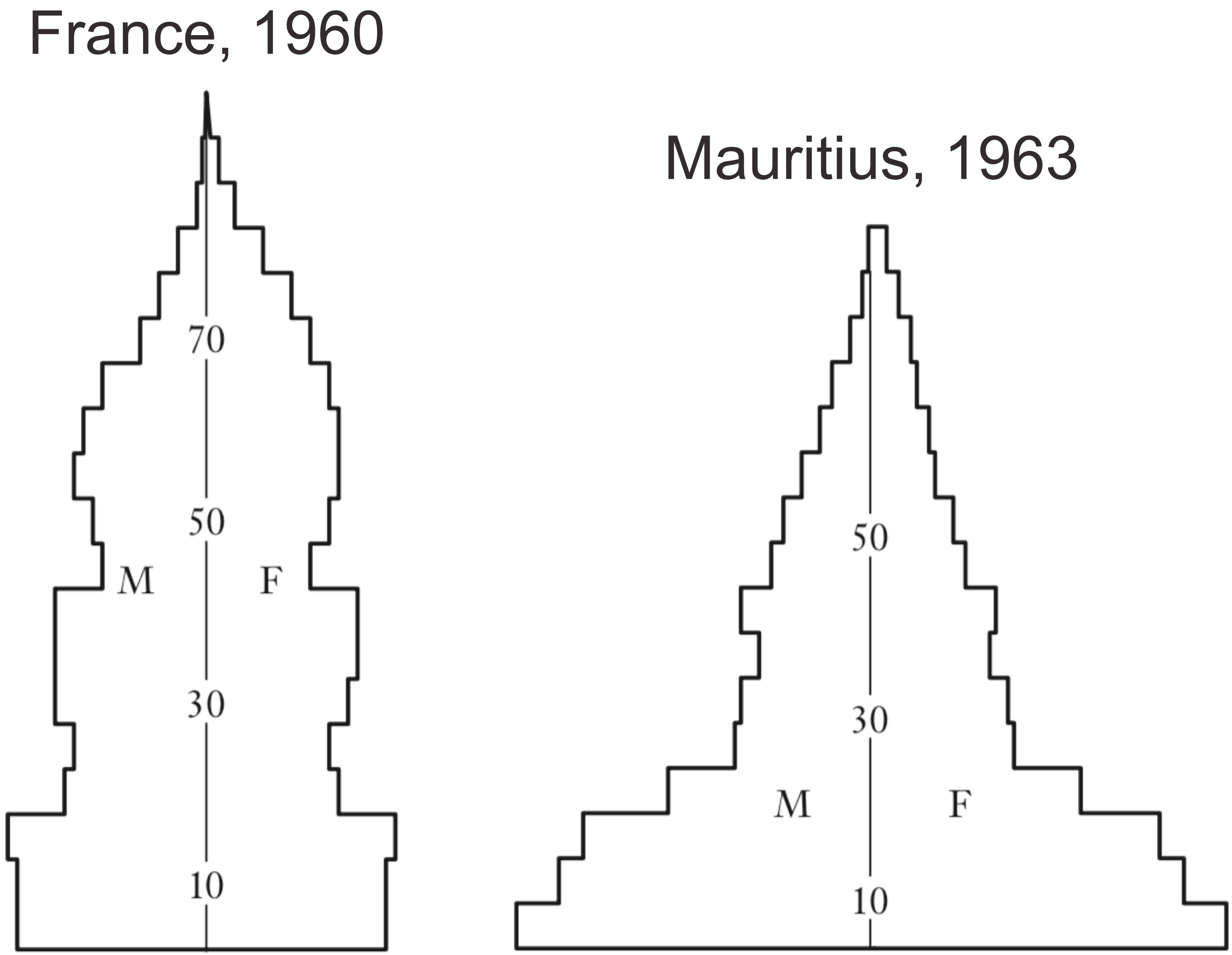


Figure 10.2 Examples of observed age pyramids

Source: Wachter, 2014.

Idealized ≠ Observed

- Stable theory captures general features well

- Observable differences from stable shapes due to each nation’s own history
  - Changing fertility and mortality rates
  - Movements across borders

Source: Wachter, 2014.

Age distribution

- The age distribution in a stable population is mathematically determined by age-specific fertility and age-specific mortality rates
- Thus, we can estimate the effect of changes in age-specific fertility and/or age-specific mortality rates on the age structures of a stable population

Constant fertility and mortality

- Without migration, populations with constant fertility and mortality patterns will
  - Increase or decrease in total size at a constant rate
  - Acquire an age distribution that does not change over time

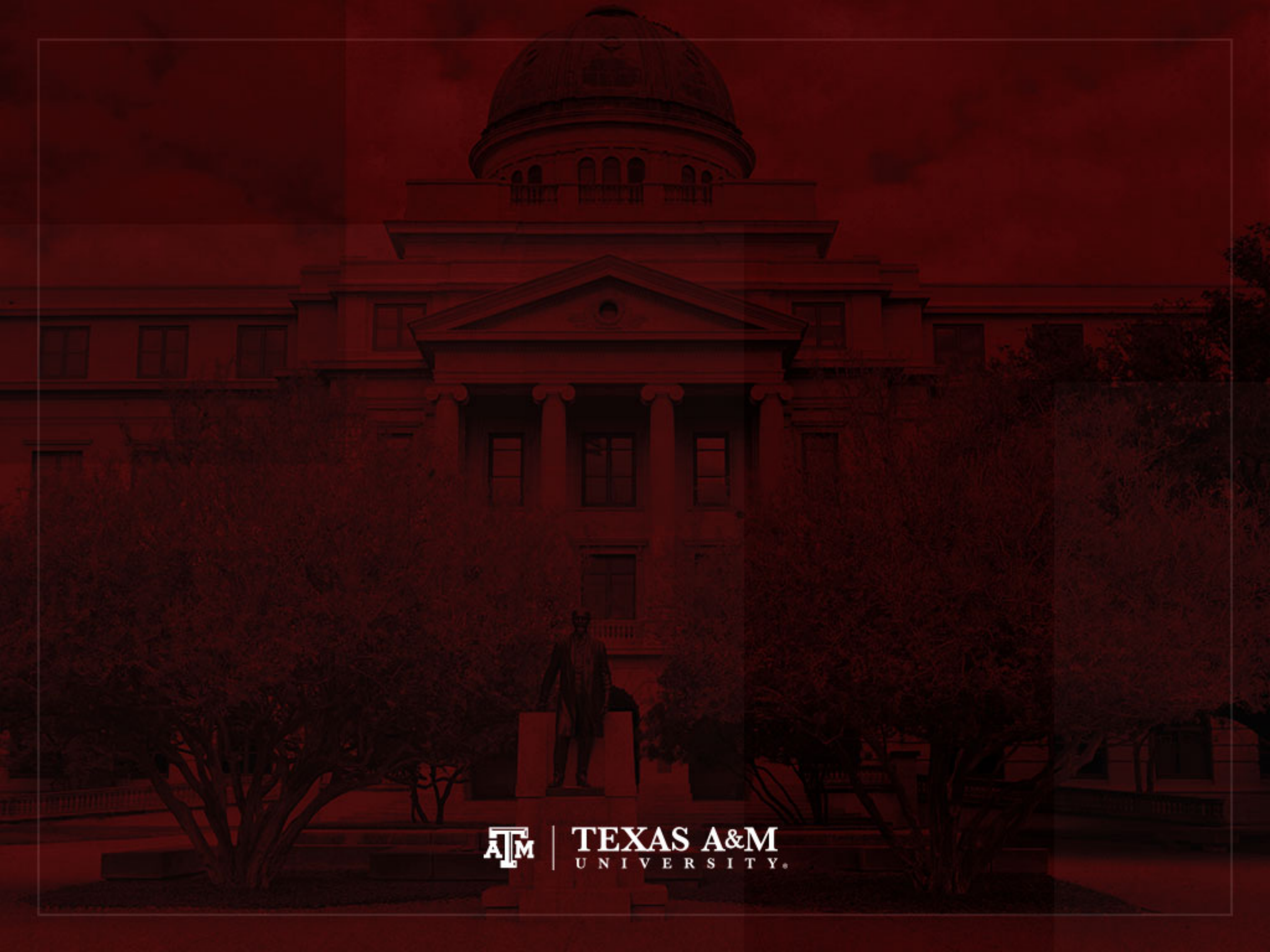
Changing fertility and mortality

- However, variation in the age structure of stable populations may arise from differences between fertility and mortality rates
  - The result of higher birth rates is evident in the proportional change of the younger population
  - Results of variations in mortality patterns depend on the specific ages in which mortality changes occur

Table 5.1 Proportion age 65 and older in stable populations with various combinations of fertility and mortality

	Gross reproduction rate					
Life expectancy	0.80	1.00	1.50	2.00	3.00	4.00
20	.165	.134	.085	.058	.032	.020
30	.178	.142	.087	.055	.031	.019
40	.189	.149	.090	.059	.030	.018
50	.198	.154	.091	.060	.030	.017
60	.201	.156	.092	.059	.029	.017
70	.212	.165	.096	.061	.030	.017
80	.259	.202	.119	.075	.036	.021

Source: Coale et al. (2013)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Population projections

- Population projections are estimates of the growth and composition of a population at a future date under a particular set of assumptions

- The accuracy of population projections depends on how close the actual trends are with respect to the assumptions about future births, deaths, and net migration

Cohort-component method

- The standard approach to population projections uses a cohort-component method
- It accounts for the age and sex structure of a population and its demographic processes (fertility rate, mortality rate, and net migration) through which populations change over time

Population projections

- The baseline U.S. projections presented for this exercise begin in 1995
  - ~12.8% of the population was age 65 and older
  - Total fertility rate (TFR) was 2.06
  - Life expectancy was 75.9 years
  - Yearly net immigration was 820,000

Table 5.2 Fertility, life expectancy, and net migration assumptions for 1995–2050

		2050 Level of assumption		
Item	1995	Low	Middle	High
Fertility	2.055	1.910	2.245	2.580
Life Expectancy	75.9	74.8	82.0	89.4
Yearly Net Migration (thousands)	820	300	820	1370

Source: Day (1996)

Alternative assumptions

- ~12.8% of the U.S. population was 65+ in 1995

Table 5.3 Alternative assumptions for percent of U.S. population projected to be age 65 and older in 2050

