Human population dynamics

Lecture 1

History of human population

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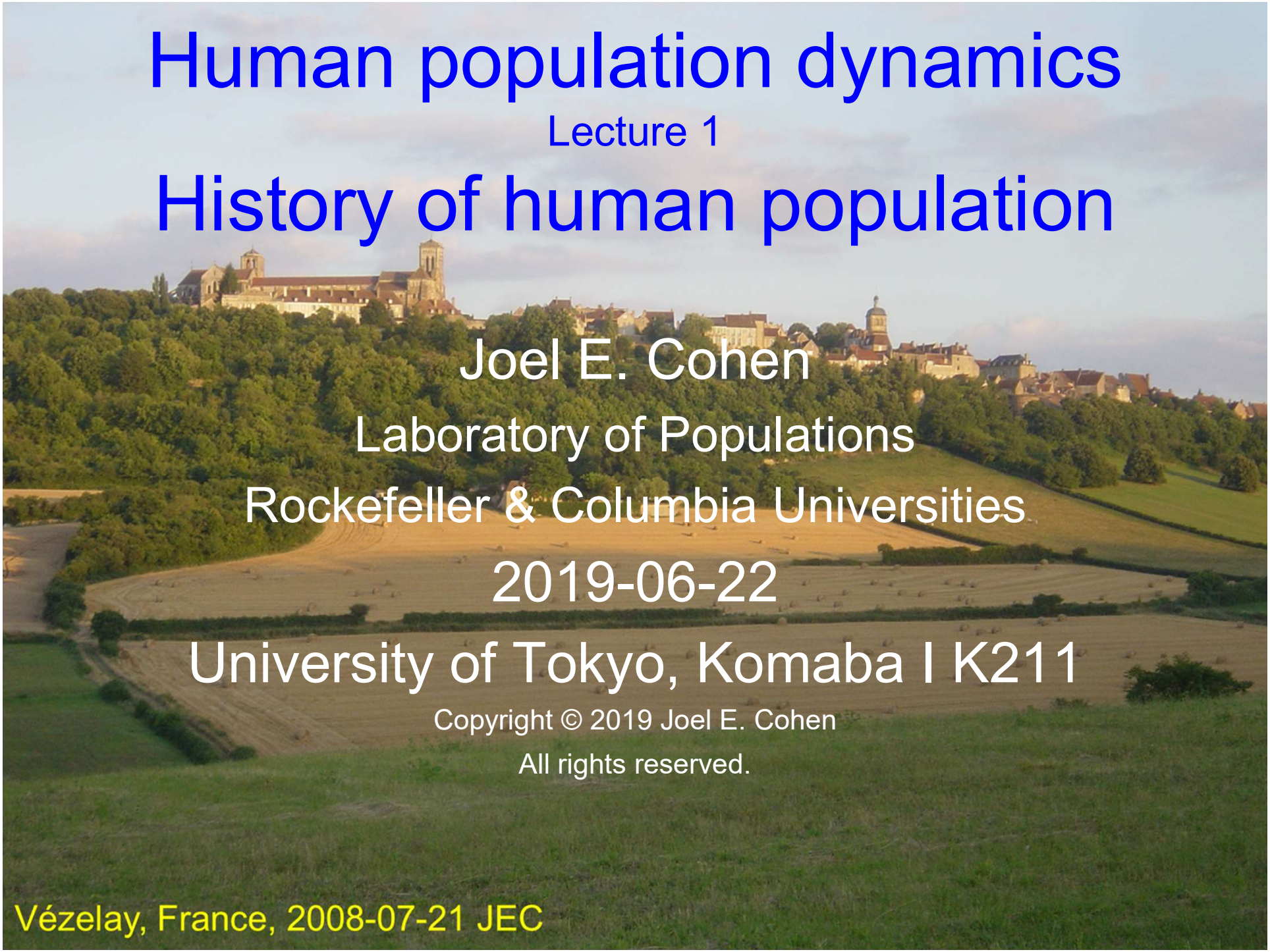
Laboratory of Populations

Rockefeller & Columbia Universities

2019-06-22

University of Tokyo, Komaba I K211



Copyright page

Preliminaries

Thank you to students for taking this course.

Thank you to Prof. Shimada, Prof. Shefferson, & teaching assistants Zhao & Truong, for teaching with me.

Zhao & Truong will introduce themselves & give their email addresses.

Students, please ask all admin & grading questions to Prof. Shimada & teaching assistants Zhao & Truong.

What I offer you

Lectures, 3 days

Slides of lectures after each day will be posted on course website for your private educational use only, not for re-posting or publication

Checklist of key words, terms, concepts, posted on course website

What I ask from you

Please ask questions during class.

Required INDIVIDUAL (not group) report on same day as each class, using the form downloaded from the course website: for EACH class, please write for 5 minutes (in English! not more than ½ page please!) on one or more of these options:

1. big idea;
2. something specific you learned;
3. something you disagree with;
4. question.

Course project.

What I ask from you: course project

- Please download & read "HPDCourseProject20190622.docx" description from course website.
- Research for project may be individual or by a group of 2, 3, or 4 people.
- Report must be written separately by each individual & uploaded individually to ITC-LMS website by 2019-07-20, 23:00.
- Important: please pick questions that interest you personally.

On-line demographic data

www.prb.org Population Reference Bureau data finder

www.un.org/esa/population/ United Nations Population Division
http://www.un.org/popin/data.html Population Information data base

http://www.census.gov/data.html United States Census Bureau U.S. & international data

On-line demographic data

http://databank.worldbank.org/data/home.aspx World Bank World DataBank

http://www.who.int/gho/database/en/ World Health Organization data repository

http://faostat3.fao.org/home/E Food & Agriculture Organization of the UN Statistics Division data base

https://www.cia.gov/library/publications/resources/the-world-factbook/ Central Intelligence Agency World Factbook

On-line demographic data

UNICEF/WHO/World Bank Joint Child Malnutrition Estimates, March 2019

https://data.unicef.org/topic/nutrition/malnutrition/

"The Joint Malnutrition Estimates (JME) country dataset9 lists, as of January 2019, estimates after re-analysis for 474 nationally representative household surveys from 112 countries."

http://www.who.int/nutgrowthdb/estimates/en/

Recommendations for data collection, analysis and reporting on anthropometric indicators in children under 5 years old. Geneva: WHO, UNICEF 2019.

On-line demographic data

http://stats.oecd.org/ Organisation for Economic Co-operation & Development OECD.Stat for OECD & selected non-member economies

http://ec.europa.eu/eurostat Eurostat European statistics

https://www.ined.fr/en/everything_about_population/data/all-countries/#r150 Institut National d'Études Démographiques data on France & other countries & regions

On-line demographic data

https://www.worldpop.org/

Open access archive of spatial demographic data sets.

On-line demographic data

http://www.mortality.org/ Human Mortality Database detailed population & mortality data for 38 countries or areas

http://www.humanfertility.org/cgi-bin/main.php Human Fertility Database

http://www.cdc.gov/nchs/ U.S. Centers for Disease Control & Prevention, National Center for Health Statistics

On-line demographic data

CLIO-INFRA, historical statistics on inequality, with section on population:

https://urldefense.proofpoint.com/v2/url?u=https-3A__clio-2Dinfra.eu_Indicators_TotalPopulation.html-23&d=DwIFAg&c=JeTkUgVztGMmhKYjxsy2rfoWYibK1YmxXez1G3oNStg&r=FKhjYc1HQoCLnnr9NvxYqNpS4P-JkIKTYMtb4yHWJA8&m=Us-2KXID8T3AJnQ7I5vPWzqMNC7n8h9J4bRIESWuUIc&s=folsztLmlfM5izrJOnnBExm18XbNyonQdKmzDuDpsJE&e=

On-line demographic data

https://www.popgrid.org/

POPGRID Data Collaborative

Enhanced Population, Settlement and Infrastructure Data

https://earthtime.org/ EarthTime

"visualizations of the Earth's transformation over time. Combining huge data sets with images captured by NASA satellites between 1984 and 2016"

On-line demographic data

https://sedac.ciesin.columbia.edu/data/collection/gpw-v4

Gridded Population of the World (GPW), v4

"a spatially disaggregated population layer that is compatible with data sets from social, economic, and Earth science disciplines, and remote sensing. It provides globally consistent and spatially explicit data for use in research, policy-making, and communications."

On-line demographic data

https://mygeohub.org/

"a geospatial science gateway that supports the geospatial modeling, data analysis and visualization needs of the broad research and education communities through hosting of groups, datasets, tools, training materials, and educational contents."

On-line energy data

United States Department of Energy, Energy Information Administration EIA

https://www.eia.gov/tools/

See International Energy Statistics.

On-line educational data

http://uis.unesco.org/

The UNESCO Institute for Statistics is the statistical office of UNESCO.

It is the UN depository for cross-nationally comparable statistics on education, science, technology, culture, and communication.

Data on households & individuals

https://usa.ipums.org/usa/ "The Integrated Public Use Microdata Series (IPUMS-USA) consists of more than fifty high-precision samples of the American population drawn from fifteen federal censuses and from the American Community Surveys of 2000-present.“

https://international.ipums.org/international/ IPUMS-International collects & distributes census data & documentation from around the world, harmonizes data, & disseminates harmonized data free of charge. 85 countries - 301 censuses - 672 million person records.

Data on households & individuals

http://dhsprogram.com/data/ "Since 1984, The Demographic and Health Surveys (DHS) Program has provided technical assistance to more than 300 surveys in over 90 countries, advancing global understanding of health and population trends in developing countries."

Multiple choice test

1. Over the last 2000 years, global human population size grew exponentially. T, F
2. Global human population size is now growing faster than ever before,

as %/year. T, F; in absolute numbers added/y. T, F

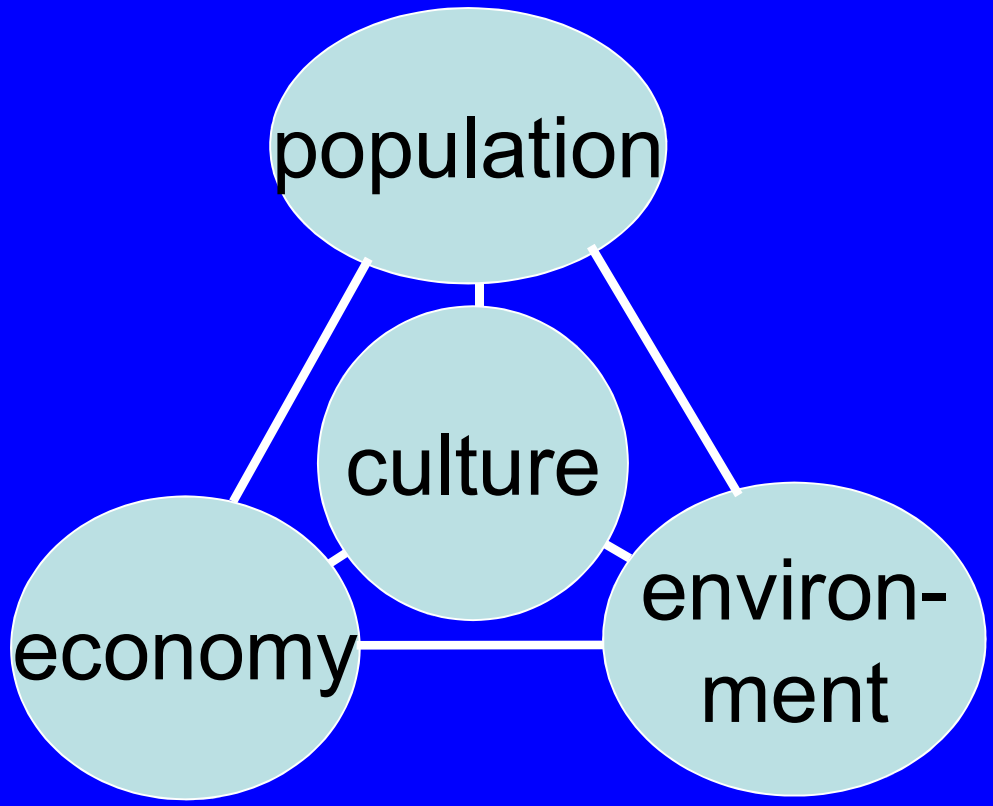
3. Average number of children per woman at current fertility rates is >3. T, F
4. At least 1/2 world's women live in countries with fertility below replacement level. T, F
5. World population exceeds 10 billion. T, F;

5 billion. T, F

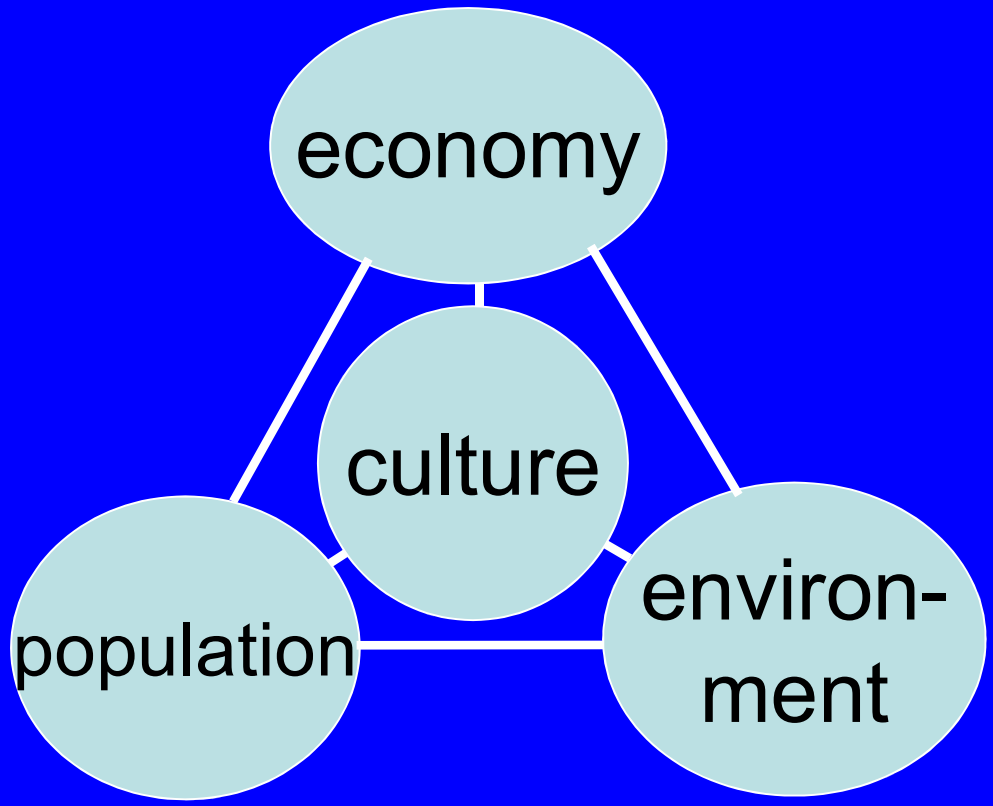
Take-home messages

1. Population problems involve much more than the total number of people on Earth.
2. Population, economics, the environment, & culture interact.
3. The human population today is unlike any in the past.

Population
Economy
Environment
Culture
interact.



Economy
Population
Environment
Culture
interact.



Environment
Population
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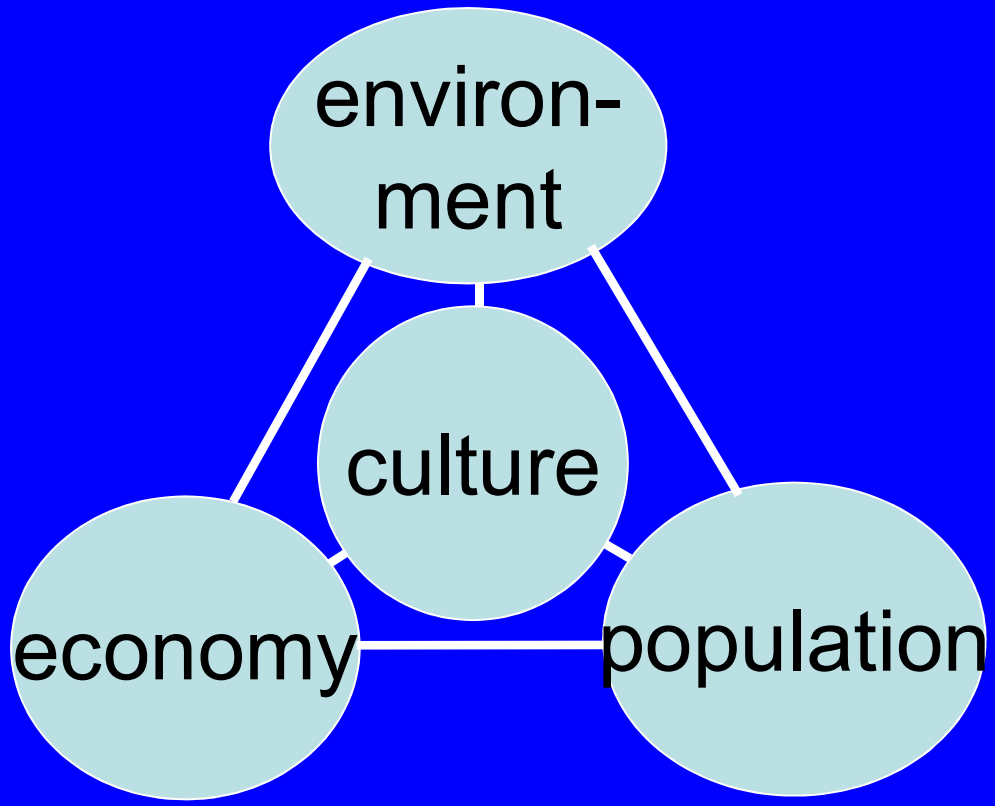
Culture
interact.



Culture
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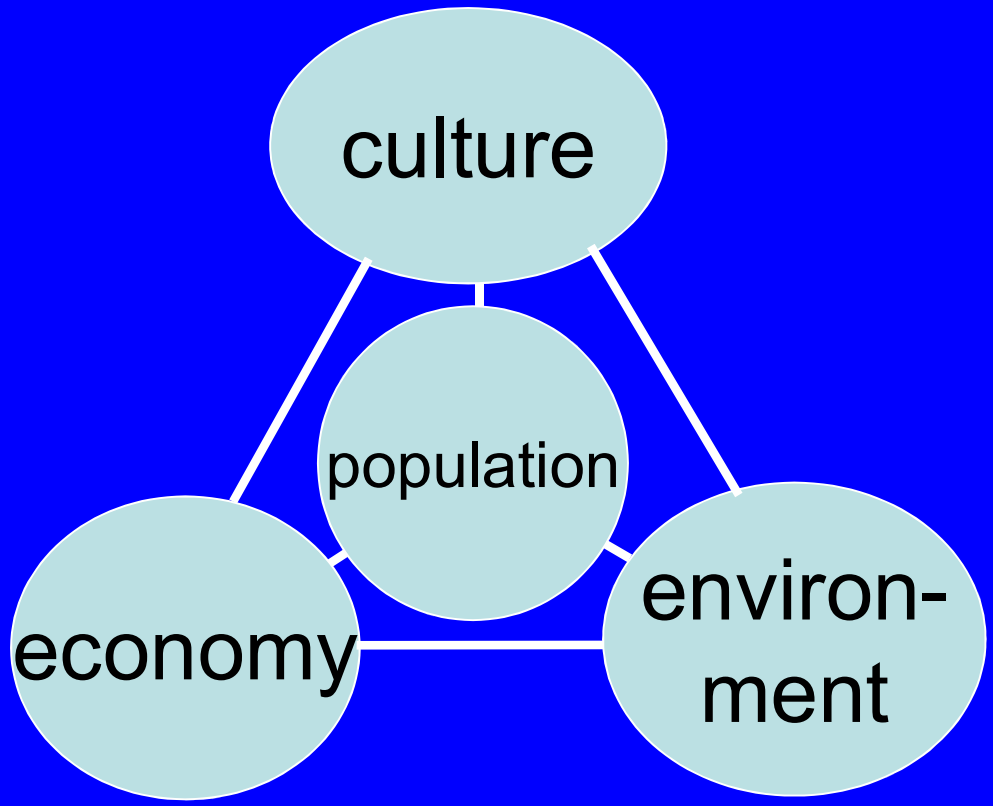
interact.



Question 1

Approximately how many people are alive today?

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Approximately how many people are alive today? (billion = 10^9 =億)

7.5 billion (CIA World Factbook, 20190607 2018 est.)

7.6 billion (https://census.gov/, June 2019)

7.7 billion = 7.550 billion (in June 2017) x $(1.011)^2$ (2017 growth rate = 1.10%/y)

(UN Population Division, World Population Prospects: The 2017 Revision; 2019 revision of World Population Prospects is available on 17 June 2019.)

How do we know?

Sources of population data

Administrative records (tax, vehicles, real estate)

Censuses (de jure, de facto)

Population registers

Vital registration systems

birth, death, marriage, divorce

Demographic sample surveys

Other e.g., refugee statistics

Population data of UN 2015 *World Population Prospects*

Census population data or official estimates based on censuses, population registers & surveys referring to 2010 or later were available for 172 countries or areas.

These represented 74% of 233 countries or areas analyzed, 83% of world population.

For 54 countries, most recent population data available were from 2000-2009. For the remaining 7 countries, the most recent data were from 1975 in Somalia, 1984 in the Democratic Republic of Congo and Eritrea, and 1998 in Pakistan.

Vital data of UN 2015 *WPP*

"… of the 201 countries or areas [with 90,000 inhabitants or more in 2015], 177 had information on fertility that referred to 2010 or later. … information on recent levels of fertility was available for 96.5 per cent of the world's population."

"… for child mortality, measured by the probability of dying between birth and age five, …information … was available for 165 countries or areas, encompassing 92 per cent of the world's population".

Question 1

Approximately how many people are alive today?

How do we know?

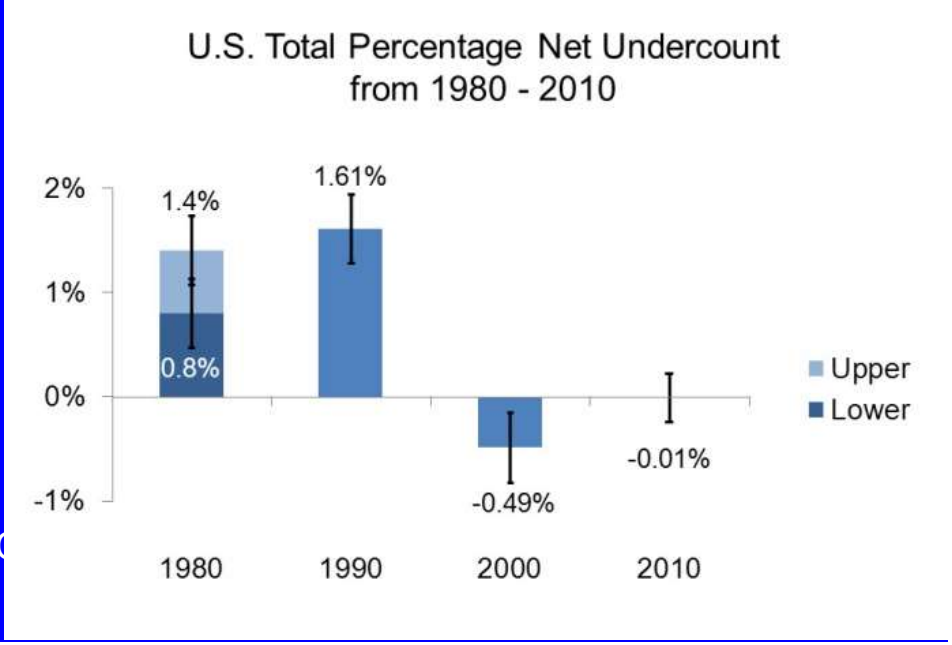
What is the uncertainty of the answer?

2010 US Census: 308.7 million ±?%

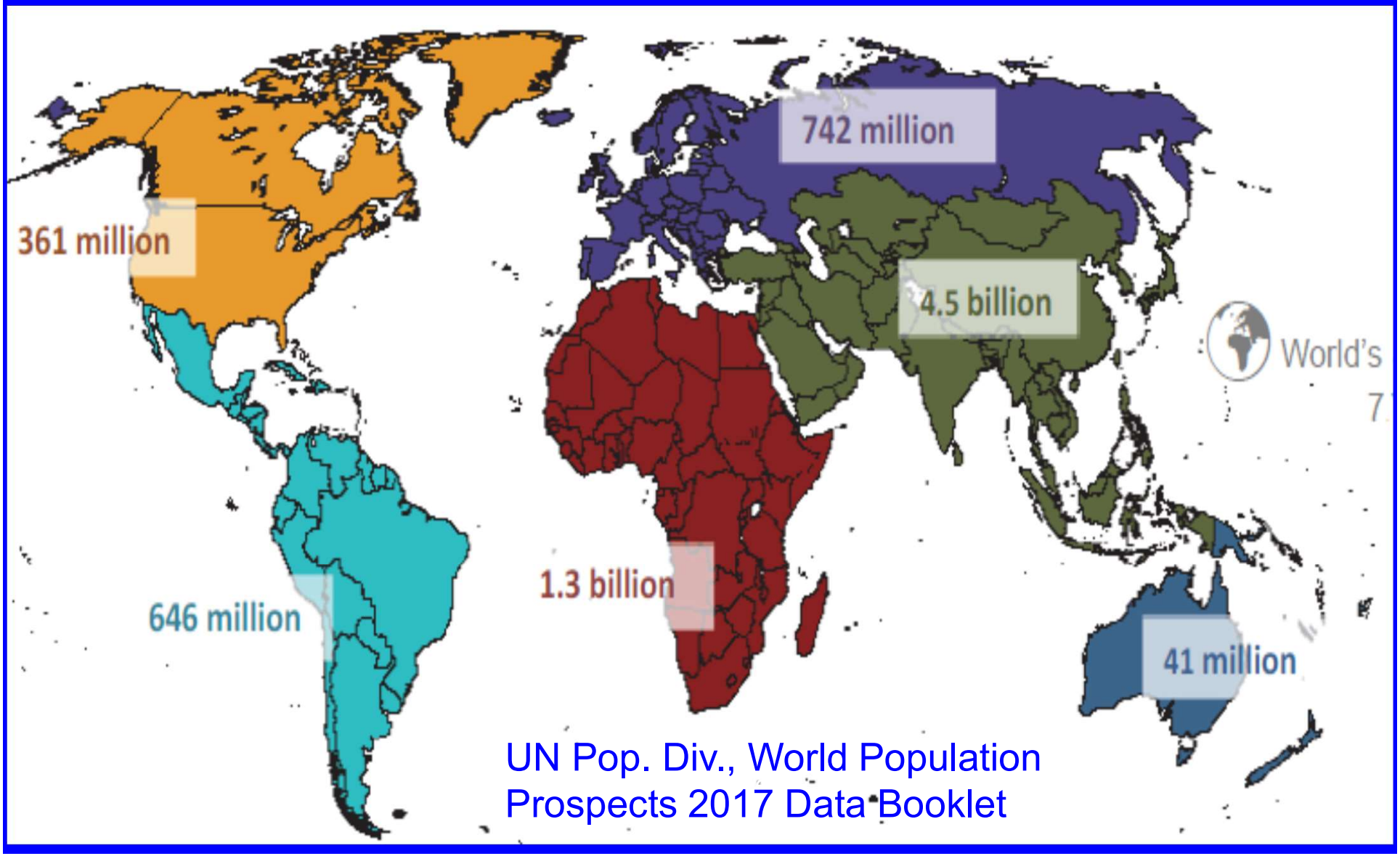
Demographic analysis for resident population estimates for April 1, 2010 (in millions)

Low	Middle Low	Middle	High Middle	High
305.7	307.4	308.5	310.0	312.7

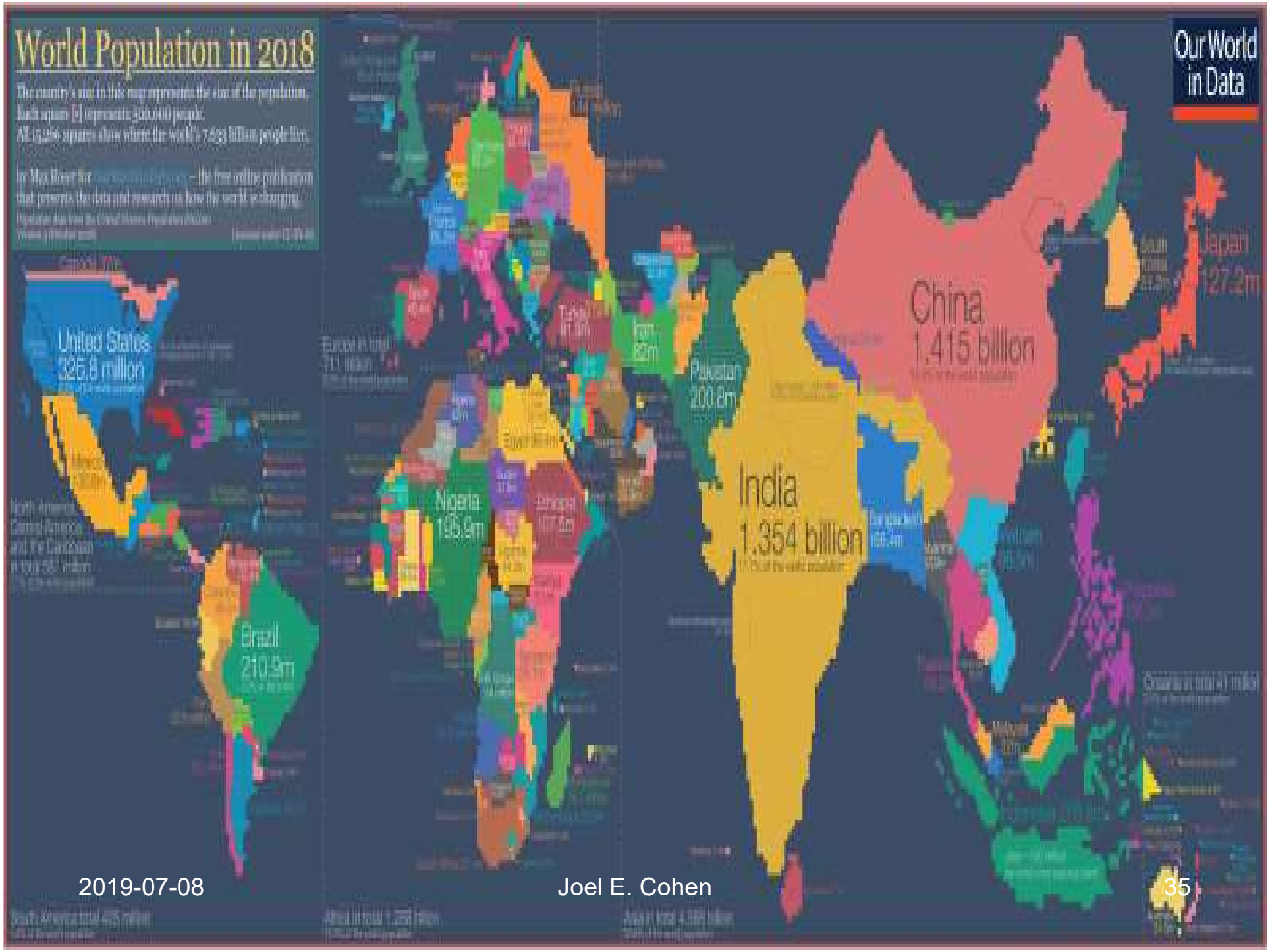
Post-enumeration survey estimate of accuracy for household population only



Of world's 7.6 billion people in 2017, Asia has 60%, Africa 17%.



