Introduction to Demography

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References:
Weeks JR. 2015. Population: An Introduction to Concepts and Issues. 12th edition. Boston: Cengage Learning. Chapters 1 (pp. 1–24), 2 (pp. 25–57).
Wachter KW. 2014. Essential Demographic Methods. Cambridge: Harvard University Press. Chapter 1 (pp. 5–29).

Outline

- Introduction to demography
  - Weeks 2015, Chapter 1, pp. 1–24
- Global population trends
  - Weeks 2015, Chapter 2, pp. 25–57
- Exponential growth
  - Wachter 2014, Chapter 1, pp. 5–29

Introduction to demography

(Weeks 2015, Chapter 1, pp. 1–24)

- What is demography?
- How does demography connect the dots?
  - Nearly everything is connected to demography
  - The relationship of population to resources
  - The relationship of population to political and social dynamics

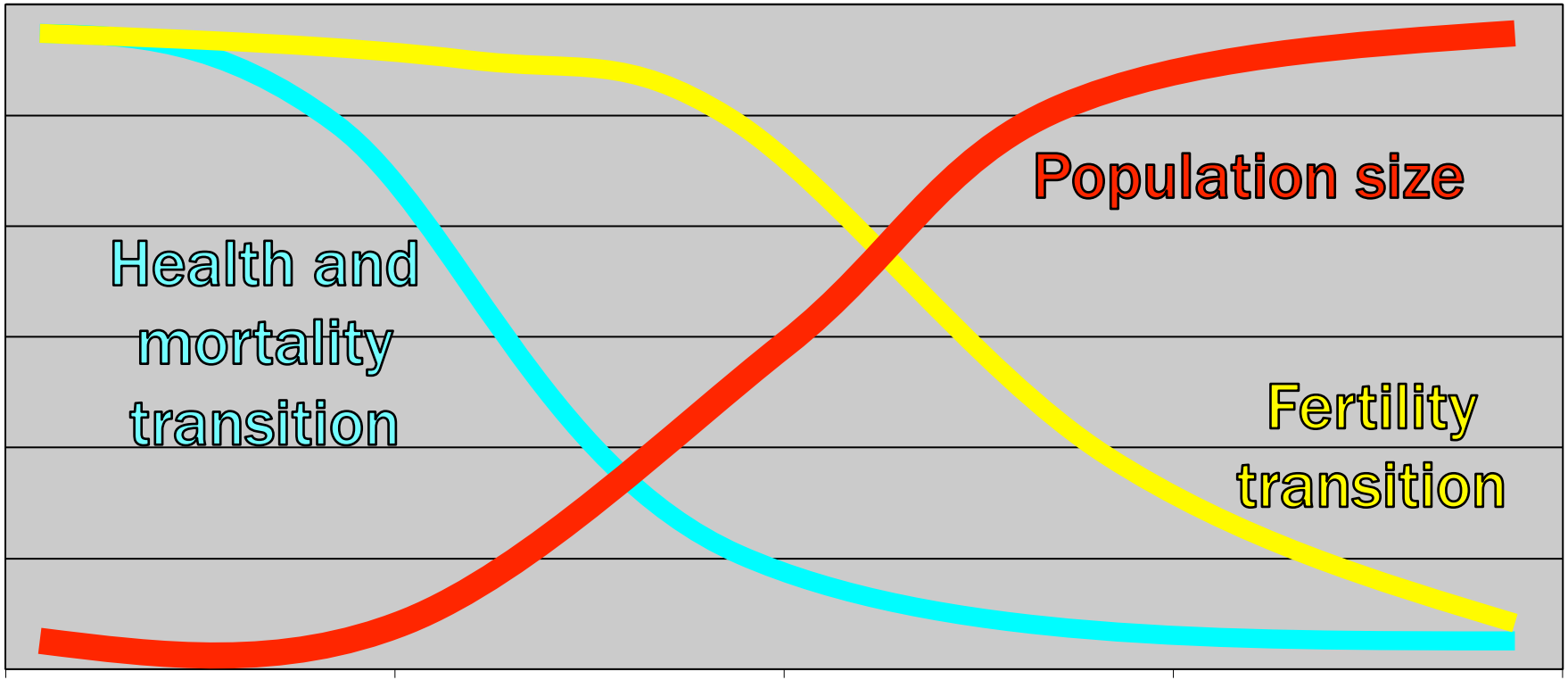
Rise in life expectancy

- Over the past two centuries
- Especially since the end of WWII
- Most important thing in human history
- Consequence and cause of a new way of viewing the world
- Transitions that accompanied it have been enormously transformative

Population growth

- The world's population will continue to increase for the rest of our lives
- Virtually all of it will take place in cities of developing countries
- We will experience the consequences and our lives will be different in the future

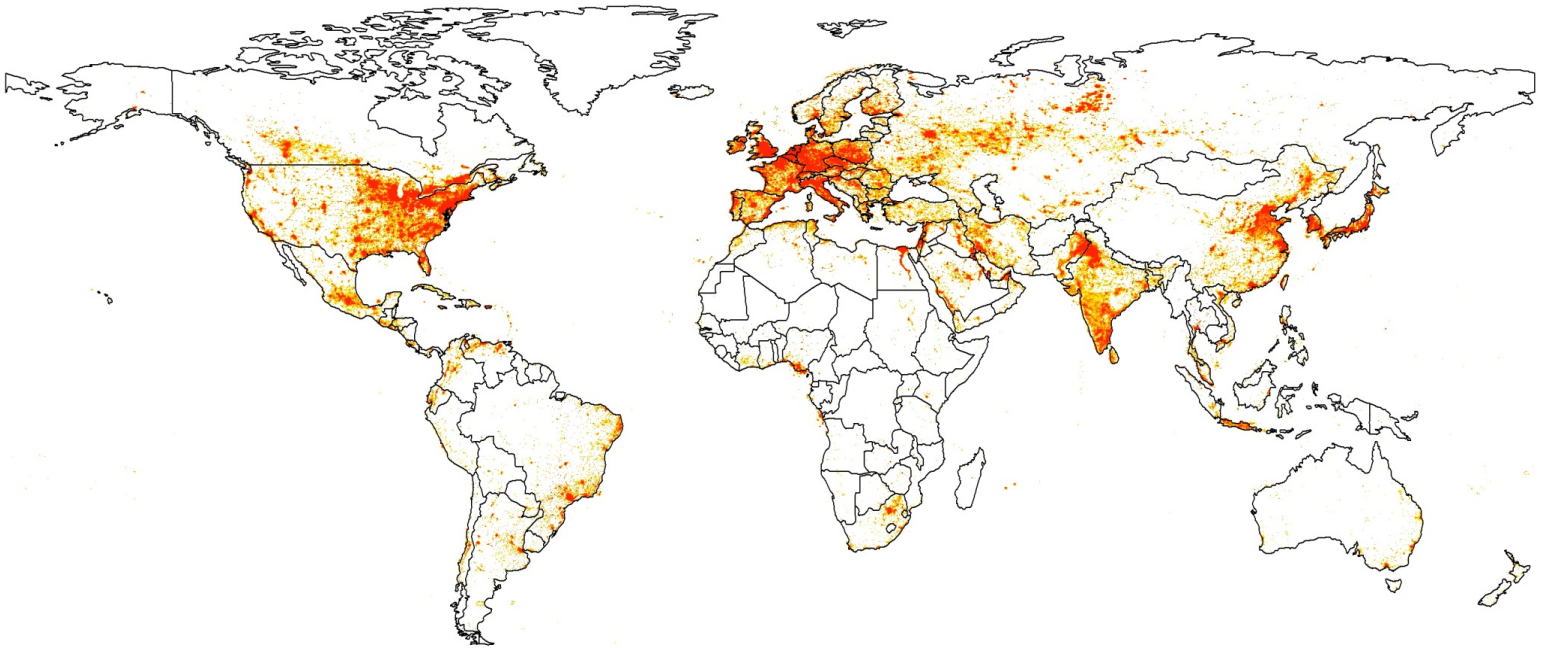
Demographic transition



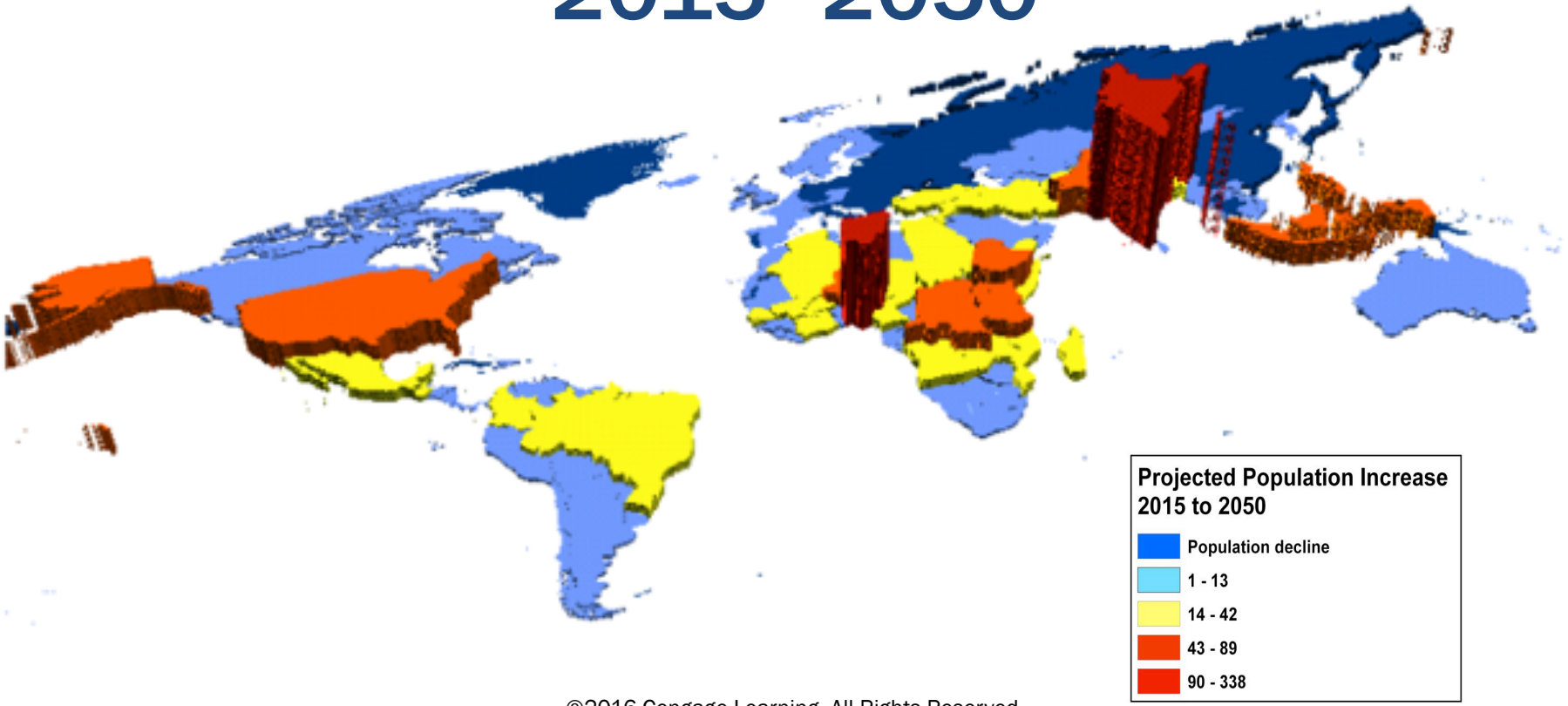
Population storm

Year	Population in billions	Annual rate of growth	Annual increase in millions
1804	1	0.4	4
1927	2	1.1	22
1960	3	1.3	52
1974	4	2.0	75
1987	5	1.6	82
2000	6	1.4	77
2011	7	1.2	80
2024	8	0.9	73
2040	9	0.7	59
2061	10	0.4	38