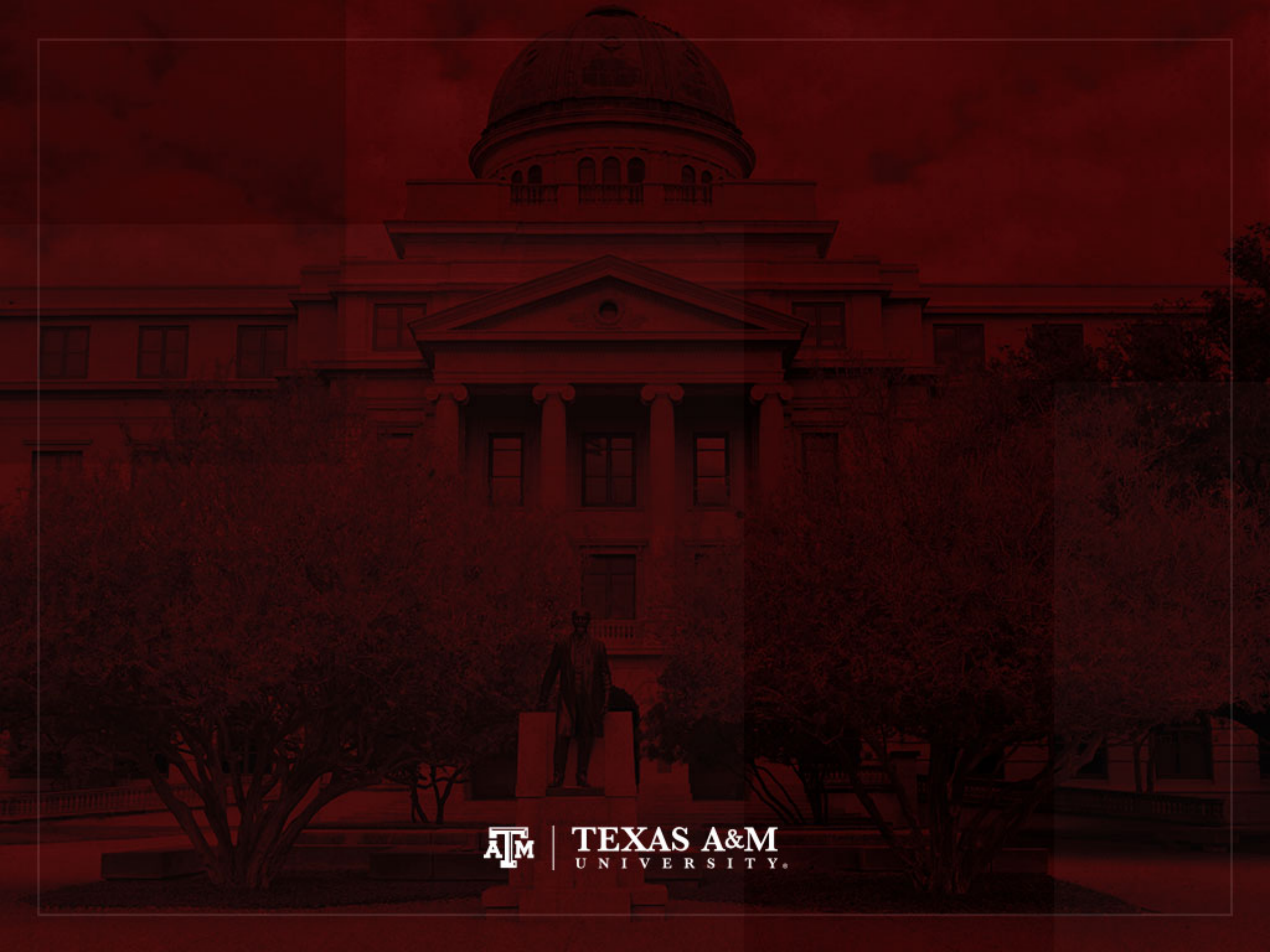
Assumptions[a]	% 65 +
Middle Series for Fertility, Life Expectancy & Immigration	20.0
Low Fertility, Middle Life Expectancy & Immigration	22.8
High Fertility, Middle Life Expectancy & Immigration	17.6
High Life Expectancy, Middle Fertility & Immigration	23.3
Low Life Expectancy, Middle Fertility & Immigration	16.5
High Immigration, Middle Life Expectancy & Fertility	19.4
Low Immigration, Middle Life Expectancy & Fertility	20.8
Zero Immigration, Middle Life Expectancy & Fertility	22.3

Source: Day (1996)

[a]See text for description of assumptions

Stable model and projections

- The stable population model and population projections lead to similar conclusions regarding the demographic processes of population aging
  - Decreases in **fertility** rates lead to an aging population
  - Decreases in **mortality** across **all age** distributions have relatively little effect on the age structure of a population
  - Decrease in **mortality** rates among **older adults** can significantly lead to population aging
  - Within typical boundaries, **net migration** has a minimal effect on population aging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Measures and methods

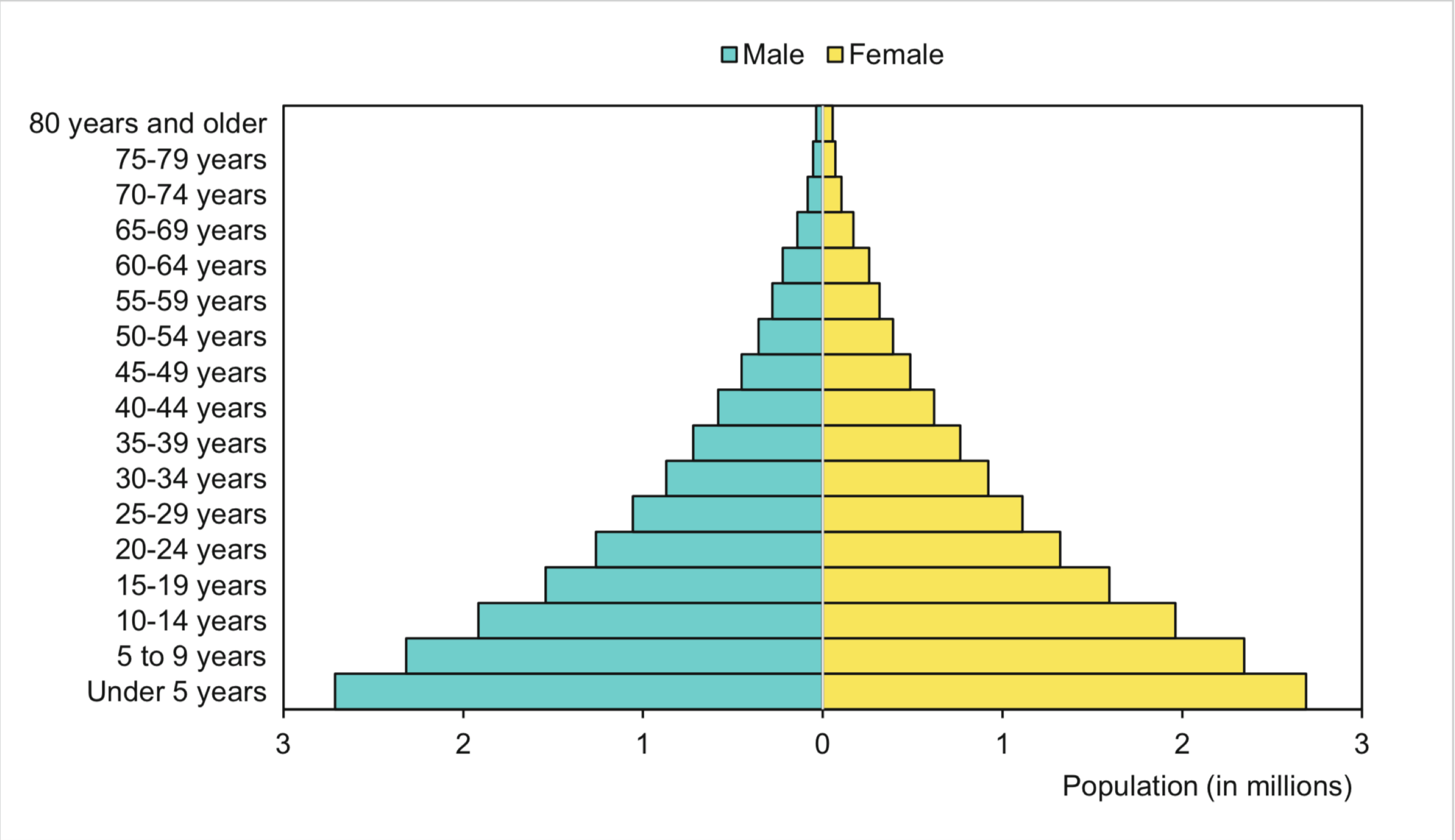
- Population pyramids
- Dependency ratios
- Life expectancy
- Median age
- Aging index