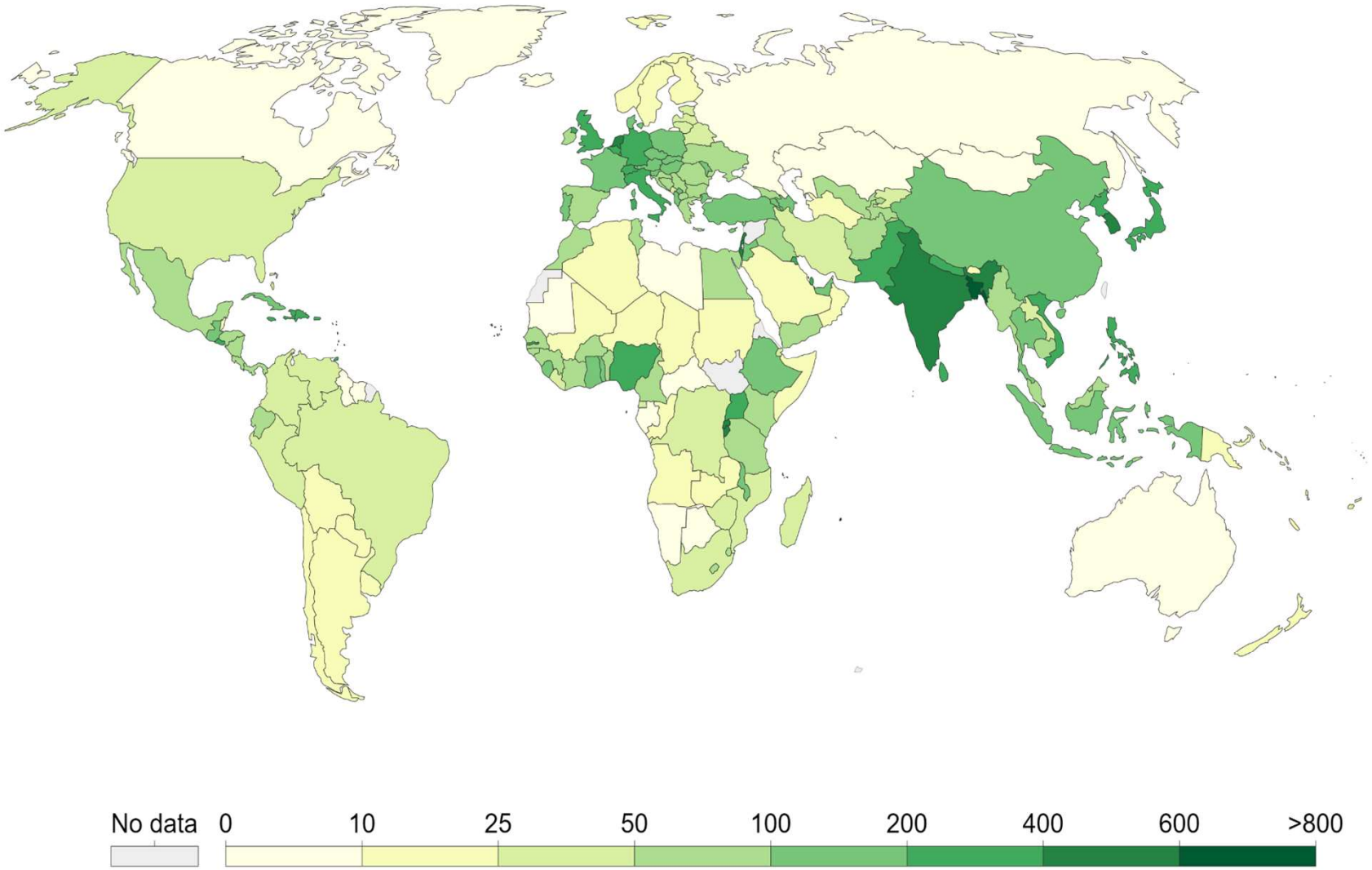
UN Pop. Div., World Population Prospects 2017 Data Booklet


World Population in 2018
Our World in Data
China
1.415 billion
India
1.354 billion
United States
326.8 million
Nigeria
195.9m
Brazil
210.9m
Pakistan
200.8m
Japan
127.2m

Population density, people per km², 2017

Population density is defined as the number of people (population) divided by land area, mesured in square kilometres (km²).

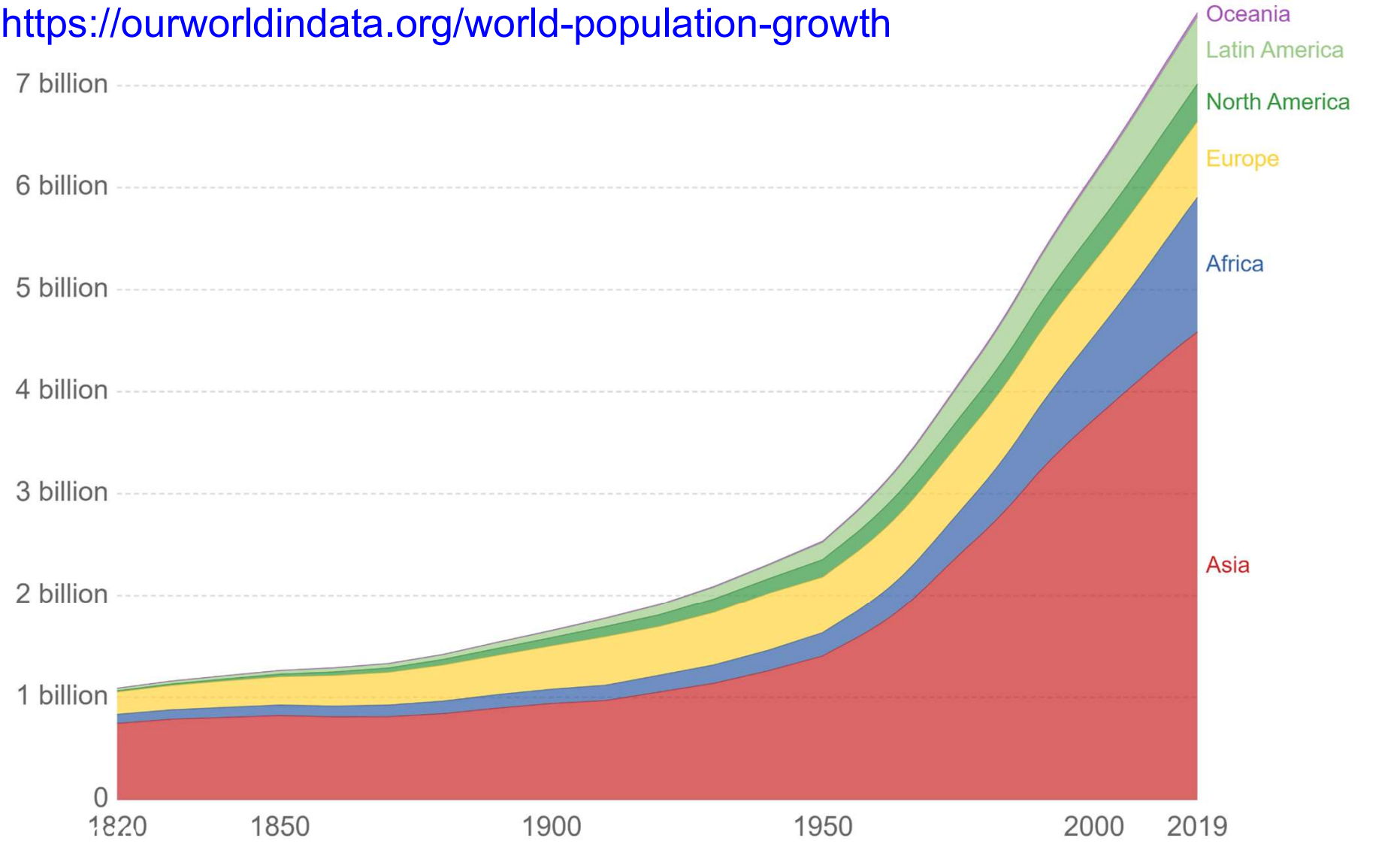
Our World in Data



Source: World Bank

World population by region

https://ourworldindata.org/world-population-growth



Question 2

Approximately when were 1 billion people alive?

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Approximately when were 1 billion people alive?

US Census Bureau	1804
UN Population Div.	1804

How do we know?

Question 2
How do we know past populations?

Babylon: 3800 BCE (roughly 6000 ybp) reports that censuses every 6-7 years counted people, livestock, other foods

Jewish & Christian Bibles

Rome: register of citizens and property every 5 years

China, Han Dynasty: 2 CE oldest census still existing: population 59.6 million, largest then

USA: 1790; UK: 1801

Question 2

When were 1 billion people alive?

US Census Bureau 1804

UN Population Div. 1804

How do we know?

What is the uncertainty of the answer?

Historical estimates of population in 1800:
813 million-1,125 million

Question 3

How fast does population increase per year in 2019?

%/year

number of people/year

Question 3

How fast does population increase per year in 2019?

%/year

number of people/year

1.0-1.1%/year

x 7.5-7.7 billion total population

= 75-85 million increase per year.

Official estimates have spurious precision!

Question 4: Theory

If world population always grew 1% per year in the past, how long ago did the world have 2 people?

(A) ~70 years ago (~1950)

(B) ~2,200 years ago (2.2ka)

(C) ~14,000 years ago (14ka)

(D) ~180,000 years ago (180ka)

(E) ~2 million years ago (2Ma)

Exponential model

Think of savings account with interest rate *r*.

Assume *r* does not change in time *(unrealistic!)*.

Let $P(t)$ = population size at time $t \geq 0$.

Assume $P(0) > 0$, $\frac{dP(t)}{dt} = r \cdot P(t)$.

Then $P(t) = e^{rt} P(0)$.

$P(t)$ is an exponential function of t.

$$\log P(t) = rt + \log P(0).$$

$\log P(t)$ is a linear function of t.

Leonhard Euler, Benjamin Franklin, Thomas R. Malthus

Doubling time in exponential model

How much time T is required for the population to double? If $P(t) = e^{rt}P(0)$, then $P(T) = 2P(0) = e^{rT}P(0)$ so $2 = e^{rT}$. Hence $\ln 2 = rT$ and $\ln 2/r = T = 0.69/r$.

Growth rate per year r	~ Time for population to double
1%	69 years
2%	35 years
3%	23 years
4%	17 years
5%	14 years

High population growth rates

CIA World Factbook for 2014; UN Population Fund 2010-2015 average

Country	r, % per year CIA	r, % per year UNPF	CIA: Time to double, years
Lebanon	9.4	3.0	7.4
Zimbabwe	4.4	2.8	15.9
South Sudan	4.1	4.0	16.8
Jordan	3.9	3.5	18.0
Qatar	3.6	5.9	19.4
Malawi	3.3	2.8	20.8
Niger	3.3	3.9	21.1
Burundi	3.3	3.2	21.1
Uganda	3.2	3.3	21.4
Libya	3.1	0.9	22.5
Burkina Faso	3.1	2.8	22.7
Mali	3.0	3.0	23.1

Example: how long to grow from 2 people to 7.6 billion people at 1%/y?

Factor of increase = 7.6 billion / 2 = 3.8 billion.

3.8~4=2^2, billion = 1000 x 1,000,000 = 2^{10} x 2^{20}

3.8 billion ~ $2^{2+10+20} = 2^{32}$, 32 doublings.

1% growth per year ~69 years per doubling.

Time required is ~32 x 69 years ~ 2208 y.

Exact calculation:

ln(7,600,000,000/2)/0.01 = 2206 years.

Theory can illuminate the past.

Humans have existed for much longer than 2,200 years.

Hence it is not possible that the global population has been growing at 1% per year.

For most of human history, the global population growth rate must have been much less than 1% per year.

Question 5: biggest countries

If you list all 230 countries or areas from largest to smallest estimated population size, how many countries must you add together to get half of all people?

A 2 B 7 C 20 D 120

7 most population countries have >1/2 of world's people.

Country	People (million)
China	1,385
India	1,297
United States	329
Indonesia	263
Brazil	209
Pakistan	208
Nigeria	203
Total	3,894

CIA World Factbook, July 2018 estimate

Life in time

3.8 Ga Earliest life (1 Ga=10^9 years ago)

2.1 Ga Multicellular life (Great Oxygenation Event 2.45 Ga)

1.5 Ga Oldest eukaryotic fossil

1.1 Ga First sexually reproducing organisms

0.570 Ga (570 Ma) First arthropods

0.014 Ga (14 Ma) First great apes

0.0025 Ga (2.5 Ma) Genus *Homo*

0.0003 Ga (0.3 Ma, 300 ka) Modern humans

0.00001 Ga (10 ka) Agriculture

Pleistocene history

2,588,000 bp (years before present) – 11,700 bp

At end of Younger Dryas, ~11.7ka, global average temperatures rose 10°C (18°F) in 10 years.

All dates are approximate!

Definitions

Hominoids – all apes (gibbons, gorillas, chimps, orangs, humans)

Hominids – all modern AND extinct GREAT apes (gorillas, chimps, orangs, humans) and their immediate ancestors (not gibbons)

Hominin – any species of early human more closely related to humans than chimps, including modern humans (e.g. Homo, Australopithecus, Ardipithecus, Paranthropus)

Modern humans – 300,000 ybp (years ago)

Human ancestors diverged from chimpanzees in Africa 4-8Ma.

Genus *Homo* arose ~2.5Ma.

Human relatives left Africa in (perhaps) four waves.
Three waves disappeared.

All living humans are of African origin (~300ka-180ka)

but have genes from interbreeding with now-extinct hominins like Neanderthals and Denisovans.

Maps of dispersals of modern humans differ.

Point of origin: south Africa vs east Africa

Route out of Africa: north (Sinai) vs south (Red Sea, Arabian peninsula)

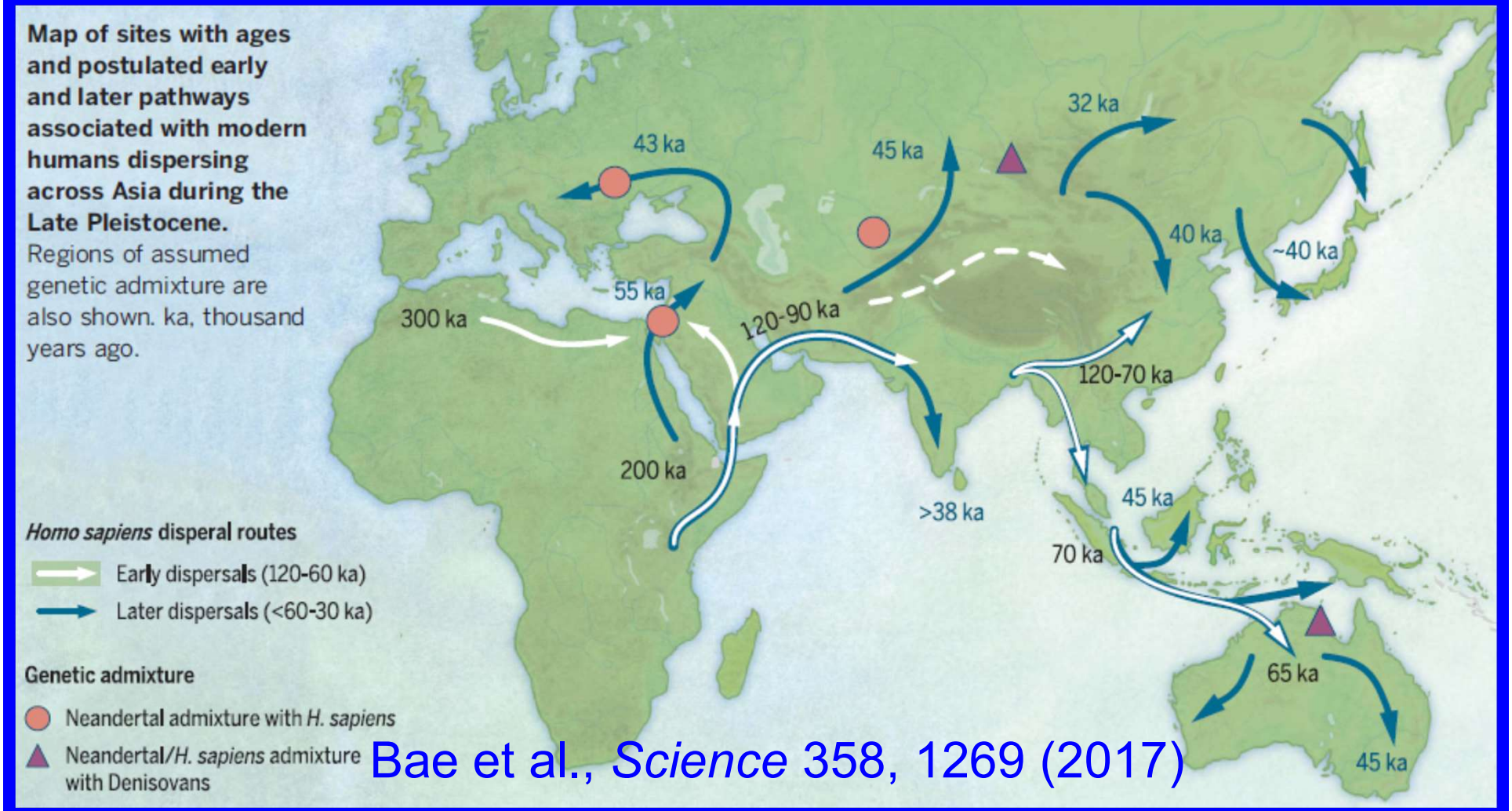
Dating of exits from Africa: early >60ka vs late <60ka

Route(s) & date(s) of entry into Europe: 40ka vs 46-50ka

Routes traveled

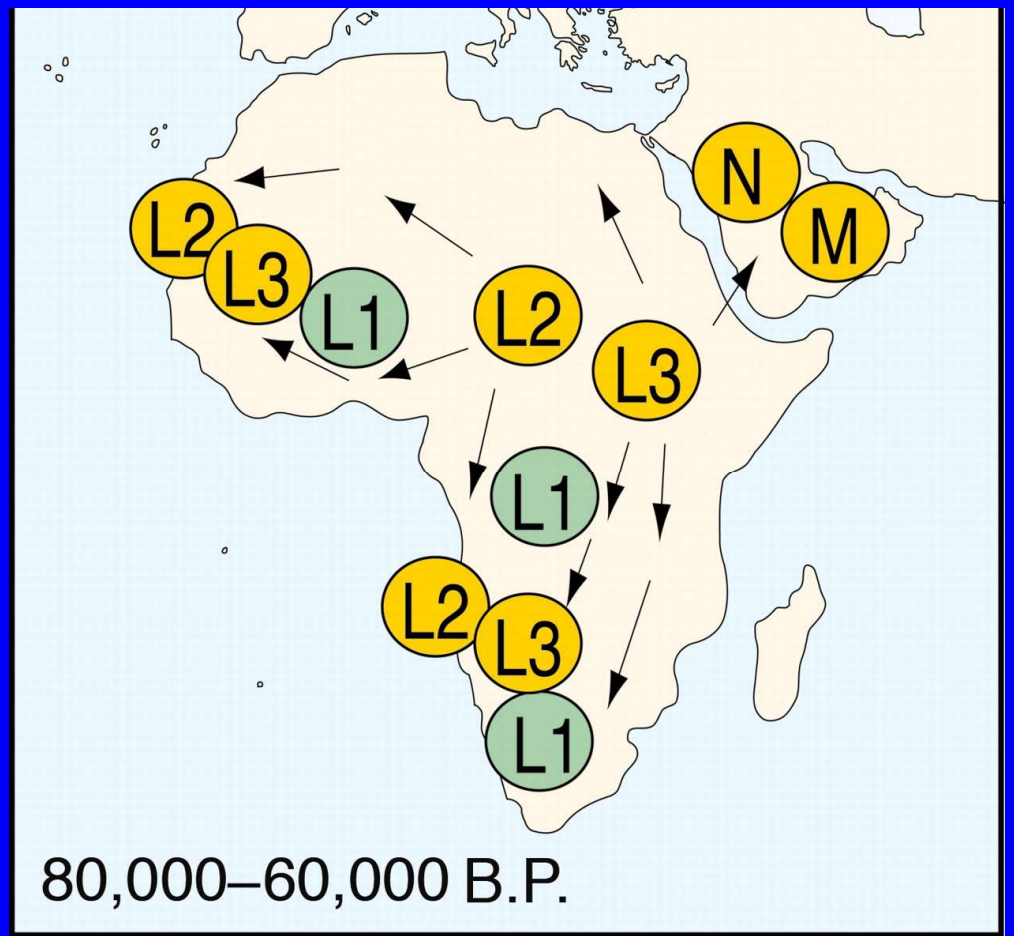
https://genographic.nationalgeographic.com/human-journey/

Multiple dispersals from Africa & mixing of modern humans in Asia



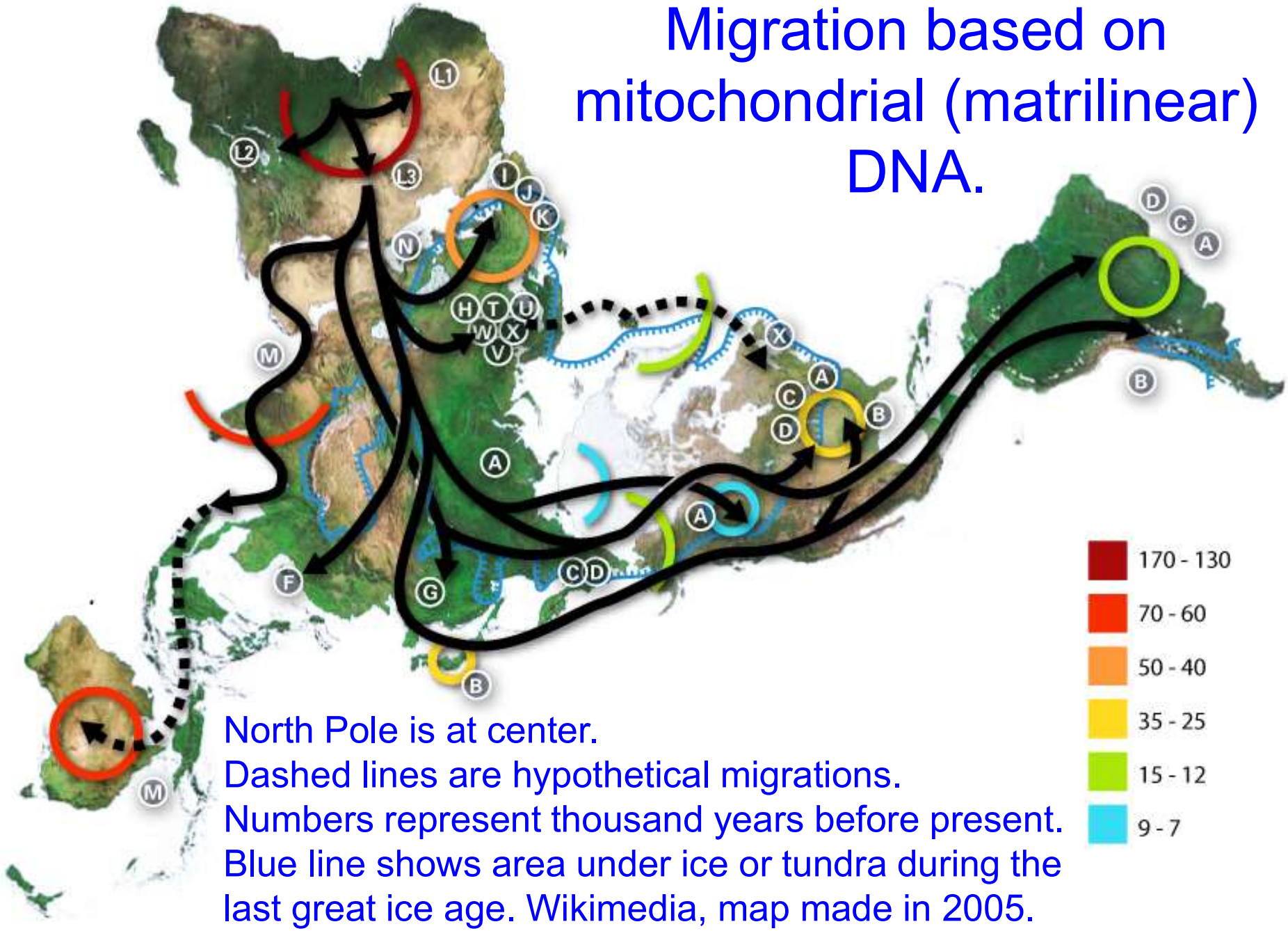
Bae et al., *Science* 358, 1269 (2017)

mtDNA lineage L3a mothered & Y chromosome lineage M168 fathered lineages ancestral to all Asians, Europeans, & Americans: 85% of world population today.



Mellars PNAS 2006

Migration based on mitochondrial (matrilinear) DNA.



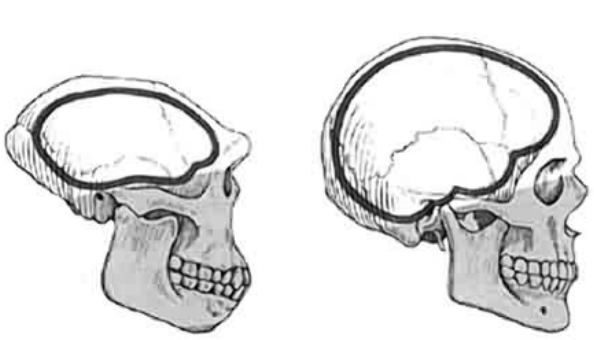
North Pole is at center.
Dashed lines are hypothetical migrations.
Numbers represent thousand years before present.
Blue line shows area under ice or tundra during the last great ice age. Wikimedia, map made in 2005.

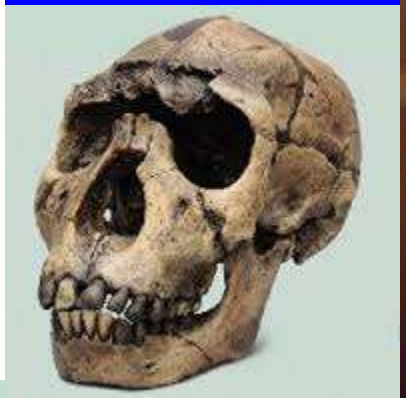
Human relatives came from Africa 1, went extinct.

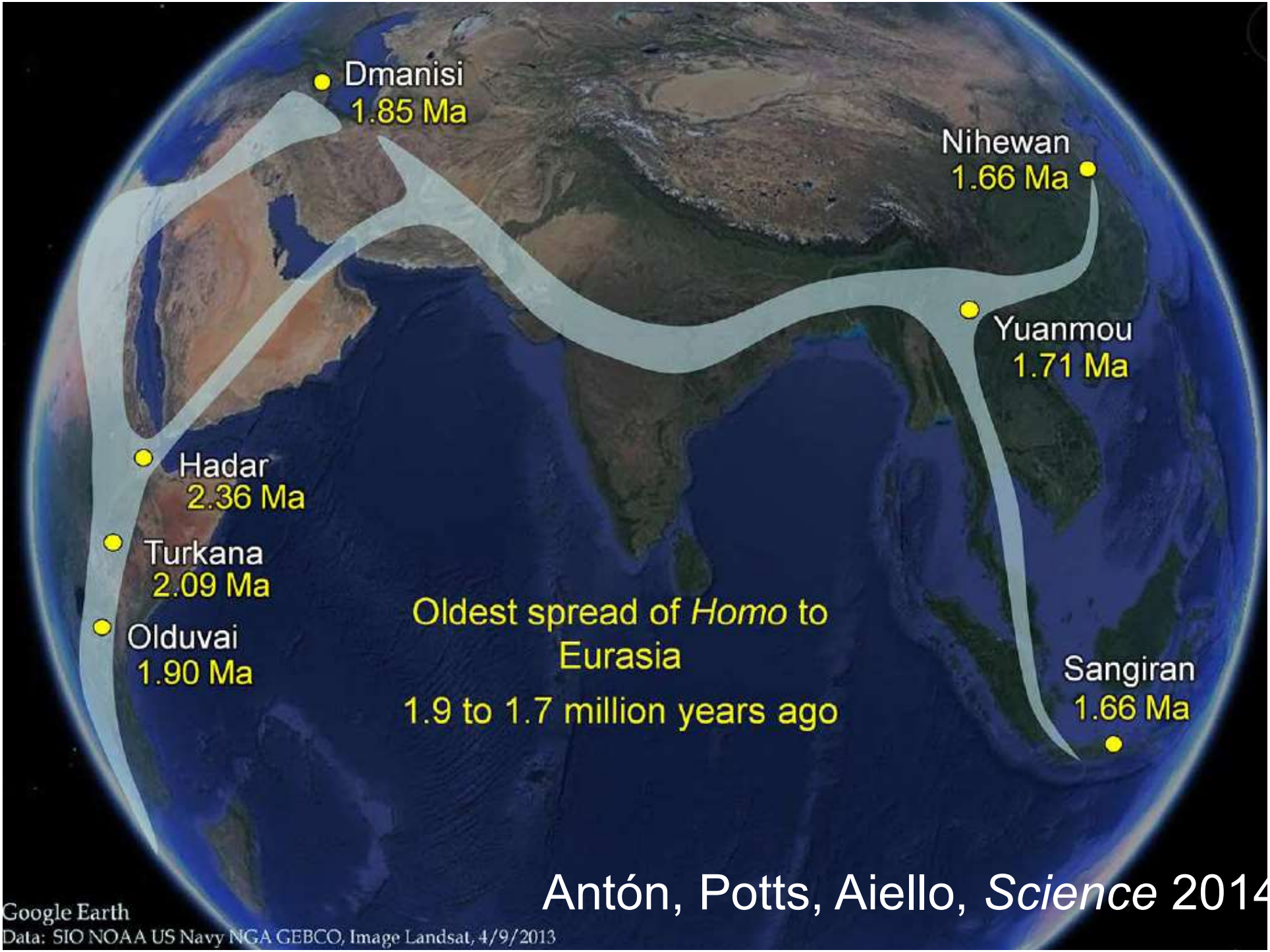
Homo erectus left Africa ~1.9-1.8 million years ago,

settled in tropical & subtropical Central & East Asia,

disappeared ~70,000 years ago.