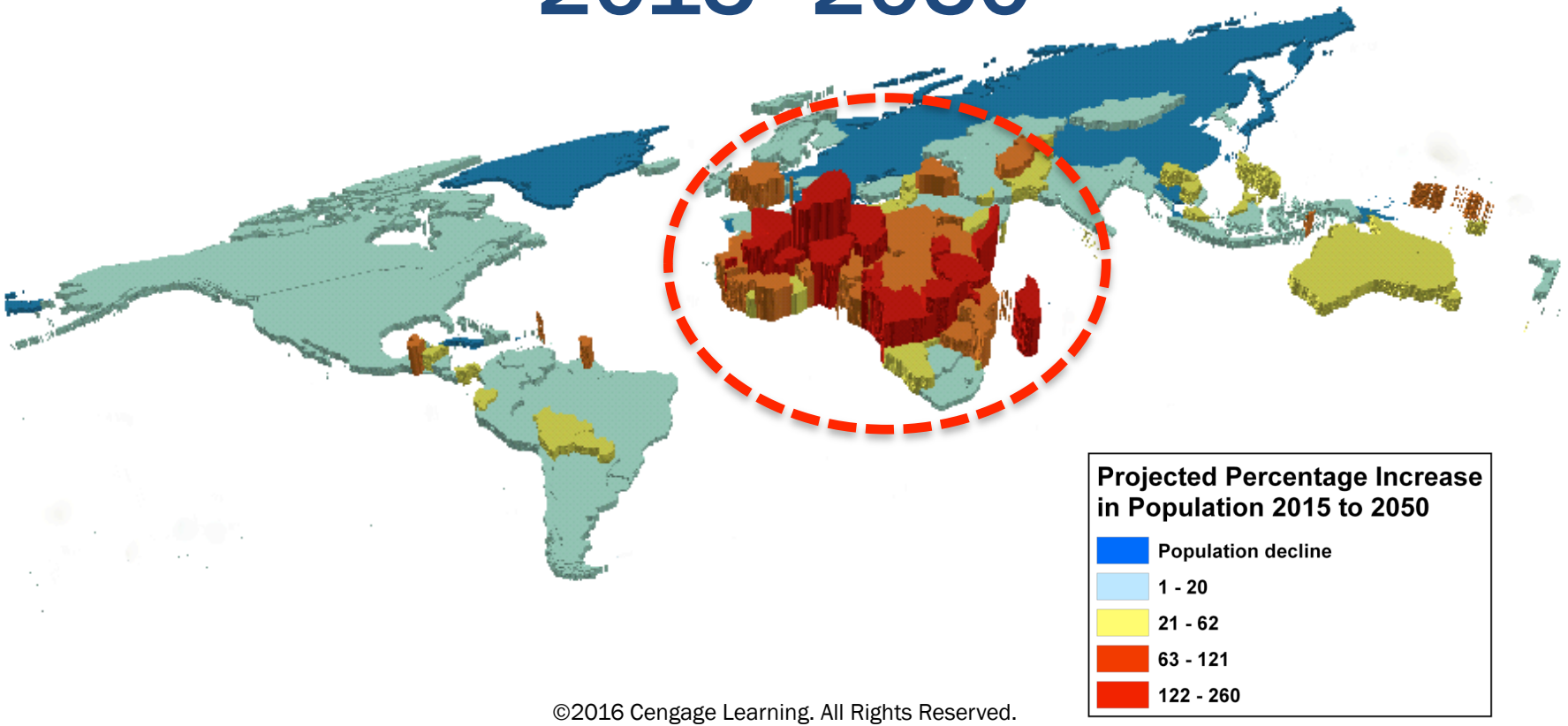
Geographic distribution of world's population



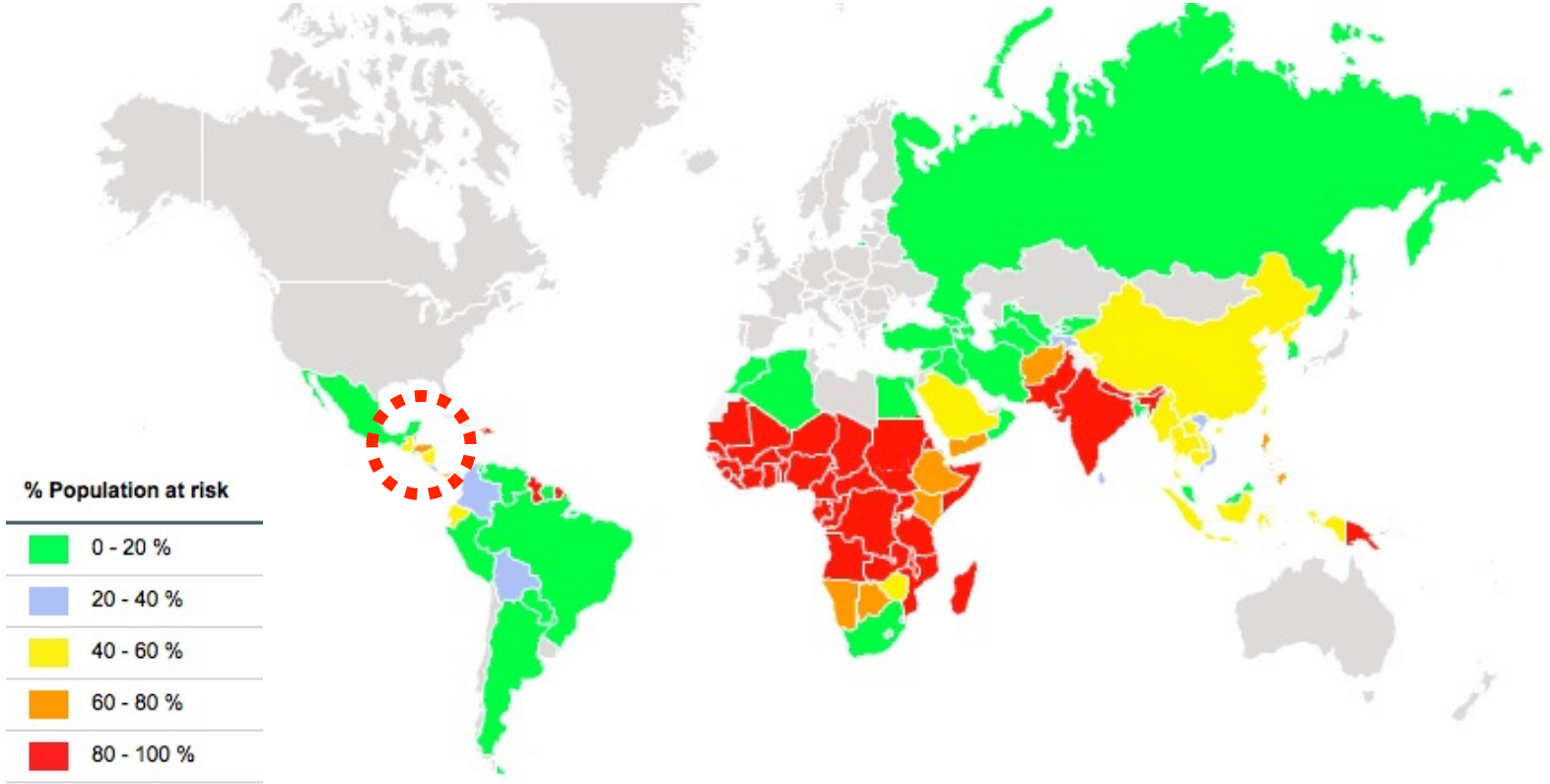
Population increase 2015–2050



Percentage population increase 2015–2050



WHO World Malaria Report 2013



What is demography?

- The scientific study of human population
- The term was coined by Achille Guillard in his 1855 book
  - *Éléments de Statistique Humaine ou Démographie Comparée*

Concerns of demography

- Population size
- Population growth or decline
- Population processes/components
- Population distribution
- Population structure
- Population characteristics

The past is a foreign country (1/3)

Indicators	1910	2010
World population (billions)	1.8	6.9
U.S. population (millions)	92	309
U.S. percent of world total	5.1%	4.5%
U.S. life expectancy	52	81
U.S. children per woman	3.5	1.9

The past is a foreign country (2/3)

U.S. indicators	1910	2010
Immigrants from Italy (1900–1909); (2000–2010)	1.2 million	28,000
Immigrants from Mexico (1900–1910); (2000–2010)	123,000	1.7 million (legal immigrants)
% Foreign-born	14.7%	12.9%
% Urban	46%	81%

The past is a foreign country (3/3)

U.S. indicators	1910	2010
Number of passenger cars	450,000	190 million
% Population under 15	32.1%	19.8%
% Population 65+	4.3%	13.0%
Average persons per household	4.4	2.6
% High school graduates	~10%	87%

Why is demography important?

- What does the past say about the future, given expected population changes?
- How does demography connect the dots?
  - Population change is a prime force behind social and technological change, because societies must adjust to demographic change
  - Population change is often provocative, bursting other dilemmas that face human society

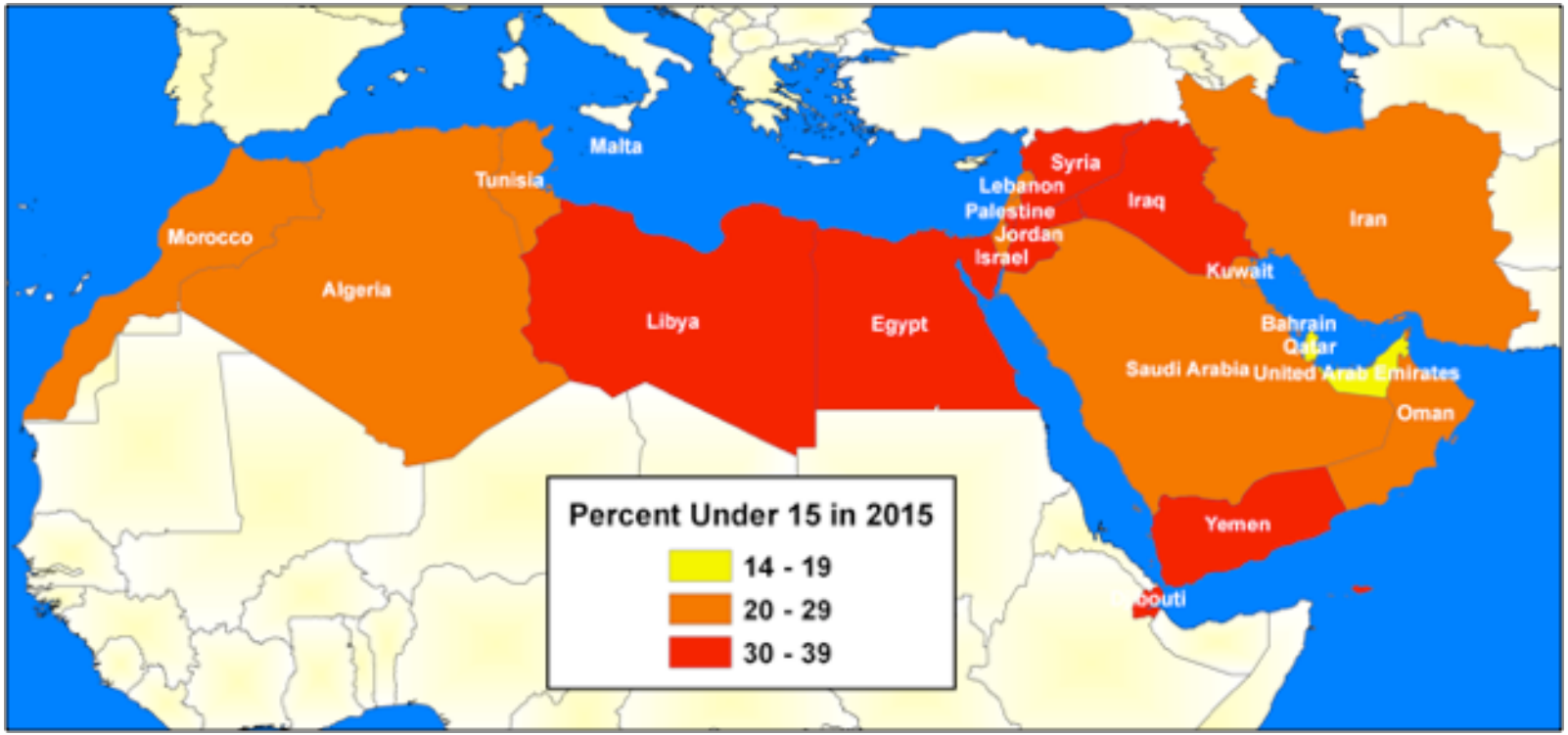
Population and earth's resources

- How will we feed an even larger population than we currently have?
- Will we have enough fresh water?
- Where will we get energy to sustain our lifestyle?
- Who will build housing and infrastructure for an increasing urban population?
- How do we minimize the environmental impact?