Population pyramids

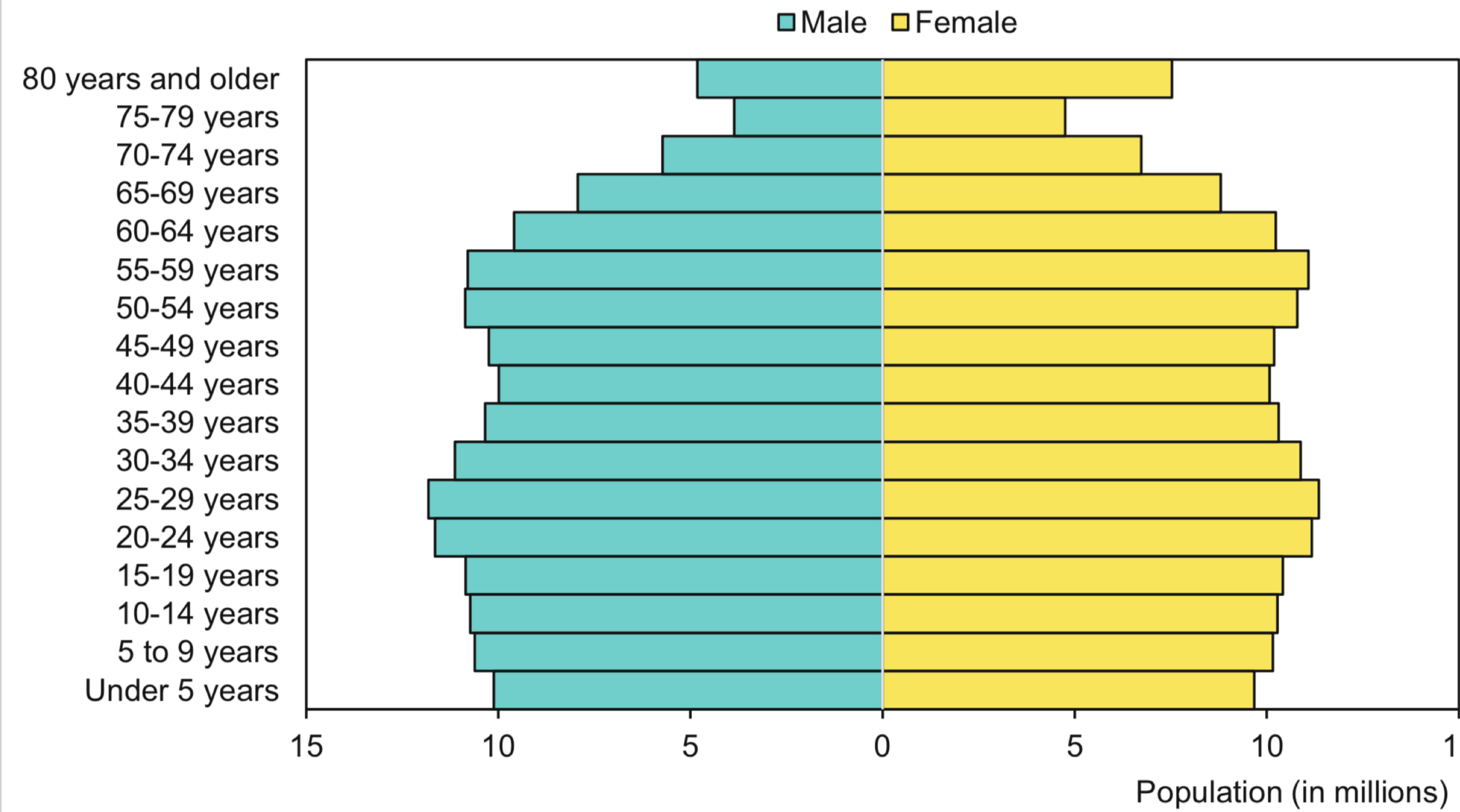
- As discussed before, a population pyramid
  - Is a graphic representation of the age/sex structure of the population
  - Is also called “age/sex pyramid”
  - Due to changes in the shape of population distributions, it has been simply called “age/sex structure”

- A population pyramid is nothing more than two ordinary histograms (bar graphs)
  - They represent male and female populations
  - Usually, demographers use 1- or 5-year age categories

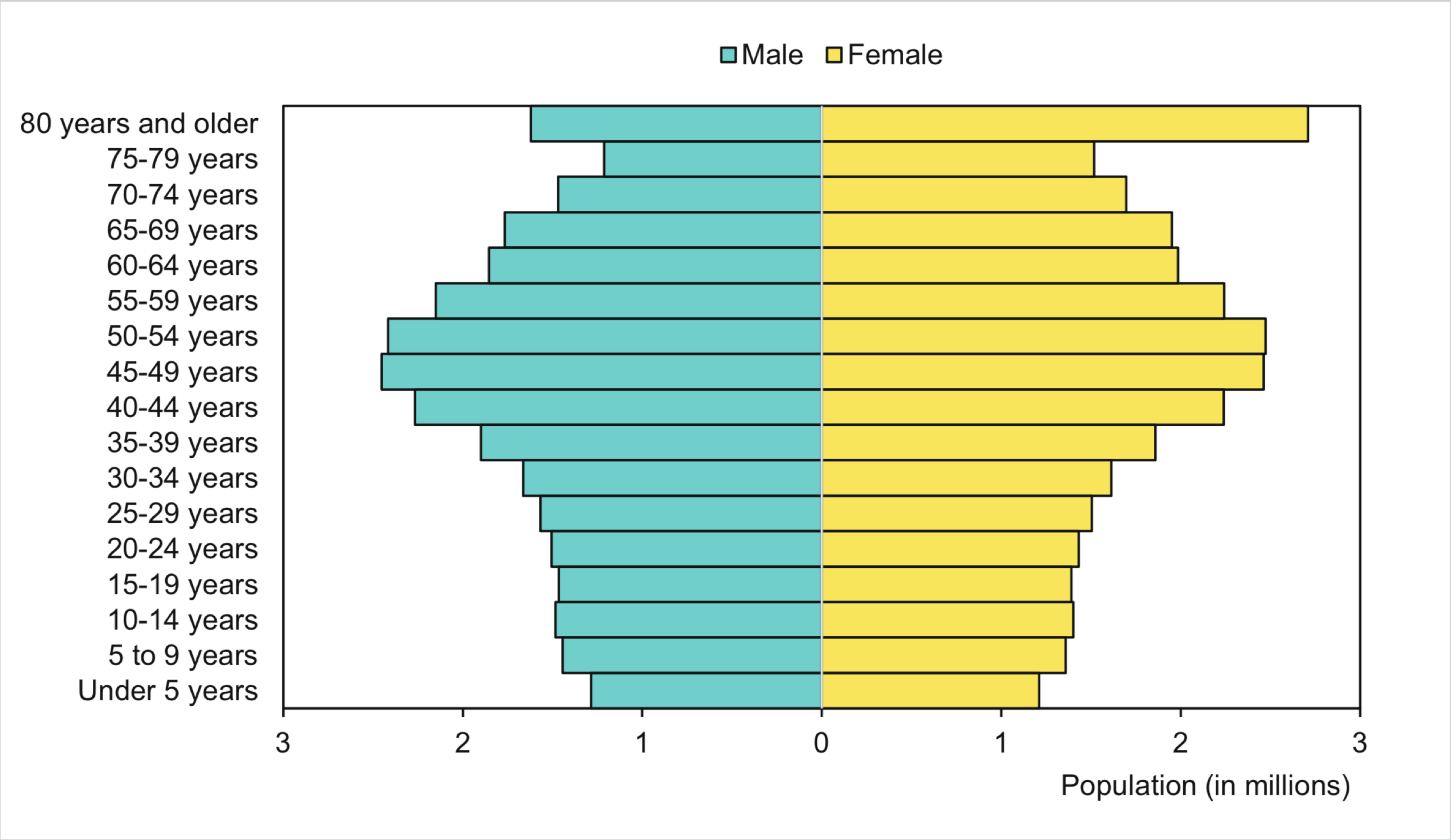
Angola, 2017


Male
Female
80 years and older
75-79 years
70-74 years
65-69 years
60-64 years
55-59 years
50-54 years
45-49 years
40-44 years
35-39 years
30-34 years
25-29 years
20-24 years
15-19 years
10-14 years
5 to 9 years
Under 5 years
3
2
1
0
1
2
3
Population (in millions)

United States, 2017



Italy, 2017



Male
Female
80 years and older
75-79 years
70-74 years
65-69 years
60-64 years
55-59 years
50-54 years
45-49 years
40-44 years
35-39 years
30-34 years
25-29 years
20-24 years
15-19 years
10-14 years
5 to 9 years
Under 5 years
3
2
1
0
1
2
3
Population (in millions)

Dependency ratios

- A popular measure of age structure is the total dependency ratio (TDR)
  - It is the ratio of the dependent-age population
    - Both young (persons 0–14 years old)
    - And old (persons 65+ years old)
  - To the working-age population
    - Persons 15–64 years old
  - It is usually multiplied by a constant of 100
- The higher the ratio
  - The more people each worker has to support
- The lower the ratio
  - The fewer the number of dependents

Ratios

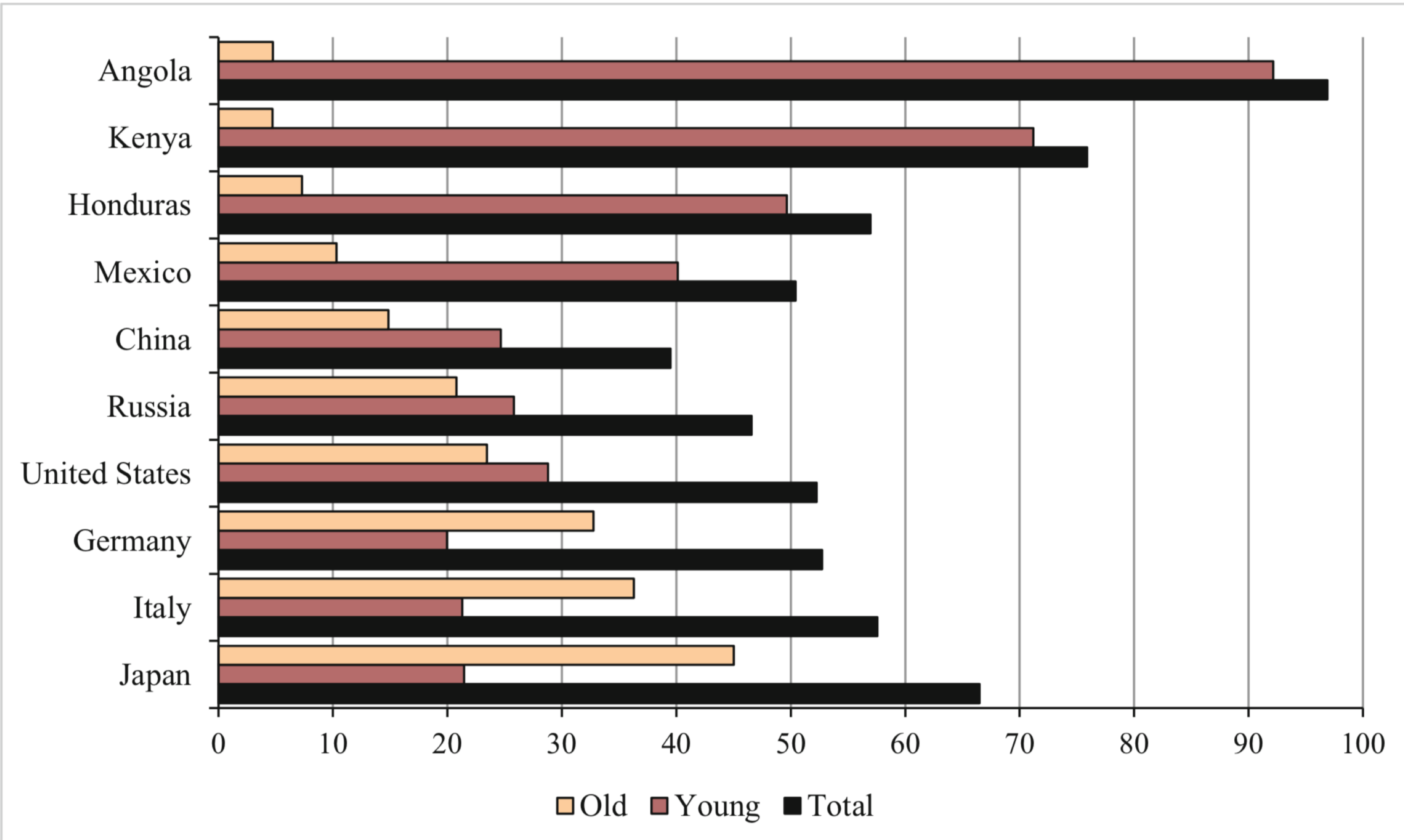
- Describe a relationship between two numbers
  - Compare the size of one number to the size of another number
  - Compare the relative sizes of categories
  - Indicate how many times the first number contains the second
  - Denominator is not at “risk” of moving to numerator
  - Optional: multiply by 100 to get percentage

$$Total\ dependency\ ratio = \frac{Pop.\ children\ (0\ to\ 14)\ +\ Elderly\ pop.(65+)}{Working\ age\ population\ (15\ to\ 64)} * 100$$