Antón, Potts, Aiello, *Science* 2014

Human relatives came from Africa 2, went extinct.

Homo heidelbergensis, ancestors of Neanderthals, left Africa 500,000 years ago,

settled Europe & Middle East,

went extinct at different times in different places 45,000-28,000 years ago.

Possible reasons for extinction: climate change, habitat change, warfare, competition, interbreeding with modern humans

Modern humans came from Africa 3, went extinct?

Homo sapiens originated about 300ka in Africa,

appeared in Middle East ~110ka,

died out from Middle East ~80ka.

Homo sapiens is absent from the fossil record in Middle East 80ka – 50ka.

Modern humans came from Africa 4, that's us!

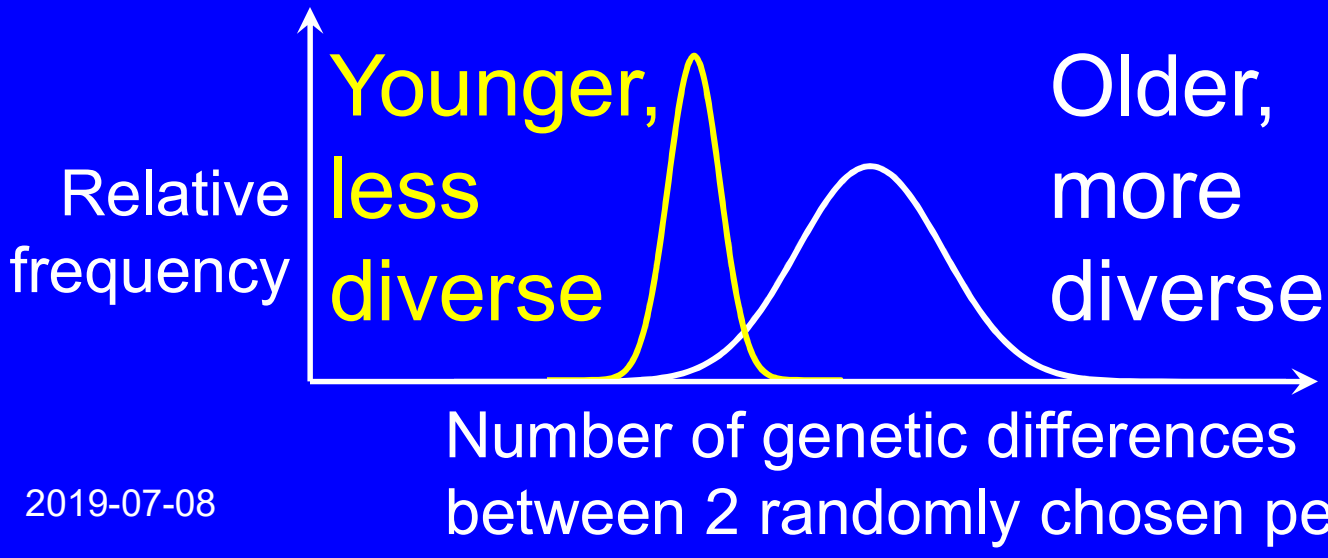
Ancestors of all modern humans outside of Africa left Africa. (Why? By what routes? How many times, & when?)

Ancestors reached all continents (except Antarctica) before last Ice Age ended.

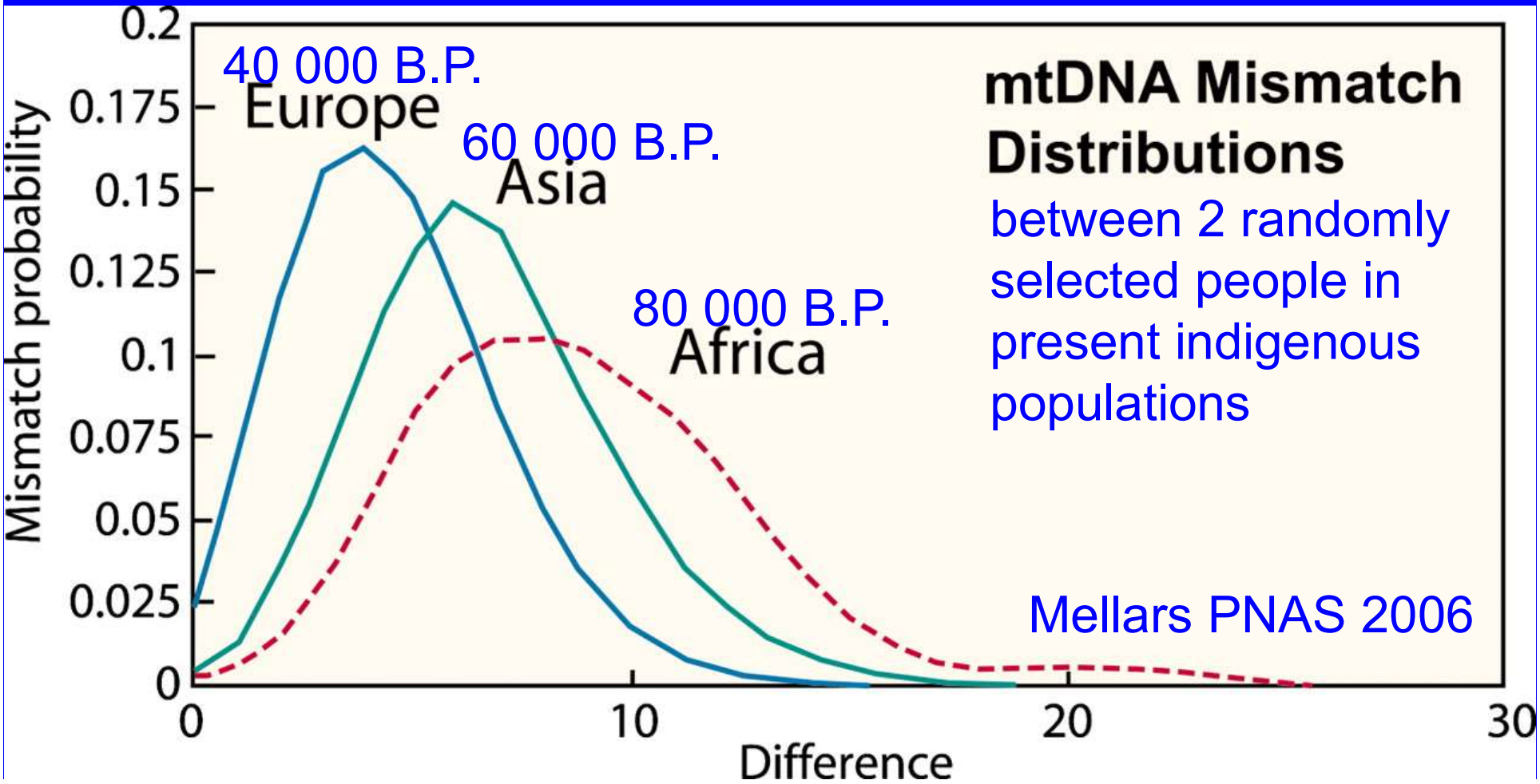
All living humans, African or not, have a most recent common African ancestor, male (~60ka) & female (~175ka).

Comparing within-population diversity between populations

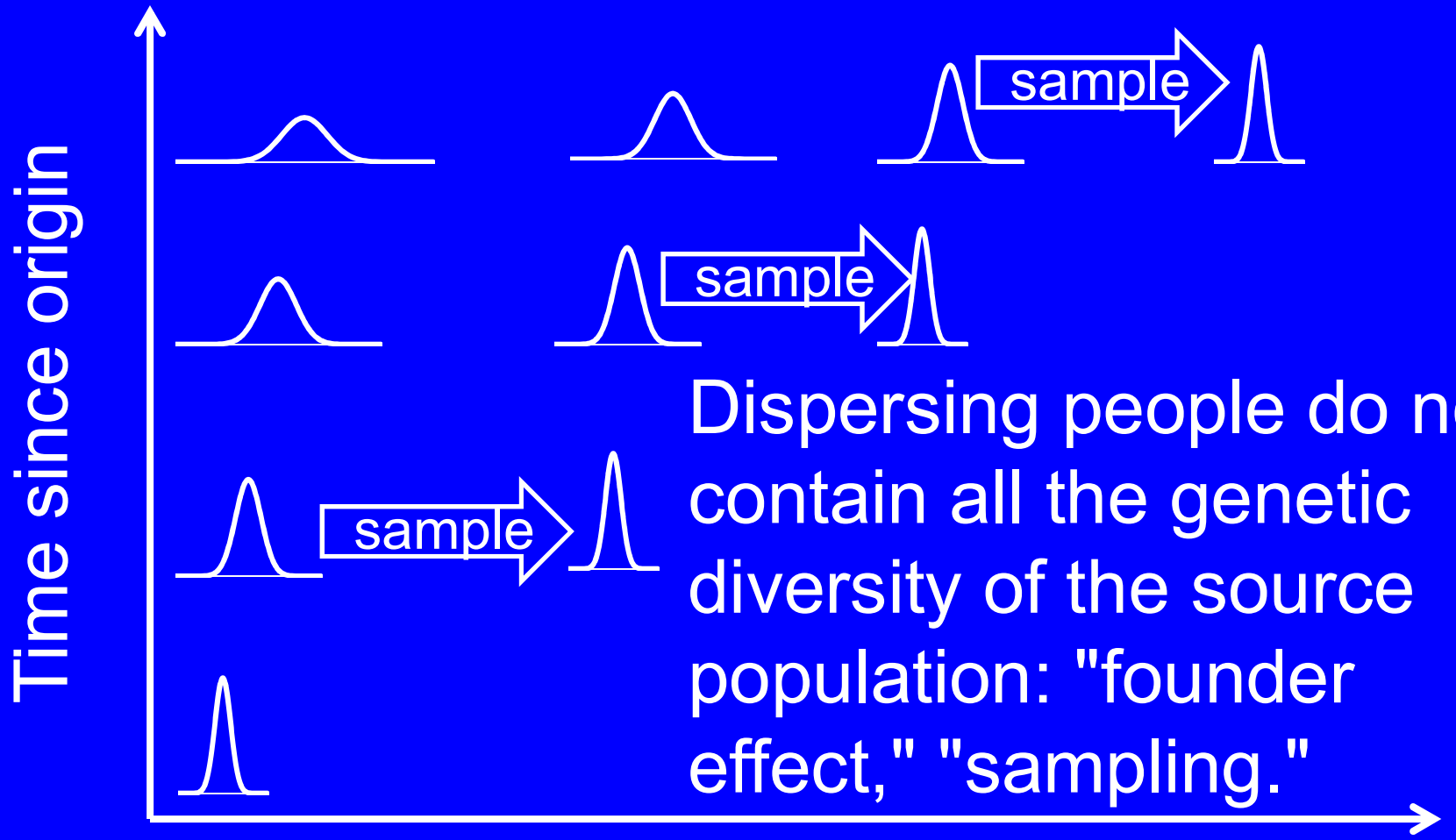
Greater average & greater spread of the number of genetic differences between 2 randomly chosen individuals indicates greater genetic diversity & longer time since the origin of the population.



Among present indigenous peoples, the greater the genetic diversity, the older the lineage.

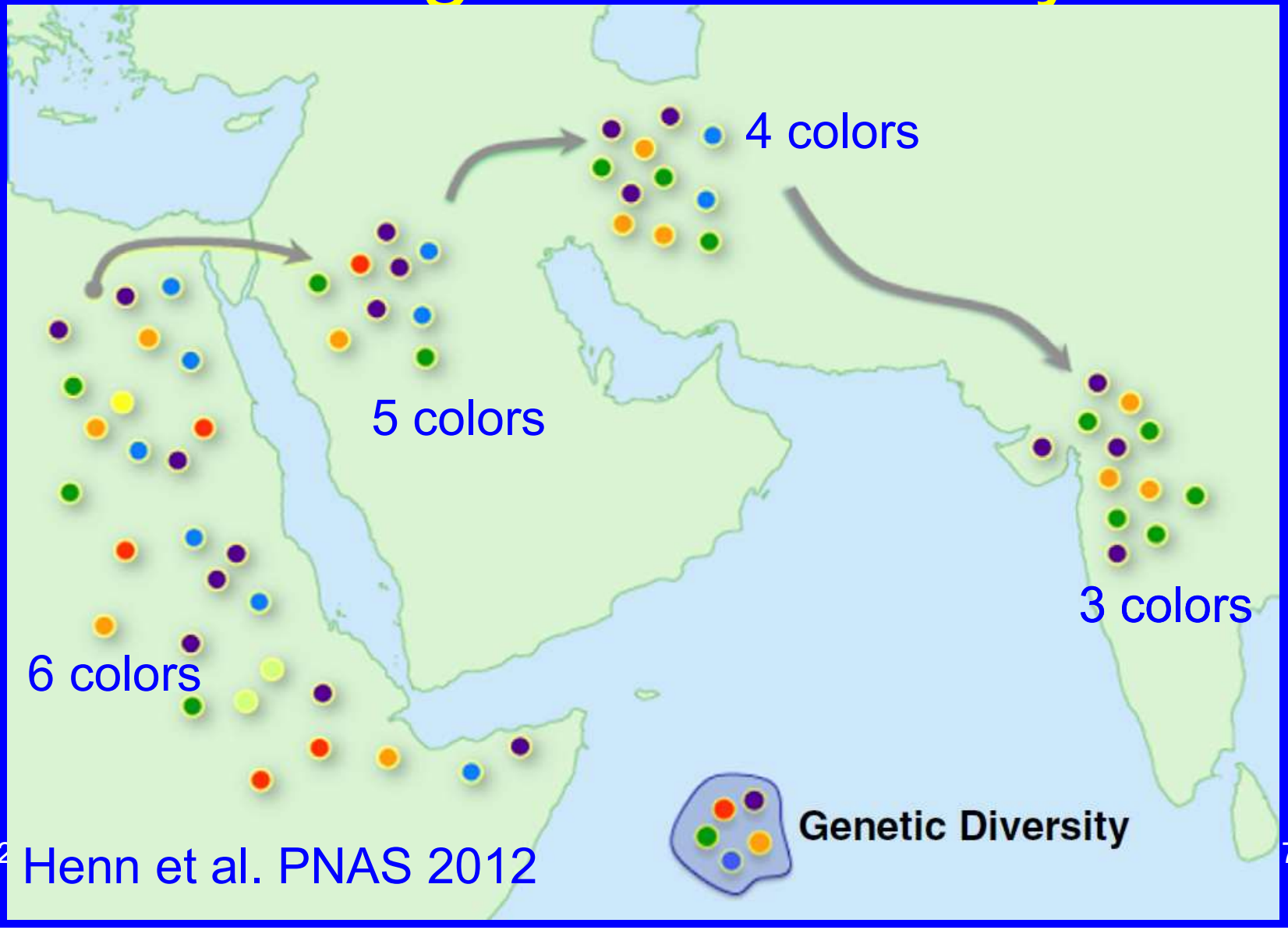


Time, distance, genetic diversity



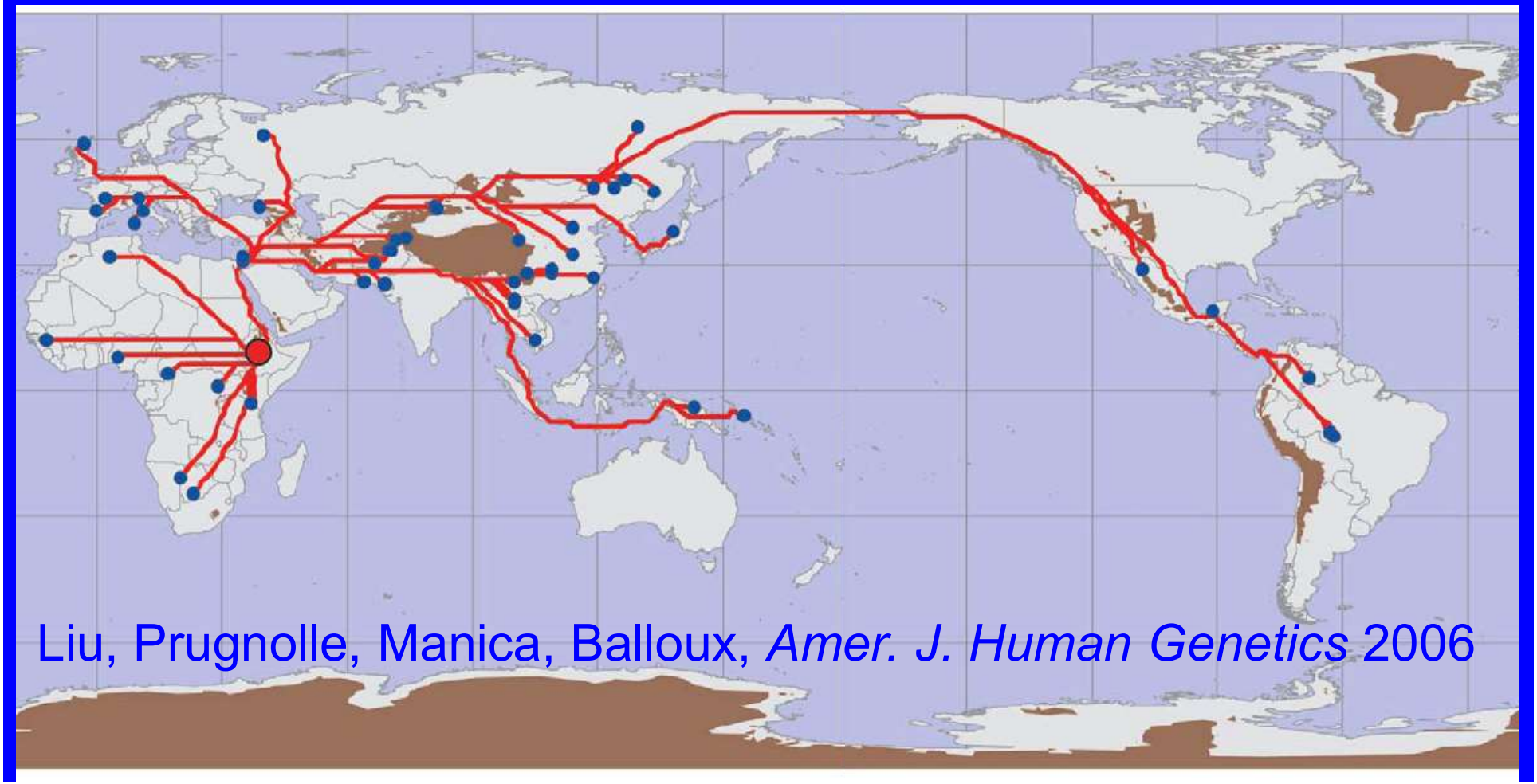
Dispersing people do not contain all the genetic diversity of the source population: "founder effect," "sampling."

Serial founder effect reduces distal genetic diversity.

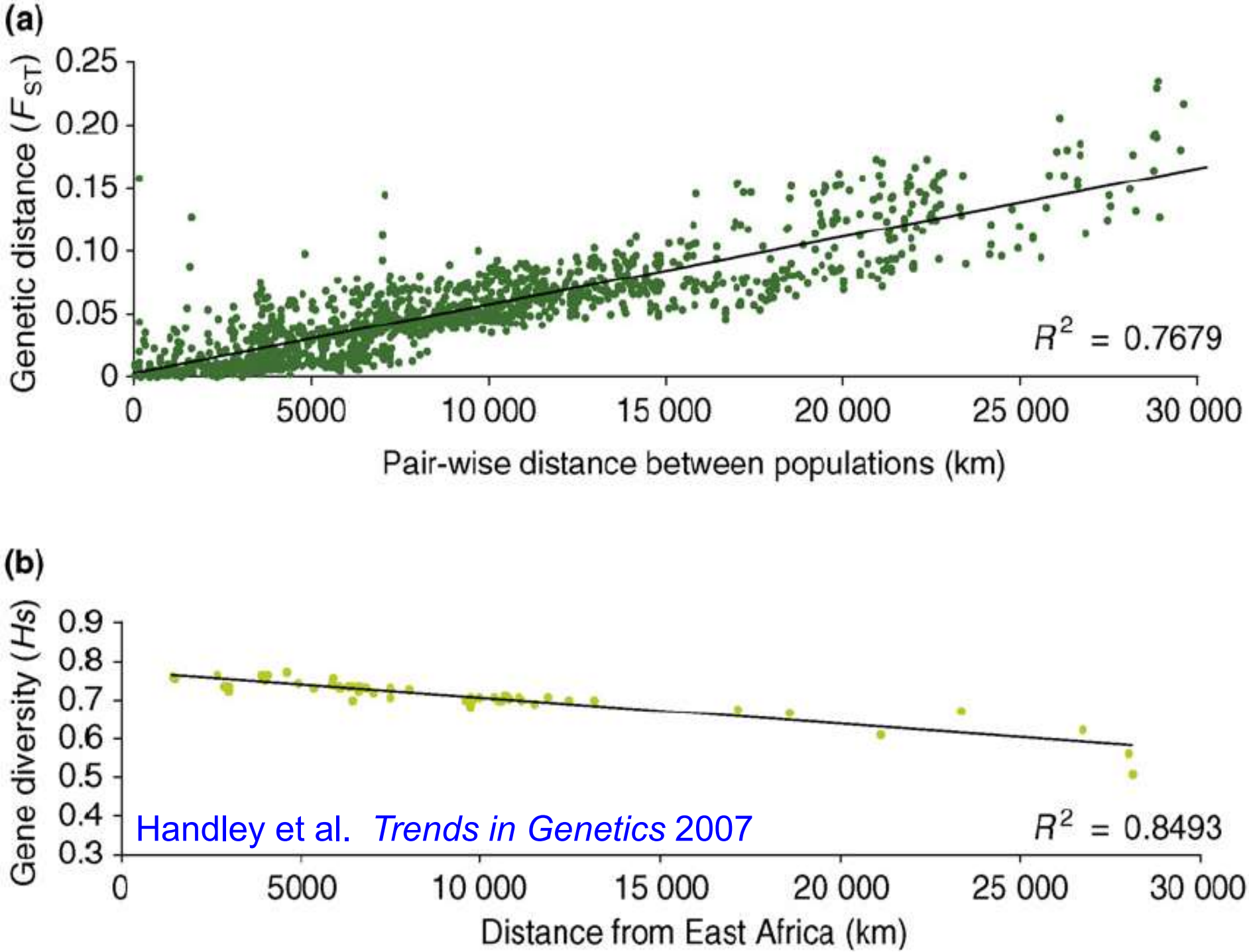


Henn et al. PNAS 2012

From 54 globally distributed populations, DNA samples from 1064 lymphoblastoid cell lines of individuals, collected by Human Genome Diversity Project at Centre d'Étude du Polymorphisme Humain

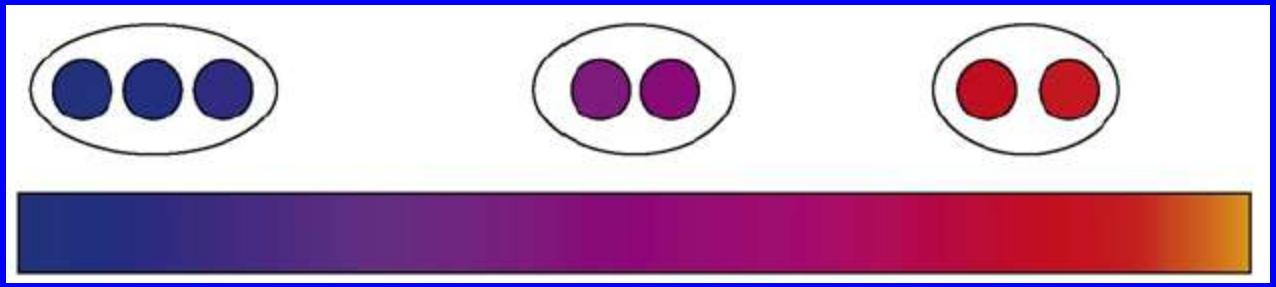


Liu, Prugnolle, Manica, Balloux, *Amer. J. Human Genetics* 2006


(a)
Genetic distance (F_{ST})
0.25
0.20
0.15
0.10
0.05
0
0
5000
10 000
15 000
20 000
25 000
30 000
Pair-wise distance between populations (km)
R^2 = 0.7679
(b)
Gene diversity (Hs)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Handley et al. *Trends in Genetics* 2007
R^2 = 0.8493
Distance from East Africa (km)

“Heterogeneous sampling can reveal genetic clusters that are biologically meaningless.”

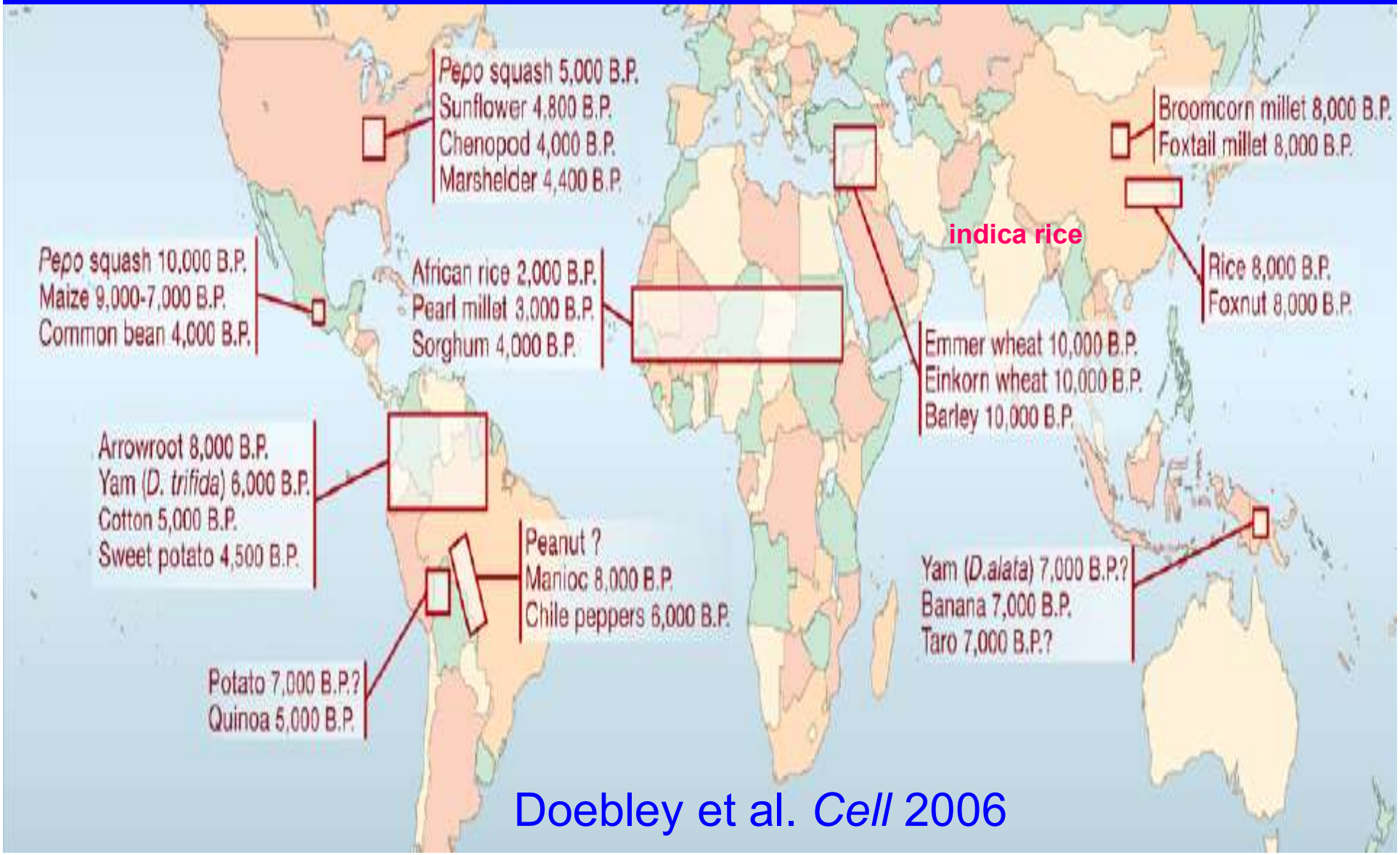
Handley et al. *Trends in Genetics* 2007



Holocene history

11,700 years before present (11.7ka) to now

Many peoples domesticated plants.