Population and social and political dynamics

- Globalization is related to search for cheap labor
- Backlash against immigrants is aggravated by xenophobia in the face of the need for workers in the richer, aging countries
- Regional conflict is aggravated by population growth and especially by youth bulges in the Middle East and South Asia

Middle East and North Africa (MENA) Region

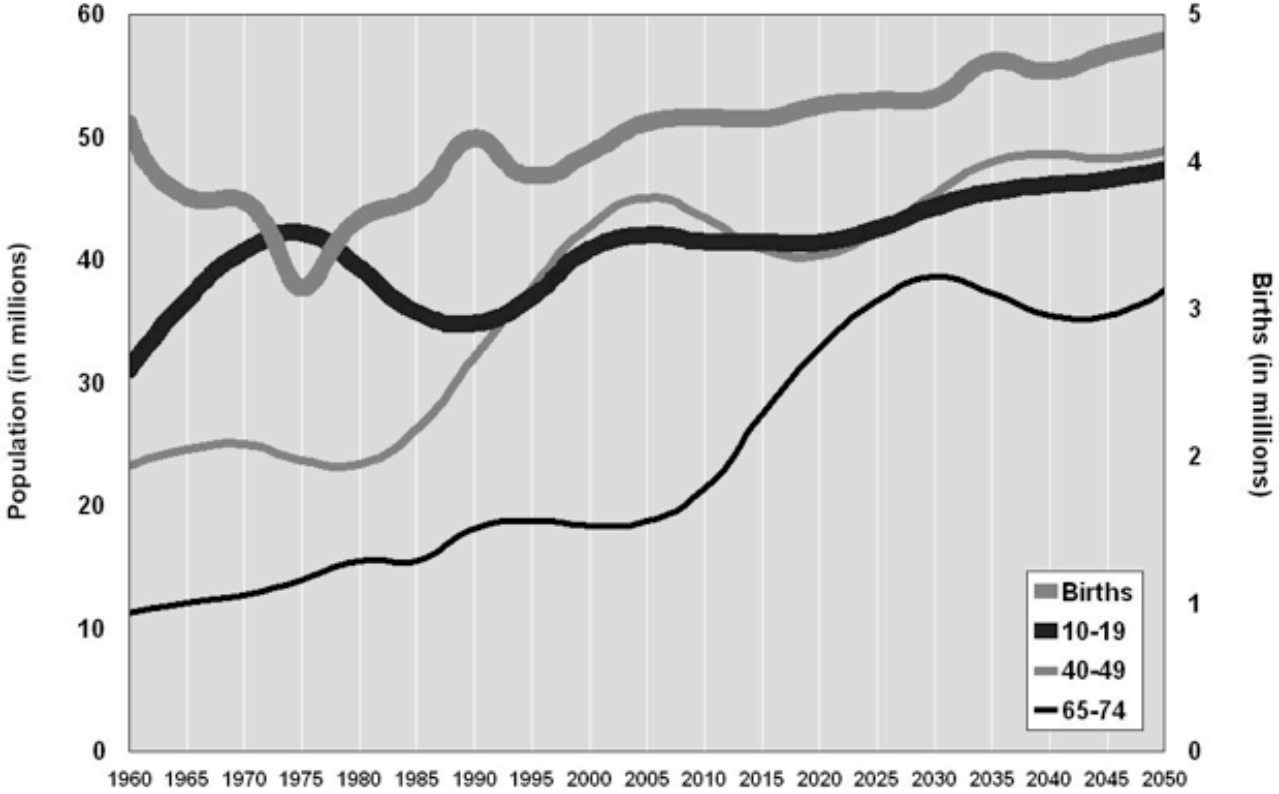


Country	Population (millions)			Ratio		% Pop < 15 in 2015
	1950	2015	2050	2015/ 1950	2050/ 2015	
MENA	81	418	604	5.1	1.4	29
Iraq	6	36	71	6.0	2.0	39
Syria	3	22	37	7.3	1.7	35
U.S.	103	325	401	3.2	1.2	19
Germany	70	83	73	1.2	0.9	13
Japan	82	127	108	1.5	0.9	13

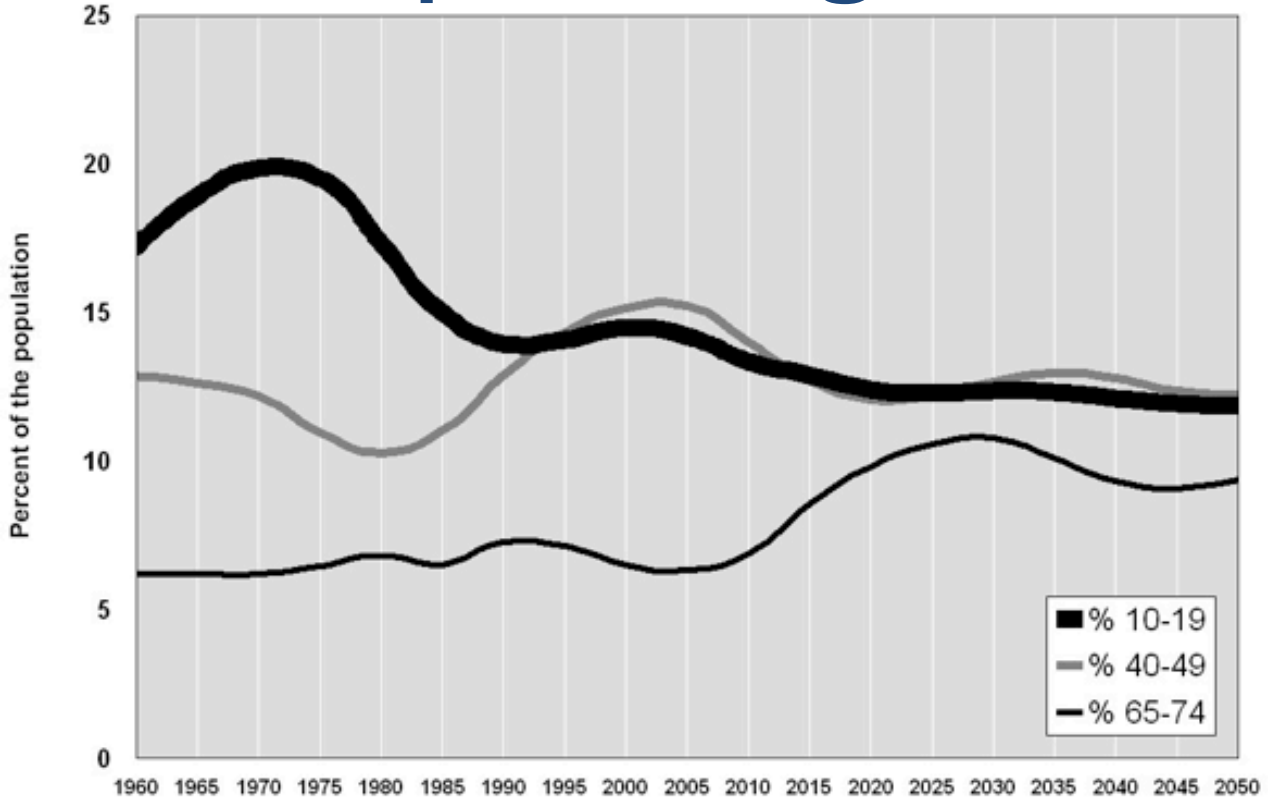
Impact of population change

- Less about population growth *per se*
- More about population growth in different age groups and places over time, affecting
  - Education
  - Health
  - Crime
  - Consumer desires and fashions
  - Economic opportunities

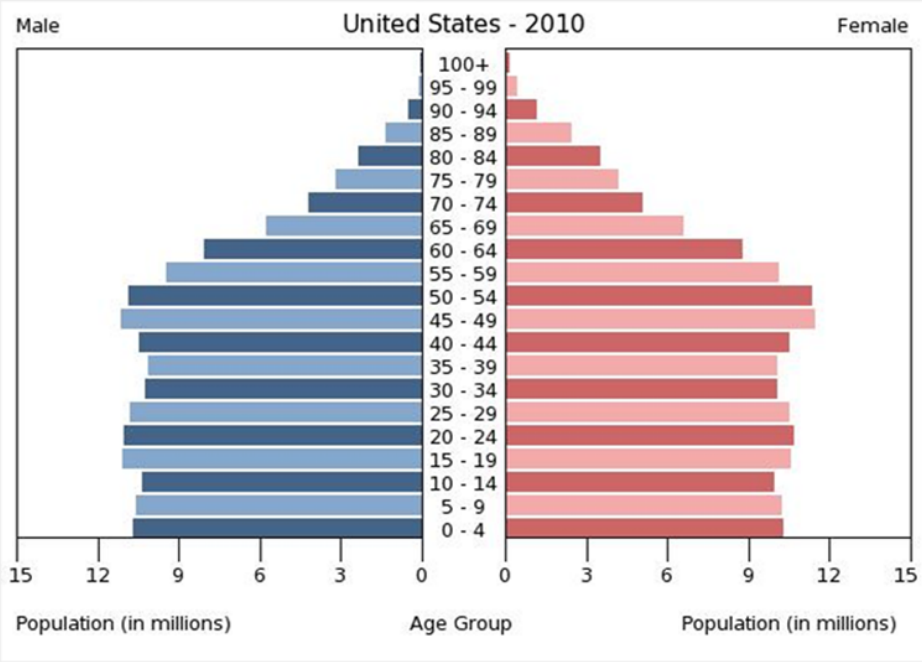
Births and selected age groups in the U.S. — absolute numbers