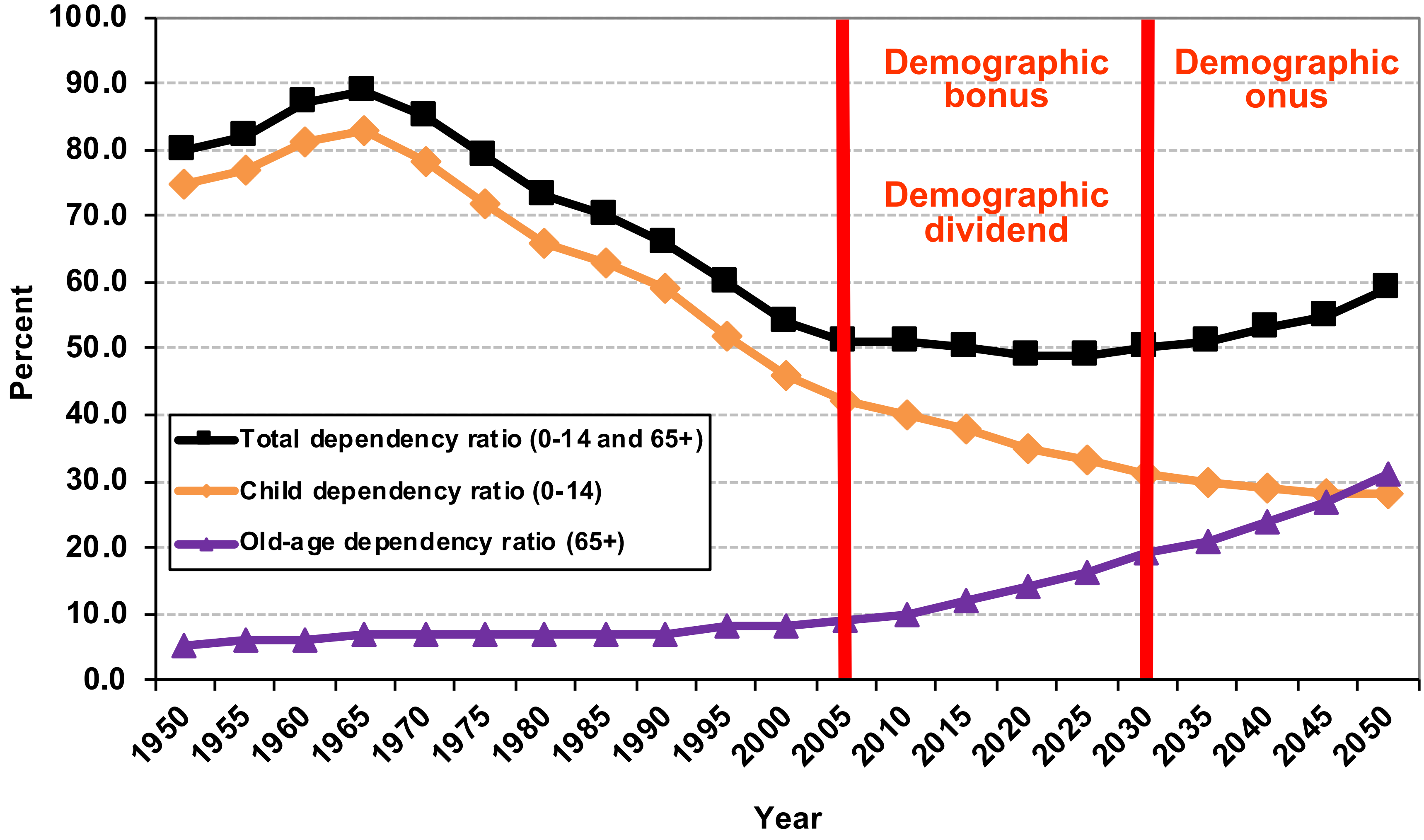
YDR and ADR

- Demographers usually split dependency ratio into
  - Youth-dependency ratio (YDR or Youth-DR)
  - Old-age dependency ratio (Old Age-DR), also known as the aged-dependency ratio (ADR or Aged-DR)
- Numerator
  - The numerator of the YDR is the population 0–14
  - The numerator of the ADR is the population 65+
- Denominator is the same: population 15–64
- YDR plus ADR equals the TDR

Dependency ratios, 2017



Dependency ratios, Brazil 1950–2050



Source: United Nations - http://esa.un.org/unpp (medium variant).

Life expectancy

- Life expectancy is used as an indicator of the quality of life, health conditions, and social development of a population
  - It is the average length of time to be lived by a group of people born in the same year, assuming that age-specific mortality levels remain constant
  - It is calculated from actual mortality data in a single year
  - It describes what would happen to a hypothetical group if they moved through their lives experiencing the mortality rates observed for the country in any given year

Life expectancy

Table 5.4 Life expectancies among high-, middle-, and low-income countries

	Life expectancy at birth, 2015[a]		Life expectancy at age 65, 2010–2015[b]	
	Men	Women	Men	Women
High Income				
Italy	80.3	84.9	18.6	22.0
Japan	80.8	87.0	19.0	23.9
United States	76.3	81.2	18.0	20.6
Middle Income				
Brazil	71.6	78.9	16.3	19.5
Mexico	74.5	79.4	17.9	19.7
Russia	65.9	76.7	12.9	17.1
Low Income				
Afghanistan	62.0	64.6	12.2	13.4
Ethiopia	63.2	66.9	13.8	14.9
Uganda	57.4	61.8	13.2	14.3

[a]Source: The World Bank

[b]Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision

Healthy life expectancy

- Healthy life expectancy refers to the number of years that an individual may expect to live in a healthy state
  - Living without disability or morbidity

- It is calculated using the Sullivan method, also known as Sullivan health expectancy (Sullivan 1971)
  - It integrates age-specific data on the prevalence of the population in healthy and unhealthy states, with age-specific mortality information

Healthy life years, 2016

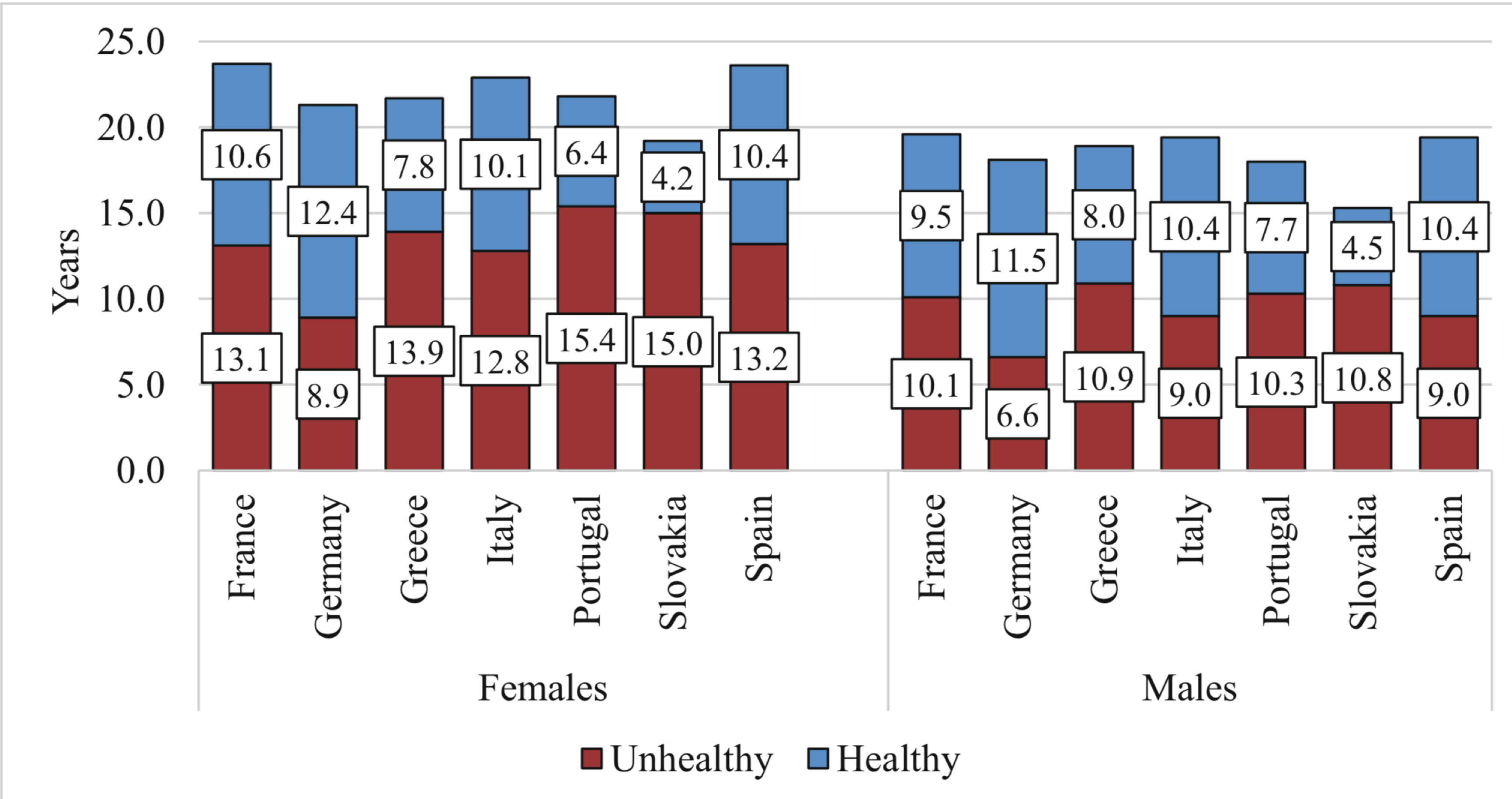


Fig. 5.5 Healthy life years and life expectancy at age 65, 2016. (Source: Eurostat (2018). http://ec.europa.eu/eurostat/en/web/products-datasets/-/TEPSR_SP320)