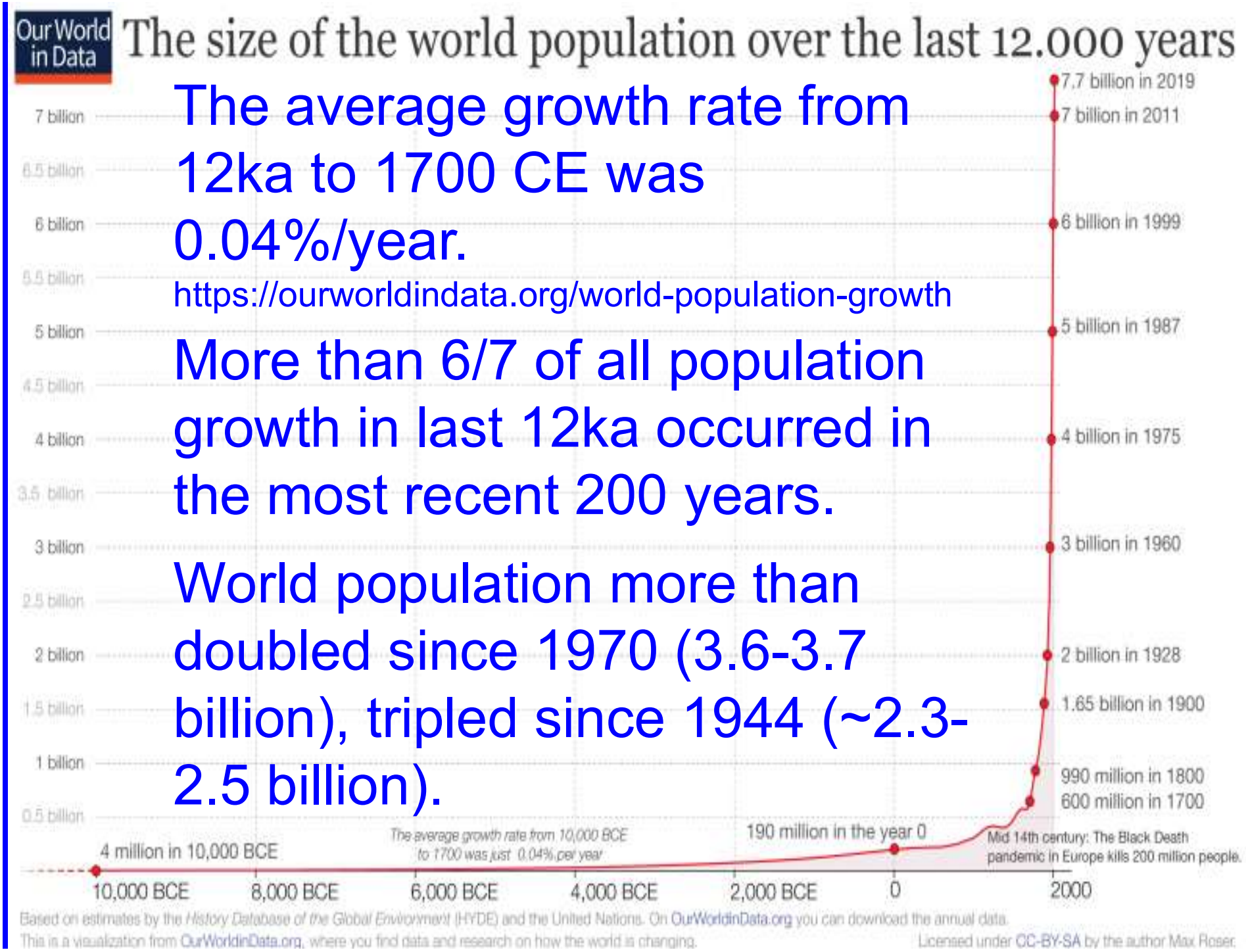
Doebley et al. *Cell* 2006

4 changes in population growth

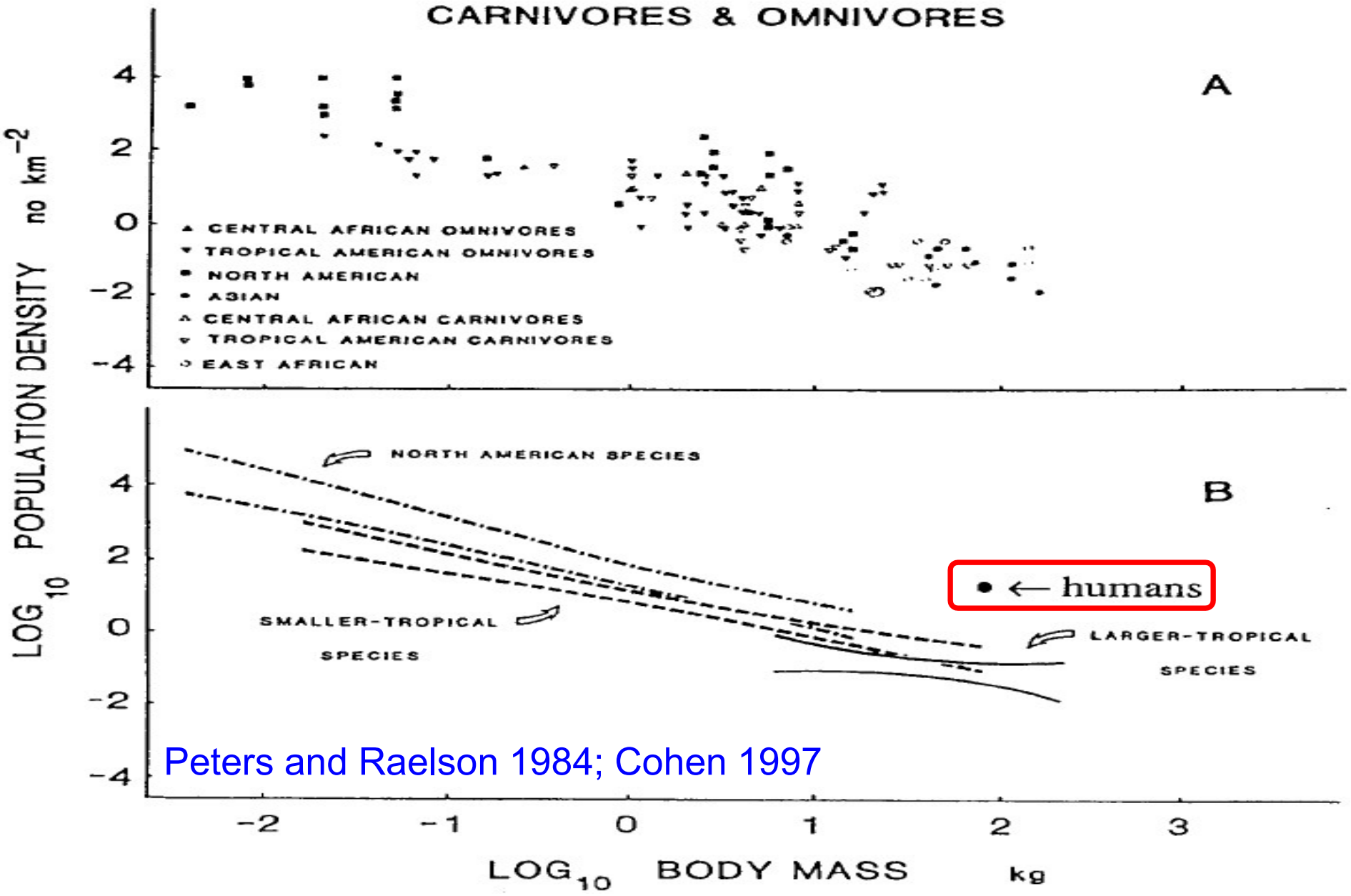
			doubling time (years)	
invention	dates	people	before	after
local agriculture	10,000-6,000 B.C.	1-10 million	35,000-350,000	1,400-3,000
independent inventions of agriculture in Middle East, Asia, Africa, America				
global agriculture	1750	750 million	750-1,800	100-130
exchange of plants, animals, people between Old World and New World				
public health	1950	2.5 billion	87	36
massive reductions in death rates, esp. among children in poor countries				
fertility control	1970	3.7 billion	34	50
decline in fertility rates				

Milestones of population growth

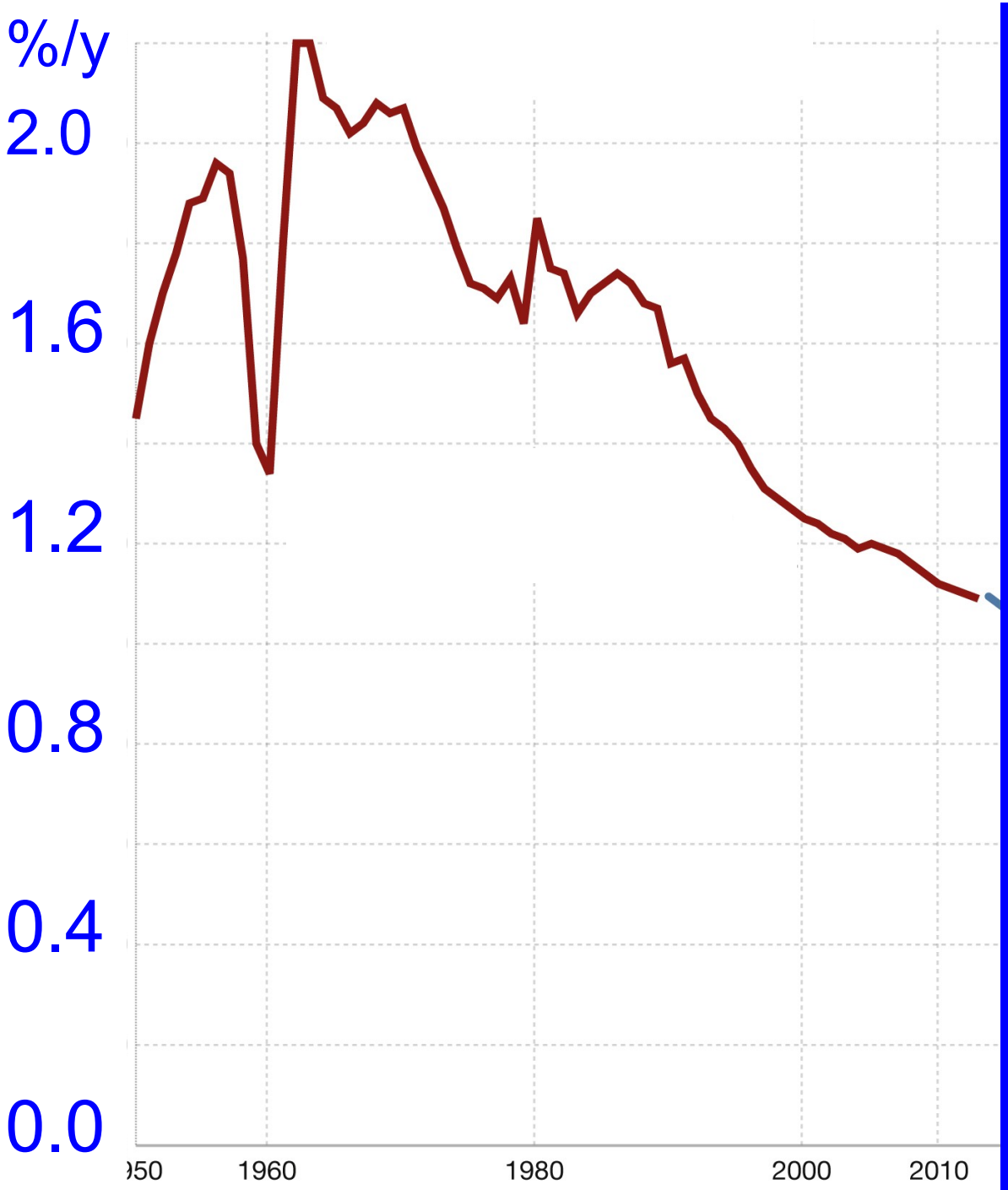
people	year	years to add latest billion
1-10 million	-10,000	
100-300 million	0	
420-500 million	1500	
1 billion	1800-20	>120,000
2	1927-30	110-130
3	1959-60	30
4	1974-75	14
5	1987	13
6	1999	12
7	2011-12	12-13


Our World in Data
The size of the world population over the last 12.000 years
The average growth rate from 12ka to 1700 CE was 0.04%/year.
https://ourworldindata.org/world-population-growth
More than 6/7 of all population growth in last 12ka occurred in the most recent 200 years.
World population more than doubled since 1970 (3.6-3.7 billion), tripled since 1944 (~2.3-2.5 billion).
7.7 billion in 2019
7 billion in 2011
6 billion in 1999
5 billion in 1987
4 billion in 1975
3 billion in 1960
2 billion in 1928
1.65 billion in 1900
990 million in 1800
600 million in 1700
190 million in the year 0
4 million in 10,000 BCE
The average growth rate from 10,000 BCE to 1700 was just 0.04% per year
Mid 14th century: The Black Death pandemic in Europe kills 200 million people.
7 billion
6.5 billion
6 billion
5.5 billion
5 billion
4.5 billion
4 billion
3.5 billion
3 billion
2.5 billion
2 billion
1.5 billion
1 billion
0.5 billion
10,000 BCE
8,000 BCE
6,000 BCE
4,000 BCE
2,000 BCE
0
2000
Based on estimates by the History Database of the Global Environment (HYDE) and the United Nations. On OurWorldinData.org you can download the annual data.
This is a visualization from OurWorldinData.org, where you find data and research on how the world is changing.
Licensed under CC-BY-SA by the author Max Roser.

Humans are numerous for their size.



Peters and Raelson 1984; Cohen 1997

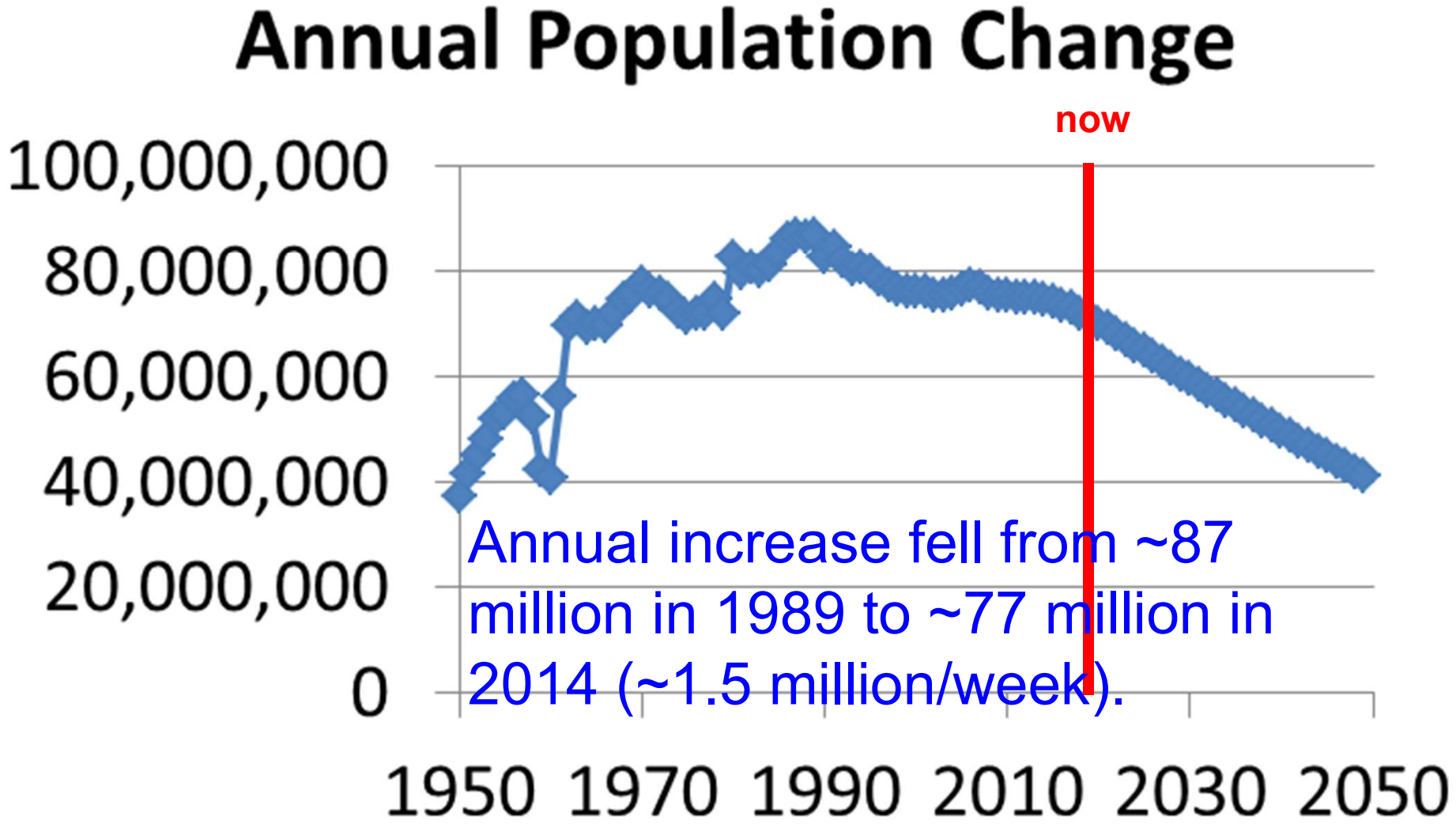


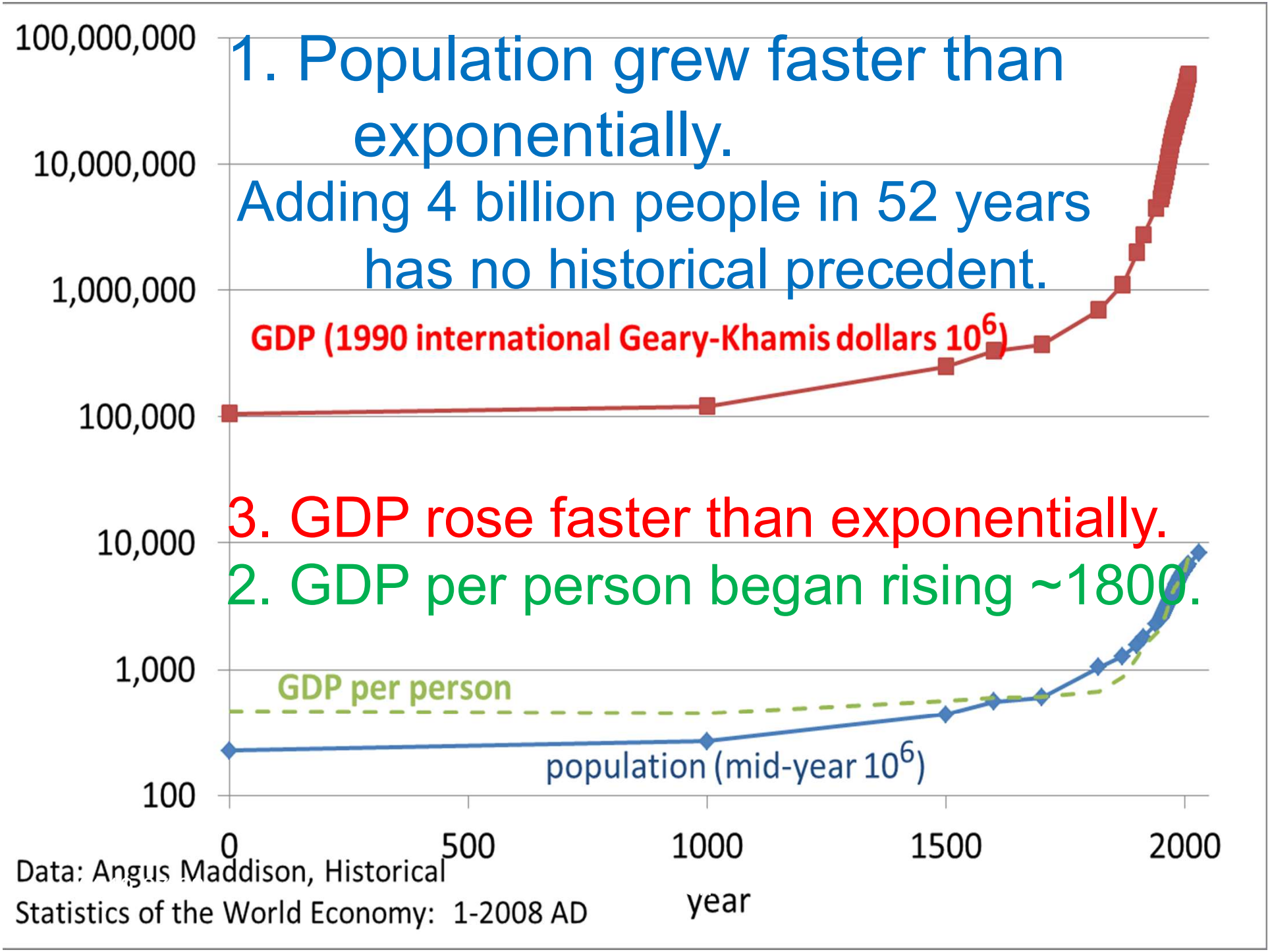
Global population growth rate peaked at 2.2%/y 1962-1963, fell to 1.1%/y in 2018-2019.

https://ourworldindata.org/world-population-growth

Global population annual additions peaked around 1990.

U.S. Census Bureau International Division 2014




1. Population grew faster than exponentially.
Adding 4 billion people in 52 years has no historical precedent.
GDP (1990 international Geary-Khamis dollars 10^6)
3. GDP rose faster than exponentially.
2. GDP per person began rising ~1800.
GDP per person
population (mid-year 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
0
500
1000
1500
2000
year
Data: Angus Maddison, Historical Statistics of the World Economy: 1-2008 AD

World economy grew ~18 fold in 20th century, faster than population.

	1900	1950	2000
GDP per person	$1,261	$2,111	$6,037

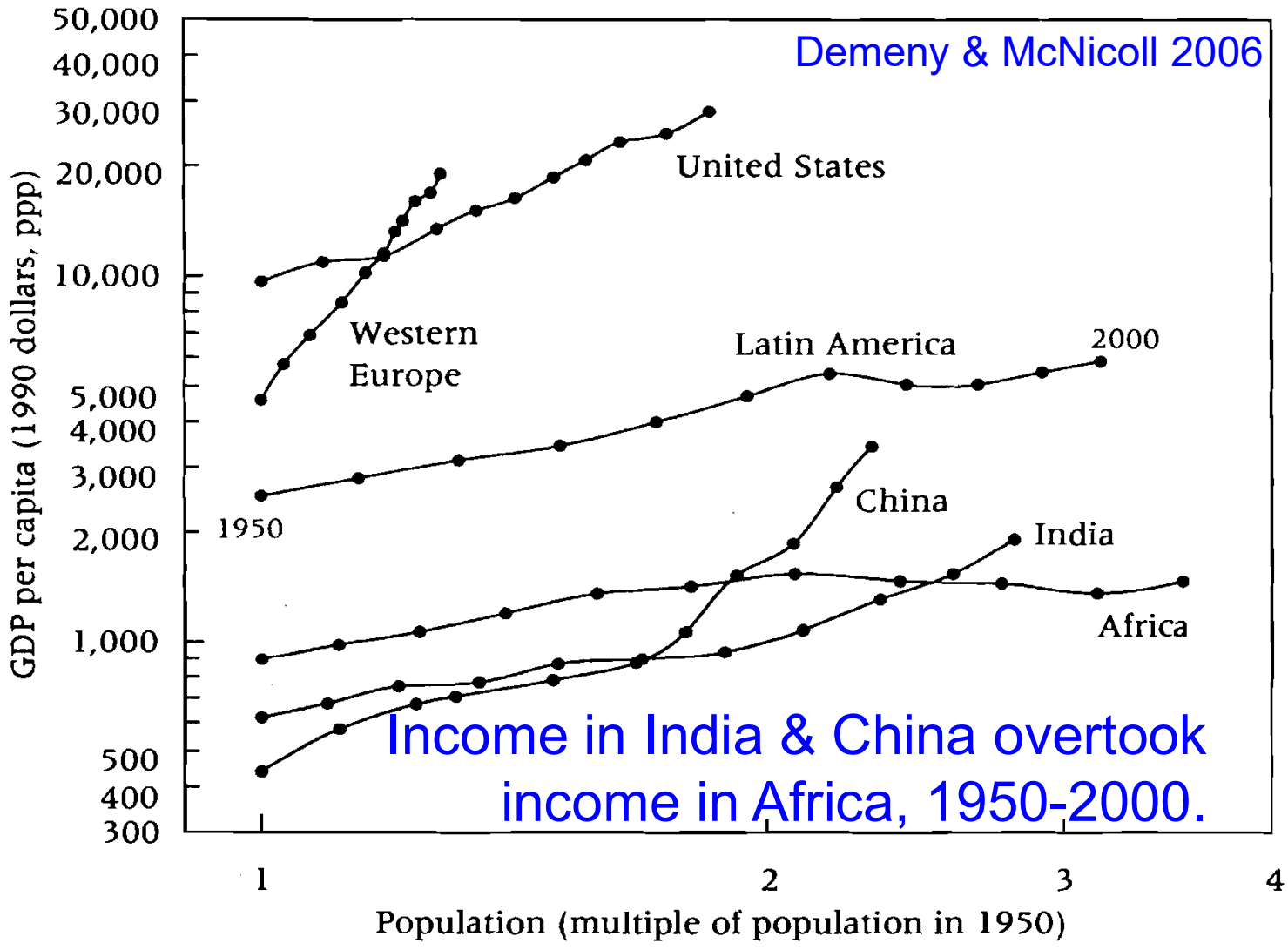
1990 international Geary Khamis dollars

World GDP	$2 trillion	$5 trillion	$37 trillion
People (billions)	1.6	2.5	6.1

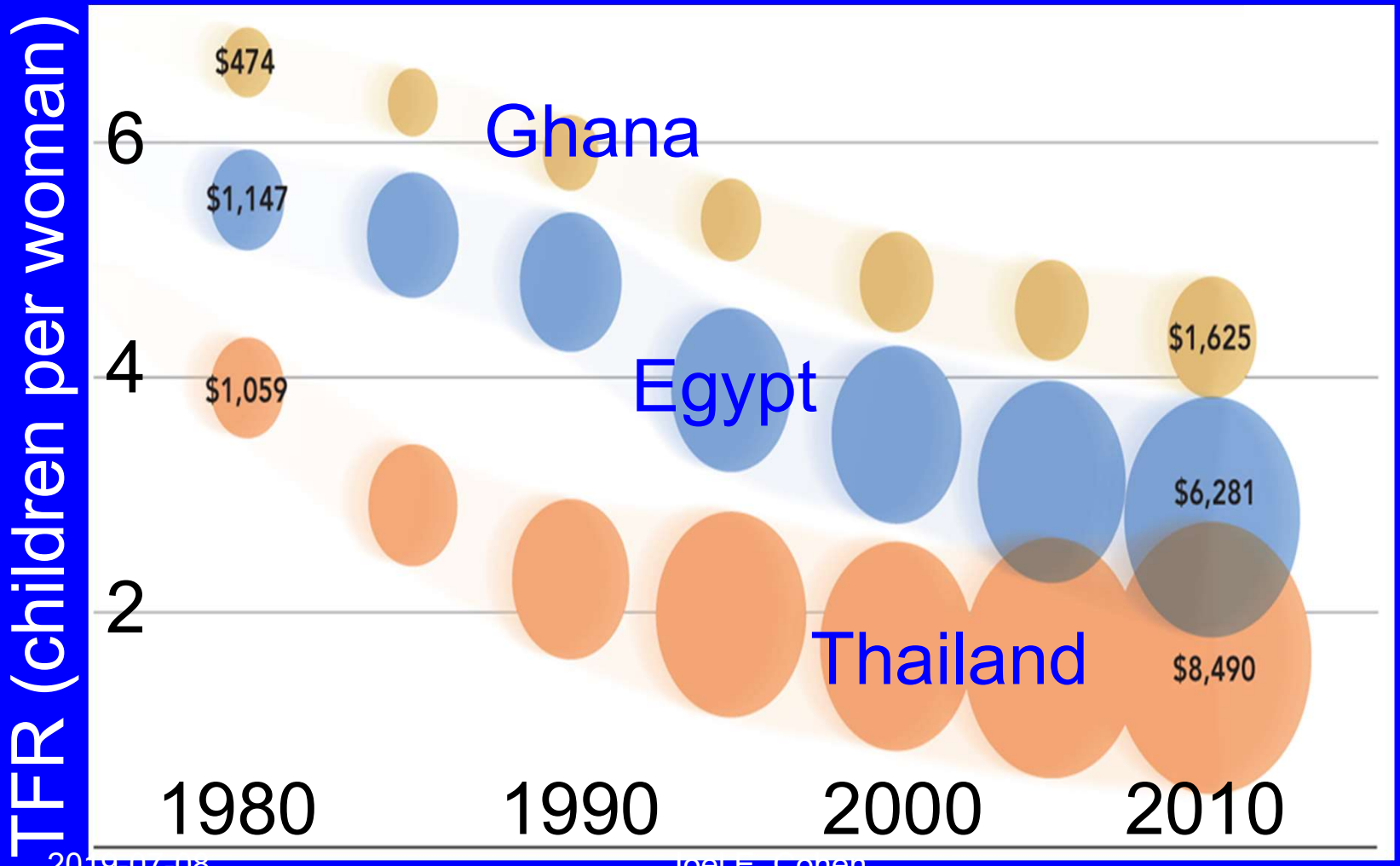
Source: Angus Maddison, Historical Statistics of the World Economy, 1-2008 AD.

Rapid population growth did not lead to rapid economic growth. On the contrary!

The faster population grew, the slower income grew, 1950-2000.

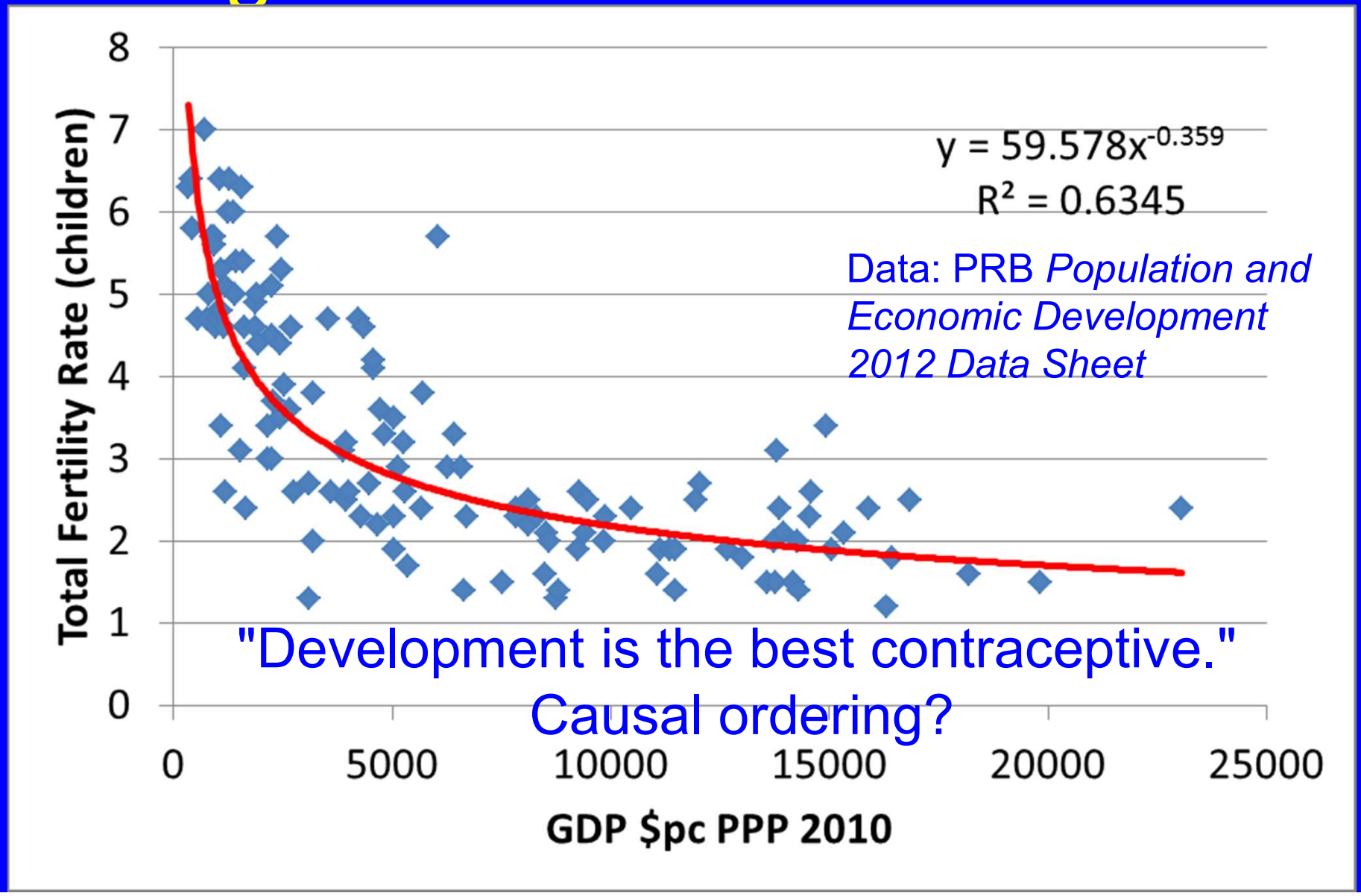


GDP per capita rose faster with lower total fertility rates.