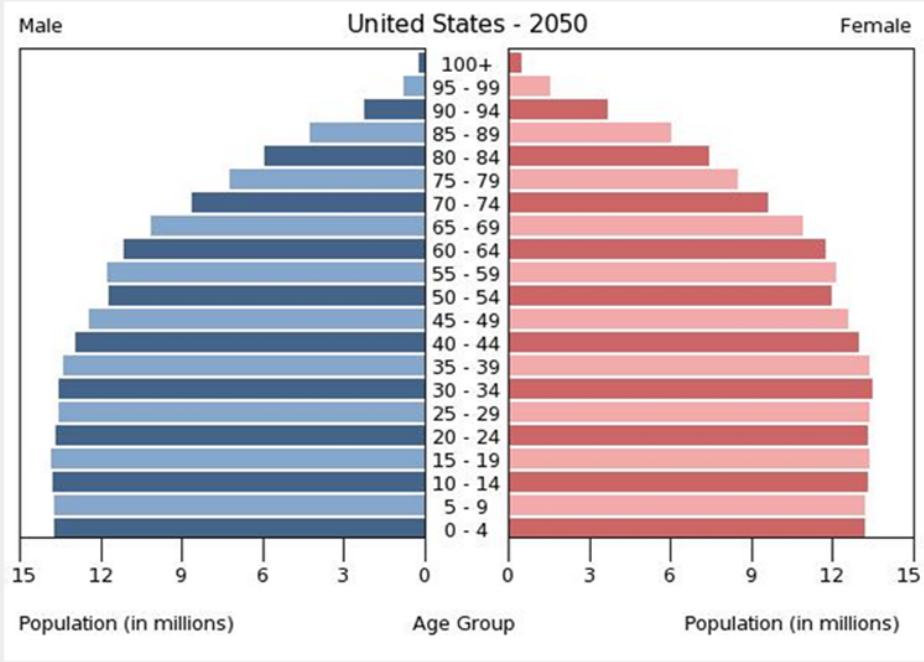


Selected age groups in the U.S. — percentage of the total



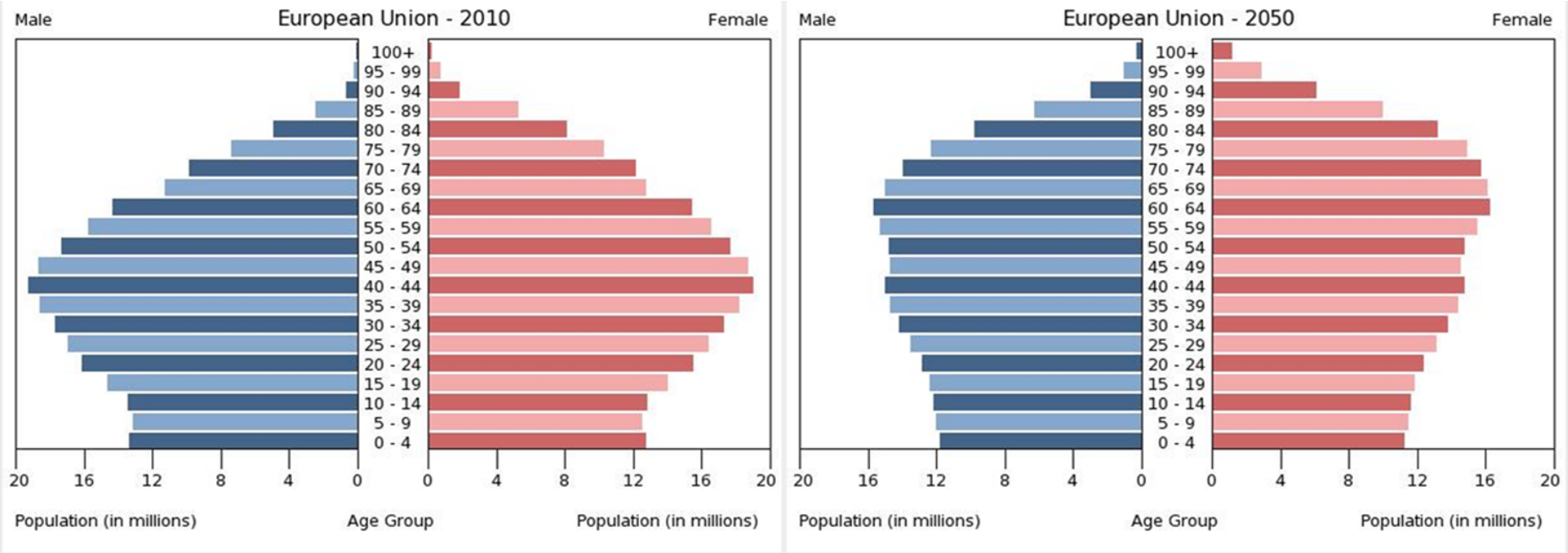
Population structure by age and sex, United States, 2010–2050





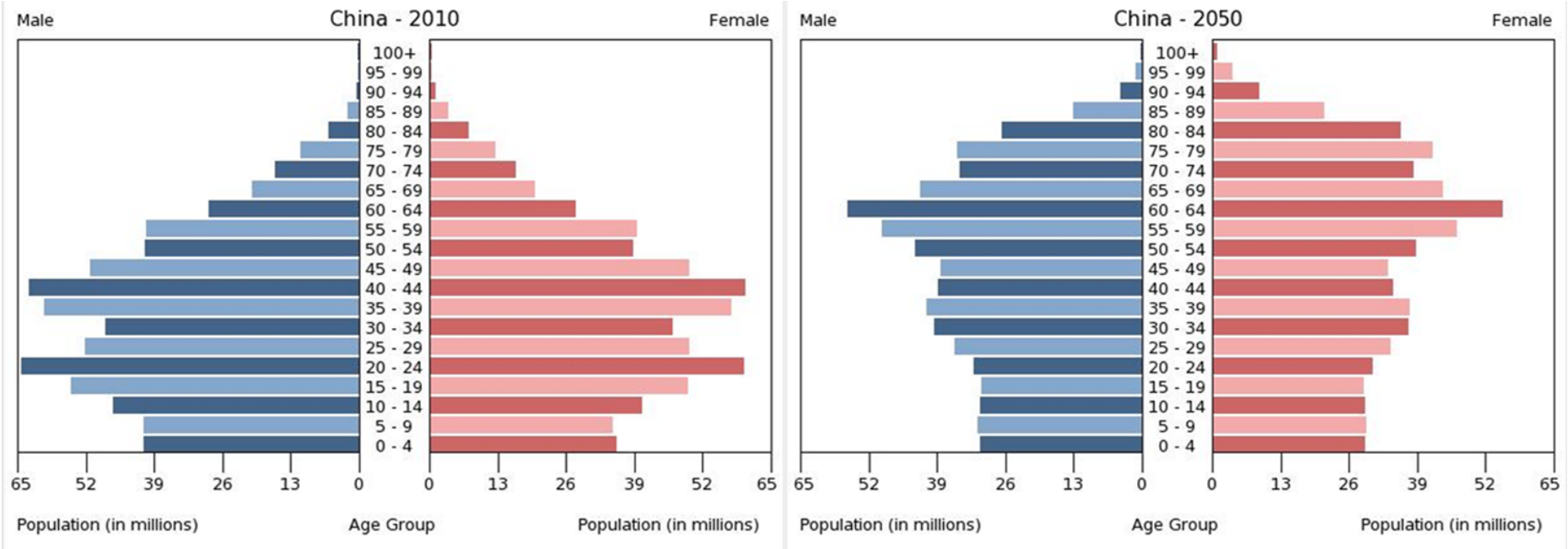
Source: http://www.fdbetancor.com/wp-content/uploads/2012/10/demochallenge2.png

Population structure by age and sex, European Union, 2010–2050



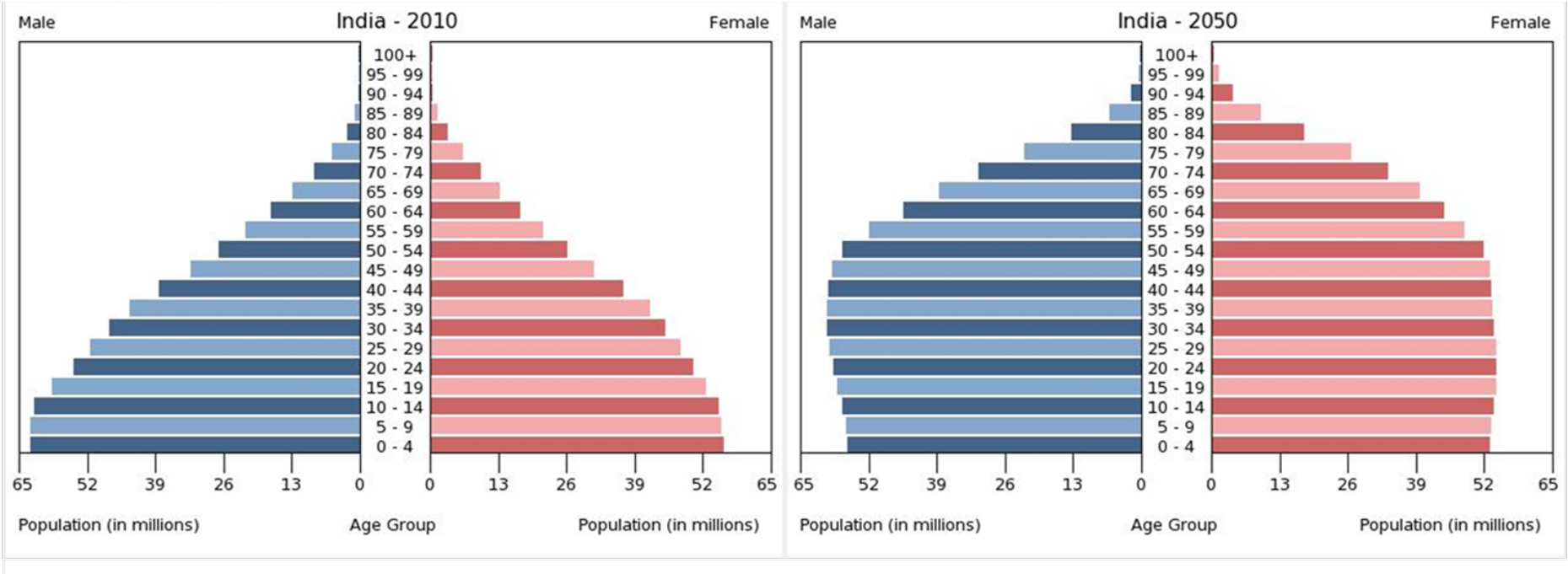
Source: http://www.fdbetancor.com/wp-content/uploads/2012/10/demochallenge2.png