Median age

- The median age of a population is a measure of central tendency that divides a population into two age groups of the same size
  - 50% of the total population is younger than the median age and the other 50% is older
- Median age is useful to compare populations when age distributions are not symmetrical
  - Median is less affected by outliers and skewed data
- A major limitation of median age is that it does not give details of the age distribution

Table 5.5 Median age, 2017

	Total	Male	Female
Japan	47.3	46.0	48.7
Italy	45.5	44.4	46.5
Germany	47.1	46.0	48.2
United States	38.1	36.8	39.4
Russia	39.6	36.6	42.5
China	37.4	36.5	38.4
Mexico	28.3	27.2	29.4
Honduras	23.0	22.6	23.3
Kenya	19.7	19.6	19.9
Angola	15.9	15.4	16.3

Source: The World Factbook, Central Intelligence Agency, United States

Aging index

- The aging index is the number of persons 60+ years per 100 persons under age 15

Aging index = Pop.60+ / Pop.<15 *100

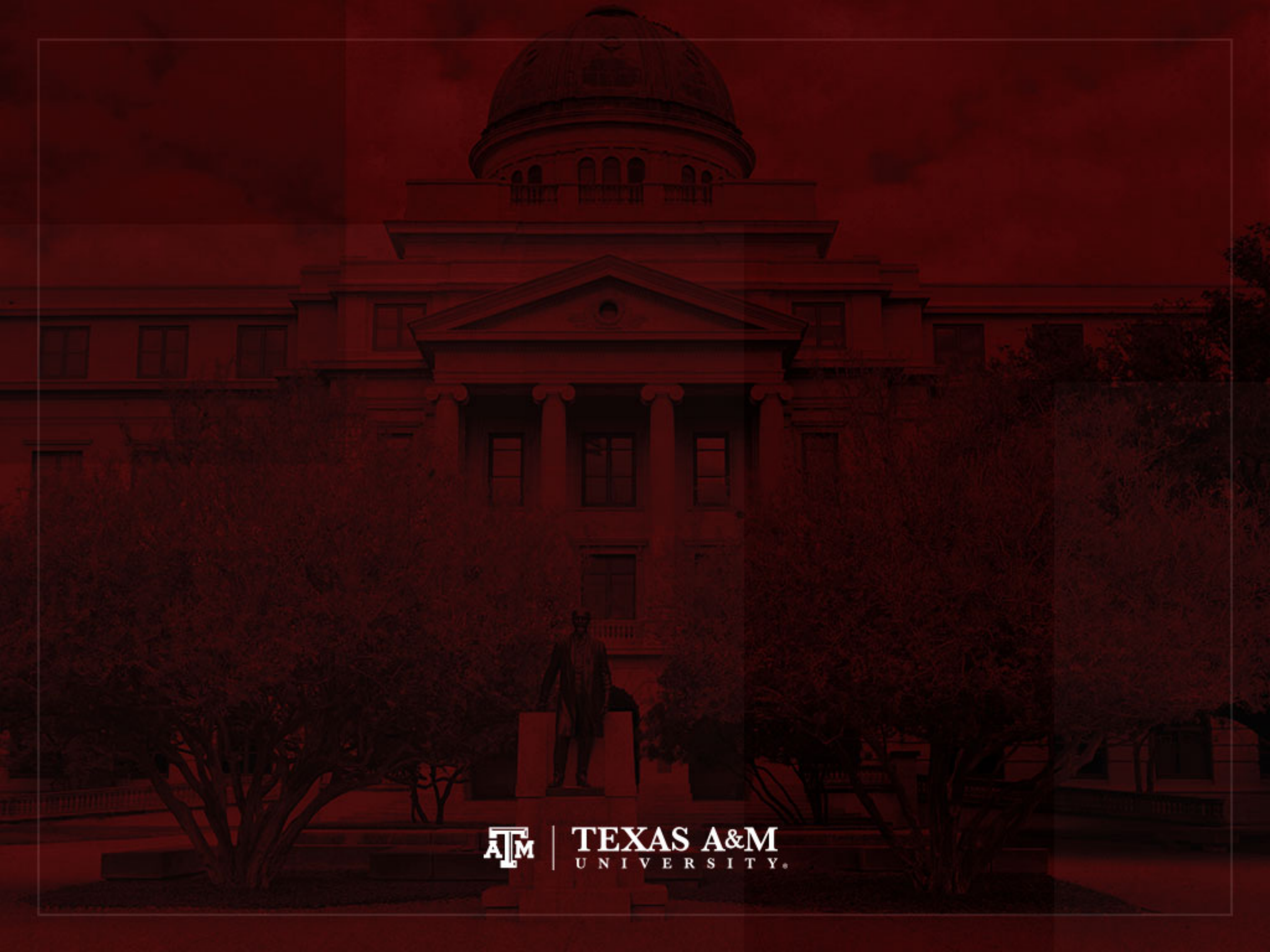
- This measure is a straightforward indicator of the relative number of older persons in a population for every 100 children

Examples of aging index

- In 2000, few countries (e.g., Japan, Germany, and Italy) had aging indexes above 100 (Gavrilov, Heuveline 2003)

- By 2030, it is expected that all developed countries will have aging indexes above 100 (Kinsella, Phillips 2005)
  – Some countries (e.g., Japan) will have an aging index above 200 (Gavrilov, Heuveline 2003)

- In developing countries, aging indexes are much lower since their populations are much younger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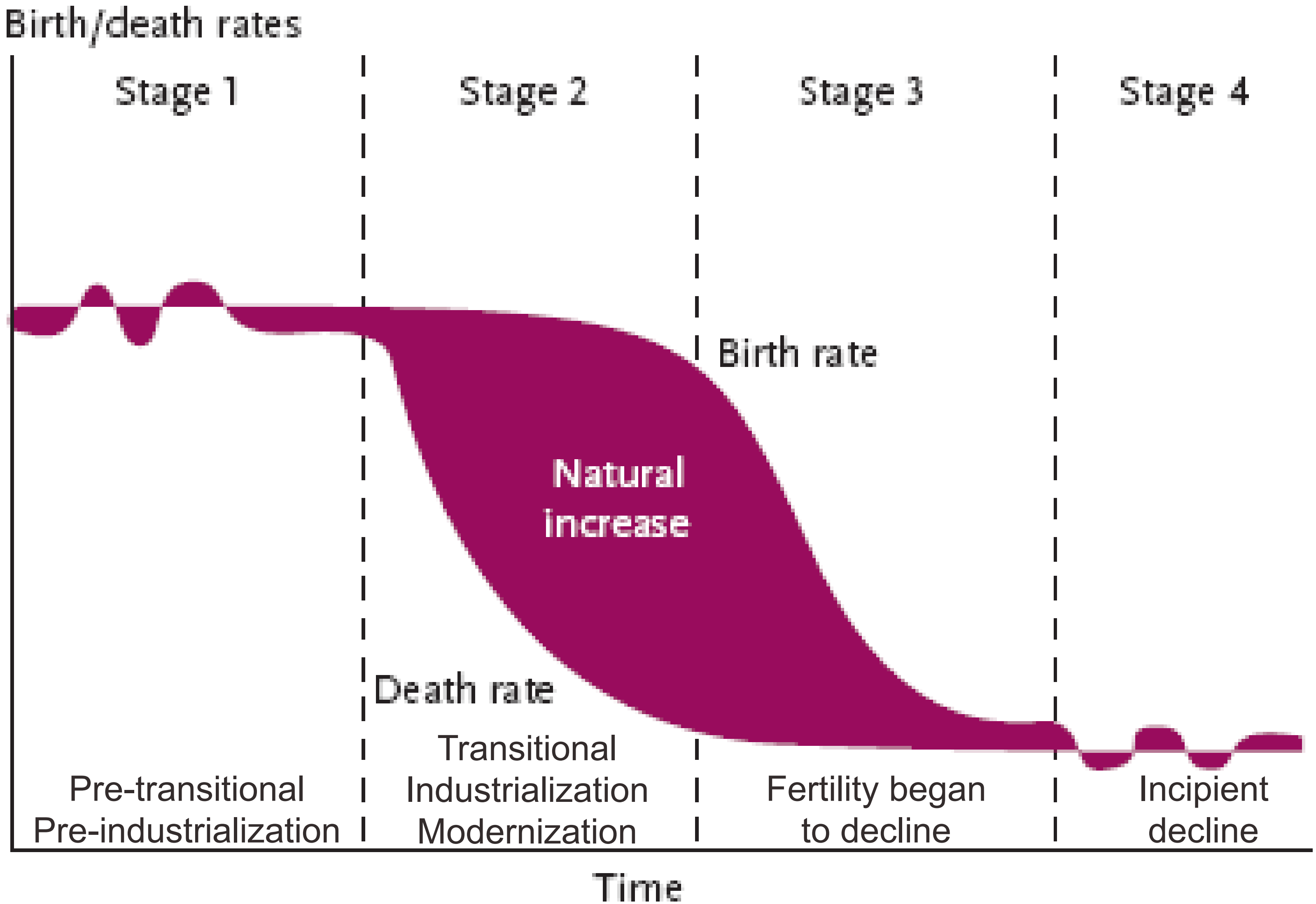
Trajectories of population aging

- The demographic transition is one of the most important historical changes that have affected
  - Population growth rate
  - Age structure of a country