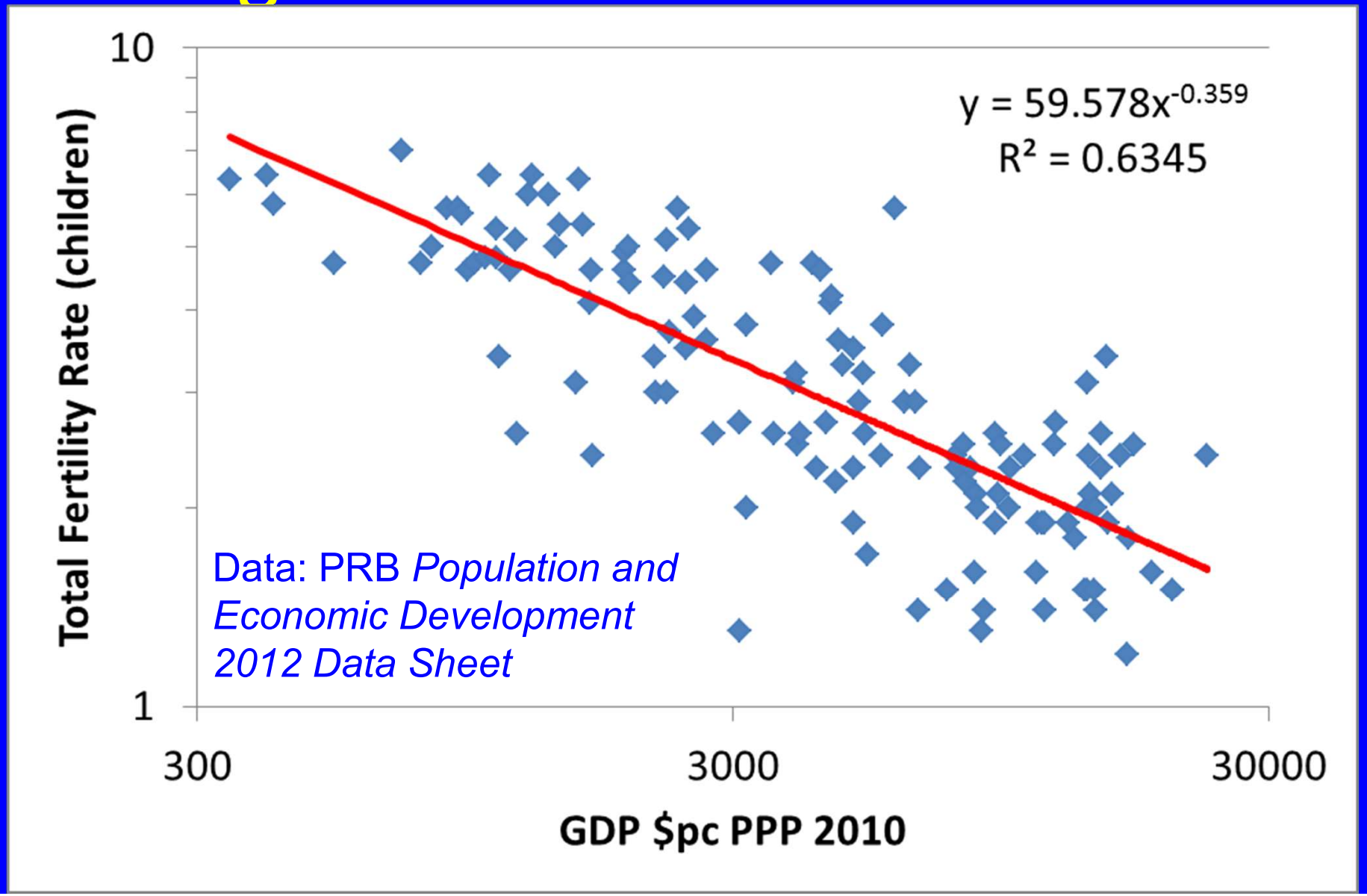


SOURCES: United Nations Population Division, World Population Prospects: The 2010 Revision (2011); and World Bank, World Development Indicators Database. Population Reference Bureau

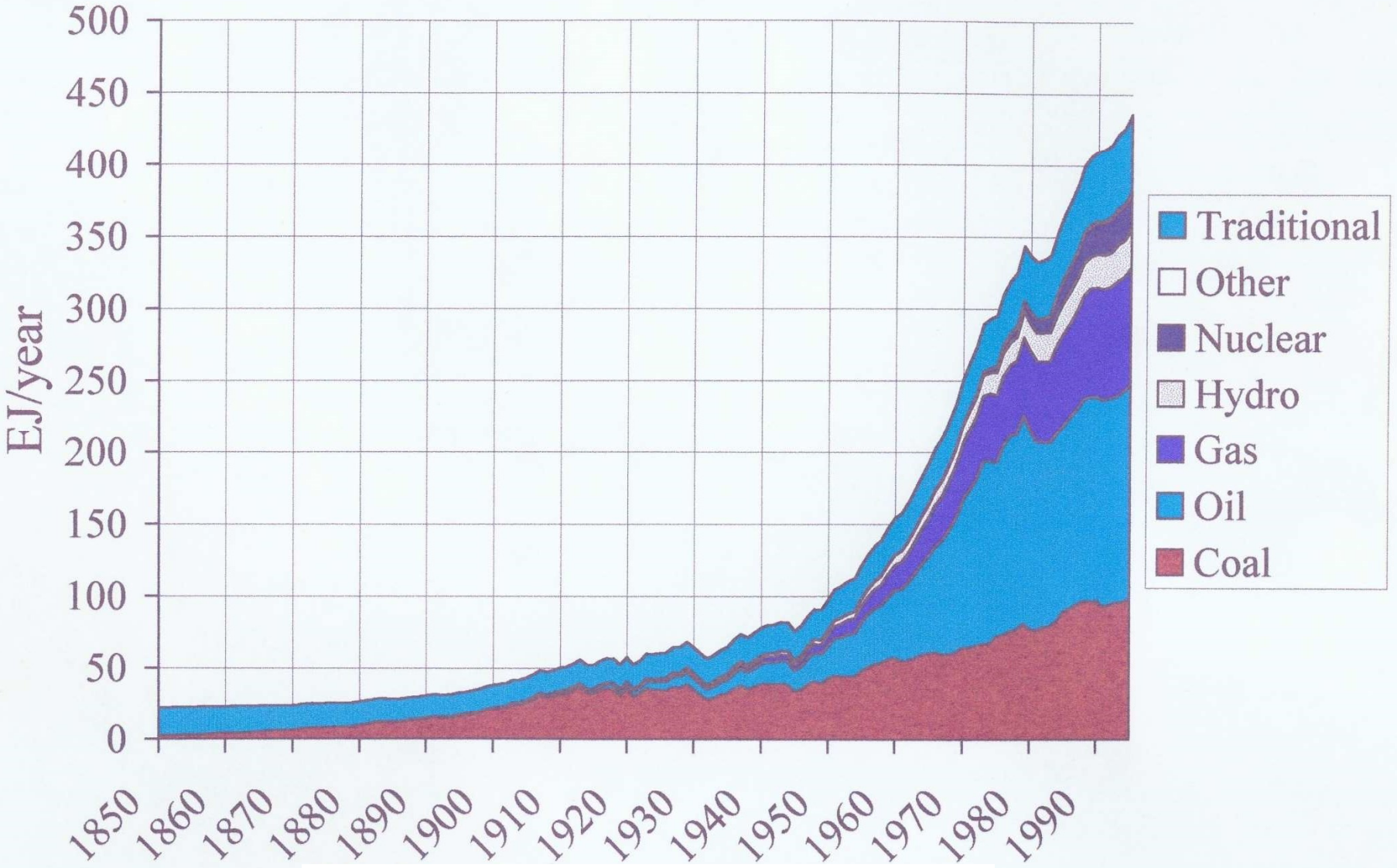
In cross-section, 10x income ↑ goes with 0.44x TFR ↓.



In cross-section, 10x income ↑ goes with 0.44x TFR ↓.



World primary energy production

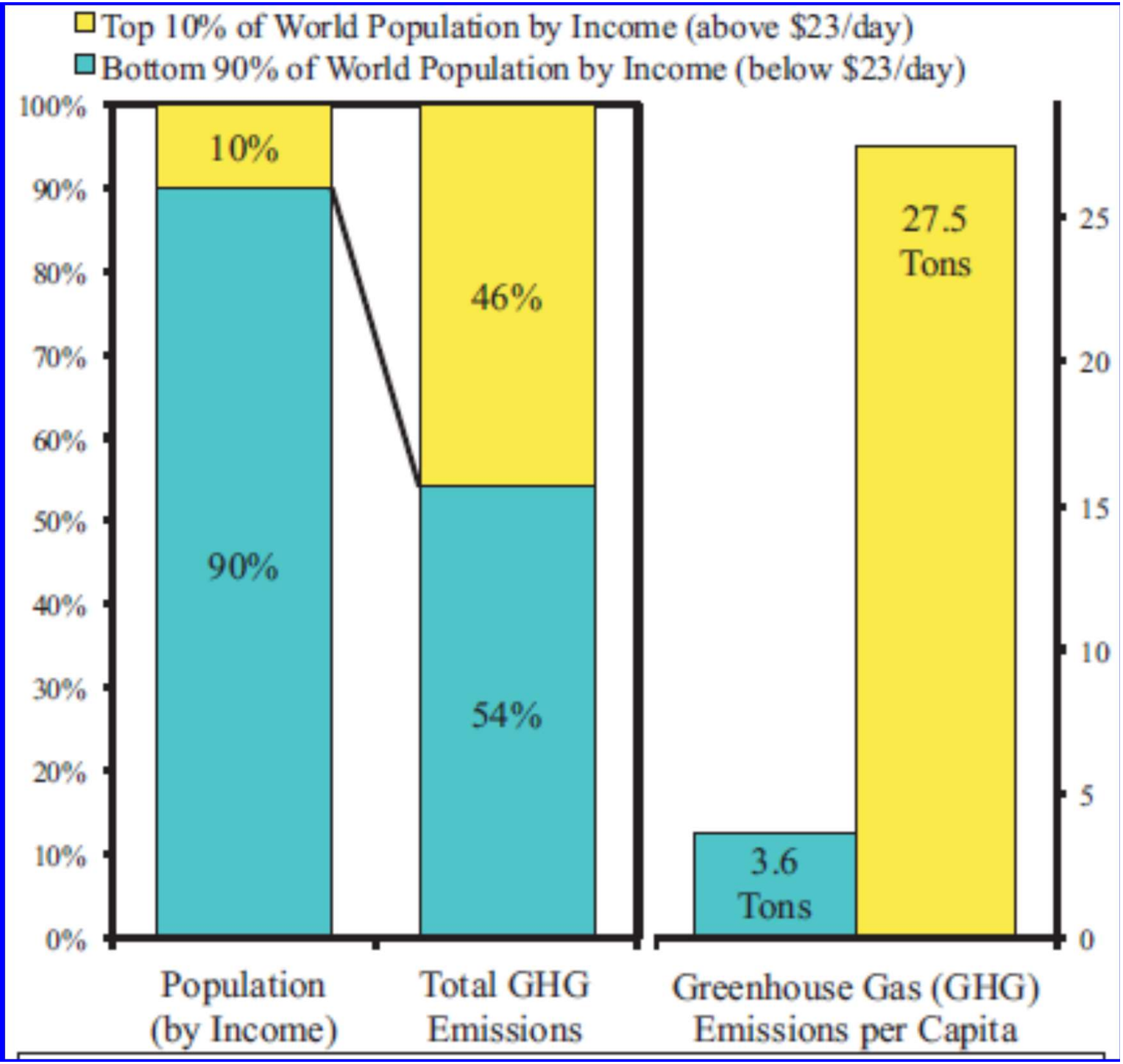


Human impacts on biogeochemistry grew faster than population.

	1900	2000	ratio
Carbon emitted to atmosphere by humans (billion tons per year)	0.5	7.3	15
Water withdrawals (thousand cubic kilometers per year)	0.5	4	8
Nitrogen in NO_x from fossil fuels (million tons per year)	1.25	25	20
People (billions)	1.6	6.1	<4

Motesharrei et al. Modeling sustainability: population, inequality, consumption, and bidirectional coupling of the Earth and Human Systems

Natl Sci Rev. 2016; 3(4): 470-494. doi:10.1093/nsr/nww081



How many people were ever born?

Year	People (10^9) born by year	Source (Table from Cohen 2014)
1682	20.32	Petty 2004 (1682), Postscript
1760	120	Ezra Stiles, in Tattersall 1996:331
1959	3,390 – 5,260	Winkler 1959:75
1960	69	Keyfitz 1966:581
1960	110	Deevey 1960:197
1962	77 – 96	Desmond 1962, reprinted 1965:21
1992	79.6	Tattersall 1996:335
2002	106	Haub 2002

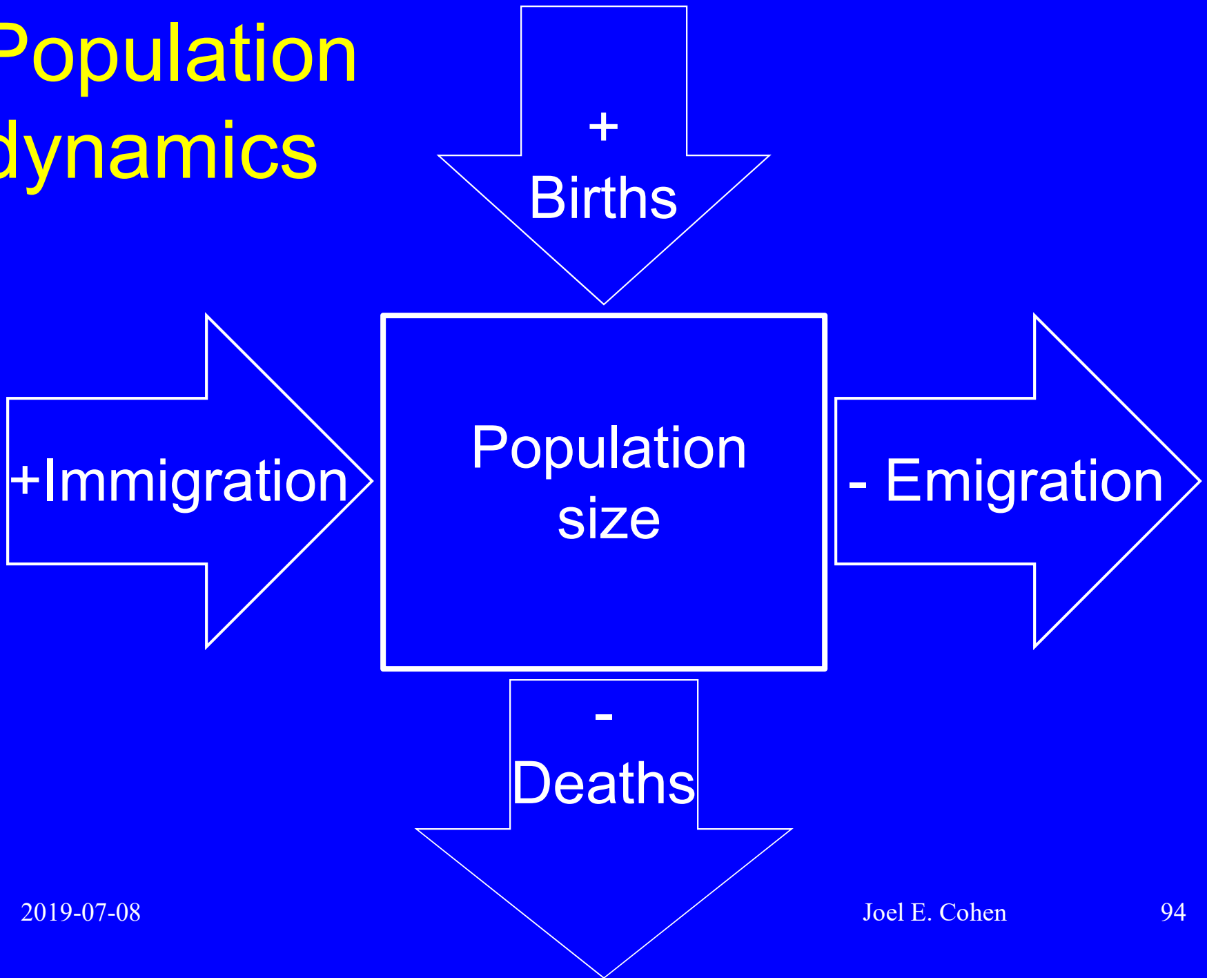
Changes in population size have 3 sources:

Fertility (recruitment, childbearing)

Mortality (death)

Migration (immigration, emigration)

Population dynamics



Balance equation:
an open population changes size by births, deaths, & migration.

Change in population size /y

= + births /y – deaths /y

+ immigration /y – emigration /y

= natural increase /y

+ “net migration” /y.

Divide both sides by initial population size to get rates of change per person /y.

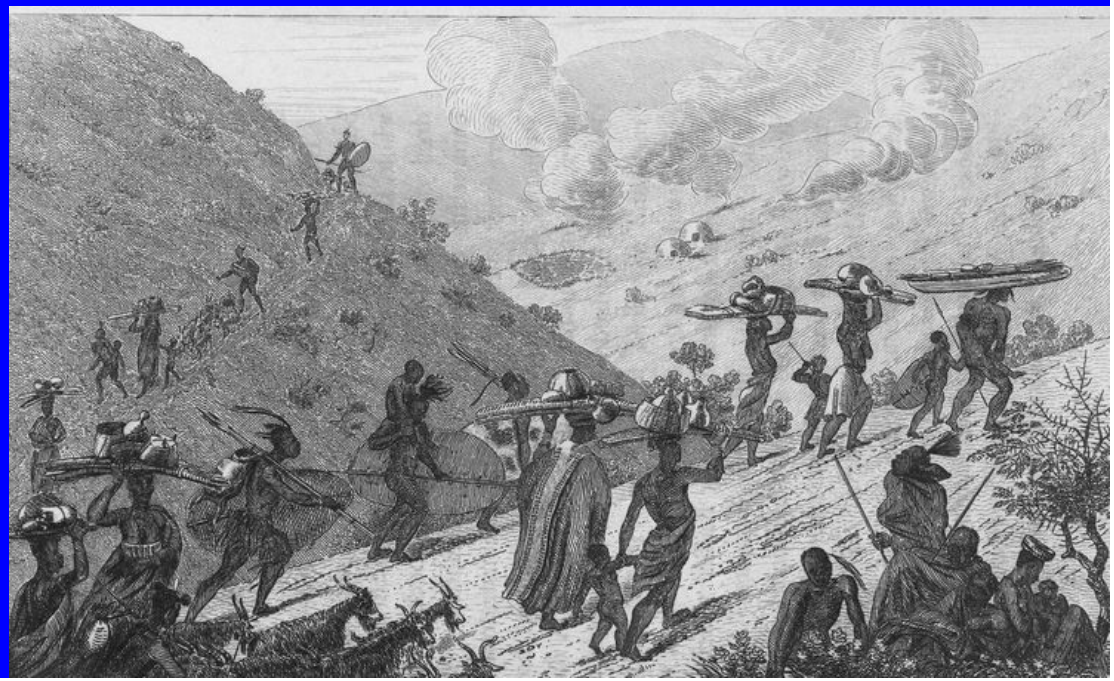
Two great migrations or expansions

Indo-European

Kurgan model: 4000BCE – 1000BCE

Anatolian model 7000BCE – 4000BCE

Bantu 2000BCE – 1000CE

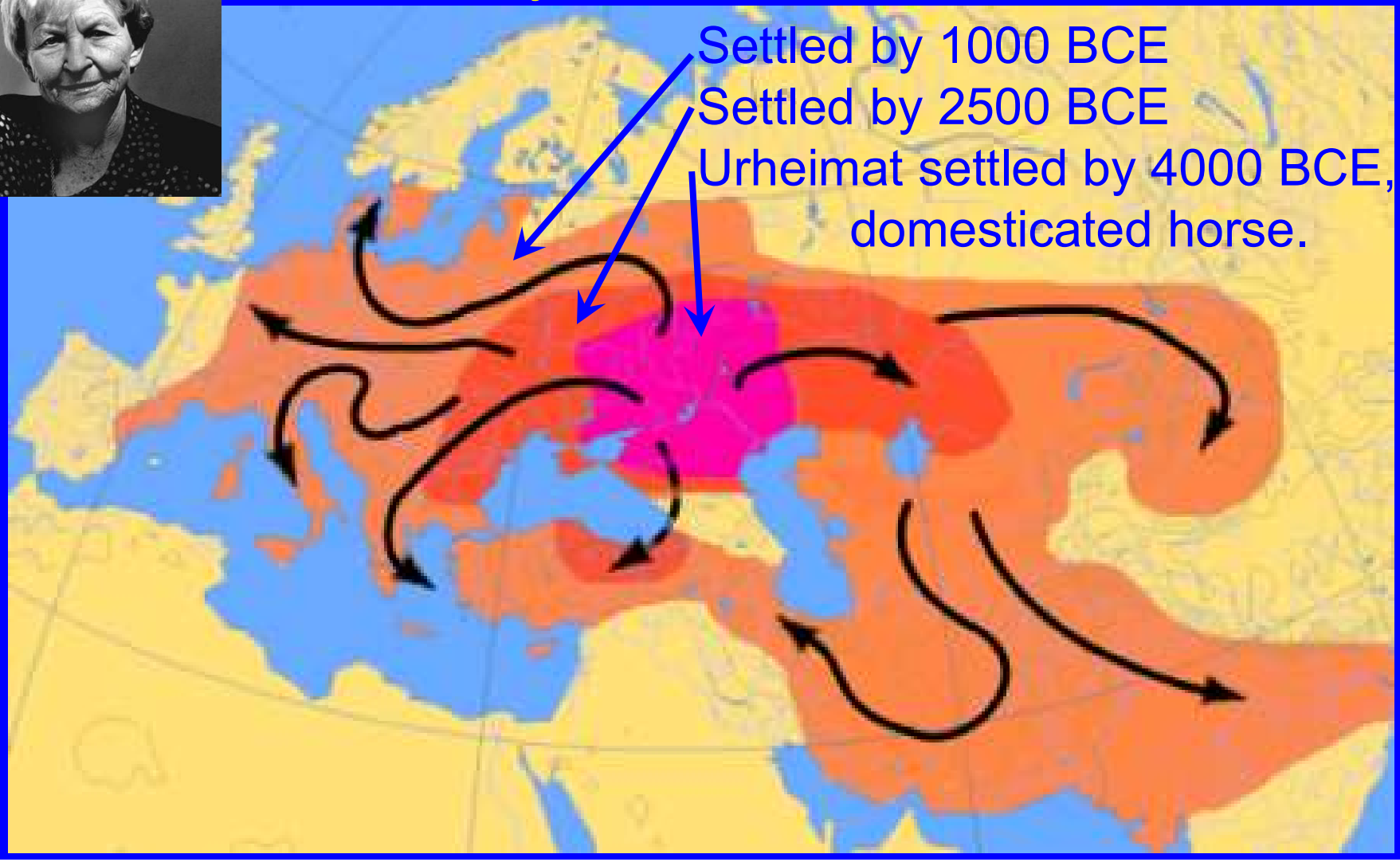


Mfecane 1815-1840 CE
Departure of the Fingoes 1840
New York Public Library
Digital Collections

2019-07-08

Indo-European migrations, 4000-1000 BCE, in the Kurgan model

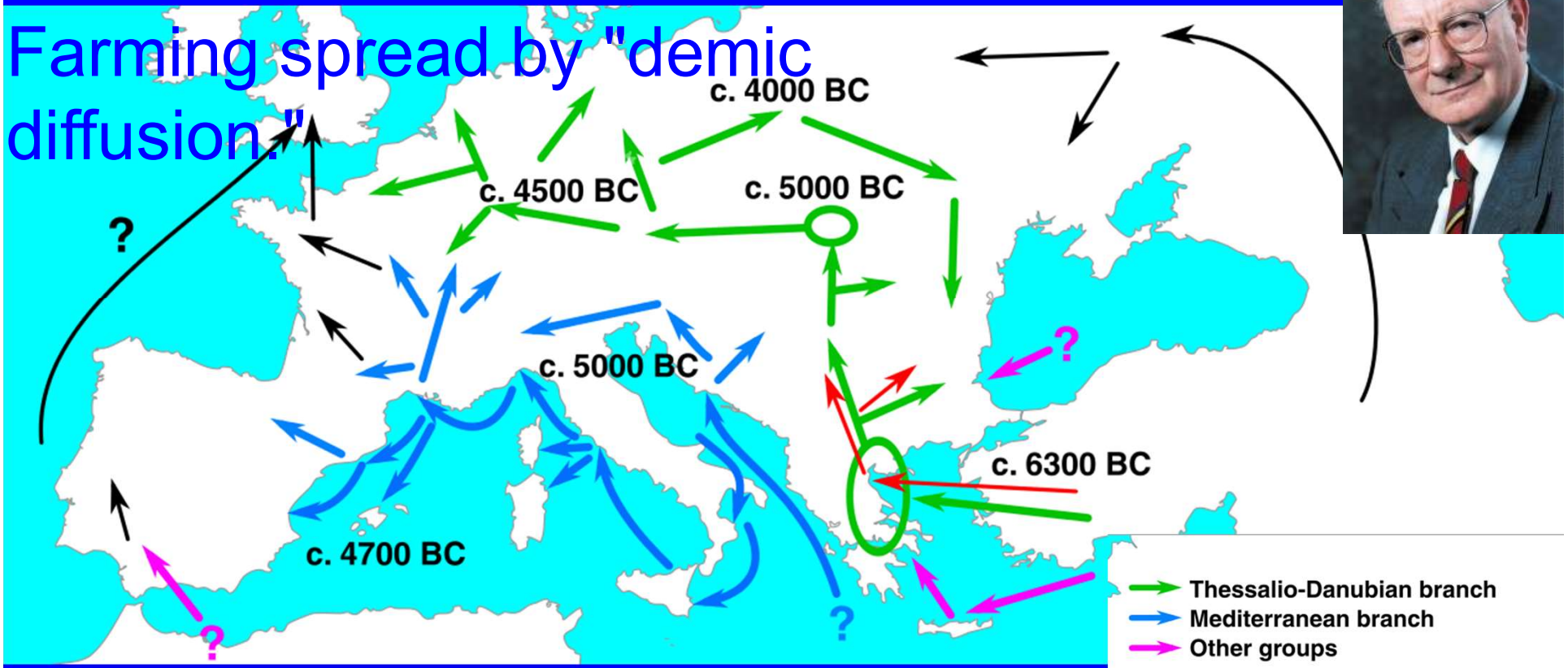
Marija Gimbutas, 1956



Indo-European migrations, 7000-4000 BCE, in the Anatolian model

Colin Renfrew, 1987-2004

Farming spread by "demic diffusion."