Population structure by age and sex, China, 2010–2050



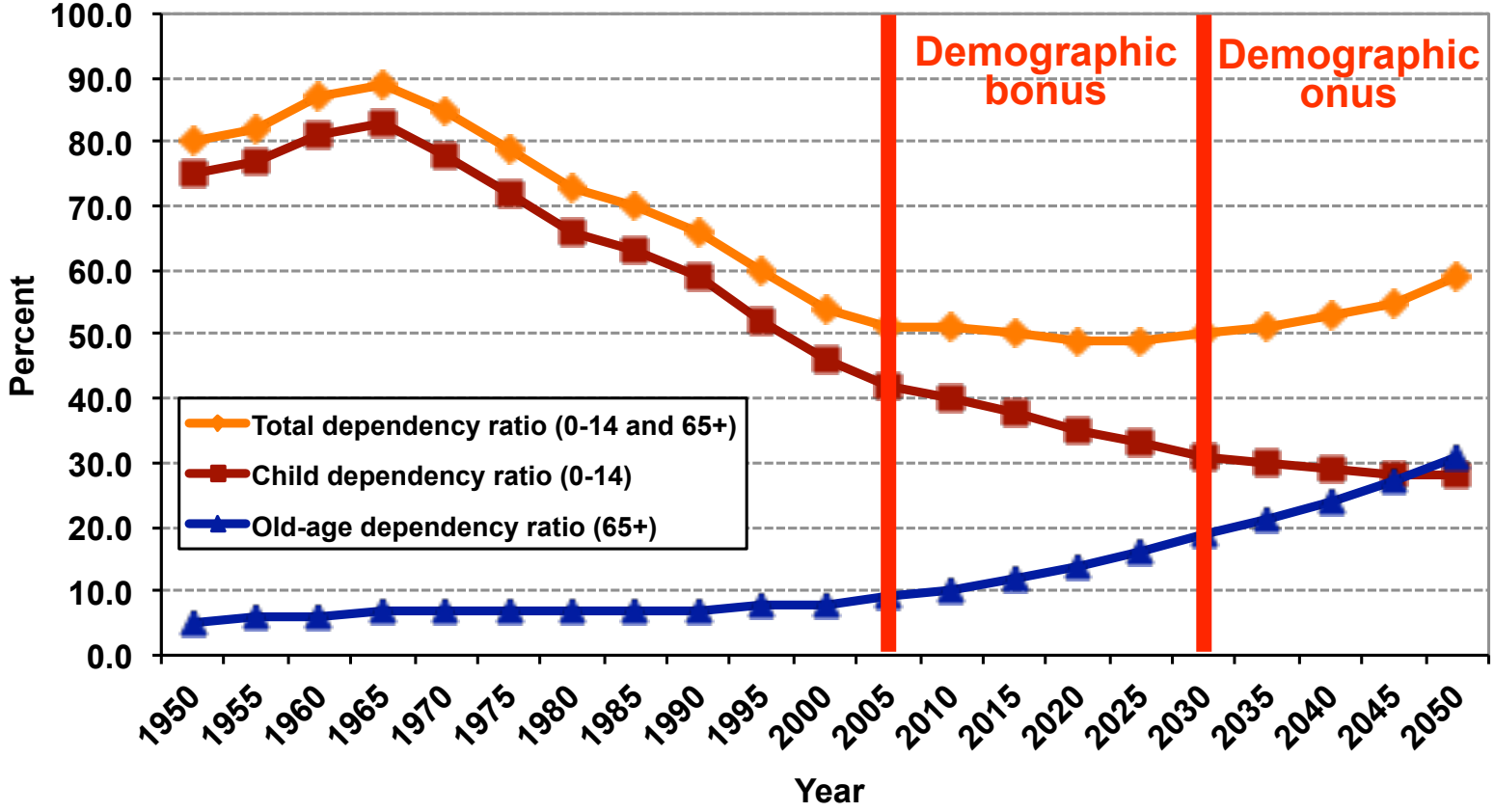
Source: http://www.fdbetancor.com/wp-content/uploads/2012/10/demochallenge2.png

Population structure by age and sex, India, 2010–2050



Source: http://www.fdbetancor.com/wp-content/uploads/2012/10/demochallenge2.png

Dependency ratios, Brazil, 1950–2050



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

Populations and women's rights

- Women live longer than men, unless society intervenes
- Getting pregnant was the most dangerous thing a woman could do until very recently
- Women are capable of the same levels of education and occupation as men
  - Many societies still do not provide these opportunities
- Status of women underlies many conflicts in the world and influences demographic trends

Is demography destiny?

- Demography shapes the world, even if it does not determine it

- Population change is an underlying component of almost everything happening in the world today, and therefore in the future as well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Global population trends

(Weeks 2015, Chapter 2, pp. 25–57)

- World population growth
  - A brief history
  - How fast is the world's population growing now?
  - Power of doubling — How fast can populations grow?
  - Why was early growth so slow?
  - Why are more recent increases so rapid?
  - How many people have ever lived?
- Geographic distribution of world's population
- Global variation in population size and growth

Brief demographic history

- Human beings have been around for at least 200,000 years, perhaps much longer
- For almost all of that time, humans were hunter-gatherers living a primitive existence
  - High fertility, high mortality, slow population growth
- Population on the eve of Agricultural Revolution (aka Neolithic Agrarian Revolution) 10,000 years ago is estimated at about 4 million

Agricultural Revolution

- Probably due to hunting-gathering populations' growth
  - Pushed the limit of their carrying capacity
- Previously, use of land extensively
  - Over tens of thousands of years humans moved to remote corners of the earth in search of sustenance
- People began to use resources intensively
  - Lead to agricultural lifestyle that has characterized society for the past 10,000 years

Historical population growth

- Between 8000 B.C. and 5000 B.C.
  - 333 people added each year
- By 500 B.C., major civilizations (China, Greece)
  - 100,000 people added each year
- By 1 A.D., almost 250 million people
  - 300,000 people added each year

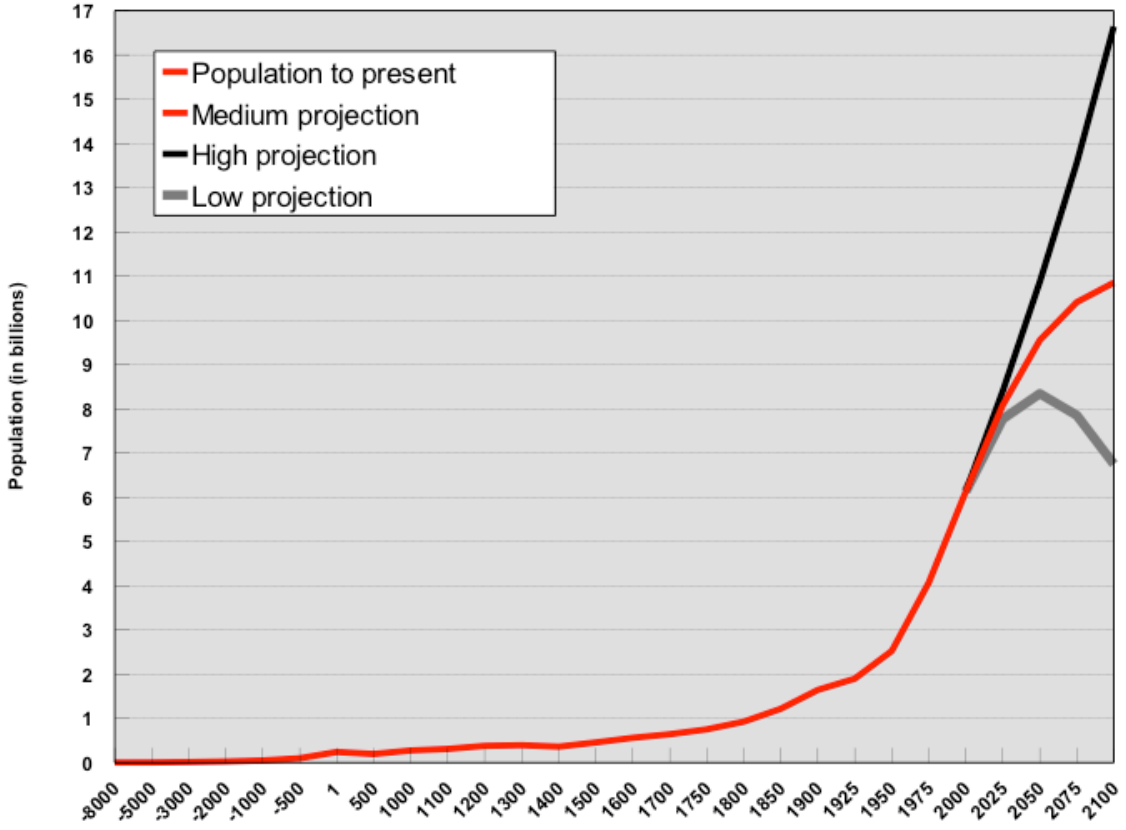
Variations in mortality

- Between 3rd and 5th centuries A.D.
  - Increases in mortality led to declining population
  - In the Mediterranean as Roman Empire collapsed
  - In China as the Han empire collapsed
- Population growth recovered until the plague arrived in Europe by middle of the 14th century

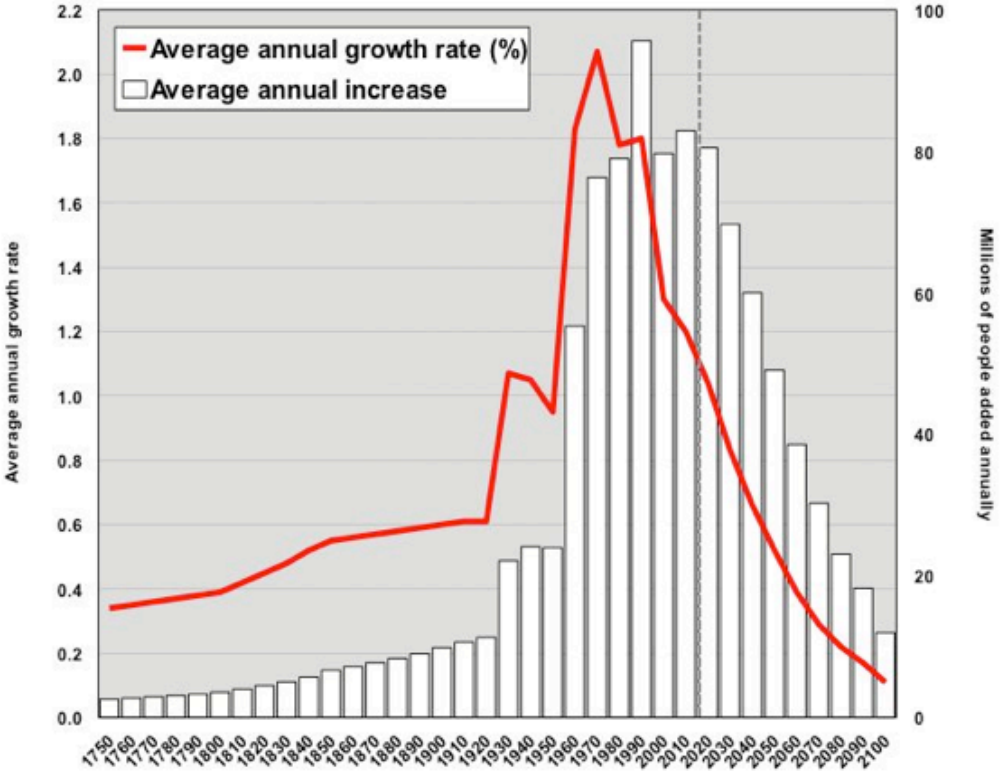
Industrial Revolution

- Middle of 18th century
  - Eve of Industrial Revolution
  - World's population approaching 1 billion
  - Increasing by about 2.2 million every year
- Since the beginning of the Industrial Revolution
  - Approximately 250 years ago
  - Size of world's population increased dramatically

World's population exploded in size



Annual growth rate & annual increase



Population increase by time period

Time period	Births	Deaths	Natural increase
Year	134,176,254	56,605,700	77,570,553
Day	367,606	155,084	212,522
Hour	15,317	6,462	8,855
Minute	255	108	148
Second	4.3	1.8	2.5

http://www.census.gov/population/international/data/worldpop/table_vitalevents.php