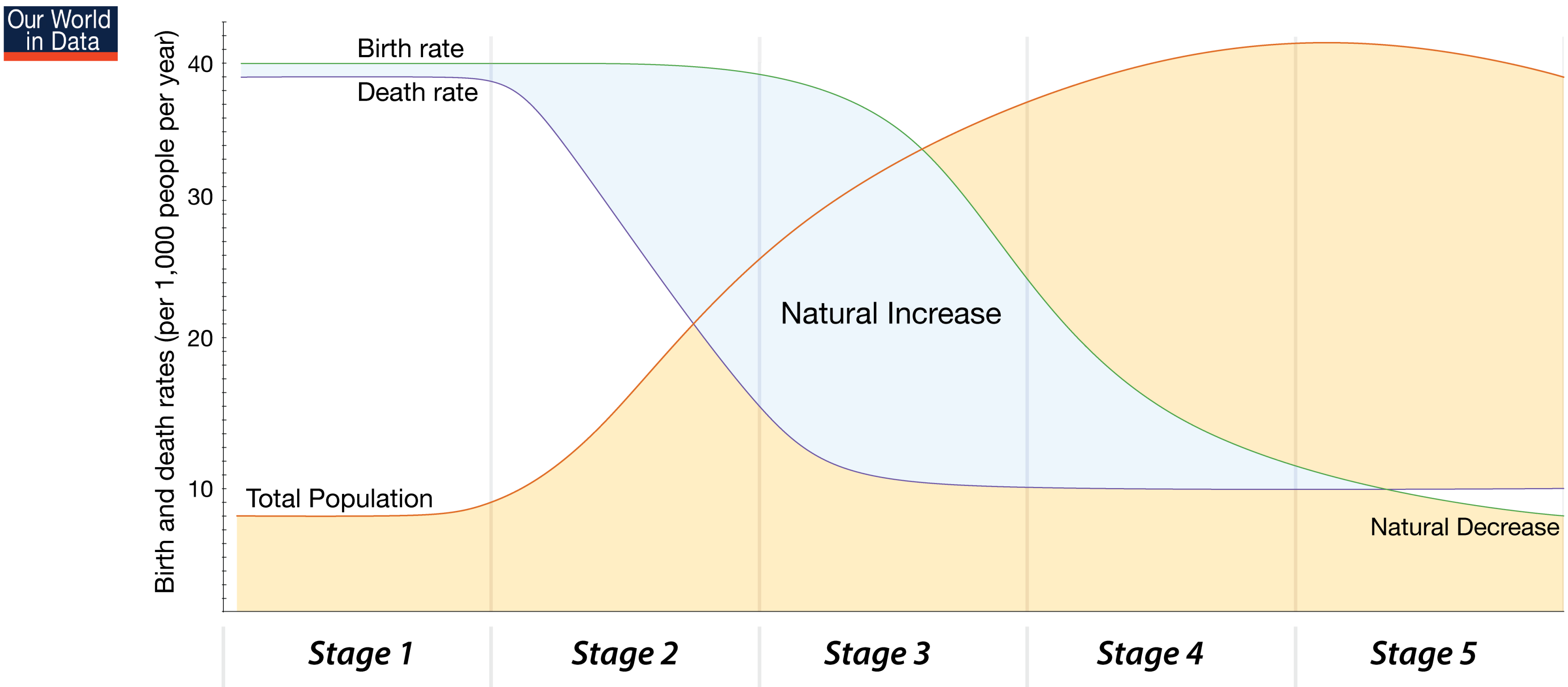
- The classical model of the demographic or epidemiological transition refers to the process
  - In which a population characterized by high fertility and mortality
  - Transitions into a population with low fertility and low mortality

Demographic transition



Source: Poston, Bouvier, 2017.

Demographic transition



	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Birth rate	*High*	*High*	*Falling*	*Low*	*Very low*
Death rate	*High*	*Falls rapidly*	*Falls more slowly*	*Low*	*Low*
Natural increase	*Stable or slow increase*	*Very rapid increase*	*Increase slows down*	*Stable or slow increase*	*Stable or slow decrease*

Epidemiological transition

- Stages of epidemiological transition model (Omran 1971)
    1. Age of pestilence and famine
    2. Age of receding pandemics
    3. Age of degenerative and man-made diseases
    4. Age of delayed degenerative diseases (Olshansky, Ault 1986; Vaupel 2010; Wilmoth 2000)

First stage

- Age of pestilence and famine
  - High and fluctuating mortality rates among children and adults due to infectious and deficiency diseases
  - Life expectancy varies across populations
  - Low average life span (maximum recorded age at death): around 20–40 years
  - Population's age structure is young with a pyramid shape
  - Natural increase (births minus deaths) is low and population growth is slow

Second stage

- Age of receding pandemics
  - High rates of fertility, declining mortality rates
  - Population growth increases, because of improvements in nutrition, hygiene, sanitation, social programs, and medical technologies
  - Reduction of infectious and deficiency diseases
  - Increase of degenerative diseases at older ages
  - Average life expectancy also increases in this stage
  - Population age structure remains young, but there is an increasing proportion of older adults

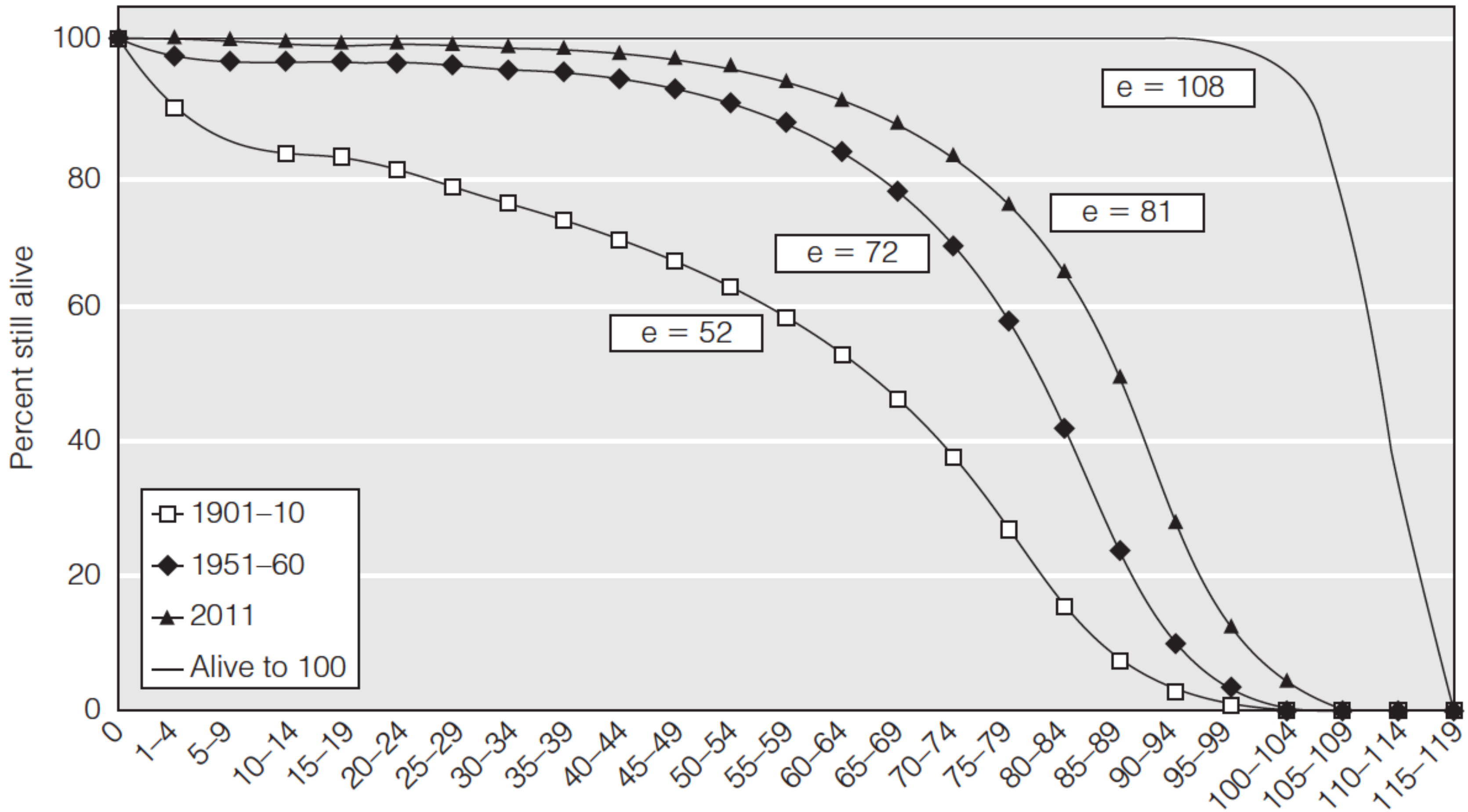
Third stage

- Age of degenerative and man-made diseases
  - Non-communicable diseases (chronic diseases) become the primary cause of death for the populations
  - Infectious and deficiency diseases become rare or nonexistent
  - Low and stable rates of infant mortality
  - Increased survival into adulthood and old age
  - Average life expectancy becomes much higher and tends to be greater than 50 years of age
  - Population age structure also starts to become older, an important determinant of population aging

Fourth stage

- Age of delayed degenerative diseases
  - Prosperity and medicine are contributing factors to the postponement of senescence, or delay in aging (Olshansky, Ault 1986; Vaupel 2010)
  - Survival curve becomes more **rectangular** in shape since the distribution of deaths have shifted to the right and become more compressed (Wilmoth 2000)
  - Low mortality and low fertility rates
  - Flattening of population growth
  - Old age structure

Rectangularization of mortality, United States



Global population aging

- Large numbers of elderly persons is not a problem if there are large numbers of producers
  - It is a problem when the ratio of elderly to producers becomes high, generating socioeconomic problems
- In 2020, projections indicate more than one billion older persons (60+) in the world
  - 23.4% will be in China and 7.4% in the US
- In 2020, projections indicate almost 149 million oldest-old people (80+)
  - 19.4% in China and 8.9% in the US

World, China, United States

World			
Year	Total	Older (60+)	Oldest-Old (80+)
2010	6,866,054,000	771,641,000	106,177,000
2020	7,631,072,000	1,047,071,000	148,476,000
2030	8,315,758,000	1,403,525,000	209,296,000
2040	8,896,845,000	1,741,939,000	315,576,000
2050	9,376,417,000	2,082,998,000	446,610,000
China			
Year	Total	Older (60+)	Oldest-Old (80+)
2010	1,330,141,000	171,050,000	19,658,000
2020	1,384,545,000	245,028,000	28,729,000
2030	1,391,491,000	349,324,000	42,482,000
2040	1,358,519,000	411,150,000	70,138,000
2050	1,303,723,000	459,525,000	113,890,000
United States			
Year	Total	Older (60+)	Oldest-Old (80+)
2010	309,326,000	57,466,000	11,301,000
2020	333,896,000	76,986,000	13,163,000
2030	358,471,000	92,228,000	19,459,000
2040	380,016,000	98,962,000	27,615,000
2050	399,803,000	106,087,000	30,942,000