Bantu expansion: agriculture, ceramics, iron

1 = 2000–1500 BCE origin

2 = ~1500 BCE first migrations

2.a = Eastern Bantu

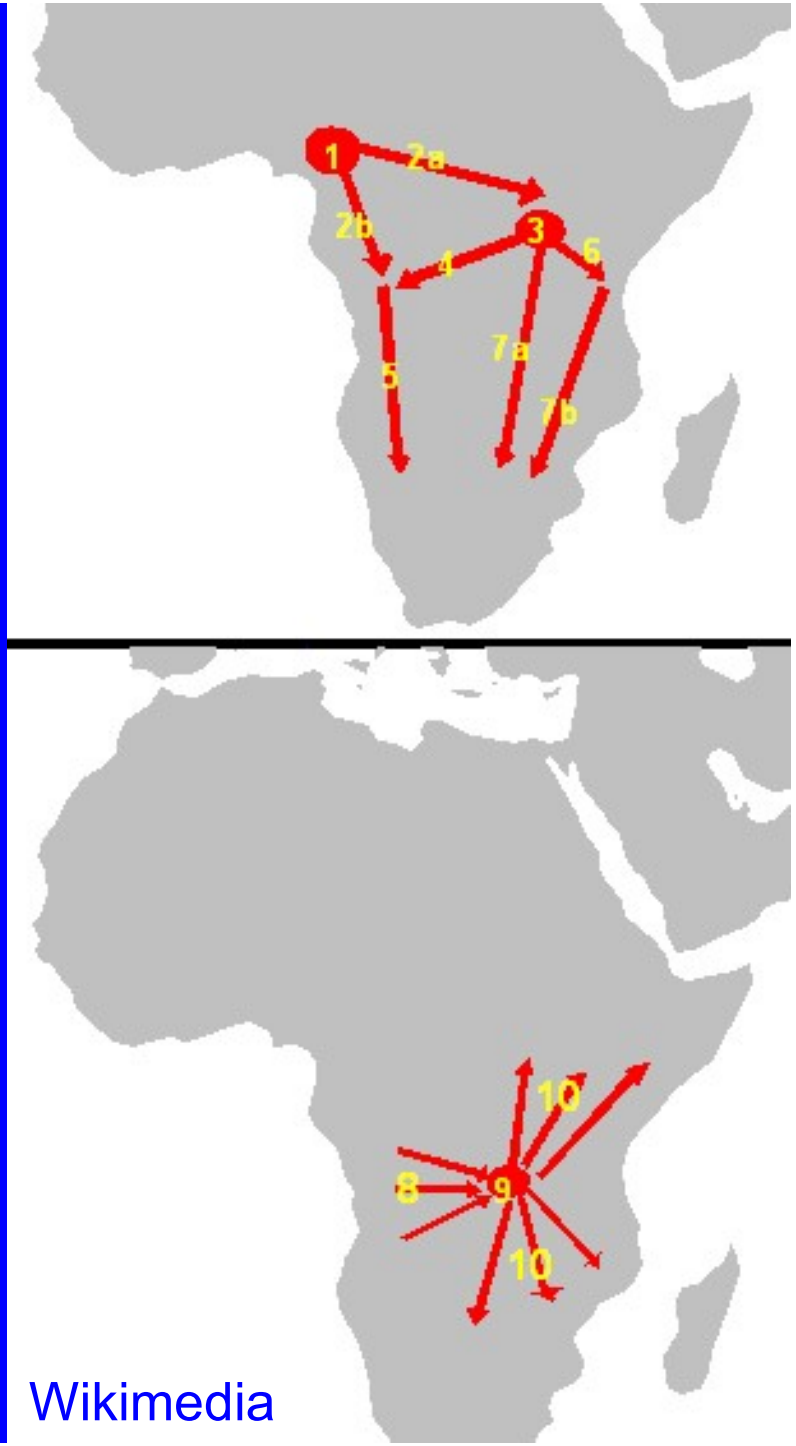
2.b = Western Bantu

3 = 1000–500 BCE Urewe nucleus of Eastern Bantu

4–7 = southward advance

9 = 500 BCE–0 Congo nucleus

10 = 0–1000 CE last phase



Wikimedia

More recent migrations

Vandals 5th century BCE – 5th cent. BC

Migration Period, *Völkerwanderung*
21CE – 700CE

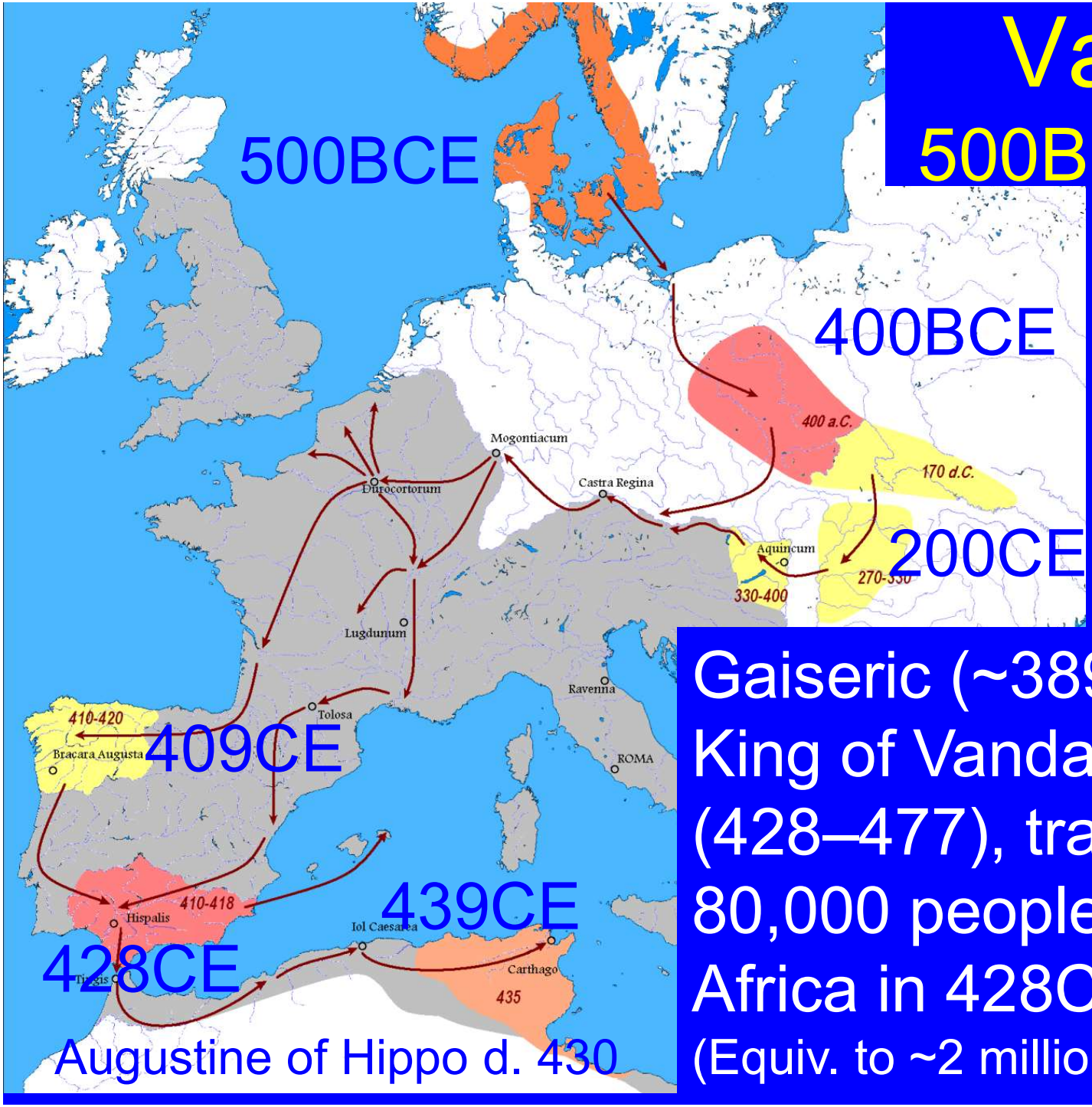
Trans-Atlantic slave trade

12.5 to 15-18 million deportations

European migration 1820 – 1924

> 60 million migrants

Vandals
500BCE-500CE



Augustine of Hippo d. 430

Gaiseric (~389-477CE), King of Vandals & Alans (428–477), transported his 80,000 people to north Africa in 428CE.

(Equiv. to ~2 million people today.)

European emigration

>60 million Europeans emigrated 1820-1914 to North & South America & Oceania.

P. Martin 2013

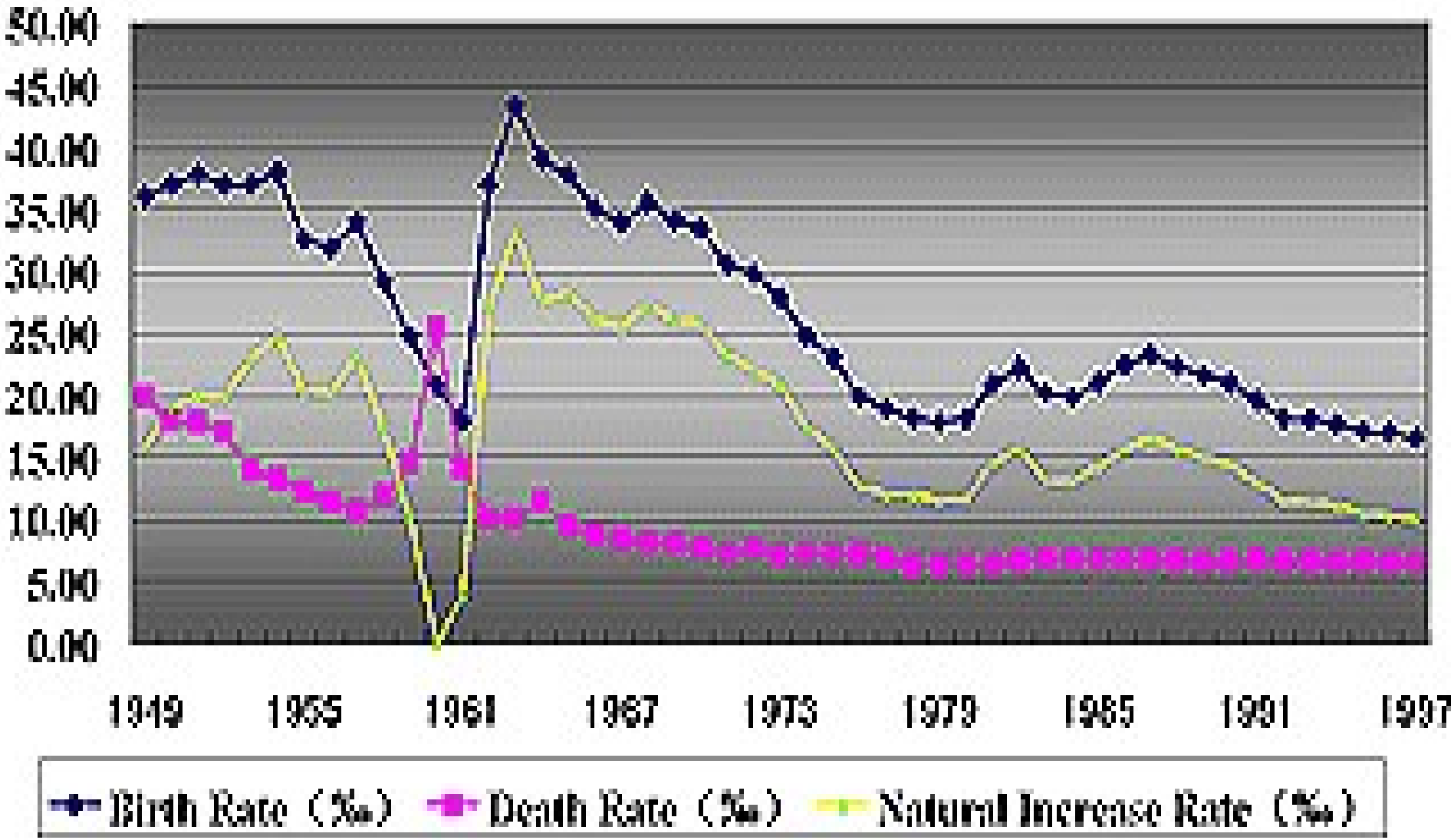
A closed population changes size by births & deaths.

Change per year in population size
= + births per year – deaths per year
= “natural increase” per year. [people/y]

Divide both sides by initial population size to get rates per person per year:

Population growth rate per person per year
= birth rate per person per year
- death rate per person per year
= rate of natural increase. [/y]

China's birth rate, death rate, & rate of natural increase per 1,000, 1949-1997



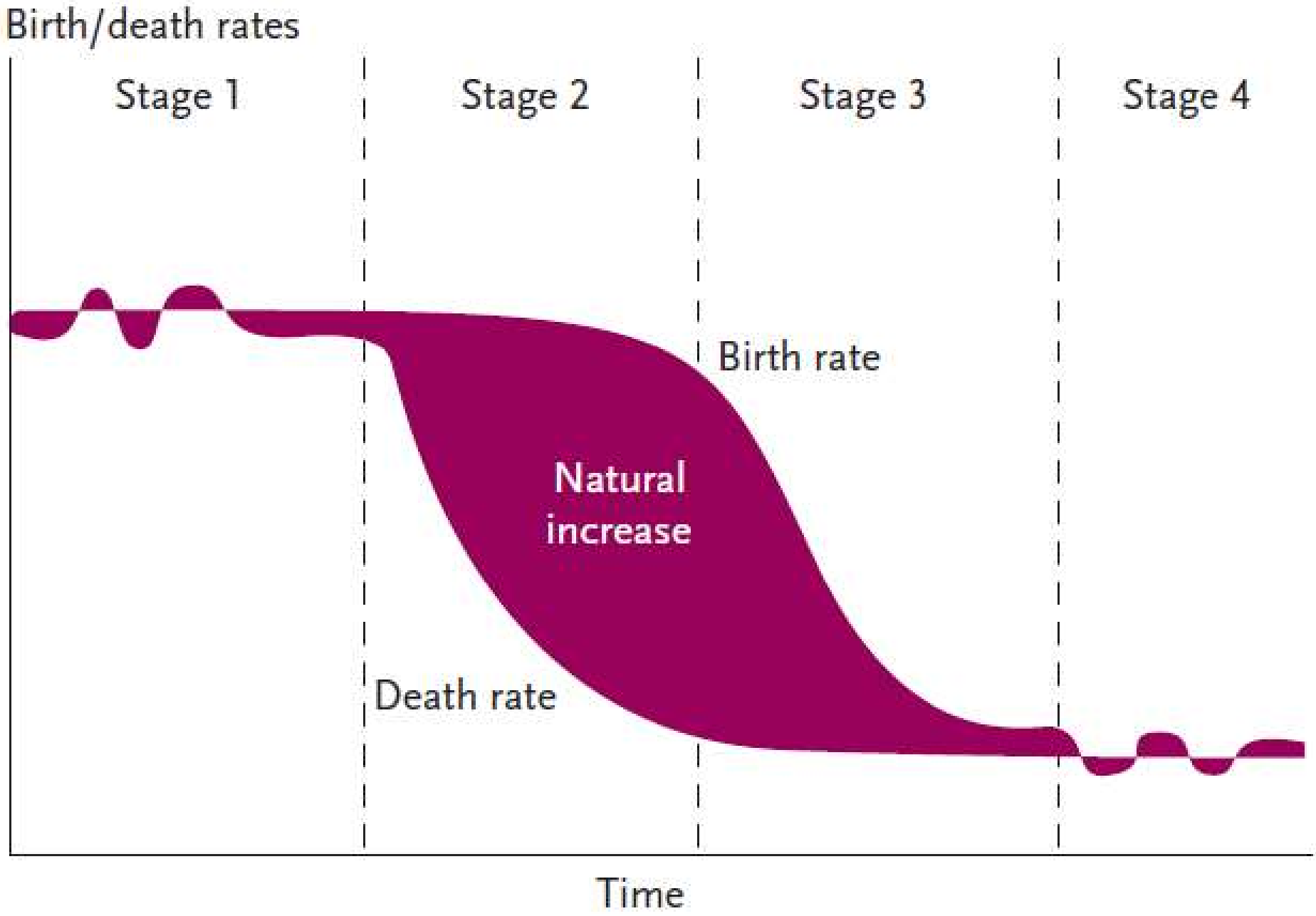
Demographic transition model

Initially, birth rates & death rates are high.

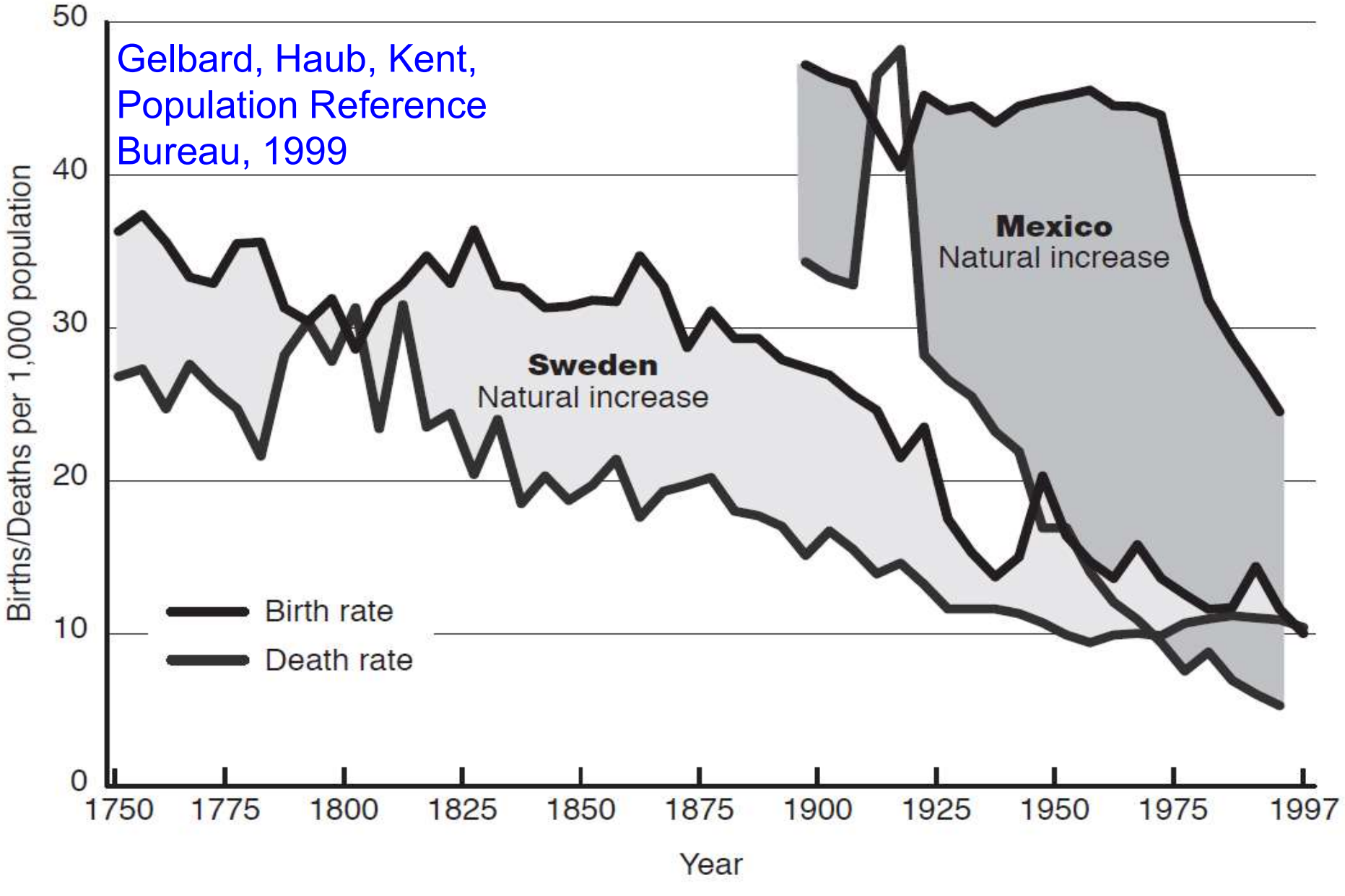
Death rates, especially child mortality rates, decline BEFORE fertility (child bearing) declines.

Historical examples: England, Germany, Sweden in 19th century; India & other developing countries in 20th century.

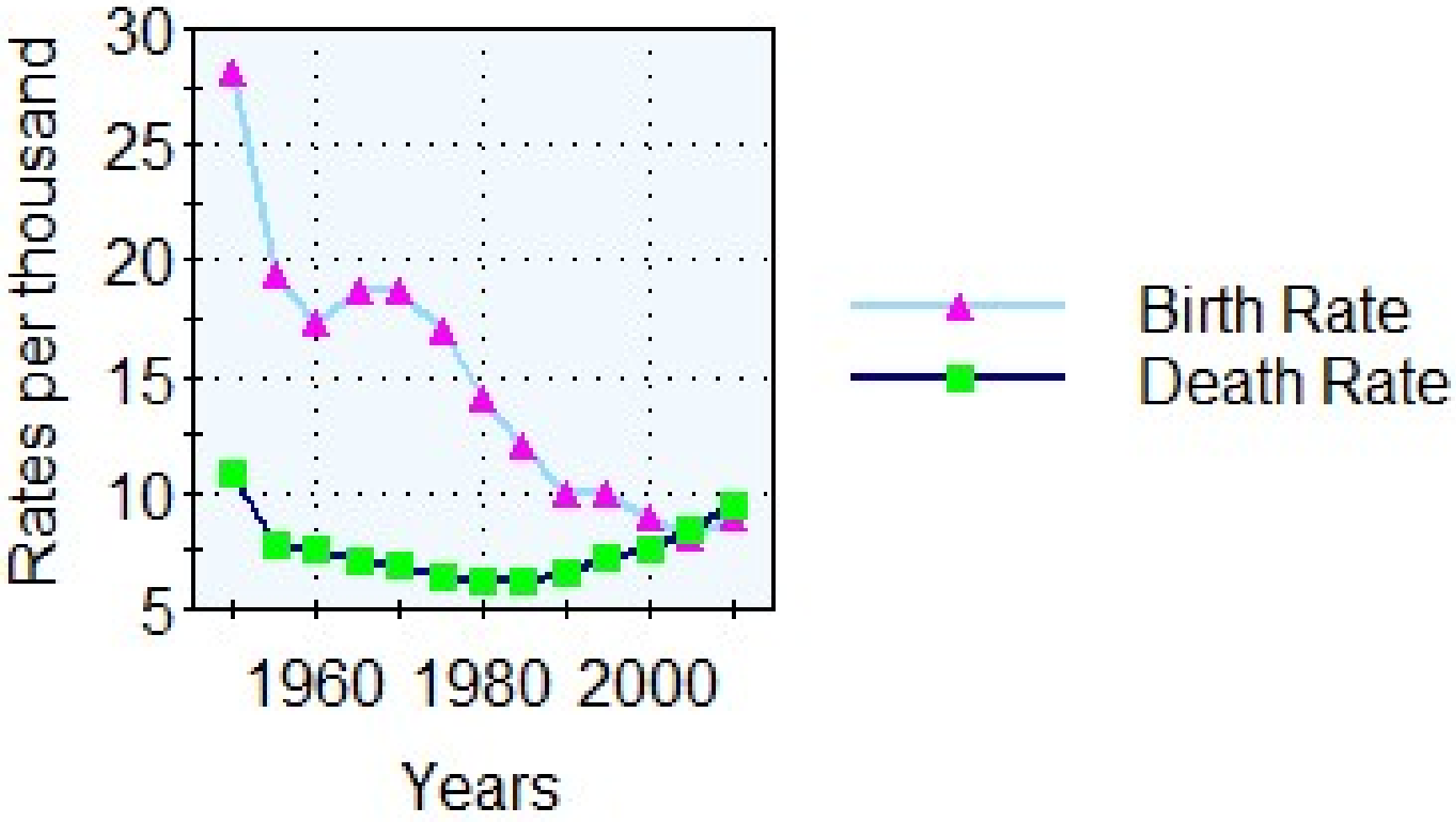
Finally, birth rates & death rates are low.


Birth/death rates
Stage 1
Stage 2
Stage 3
Stage 4
Birth rate
Natural increase
Death rate
Time

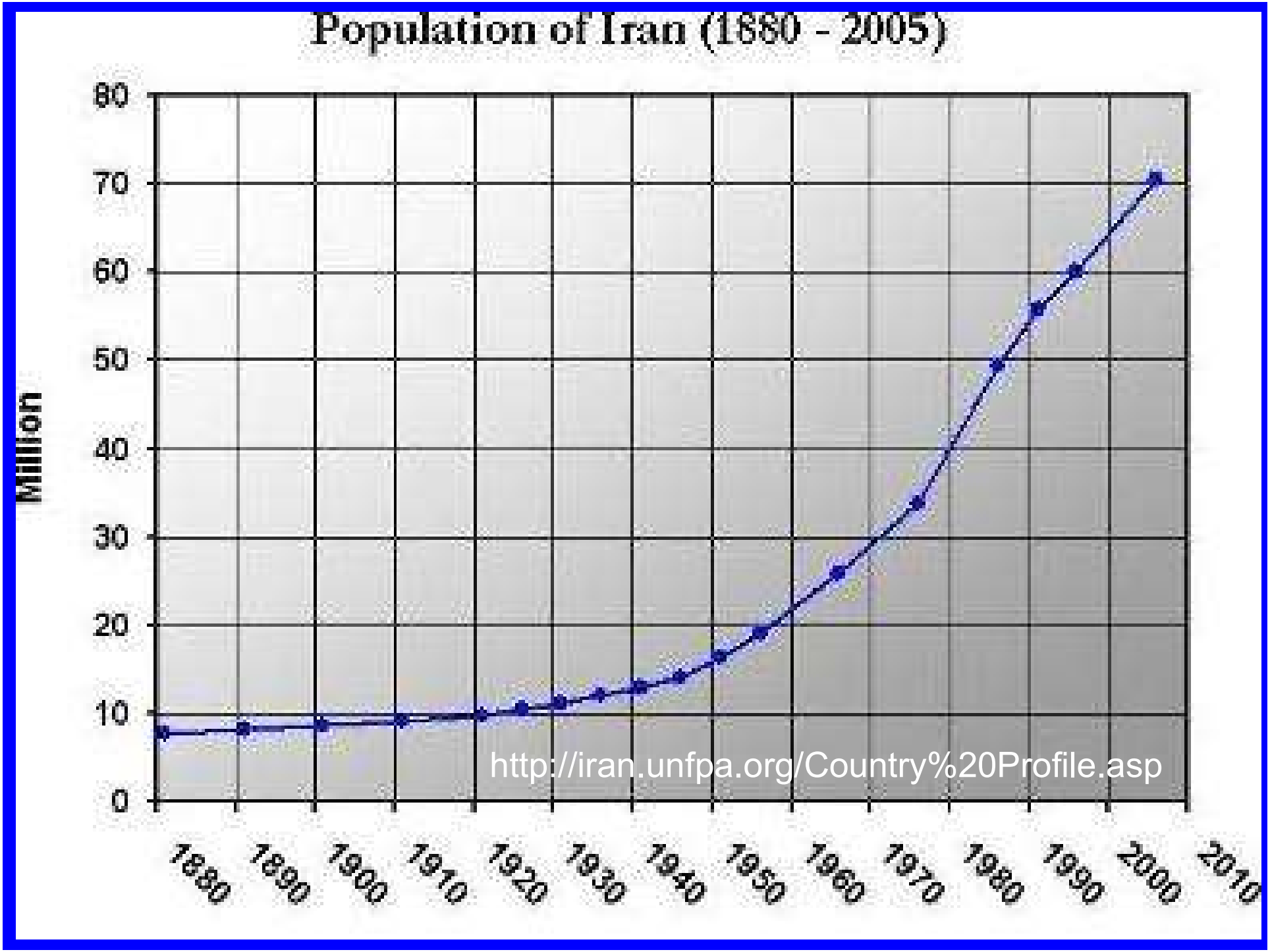
Demographic transition examples



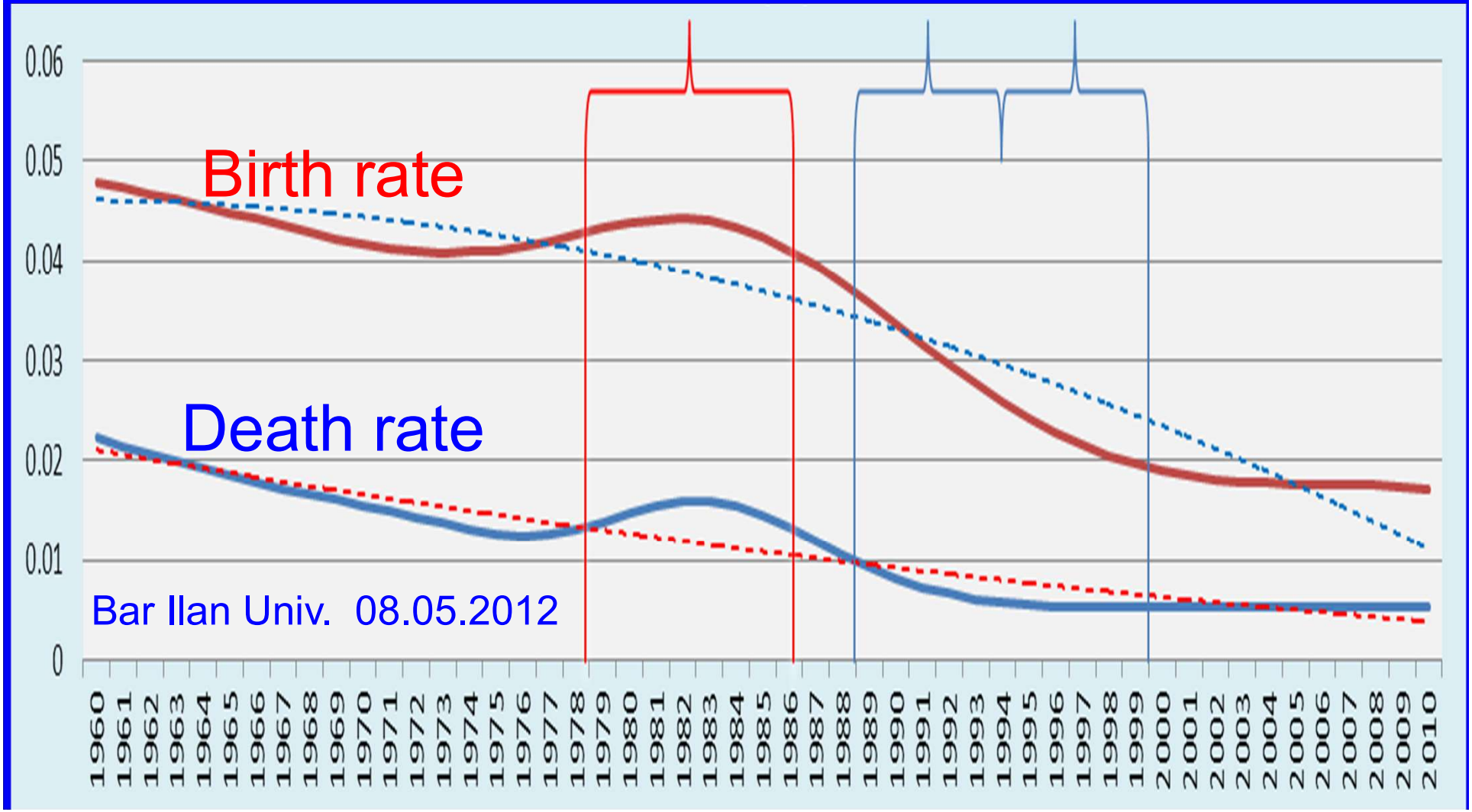
Democratic Transition - Japan



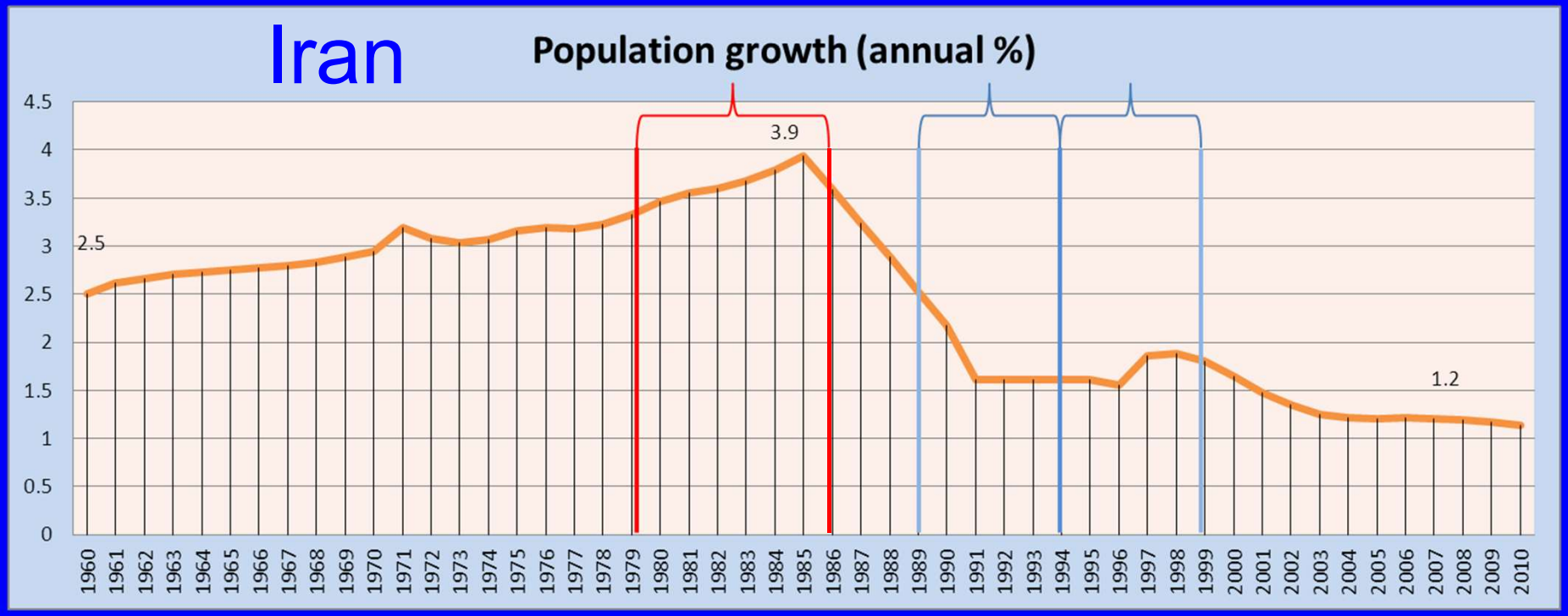
https://sites.google.com/a/richland2.org/japan-austin-dyer3/population-and-migration