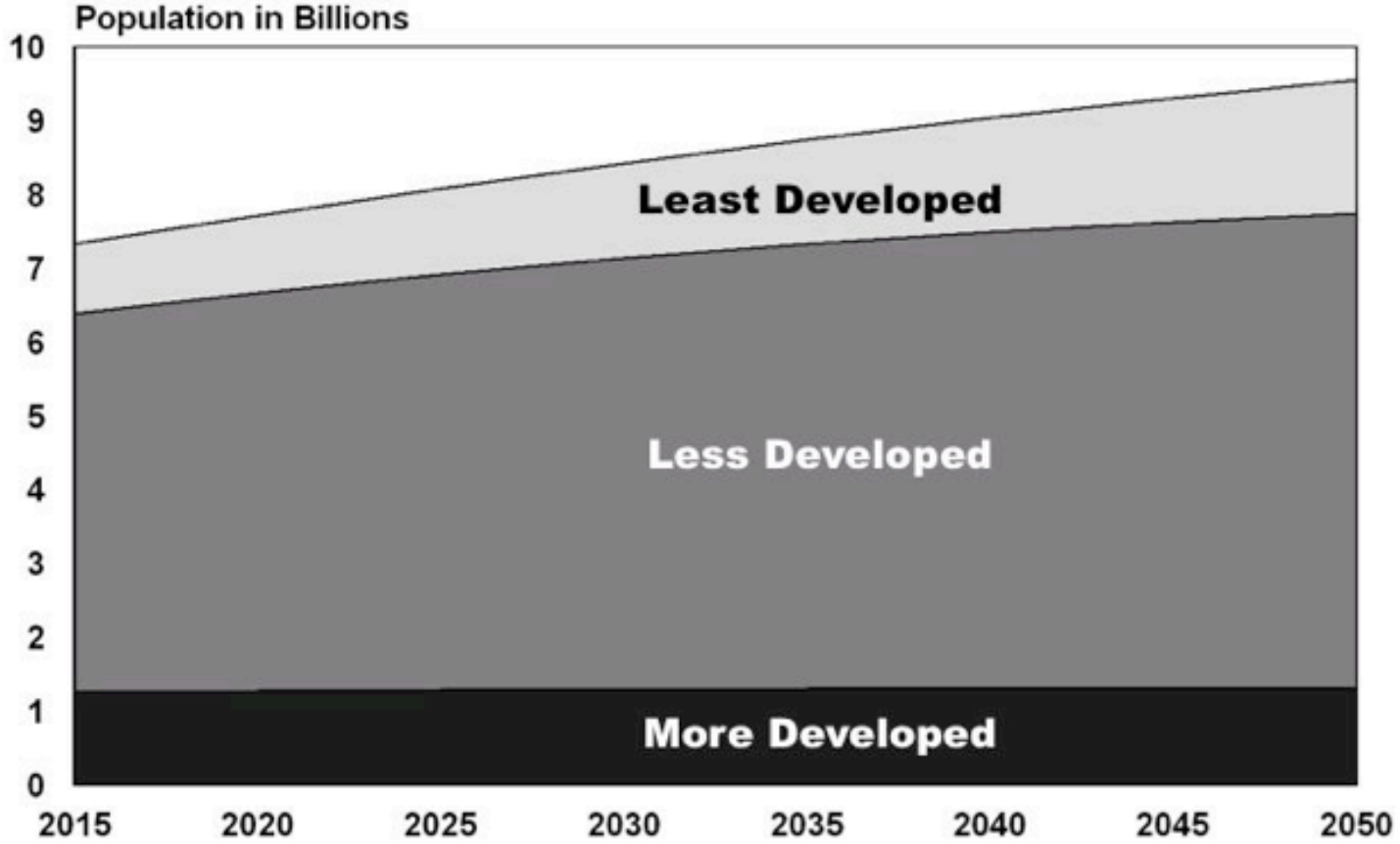
Why was early growth slow?

- During the hunting-gathering phase, life expectancy was very low: ~ 20 years
- More than half of children born died before their 5th birthday
- The average woman who survived the reproductive years would have to bear nearly 7 children to assure that 2 survived to adulthood

Why are recent increases so rapid?

- Acceleration in population after 1750
  - Declines in death rate related to Enlightenment, scientific advances, and Industrial Revolution
  - Eating better, bathing more often, drinking cleaner water, and vaccinations were being discovered
- Continuing population increases
  - Dramatic declines in mortality without compatible decline in fertility, even though fertility was declining

Population growth, 2015–2050



Medium variant fertility projections

How many people ever lived?

- Current contribution to history's total population is relatively small, but steadily growing fraction of all people who have ever lived
- Formulas of Nathan Keyfitz suggest
  - 63 billion people have been born over the past 200,000 years
  - 7.3 billion alive in 2014 constitutes 11.7%
  - Lower percentages assume more years of human history, higher birth/death rates in earlier periods

Geographic distribution

- Migration flows from rapidly growing areas into less rapidly growing ones
  - European expansion: 14th to 20th centuries
    - Europe to North and South America and Oceania
    - Africa to Latin America, Caribbean and North America
  - South to North migration: 20th & 21st centuries
    - Latin America and Asia to the United States
    - Asia to Canada
    - Africa, Asia, and Latin America to Europe

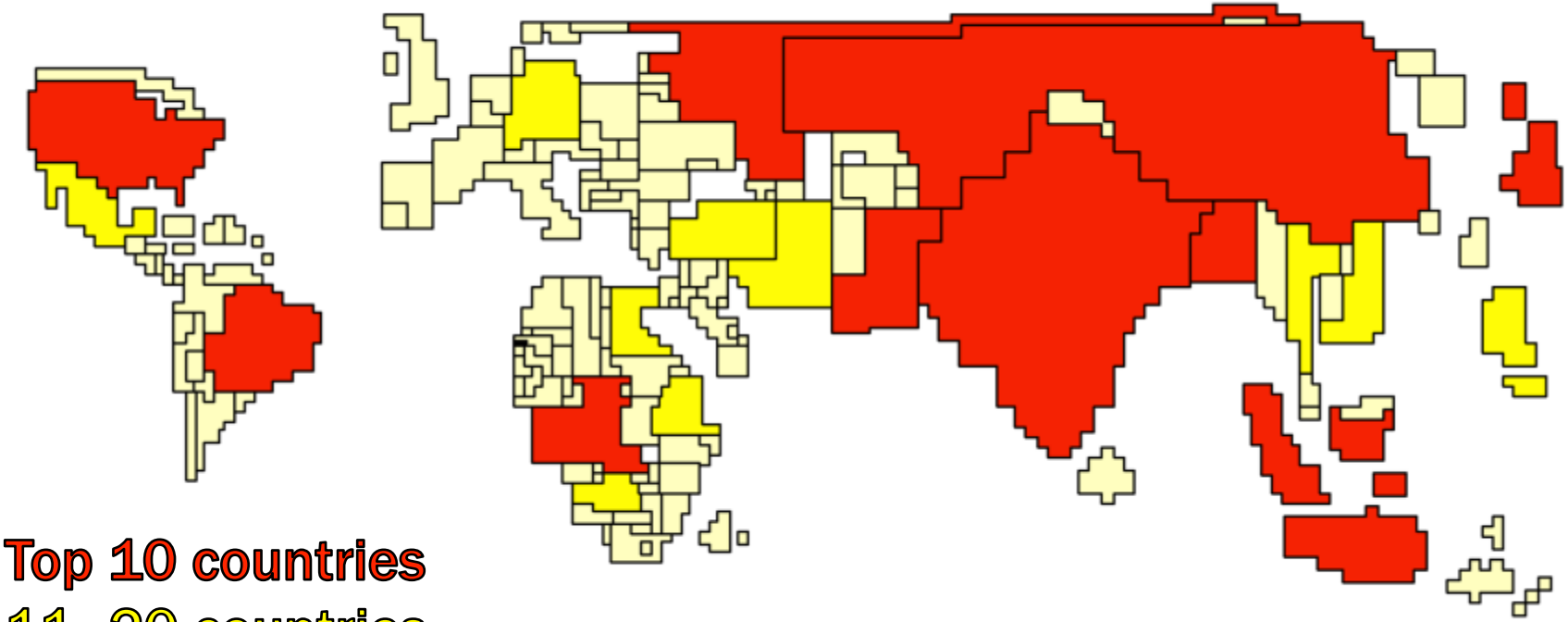
Urban revolution

- In earlier decades, as population grew dense, people moved to less populated areas
  - In 1800, less than 1% of world's population lived in cities of 100,000 or more
- Now they move to urban areas
  - More than 1/3 of humans live in 100,000+ cities
  - More than 50% live in urban places of any size
  - Urbanization grew even without industrialization
    - People moved to areas where goods and services were exchanged

10 most populous countries, millions

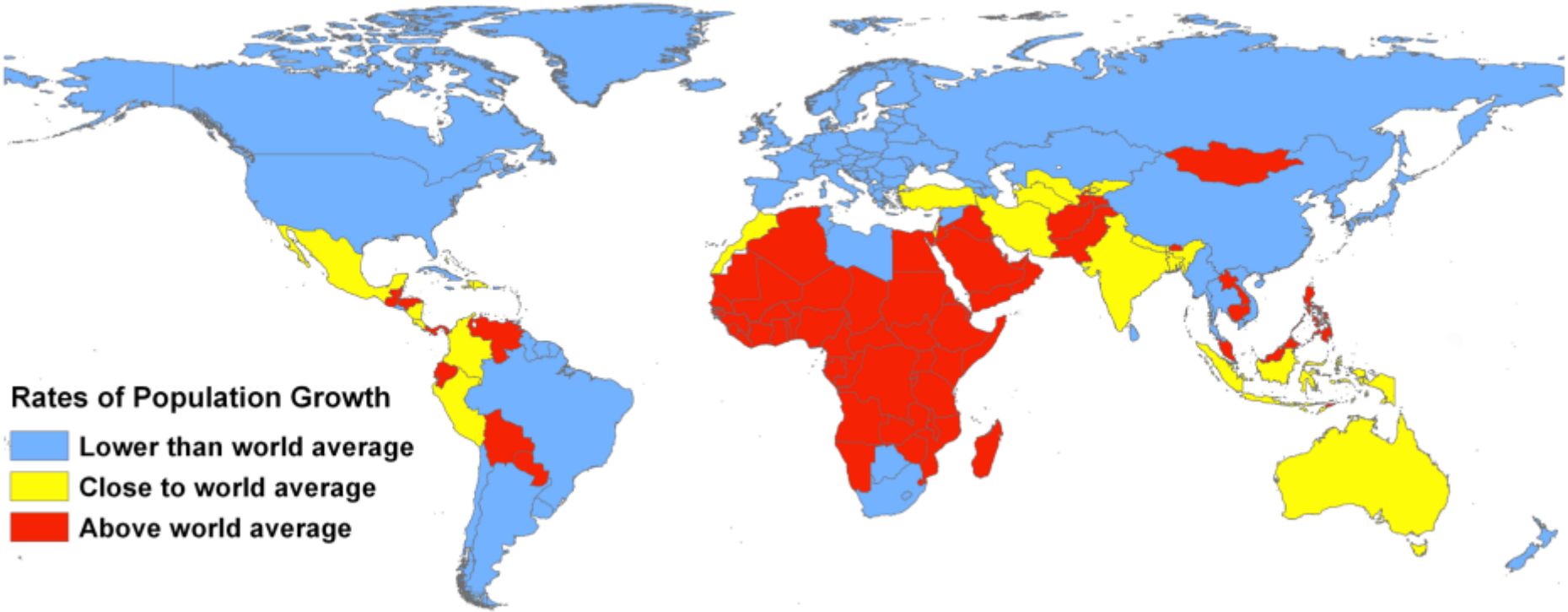
	Country	2015	Country	2050
1	China	1,402	India	1,620
2	India	1,282	China	1,385
3	United States	325	Nigeria	404
4	Indonesia	256	United States	401
5	Brazil	204	Indonesia	321
6	Pakistan	188	Pakistan	271
7	Nigeria	183	Brazil	231
8	Bangladesh	160	Bangladesh	202
9	Russia	142	Ethiopia	188
10	Japan	127	Philippines	157

Countries by population size, 2015



Top 10 countries
11–20 countries
All others

Rates of population growth, 2012



United States

- One of highest rates of population growth among rich nations
- Fertility slightly above replacement
- High life expectancy, although one of lowest among rich nations
- High levels of legal and undocumented immigration

Canada

- Demographics are more like Europe than the U.S.
- Below replacement fertility
- Higher life expectancy than the U.S.
- Very high level of immigration per person (especially from Asia), which keeps the population growing

Mexico

- Fertility rates have dropped a lot since the 1970s when the government started promoting family planning
- Life expectancy nearly as high as in the U.S.
- Net outmigration mainly to the U.S.
- Immigrants in the south from Central America
- Southern Mexico is heavily indigenous.