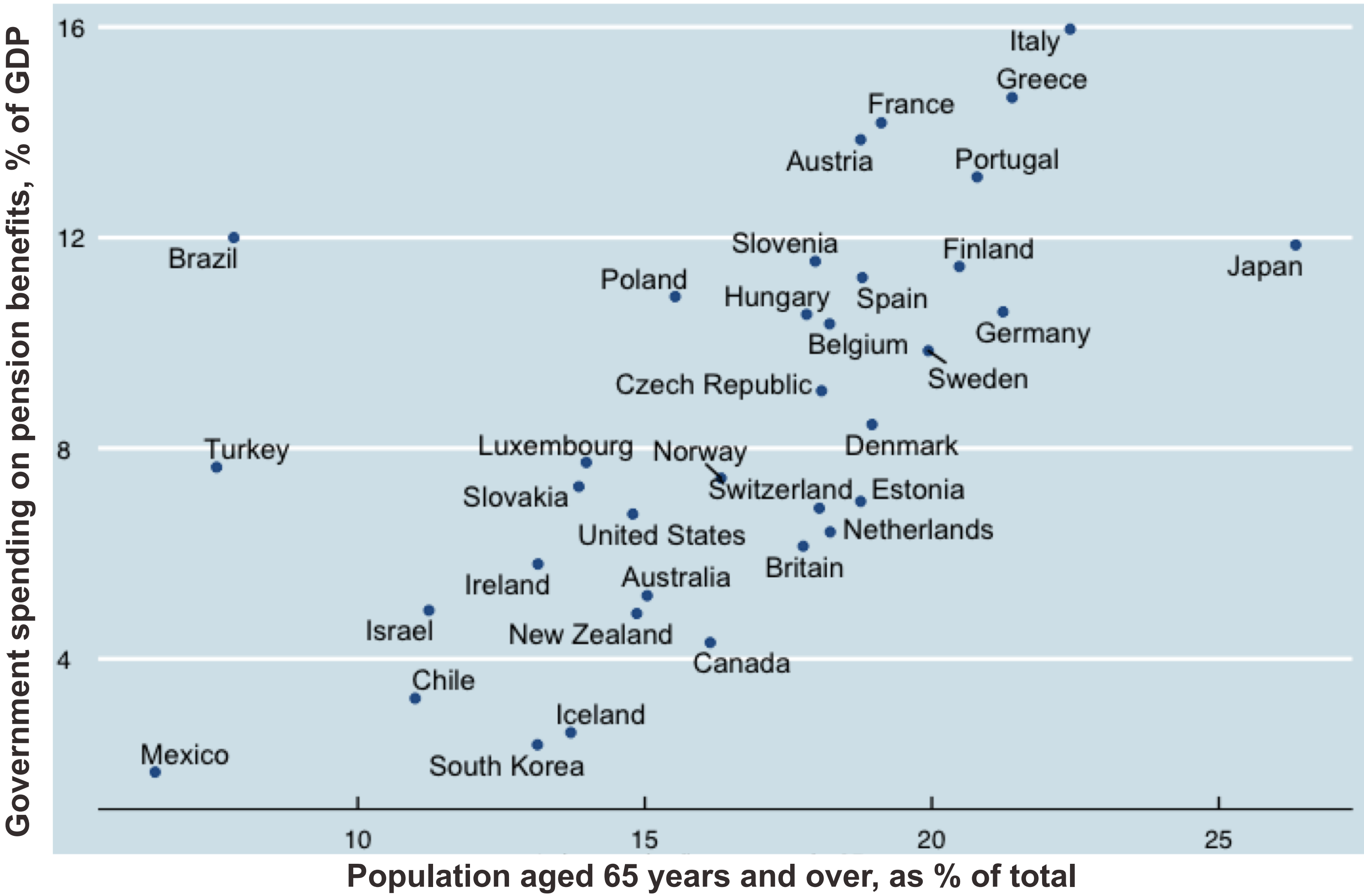
Source: Poston, Bouvier (2017).

Table 5.6 Percent of population over age 60 and 80 for the world, development groups, regions, and income groups, 2000, 2015, 2030, and 2050

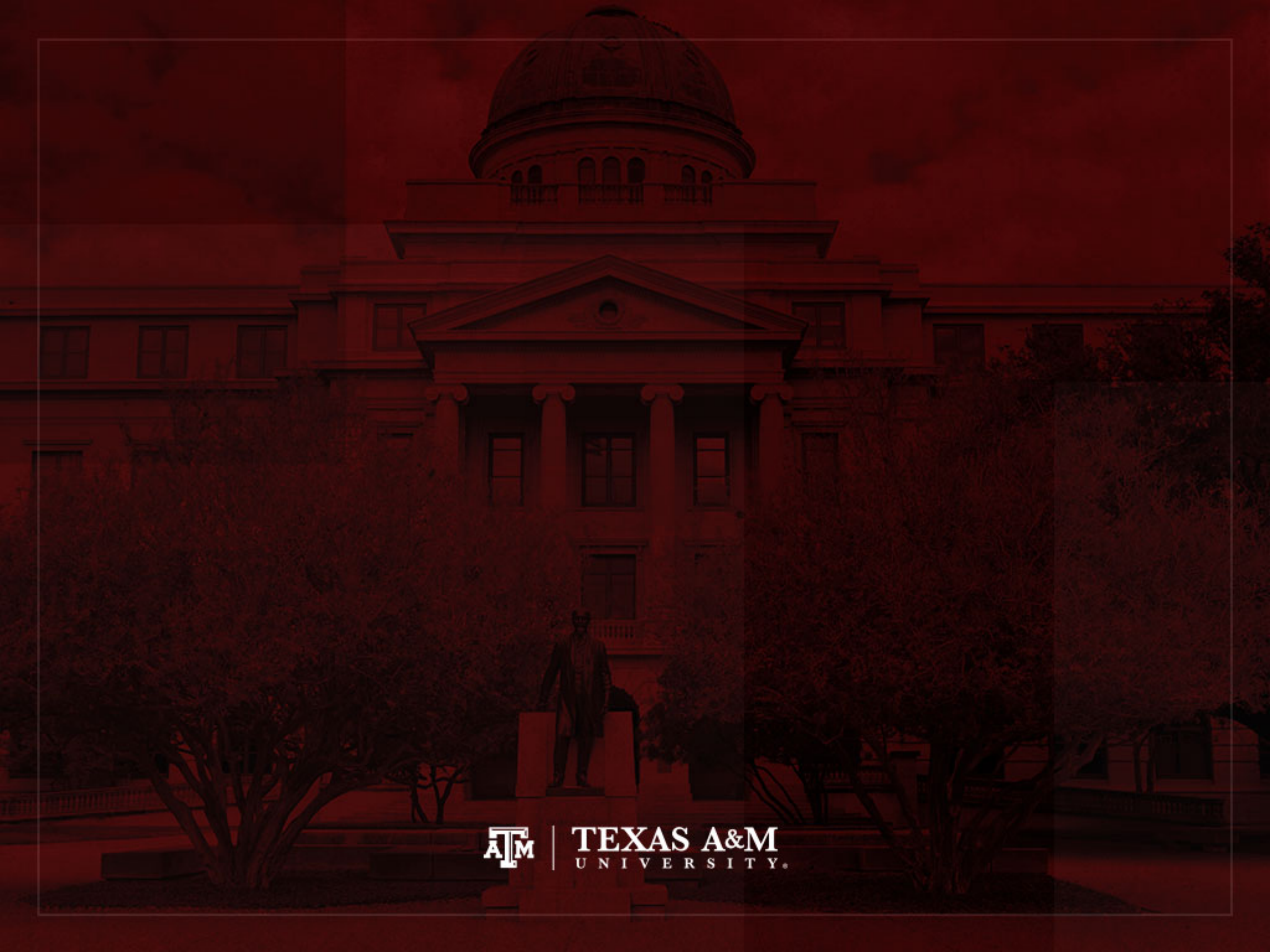
	60+				80+			
Area	2000	2015	2030	2050	2000	2015	2030	2050
World	9.9	12.3	16.5	21.5	1.2	1.7	2.4	4.5
Development Groups								
More Developed regions	19.5	23.9	29.2	32.8	3.1	4.7	6.6	9.9
Less Developed regions	8.0	10.7	15.9	22.7	0.7	1.2	1.8	4.4
Least Developed regions	5.1	5.5	6.7	9.8	0.4	0.5	0.6	1.1
Regions								
Africa	5.2	5.4	6.3	8.9	0.4	0.5	0.6	0.9
Asia	8.6	11.6	17.2	24.6	0.8	1.4	2.1	4.9
Europe	20.3	23.9	29.6	34.2	2.9	4.7	6.3	10.1
Latin America and the Caribbean	8.1	11.2	16.8	25.5	1.0	1.6	2.6	5.7
Oceania	13.4	16.5	20.2	23.3	2.2	2.9	4.3	6.4
North America	16.2	20.8	26.4	28.3	3.2	3.8	5.6	8.6
Income Groups								
High-Income Countries	18.0	22.1	27.7	31.9	2.9	4.3	6.2	9.6
Upper-Middle-Income Countries	9.2	13.4	21.2	30.5	0.9	1.6	2.6	7.0
Lower-Middle-Income Countries	6.9	8.1	11.2	16.5	0.6	0.8	1.1	2.3
Low-Income Countries	5.0	5.2	5.8	8.3	0.3	0.4	0.5	0.8

Source: United Nations (2015). *World Population Prospects: The 2015 Revision*

Government spending on pensions by population 65+



Source: Figure elaborated by Jairo Nicolau with data from The Economist (2017).



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Theoretical issues

- Migration and population aging
- Migration and population aging in the U.S.
- Replacement migration

Migration and population aging

- Migration may not be a driver of change in the age structure of a population
  - However, it can be important for some countries (Sudharsanan, Bloom 2018)
- Immigration may contribute to the decline of population aging (Canada, Europe)
  - Immigrants tend to be younger and have higher fertility than the receiving population
- Emigration of working-age adults may contribute to population aging
  - Older adults tend to migrate less than younger adults

Migration and aging in the U.S.