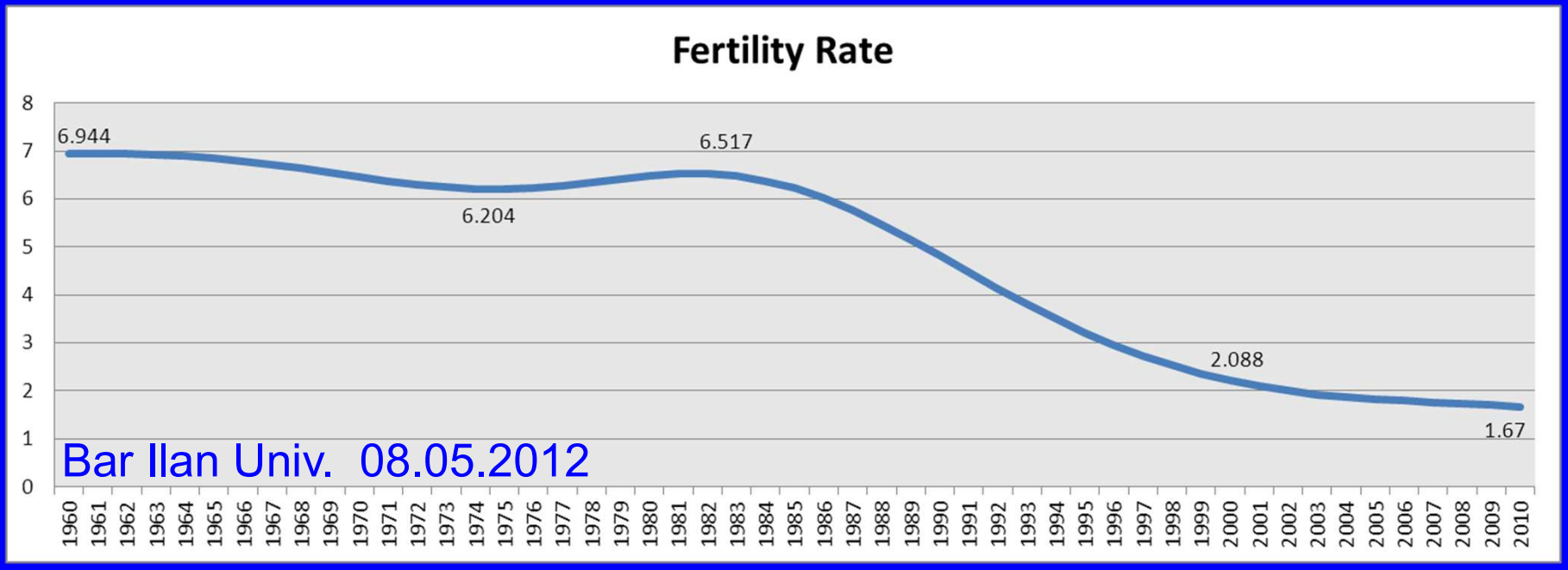

Population of Iran (1880 - 2005)
Million
80
70
60
50
40
30
20
10
0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
http://iran.unfpa.org/Country%20Profile.asp

Iran's demographic transition 1960-2010

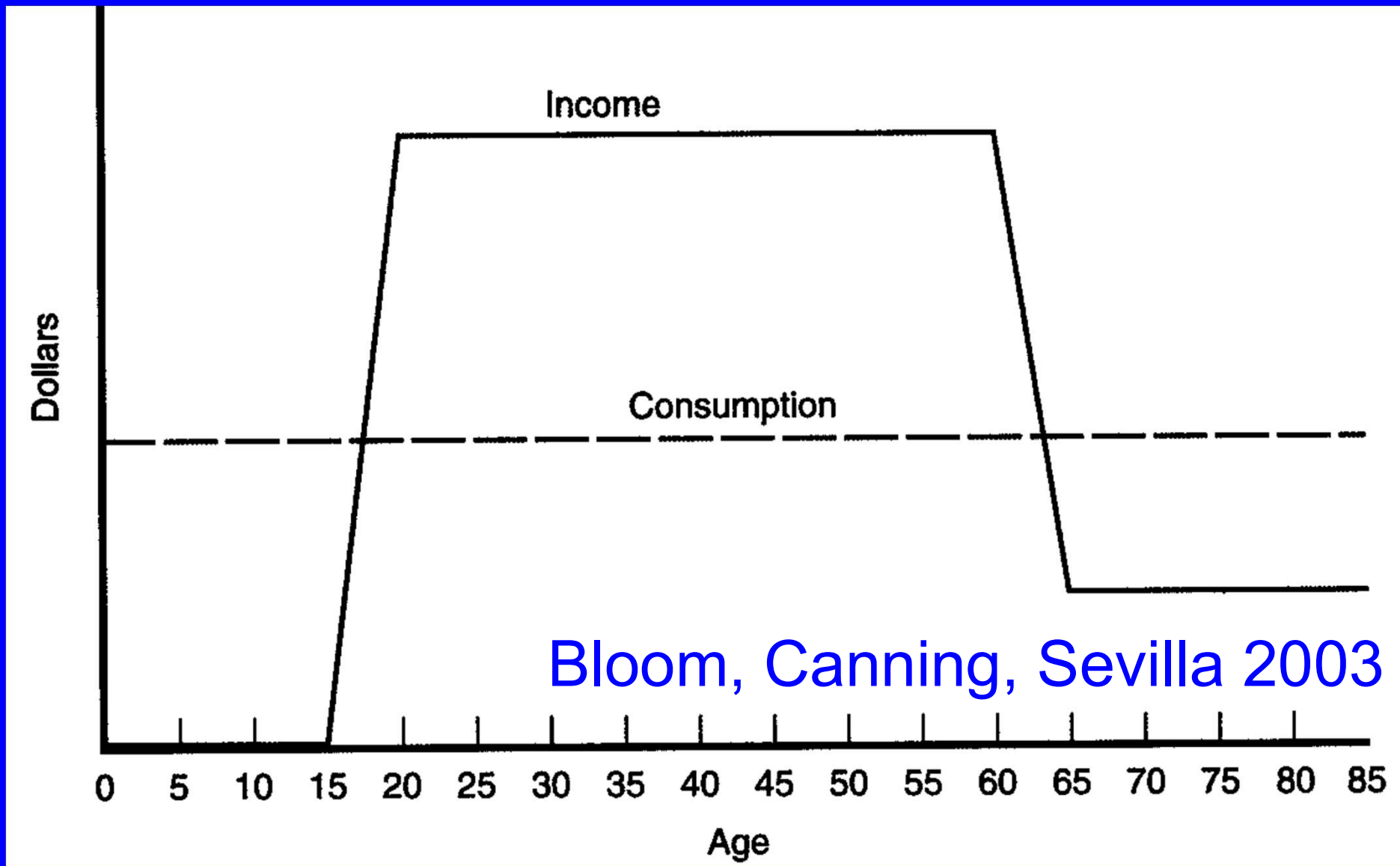


Iran


Population growth (annual %)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2.5
3.9
1.2
1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

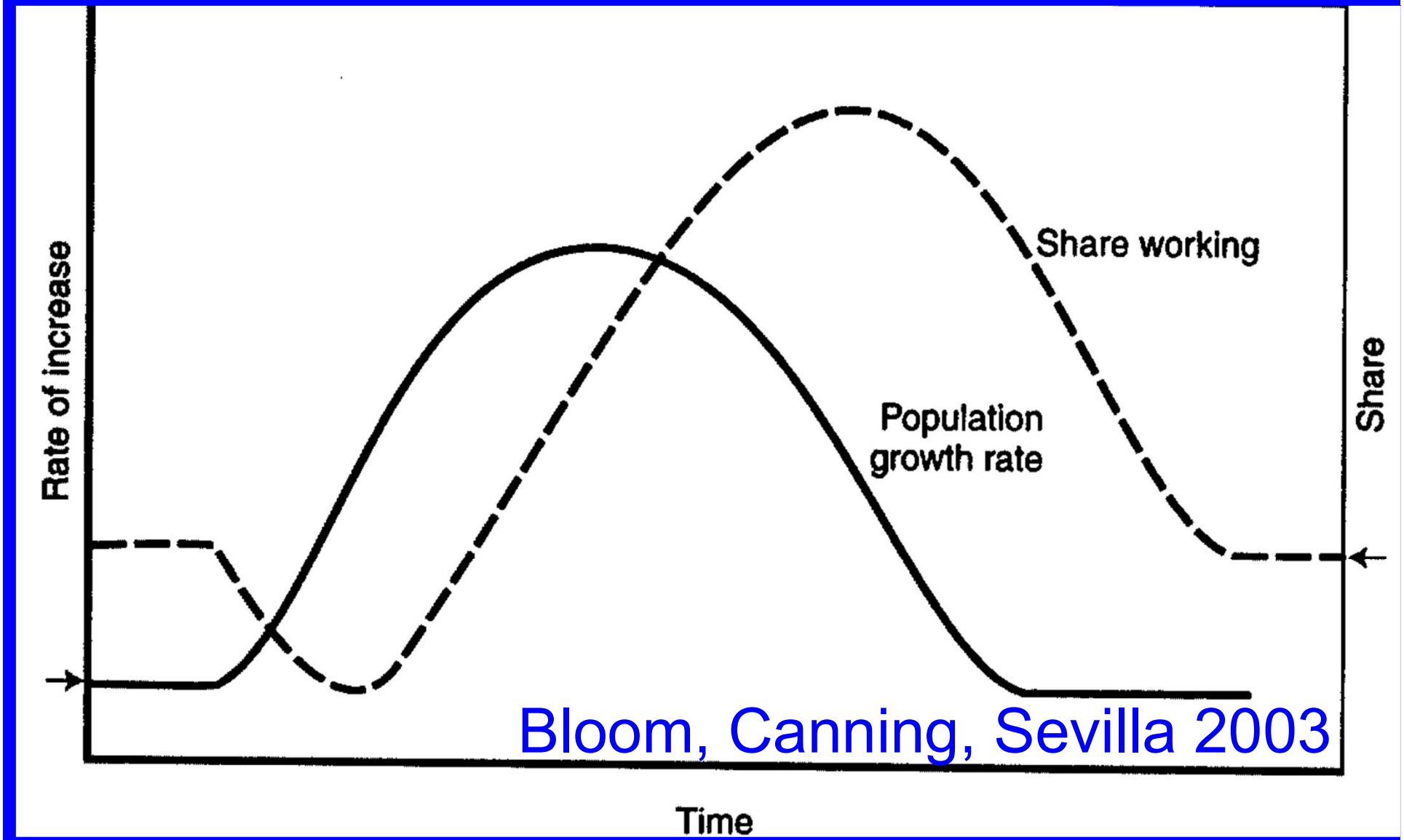

Fertility Rate
8
7
6
5
4
3
2
1
0
6.944
6.204
6.517
2.088
1.67
Bar Ilan Univ. 08.05.2012
1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

Life cycle income & consumption



Bloom, Canning, Sevilla 2003

Demographic dividend of demographic transition



Bloom, Canning, Sevilla 2003

Fertility

Fertility versus fecundity:

In demography, fertility describes behavior of giving birth.

Fecundity describes physiological capacity to reproduce.

"Fertility is the number of children born to a woman, while fecundity is her physiological potential to bear children."

Mary K. Shenk, International Encyclopedia of Human Sexuality (Wiley, 2015)

Fertility began to fall centuries ago.

Fertility began to fall in France ~1750.

- Before industrial revolution
- Before modern contraception
- Before widespread literacy
- Before civil rights for women

Reasons for fertility decline may vary, and are not fully understood.

French nobility & peasantry probably used coitus interruptus.

3 measures of fertility

1. Birth rate (BR) = number of births (both sexes) per year per person (both sexes, including non-reproductive ages)
2. Total fertility rate (TFR) = average number of births (both sexes) per woman's lifetime at age-specific birth-rates, no female mortality
3. Net rate of reproduction (NRR) = average number of daughters per woman's lifetime at age-specific female birth- & female death-rates (includes effects of sex-ratio at birth)

Replacement level fertility

Birth rate BR = (death – immigration + emigration) rates per person (from balance equation) = death rate if no migration

Total fertility rate TFR = 2.1 births per woman per lifetime in developed countries, >2.3 in developing countries, as high as 3 in areas of very high mortality

Net rate of reproduction NRR = 1 daughter per woman per lifetime

Why do fertility measures speak only of women?

Historical reason: it was easier to identify mother of a child than father.

Theoretical reason: sexually reproducing populations have (highly!) nonlinear dynamics. No widely accepted 2-sex mathematical theory exists.

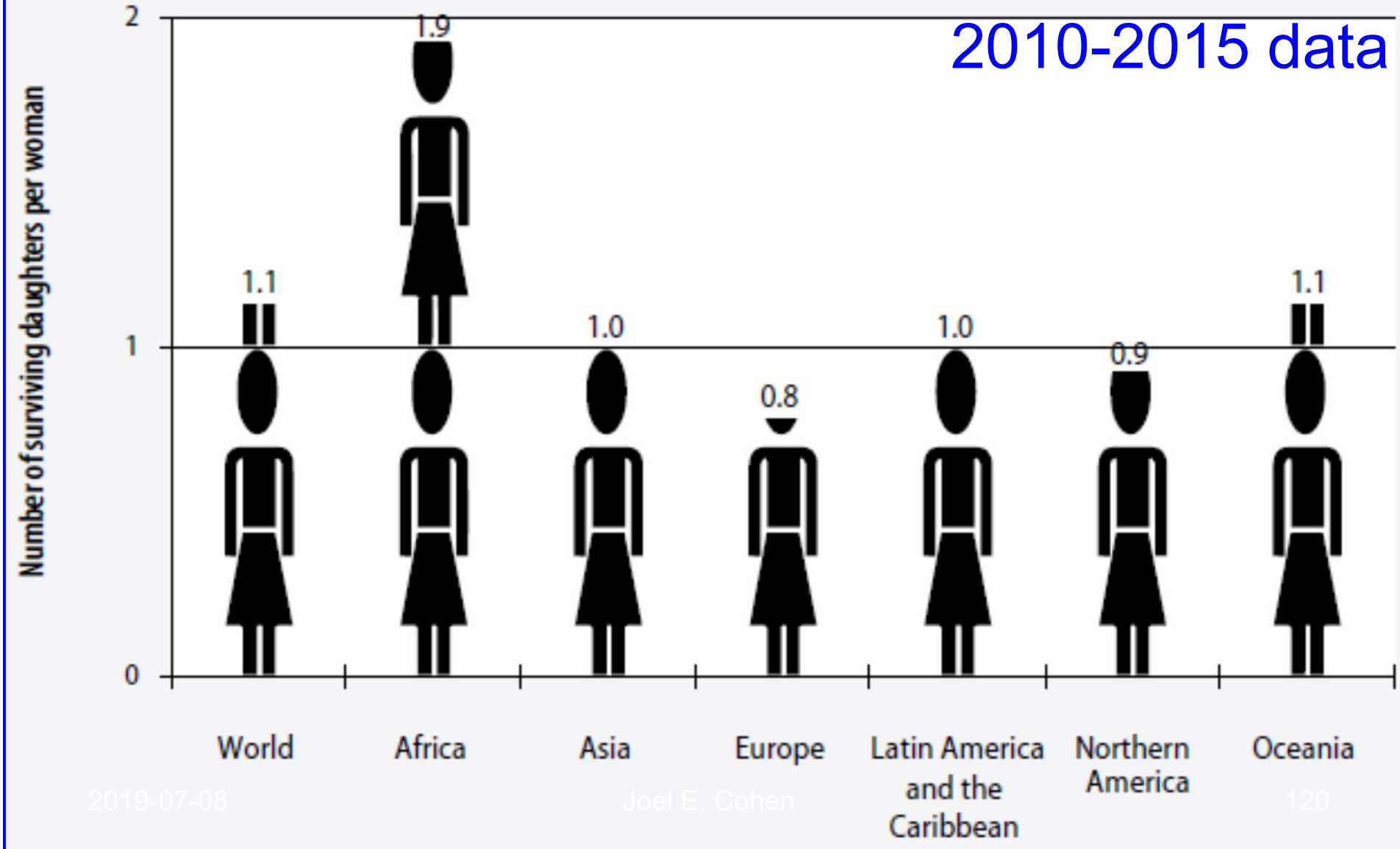
Net rate of reproduction (NRR)

NRR is the average number of daughters born to 1 newborn girl, considering the girl's probability of survival to each age, number of children at each age, & sex ratio at birth.

When NRR=1, each woman replaces herself with 1 daughter, & fertility is at replacement level.

Global NRR=1.1 daughter/woman.

UN, World Fertility Patterns 2015



Fertility schedule, maternity schedule

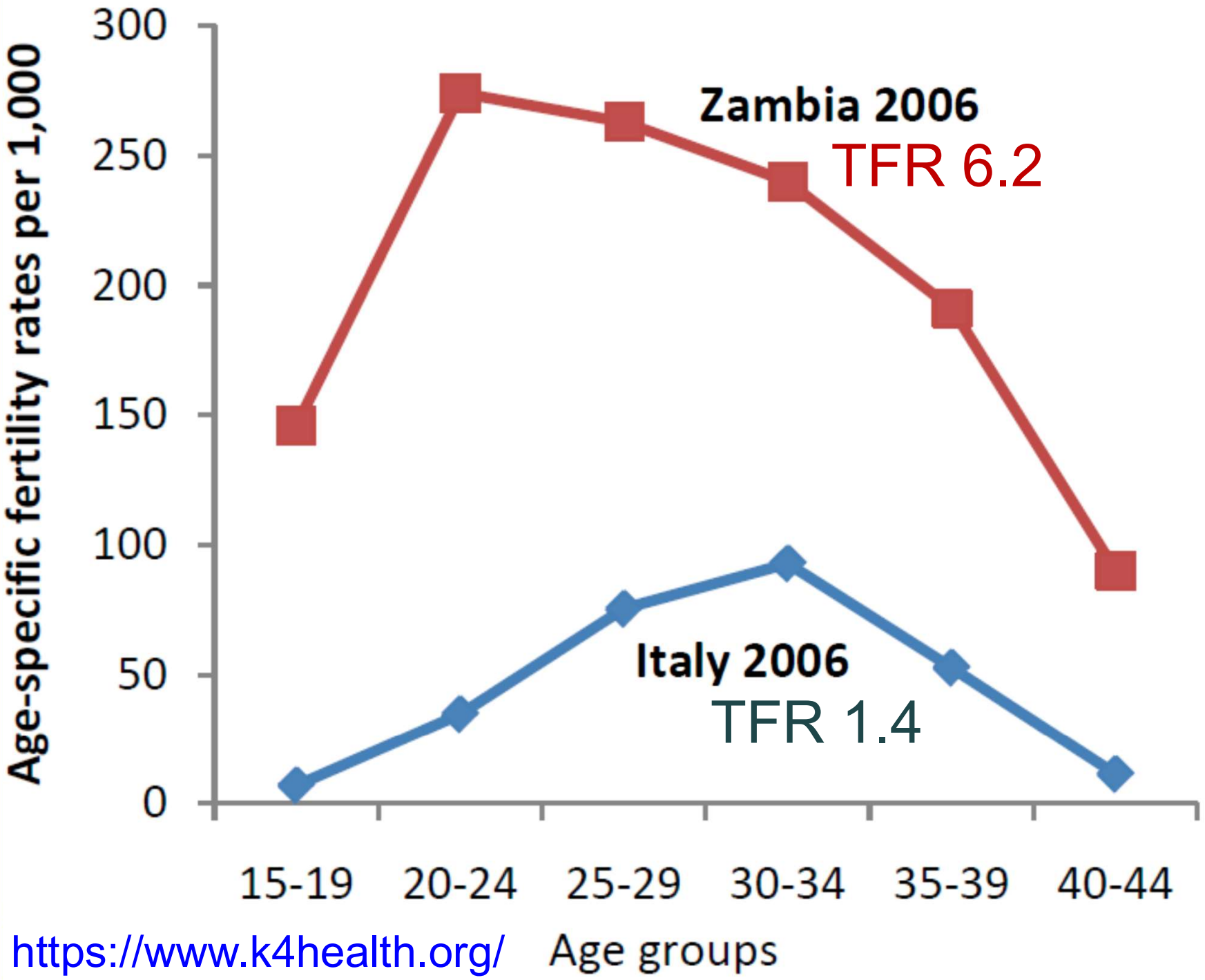
Age-specific fertility rate (ASFR) of women aged x in year t is the average number of live births per woman aged x in a specified geographic area in year t.

m(x,t)

= number of live births to women aged x

/ number of women aged x, in year t.

Sources: vital registration, population censuses, population surveys.



https://www.k4health.org/

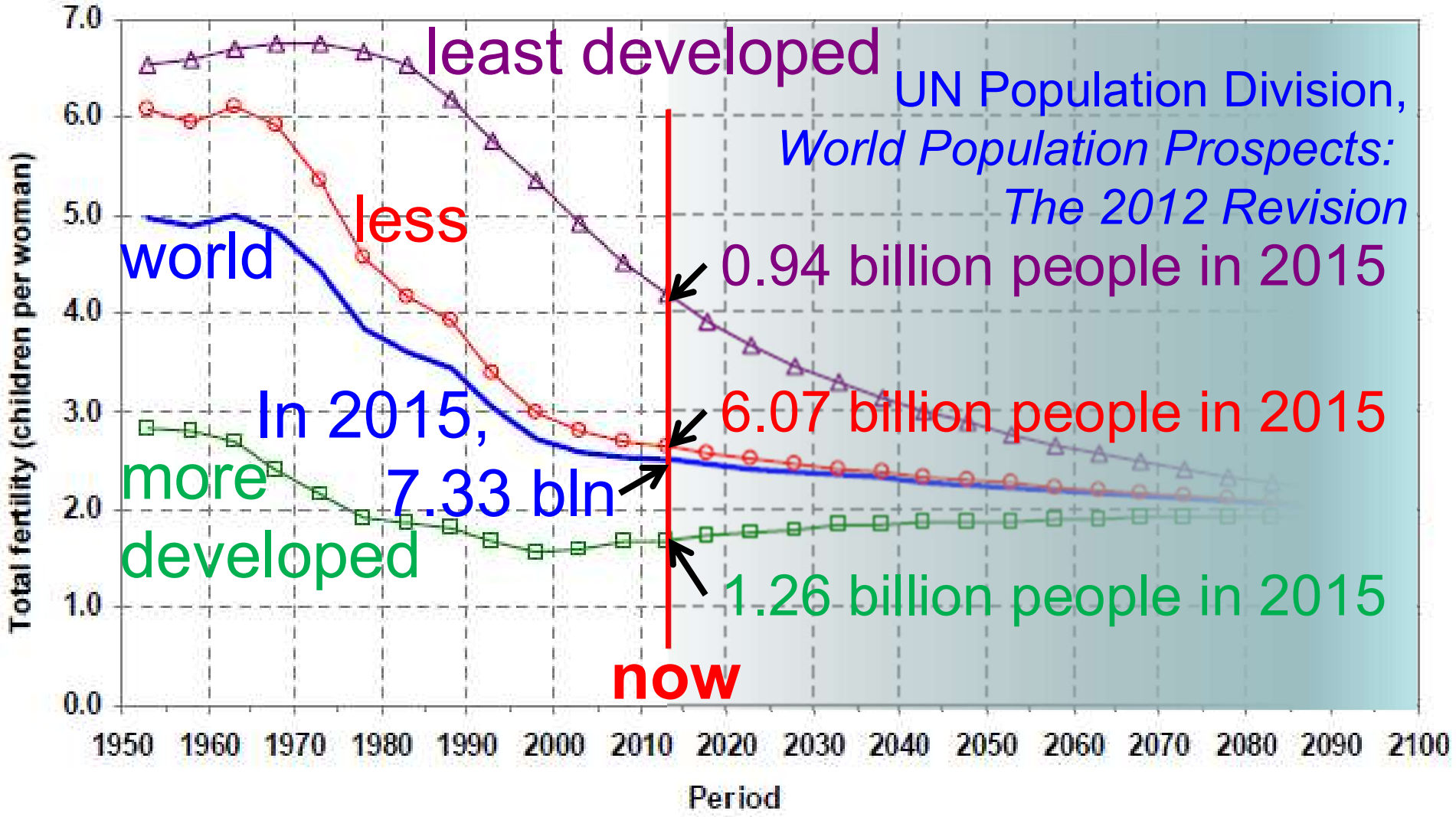
Total fertility rate (TFR)

TFR is the most widely used, but not the best, measure of fertility.

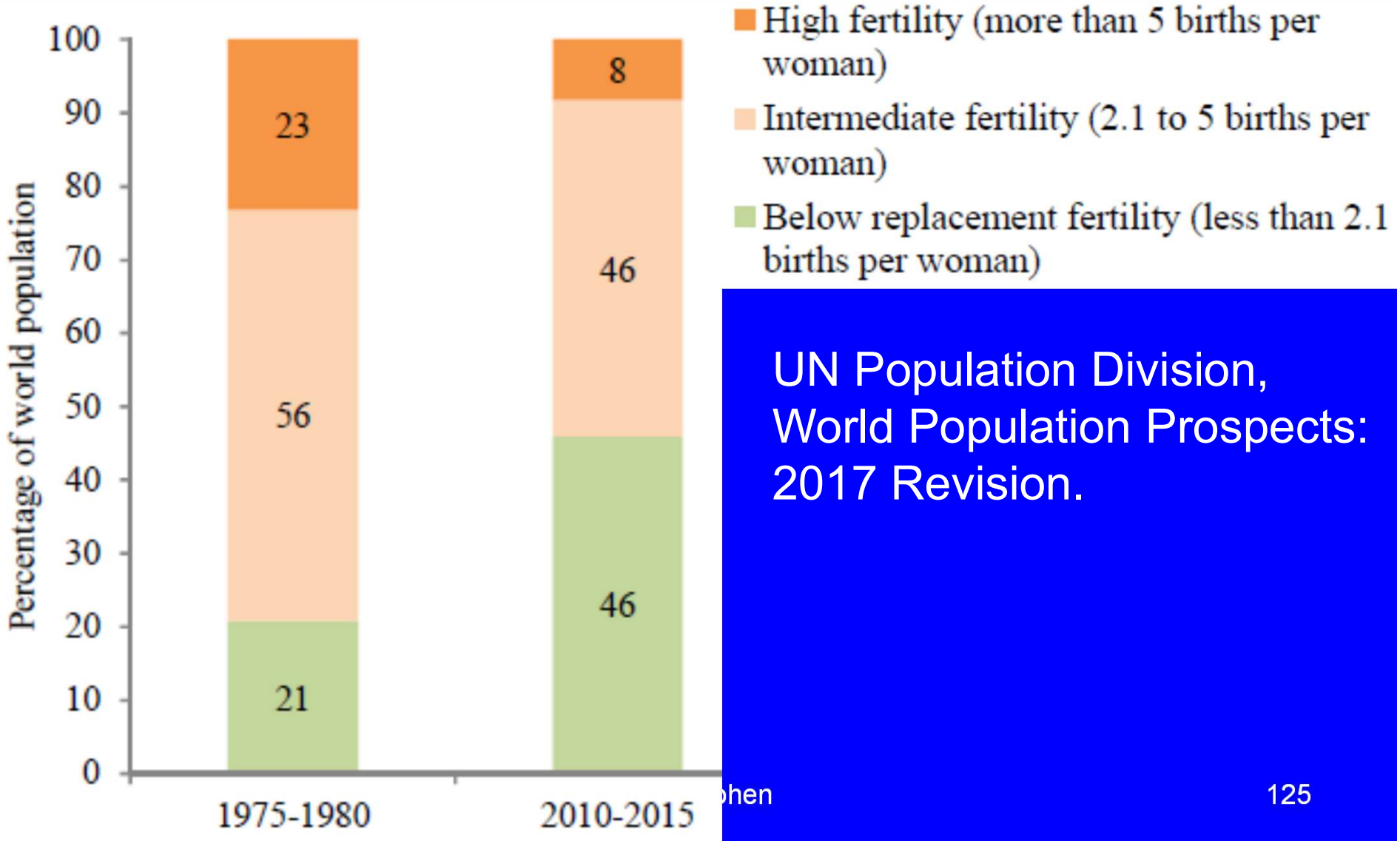
TFR = sum of age-specific birth rates

= average number of children born per woman who lives to last age of reproduction (i.e., assuming no maternal deaths during childbearing ages)

Fertility fell rapidly since 1950.



Low & medium fertility increased.

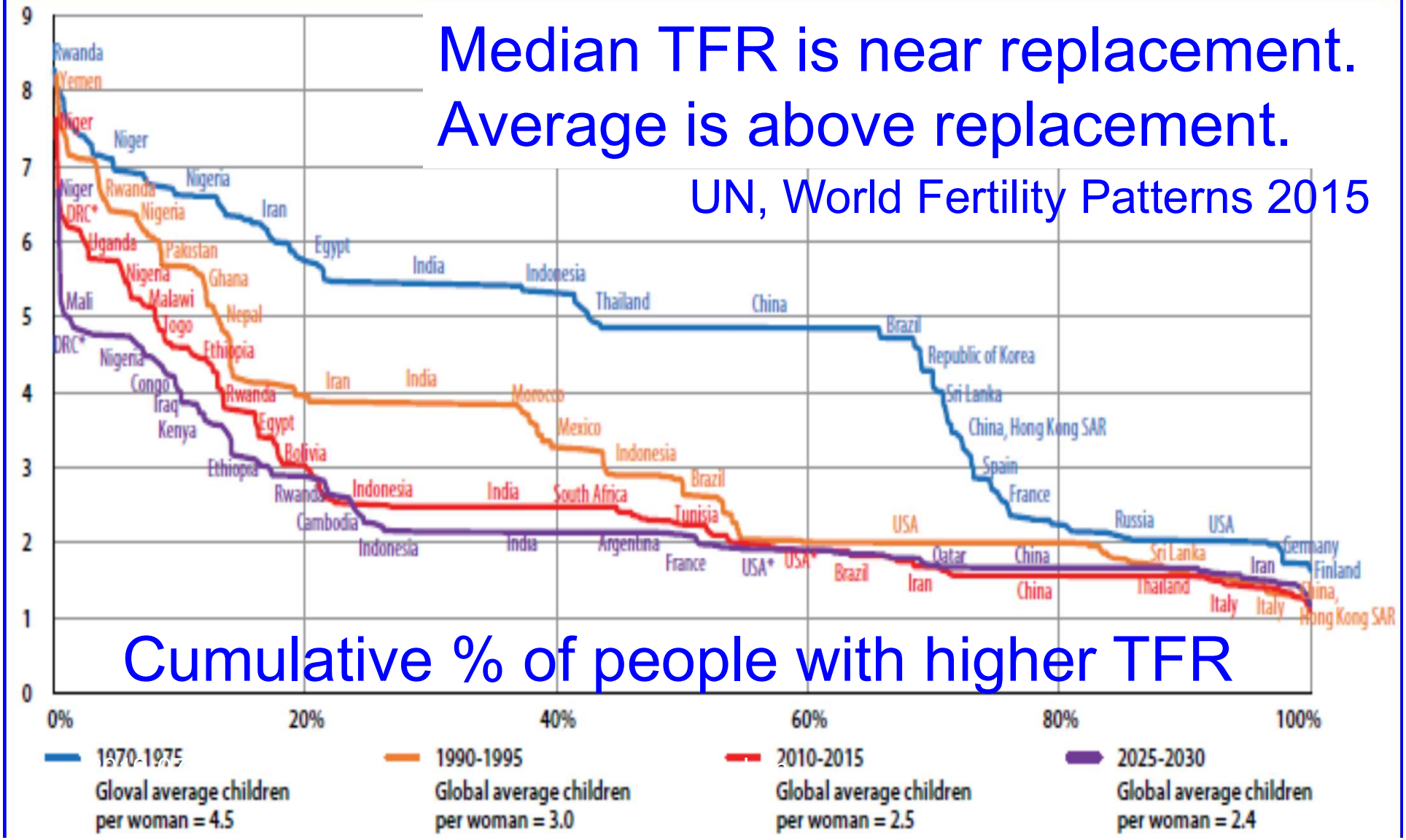


UN Population Division, World Population Prospects: 2017 Revision.