Central America

- Heavily indigenous
  - Higher than average fertility
  - Lower than average life expectancy
- Out-migration aggravated by socioeconomic (poverty) and security (crime) issues
- Costa Rica is an exception, with European-style demographics

Brazil

- Accounts for half the population of South America
- Since the 1960s, it has experienced significant decline in fertility to below replacement level
- Predominantly Catholic country, but growing Protestant population
- Life expectancy is well above the world average

Rest of South America

- Divided roughly in two groups
- Predominantly European-origin populations with European-style demographics
  - Argentina, Chile, Uruguay
- Other nations have larger fractions of indigenous population
  - Higher fertility and mortality

Europe

- Experiencing depopulation, especially because
  - Russia and Germany have very low levels of fertility
  - Russia has experienced low life expectancy
- Eastern and southern
  - Fertility well below replacement level
  - High life expectancy
  - Lack of interest in receiving many immigrants
- Northern and western
  - Highest fertility levels: support for working mothers
  - Immigrants are not unwelcome: political issue

Northern Africa and Western Asia

- Predominantly Muslim: exception of Israel
  - Rapid rates of population growth
    - Contributing to conflict in the region
  - Fertility is declining, but still above death rates
    - Young populations
- Iran (technically in South Asia) and Turkey
  - Populous and European-style demographics
  - Below-replacement fertility, high life expectancy
  - Southeastern Turkey: high fertility, low female literacy, similar to Syria and Iraq

Sub-Saharan Africa

- The most rapidly growing region in the world
- Nigeria, Ethiopia, Congo: large and growing
- High birth rates, although generally declining
- Death rates: world's highest, but declining
- High incidence of HIV and Ebola
- Young populations and migration within region

South and Southeast Asia

- 1/3 of the world's population
  - India, Pakistan, Bangladesh, Indonesia, Philippines, Vietnam, Thailand
- India projected to become most populous nation by middle of this century
  - Higher birth and death rates than China
- Indonesia (1st), India (2nd), Pakistan (3rd)
  - Highest numbers of Muslims in the world

East Asia

- 1.6 billion people in all region
  - China has 1.4 billion
  - Japan, South Korea, Taiwan: next largest in pop. size
- Fertility is below replacement level
  - China had an official one-child policy
  - High life expectancy, but population will decline
- Immigration is not very popular
  - Low birth rate, aging population: not supplemented by inflow of migrants

Global demographic contrasts

- North-South divide
- South has higher birth rates, higher death rates, younger populations than north
- These differences and variability within the south will drive the future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Exponential growth

(Wachter 2014, Chapter 1, pp. 5–29)

- Balancing equation
- Growth rate R
- Exponential curve
- Doubling times

Balancing equation

- Balancing equation for the world, 2010–2011

$$K(2011) = K(2010) + B(2010) - D(2010)$$

  - $K(2010)$: world population at start of 2010
  - $B(2010)$: births during 2010
  - $D(2010)$: deaths during 2010
  - $K(2011)$: population at start of 2011

World population 2010 to 2011

Population 1 January 2010	**6,851 million**
+ Births 2010	+140 million
+ Deaths 2010	–57 million
= Population 1 January 2011	6,934 million

Source: 2010 Population Data Sheet of the Population Reference Bureau (PRB). Wachter 2014, p. 6.

General form of balancing equation

- For closed population

$$K(t + n) = K(t) + B(t) - D(t)$$

  - n: length of a period, e.g. 1 year or 10 years
  - $B(t)$, $D(t)$: births, deaths during period from t to $t+n$

- Equation for national or regional populations more complicated due to migration
  - Closed population examples to understand concepts

Pattern when combining equations

- Decompose next year's "stock" into this year's "stock" plus "flow"

$$K(1) = K(0) + [B(0) - D(0)]$$

- t=0 for present year, n=1 year long

Separate elements

- Multiply and divide by starting population $K(0)$

$$K(1) = K(0)\left(1 + \frac{B(0)}{K(0)} - \frac{D(0)}{K(0)}\right)$$

- Following year

$$K(2) = K(1)\left(1 + \frac{B(1)}{K(1)} - \frac{D(1)}{K(1)}\right)$$

- Substituting for $K(1)$

$$K(2) = \left(1 + \frac{B(1)}{K(1)} - \frac{D(1)}{K(1)}\right)\left(1 + \frac{B(0)}{K(0)} - \frac{D(0)}{K(0)}\right)K(0)$$

From starting to later population

- Geometric growth through time intervals
  - Population growth as multiplicative process
  - B/K and D/K are less dependent on K than B and D

- Exponential growth
  - When fractions of intervals are involved, we use exponential function

Simple case

- When B/K and D/K are not changing much

$$A = 1 + \frac{B}{K} - \frac{D}{K}$$

$$K(1) = A\,K(0)$$

$$K(2) = A^2\,K(0)$$

...

$$K(T) = A^T\,K(0)$$

Example

- In 2000, 6.048 billion people with births exceeding deaths by 75 million

$$A = 1 + \frac{B}{K} - \frac{D}{K} = 1 + \frac{B - D}{K} = 1 + \frac{75}{6{,}048} = 1.0124$$

$$K(0) = 1.0124^0 * 6.048 = 6.048$$

$$K(1) = 1.0124^1 * 6.048 = 6.123$$

$$K(10) = 1.0124^{10} * 6.048 = 6.841$$

$$K(12) = 1.0124^{12} * 6.048 = 7.012$$

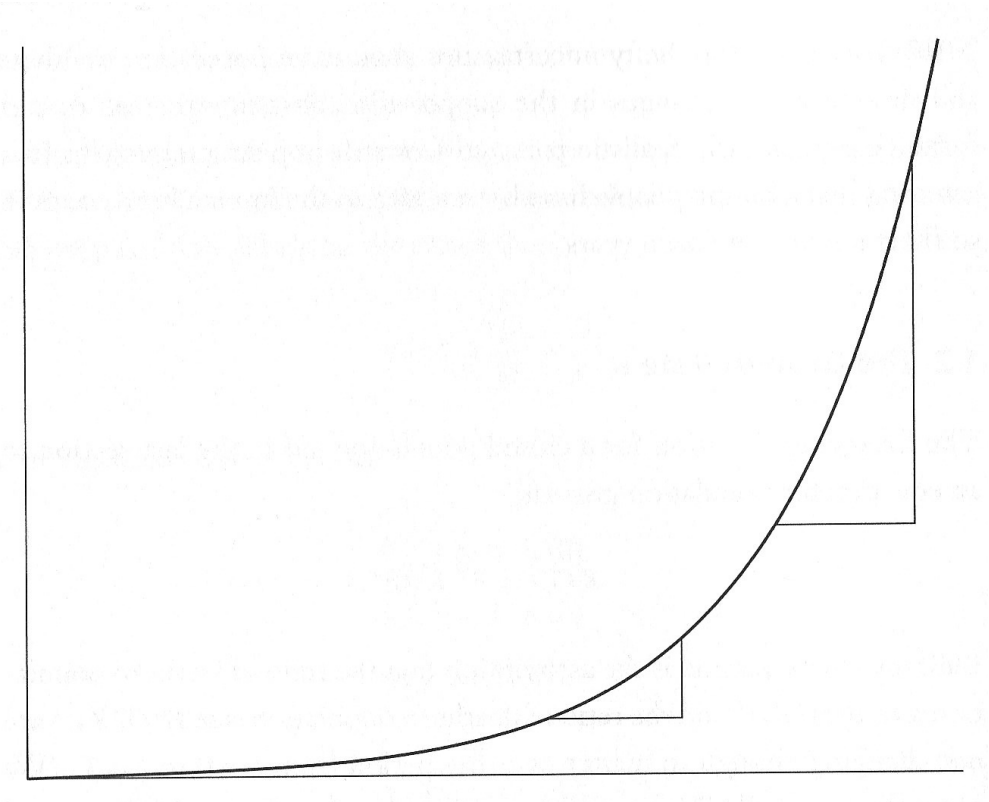
Growth rate R

- Balancing equation for closed population led to equation for population growth

$$K(T) = A^T K(0)$$

- $B(t)/K(t)$ and $D(t)/K(t)$ not changing much
- When births exceed deaths, A is bigger than 1 and population increases
- Keeping same value of A through time, we get…

K(t) with ever-changing slope



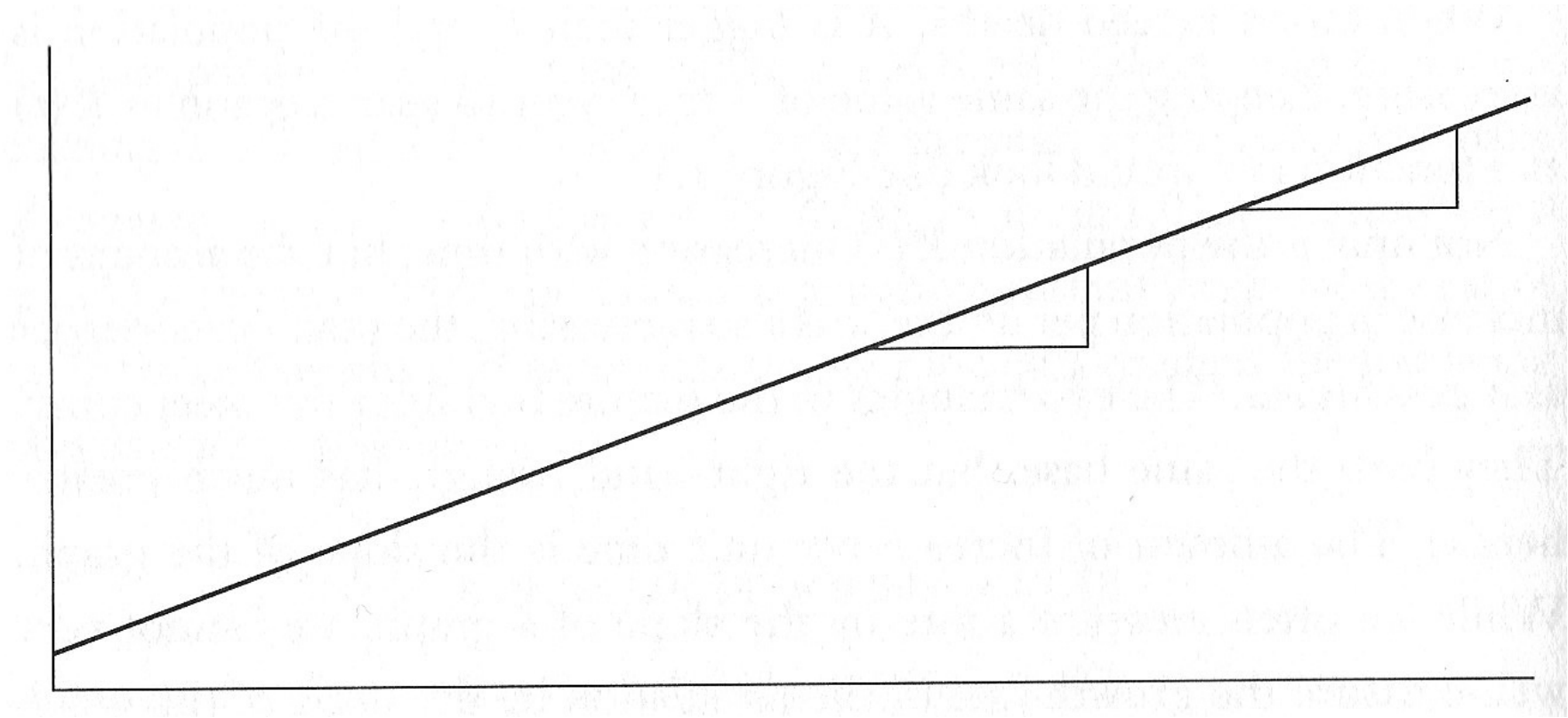
Source: Wachter 2014, p. 10.