- In 2010, 40.3 million adults (13%) were 65+ in the United States (West et al. 2014)
- 11 states had over one million adults 65+
  - 17.3% in Florida were 65+
  - 7.7% in Alaska were 65+
- These variations are related to internal migration
  - Florida attracts in-migrants

Replacement migration

- Estimate the volume of immigration that would be required to offset population decline and population aging
  - These are the results of low rates of fertility and mortality in developed countries

- Potential support ratio (PSR)

$$PSR = Pop.15\text{–}64 \,/\, Pop.65+$$

Table 5.7 Population data and indexes for Japan, European Union, and the United States in 2050 under alternative demographic scenarios

Country and Indicator	1950	2000	2050 Proj. 1[e]	Proj. 2[f]	Proj. 3[g]	Proj. 4[h]
Japan						
1. PSR[a]	12.1	4	1.7	1.7	3.0	4.8
2. Average Immigration[b]			0	0	1897	10,471
3. % Immigration[c]			0	0	54.2	87.2
4. Population Increase[d]			0.83	0.83	1.81	6.46
European Union						
1. PSR[a]	7.0	4.1	2.0	1.9	3.0	4.3
2. Average Immigration[b]			270	0	3073	13,480
3. % Immigration[c]			6.2	0	40.2	74.7
4. Population Increase[d]			0.88	0.83	1.39	3.27
United States						
1. PSR[a]	7.8	5.3	2.8	2.6	3.0	5.2
2. Average Immigration[b]			760	0	816	10,777
3. % Immigration[c]			16.8	0	17.4	72.7
4. Population Increase[d]			1.25	1.04	1.26	3.83

Source: United Nations (2000)

[a]PSR = Potential Support Ratio ($^{\text{pop. }15-64}/_{\text{pop. }65+}$)

[b]Average Immigration = Average annual volume of immigration in 1000s, 2000–2050

[c]% Immigration = Percent of population composed of post-2000 immigrants and their descendants

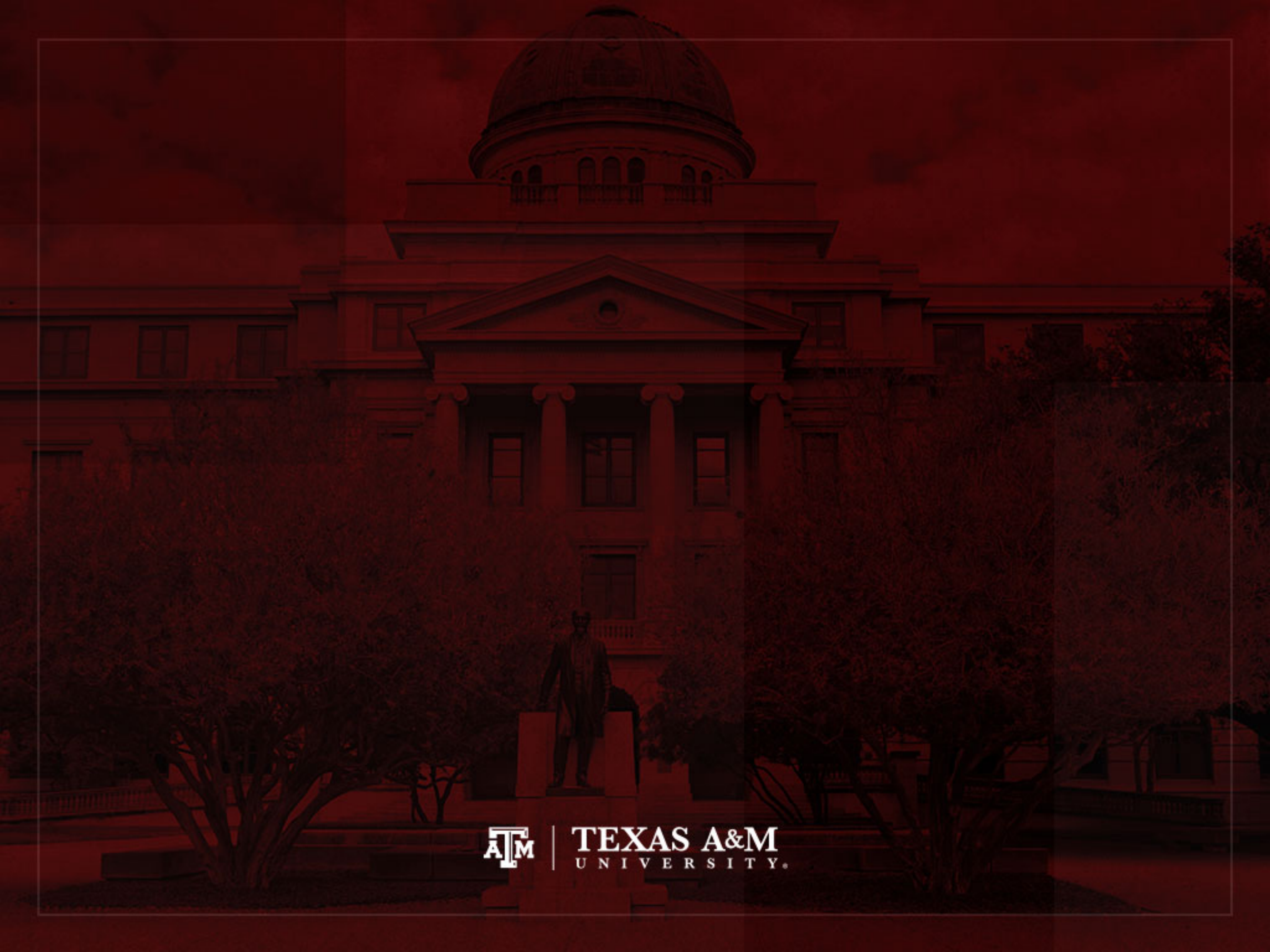
[d]Population Increase = Ratio of total population to total population in 2000

[e]Projection 1 – Median variant

[f]Projection 2 – Median variant, except zero migration

[g]Projection 3 – Maintain PSR of 3.0

[h]Projection 4 – Maintain PST existing in 1995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Future research directions

- International and longitudinal data sets on aging
  - Health and Retirement Study (HRS) in the U.S.
  - Other databases for several countries
- Multidisciplinary cross-national comparisons to understand social, economic, political, and health implications of population aging
  - Measures of social networks, sexuality, genetics
  - Biological and functional measures of health
- Combine these survey data with administrative and medical records

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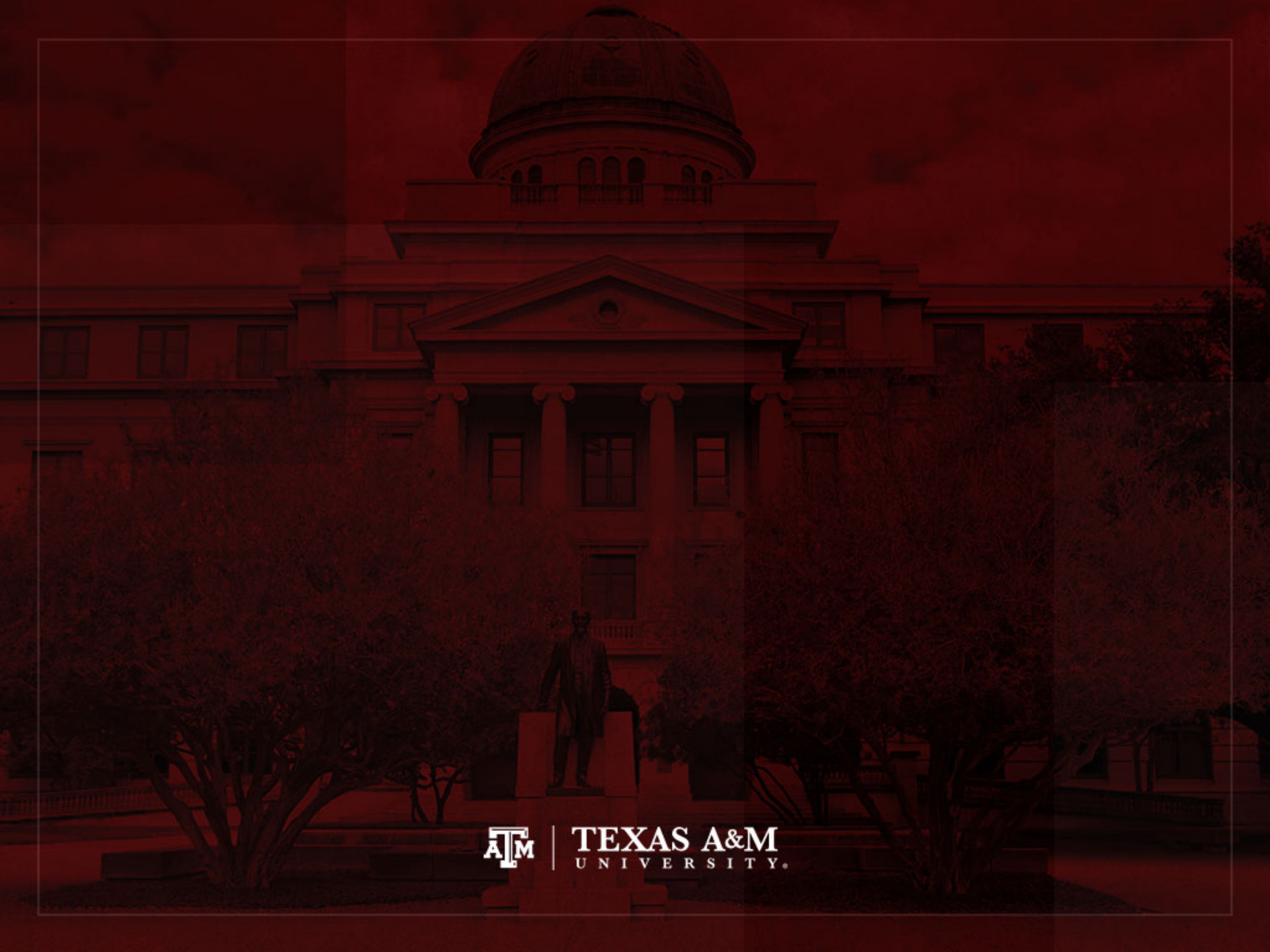
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