Constant slope

- Previous graph, we cannot measure growth rate by graph slope, because it varies
  - Slope changes even when B/K and D/K are fixed

- We need a measure of growth that stays fixed when B/K and D/K are fixed
  - Take logarithms of K(t)
  - Usual way of converting multiplication into addition
  - log K(t) versus t has constant slope…

Log *K(t)* with constant slope



Source: Wachter 2014, p. 10.

Linear equation

- Taking logarithms converts the equation

$$K(t) = A^t K(0)$$

- Into the equation

$$\log(K(t)) = \log(K(0)) + \log(A)t$$

- General form

$$Y = a + bX$$

- Slope b is log(A), which is called slope R
  - Measure of population growth

Example of slope R

Population 1 January 2010	**6,851 million**
+ Births 2010	+140 million
+ Deaths 2010	–57 million
= Population 1 January 2011	6,934 million

- R = log(1+(B–D)/K) = log(1+(140–57)/6,851)=0.012042
- World population has been growing at a rate of about 12 per thousand per year since 2000

Natural logarithms

- We use natural logarithms, which have base e=2.71828
  - "e" is the choice for A that makes the slope of the graph of K(t) equal 1 when t=0 and K(0)=1

- Population growth rate R
  - Slope of the graph of the logarithm of population size over time
  - Proportional rate of change in population size

Population growth rate (R)

- Ratio of change in vertical axis (rise) to horizontal axis (run)

$$R = \frac{\log\big(K(T)\big) - \log\left(K(0)\right)}{T - 0}$$

- It can also be written as

$$R = \frac{1}{T} log\left(\frac{K(T)}{K(0)}\right)$$

Average growth rate

- As slope of logarithm of population size

$$R = \frac{1}{T} log\left(1 + \frac{K(T) - K(0)}{K(0)}\right)$$

- As proportional rate of change in population size

$$R \approx \frac{K(T) - K(0)}{T} \frac{1}{K(0)}$$

  - When T (interval in years) is close to zero
  - First factor is ratio of vertical to horizontal axis
  - Divide it by K(0) to get slope as proportion of size

Exponential function

- Population over time when ratios of births and deaths to population remain constant

$$K(t) = A^t K(0) = e^{Rt} K(0) = \exp(Rt)K(0)$$

- Exponential function is the inverse function for natural logarithms

$$e^{\log(x)} = \exp(\log(x)) = x$$

$$\log(e^y) = \log(\exp(y)) = y$$

Exponential curve

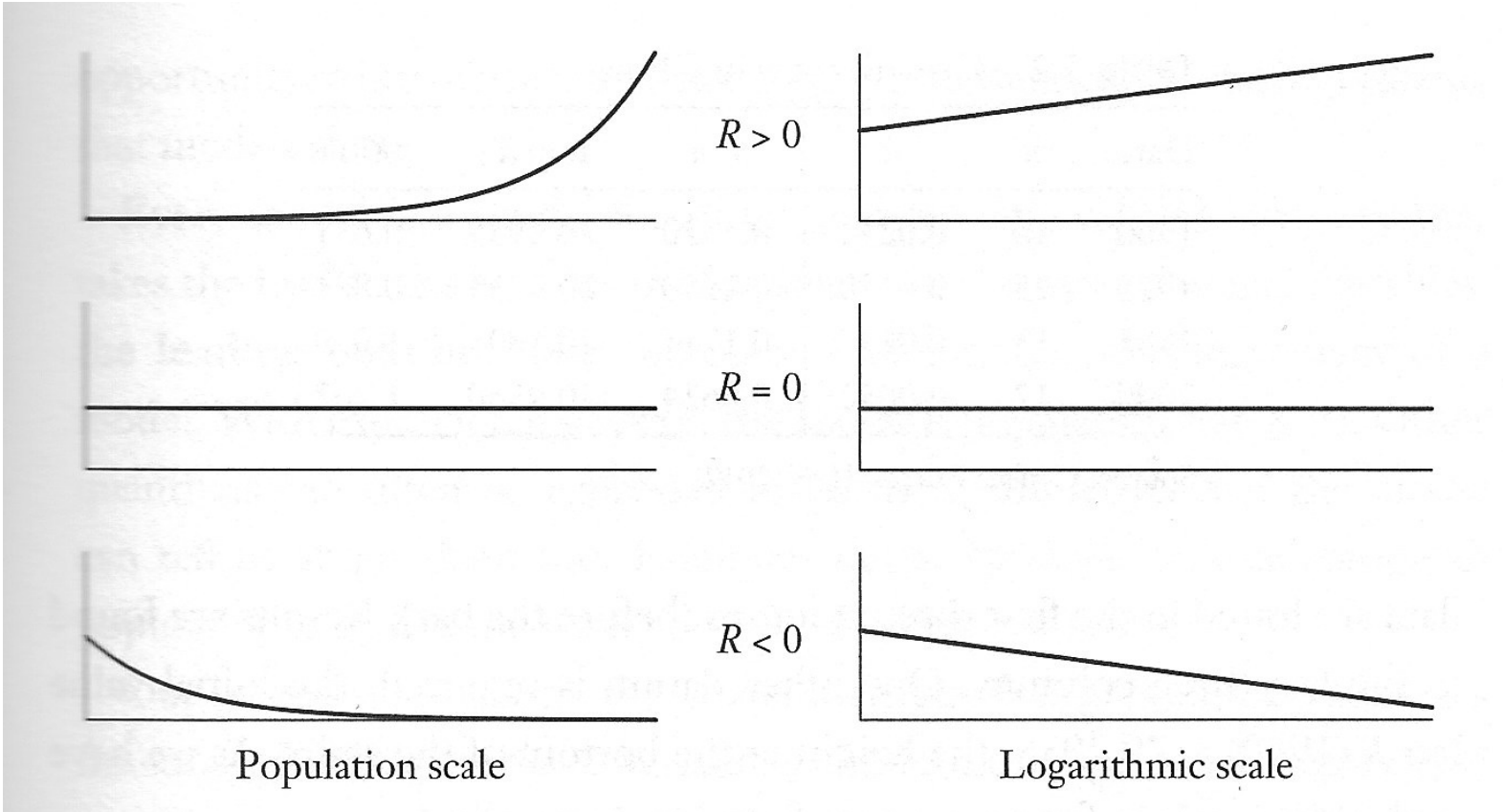
- We know that log(A) is R

$$A = e^{\log(A)} = e^{R}$$

$$A^{t} = (e^{R})^{t} = e^{Rt} = \exp(Rt)$$

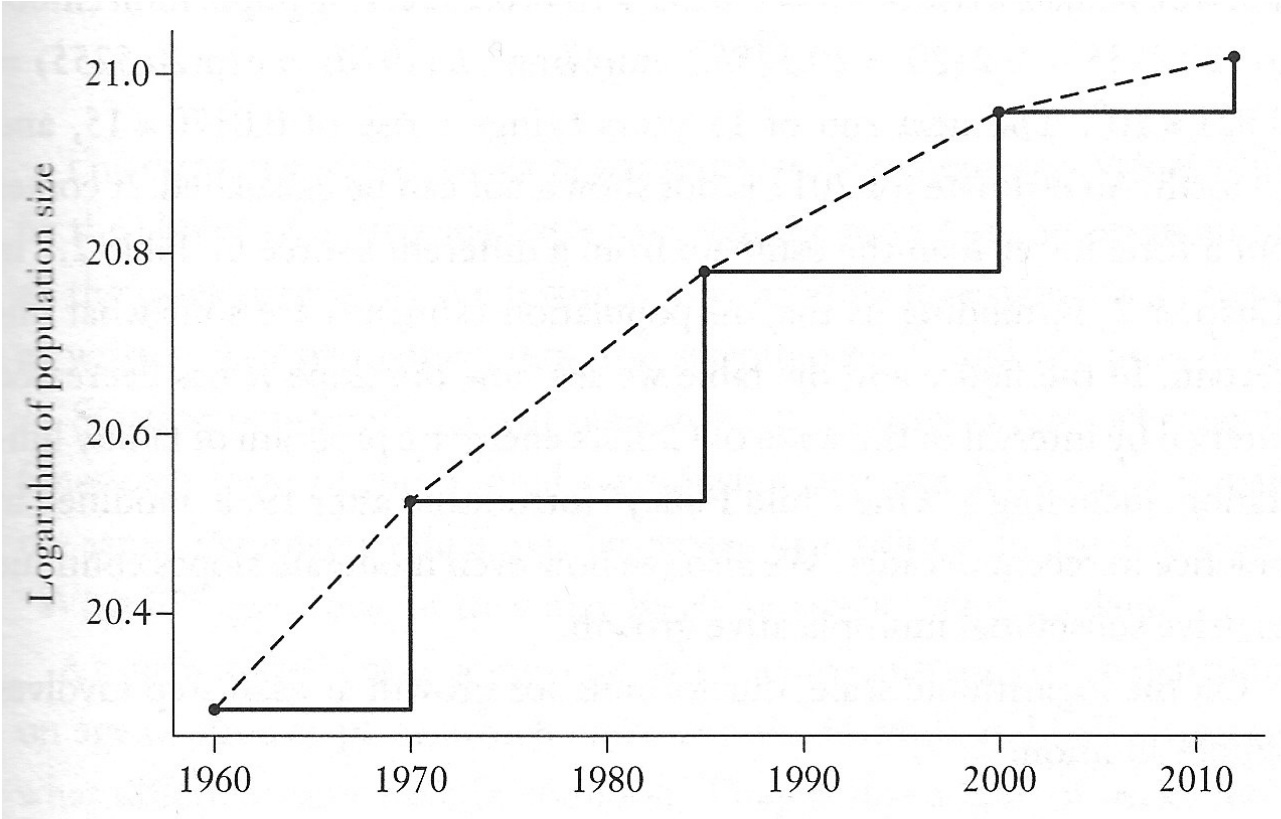
- Exponential curve
  - Graph of exp(Rt) as a function of *t*
  - Continuous-time version of the curve for geometric growth

Trajectories of exponential growth



Source: Wachter 2014, p. 15.

Rise and run: China's log-population



Source: Wachter 2014, p. 15.

Growth rates in China

$$\log K(t+n) = \log K(t) + Rn$$

$$K(t + n) = K(t)e^{Rn}$$

Date	*n* *"run"*	R	R *n* *"rise"*	log(*K*)	*K*(*t*)
1960	10	0.0232	0.2320	20.2935	0.651
1970	15	0.0170	0.2550	20.5255	0.821
1985	15	0.0117	0.1755	20.7805	1.059
2000	12	0.0052	0.0624	20.9560	1.262

Source: Census Bureau IDB (2012). Wachter 2014, p. 16.

Doubling times

- Doubling times:

$$K(t) = \exp(Rt)\, K(0)$$

$$K(T_{double}) = 2K(0) = \exp(RT_{double})\, K(0)$$

$$2 = \exp(RT_{double})$$

$$\log(2) = RT_{double}$$

$$T_{double} = \log(2)/R \approx 0.6931/R$$

- Growth rate: $R = \frac{1}{T} log \left(\frac{K(T)}{K(0)} \right)$

World population and doubling times

Date	*Population*	Growth rate	*Doubling time*
8000 B.C.	5 million	0.000489	1417 years
1 A.D.	250 million	–0.000373	–1858 years
600	200 million	0.000558	1272 years
1000	250 million	0.001465	473 years
1750	750 million	0.004426	157 years
1815	1,000 million	0.006957	100 years
1950	2,558 million	0.018753	37 years
1975	4,088 million	0.015937	43 years
2000	6,089 million		

Source: Estimates drawn from Cohen (1995) and IDB (2012). Wachter 2014, p. 25.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