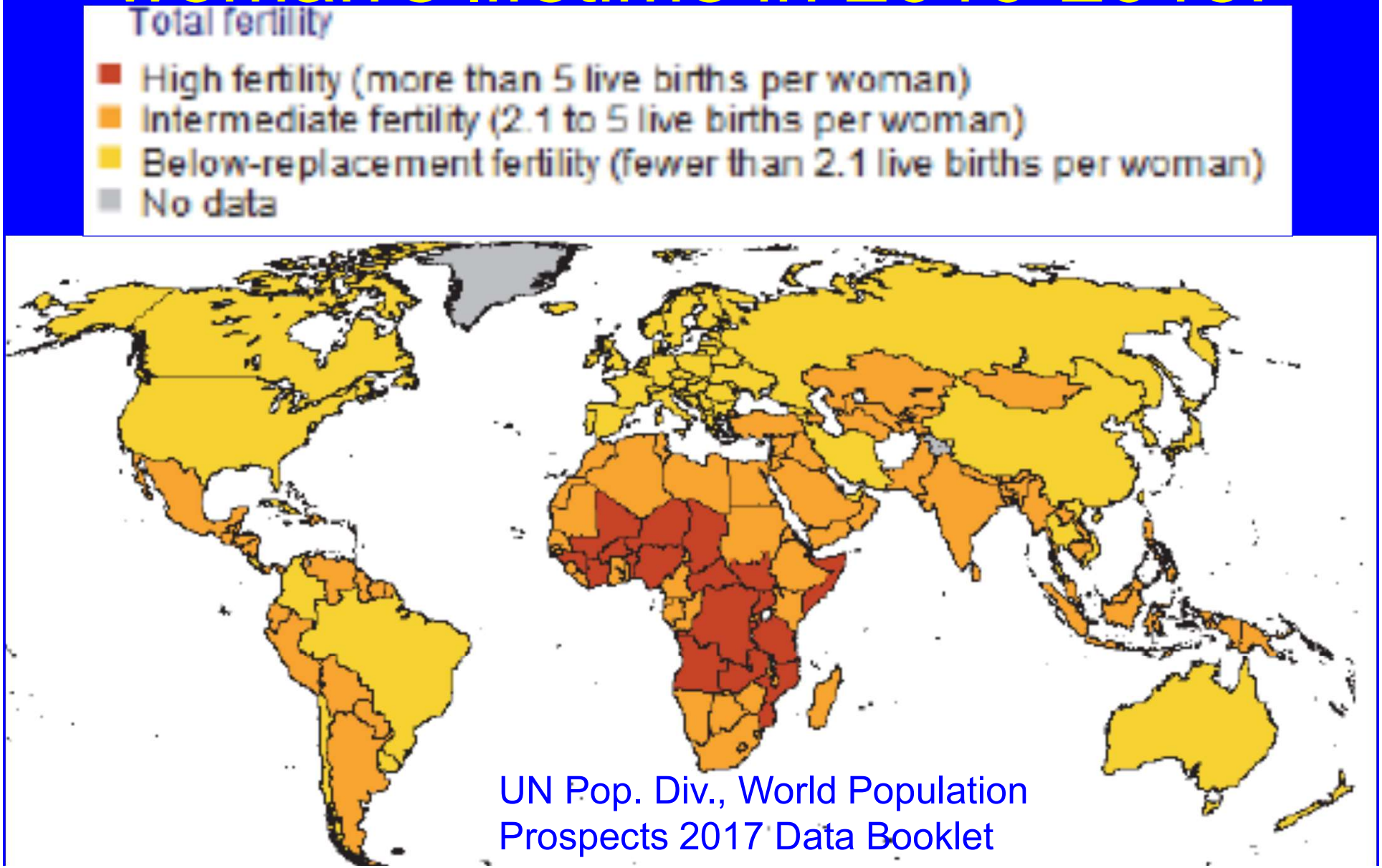
Since ~2007, for the first time in human history, more than half of all people live in countries with TFR below replacement level.

Changes in birth rates affect age structure more than changes in death rates!

~1/2 of people live in countries with fertility at or below replacement.

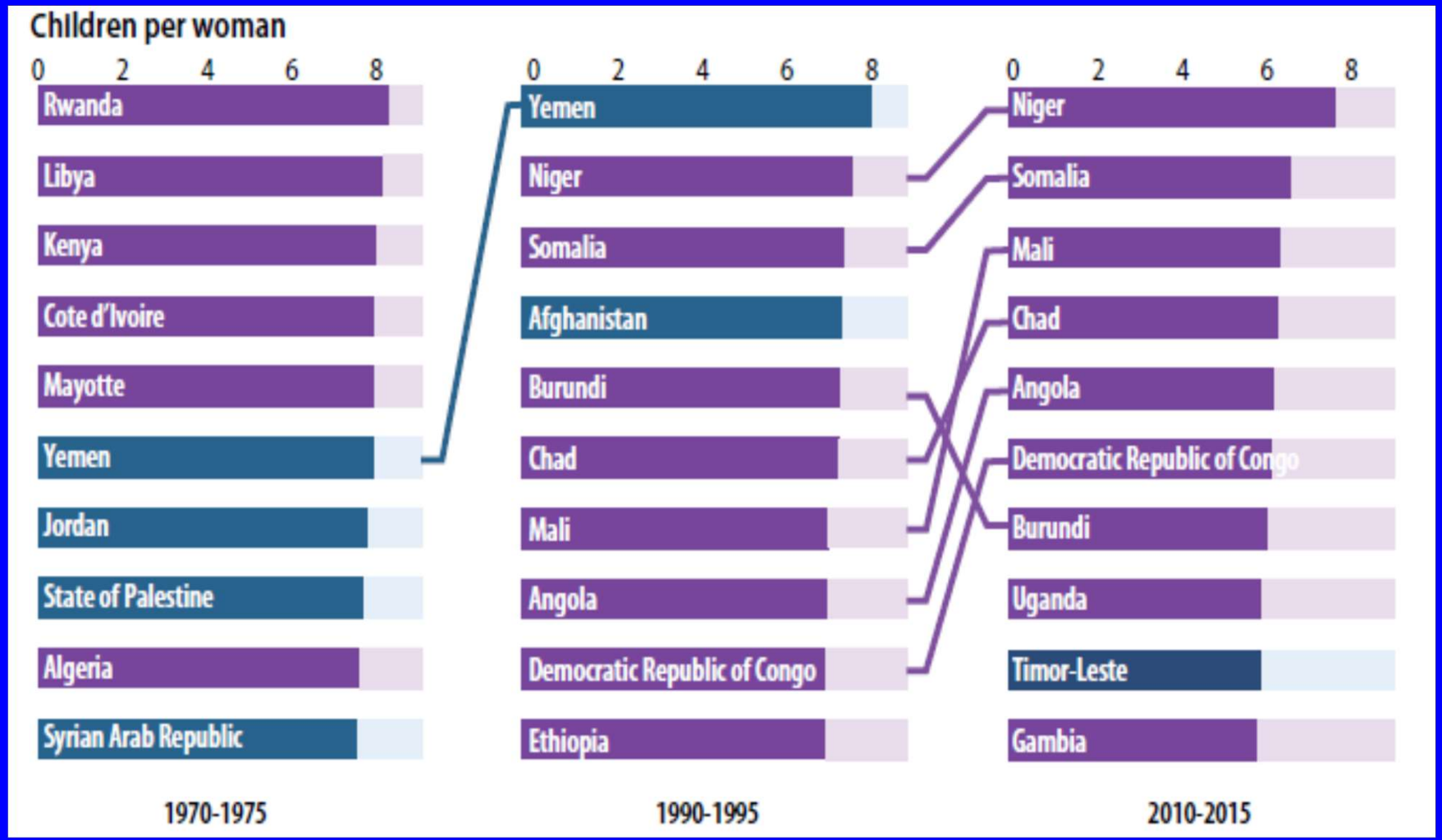


Global TFR was 2.5 births per woman's lifetime in 2010-2015.



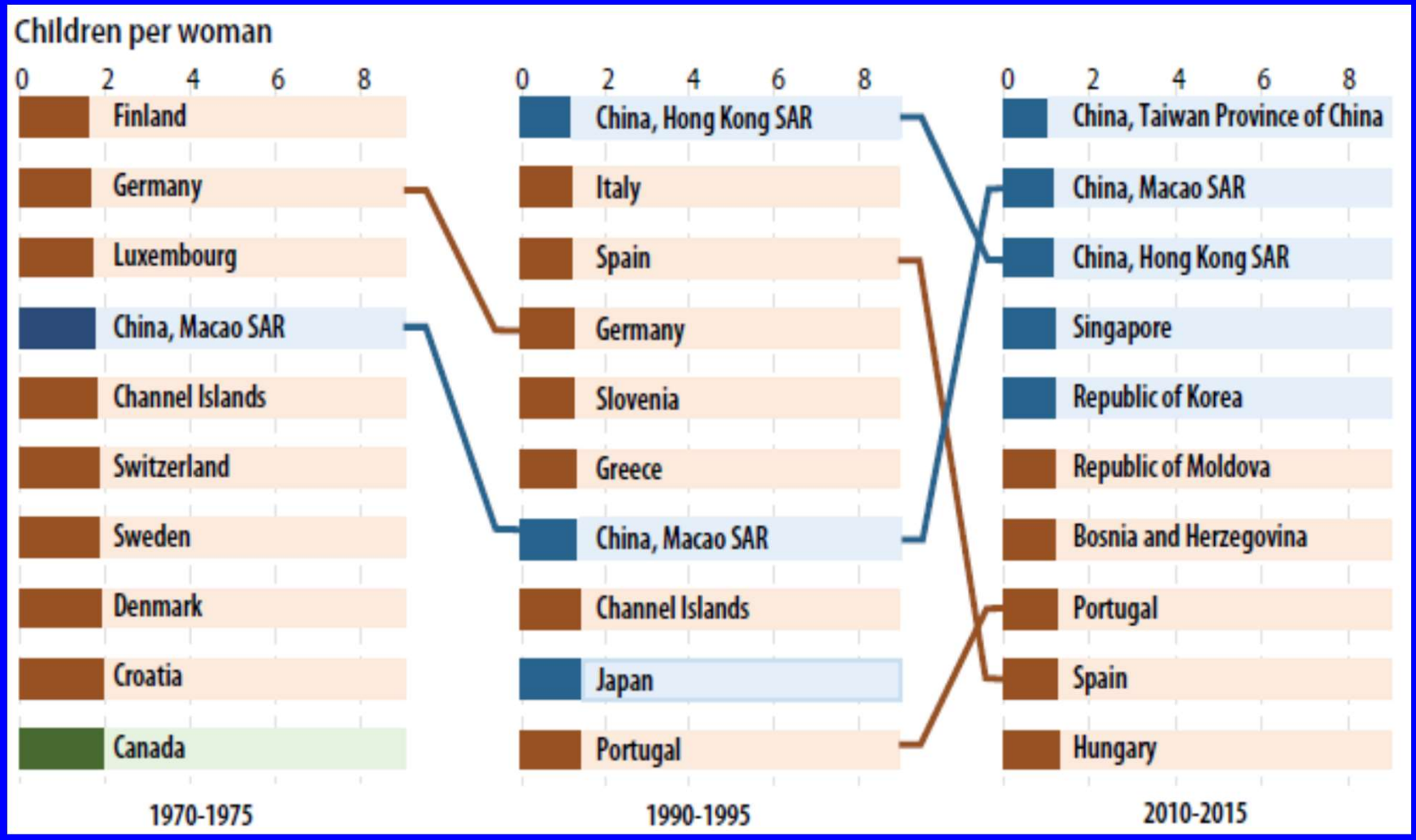
UN Pop. Div., World Population Prospects 2017 Data Booklet

10 countries with highest TFR: more in sub-Saharan Africa.



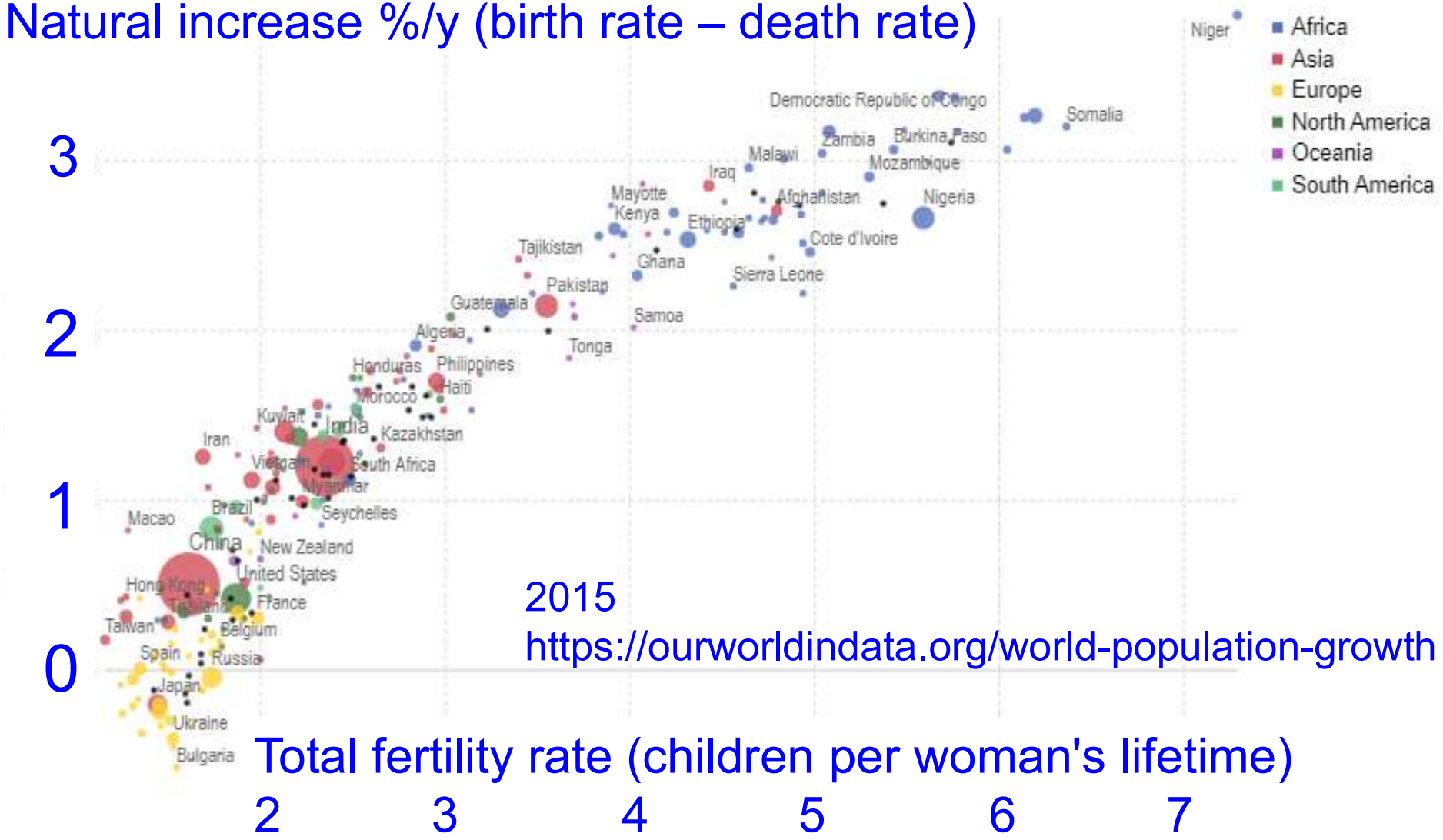
UN, World Fertility Patterns 2015

10 countries with lowest TFR: more in Asia, fewer in Europe.



UN, World Fertility Patterns 2015

Natural increase is birth rate – death rate (no migration).



Source: UN Population Division (2017 Revision)

OurWorldInData.org/world-population-growth/ • CC BY-SA

"Childbearing is becoming less connected with marriage."

"In 64 [of 198] countries with data on extra-marital births for all three periods [1970s, 1995, 2000+], the median percentage of births that occurred outside of formal (legal) marriage rose substantially, from 7.2 per cent in the 1970s to 35.9 per cent in the first decade of the twenty-first century."

In 2000-11, only 91 countries reported data on extra-marital births.

United Nations Population Division (2013), *World Fertility Report 2012*

Unintended pregnancy is mistimed or unwanted.

“unintended”

Intended	Mistimed	Unwanted
Desired pregnancy at the time it occurred or sooner	Did not want to become pregnant at the time the pregnancy occurred, but did want to become pregnant at some point in the future	Did not want to become pregnant then or at anytime in the future

40% of global pregnancies are unintended.

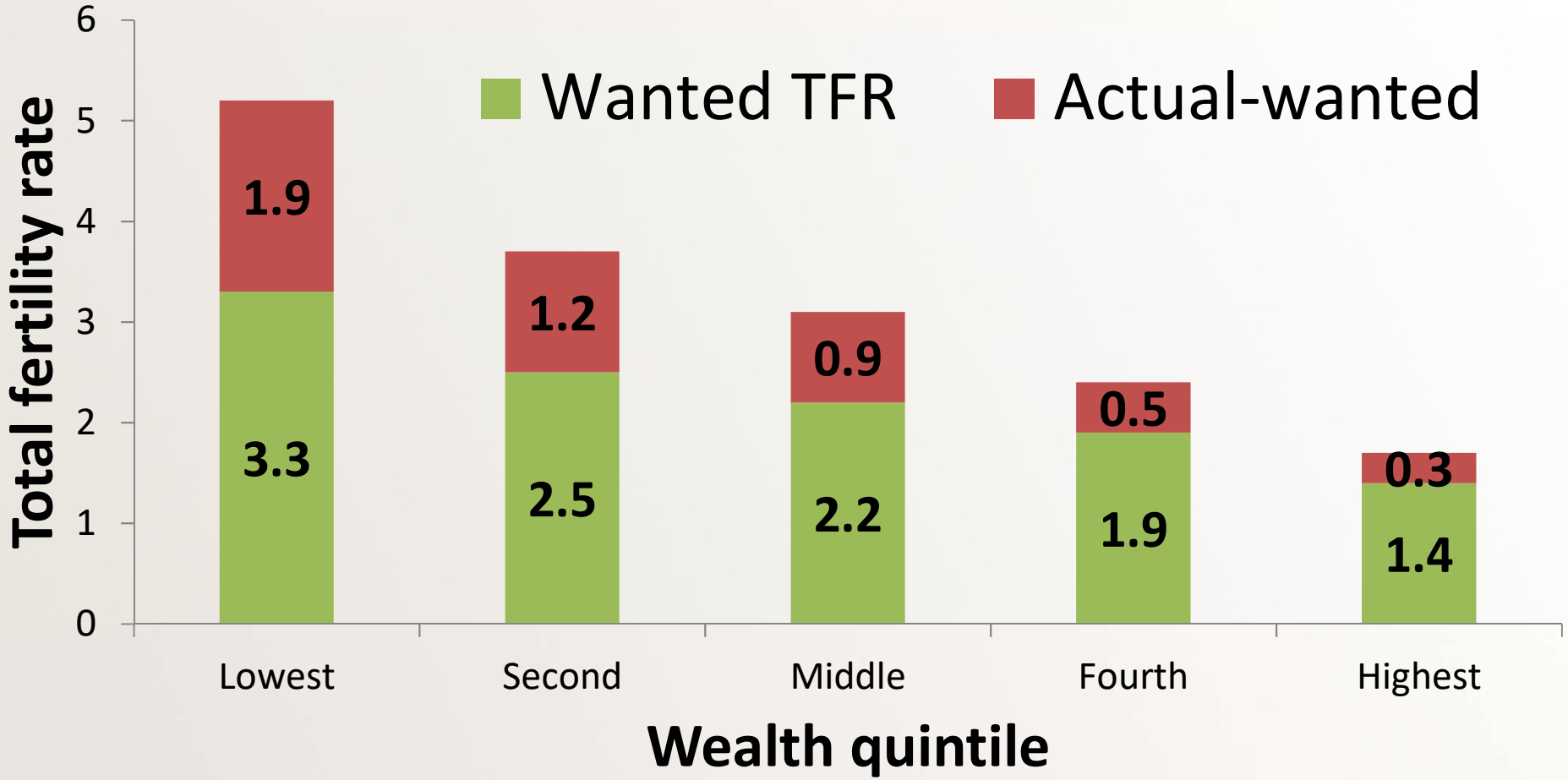
213 million pregnancies occurred worldwide in 2012, 190 million (89%) in developing world.

85 million pregnancies (40%) were unintended,

- 47% unintended in more developed,
- 39% unintended in less developed,
- 35% unintended in Africa,
- 56% unintended in LAC.

Sedgh, et al. 2014

Gap between Philippines actual and wanted fertility increases with poverty.



Jessica D. Gipson 2016, based on Philippines Demographic & Health Survey 2013

45% of US pregnancies are unintended.

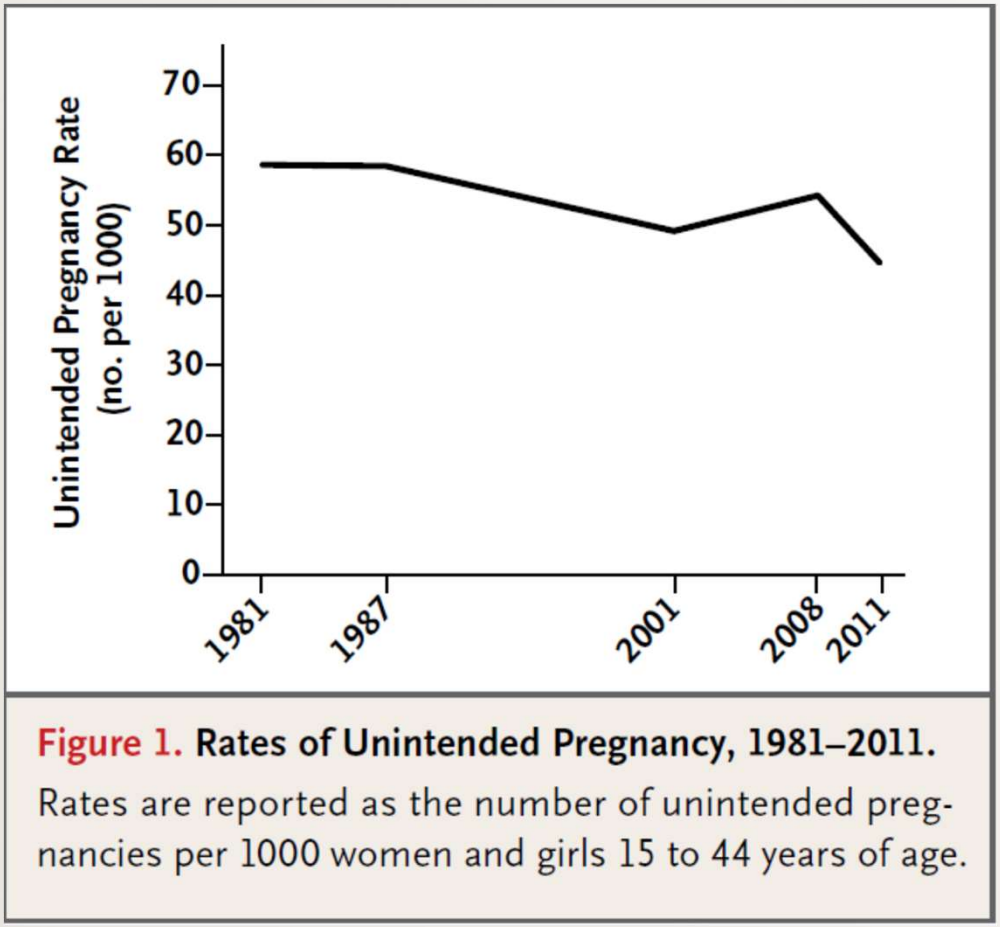
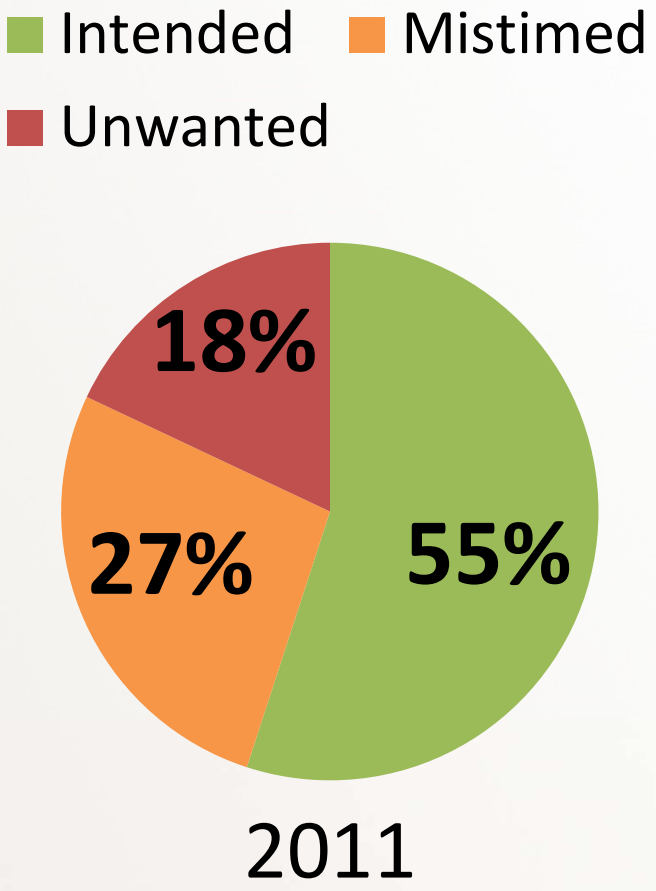


Figure 1. Rates of Unintended Pregnancy, 1981–2011.

Rates are reported as the number of unintended pregnancies per 1000 women and girls 15 to 44 years of age.



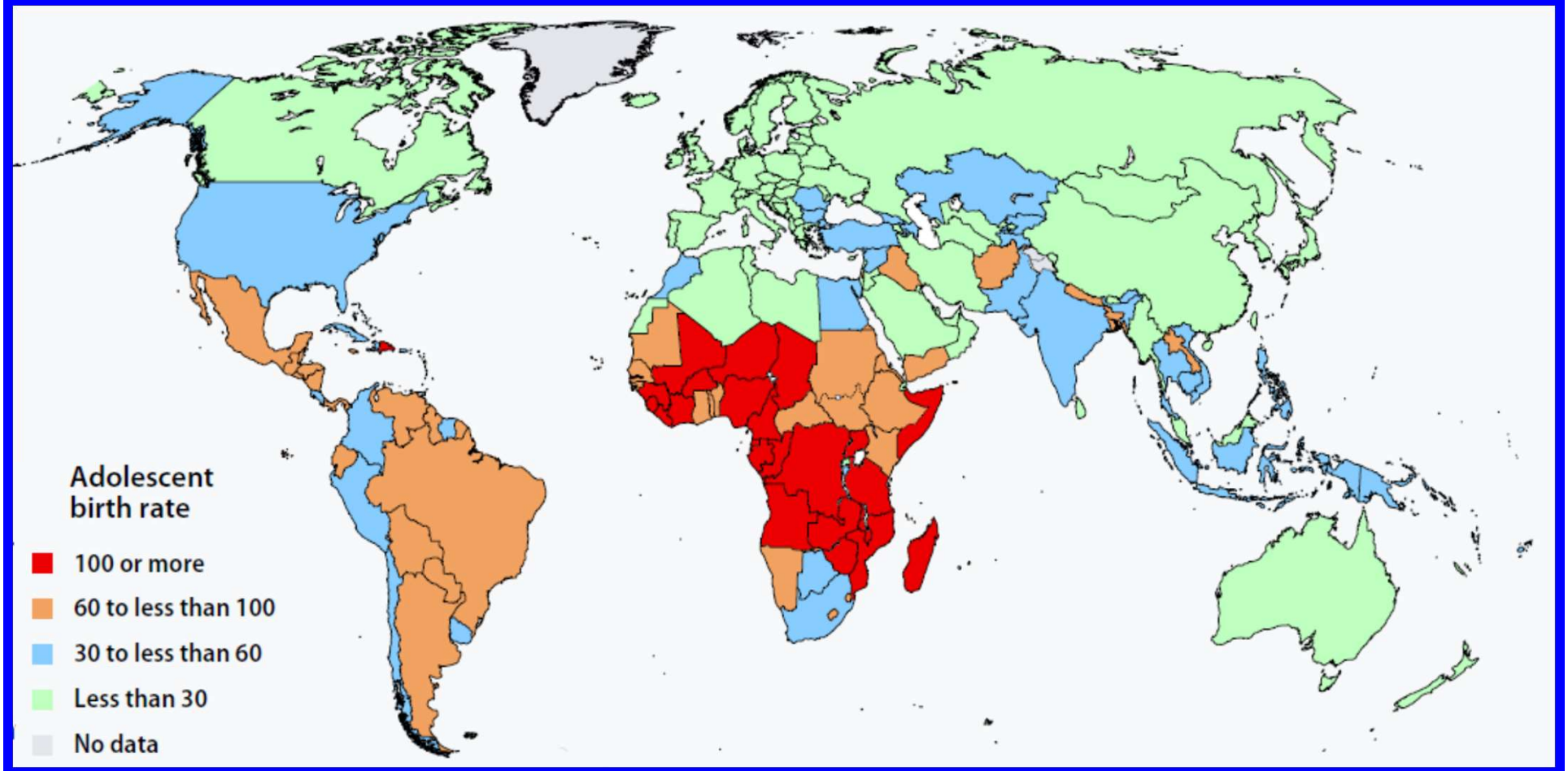
2011

Finer and Zolna, NEJM, 2016

JEC Chicago
2014-05-11

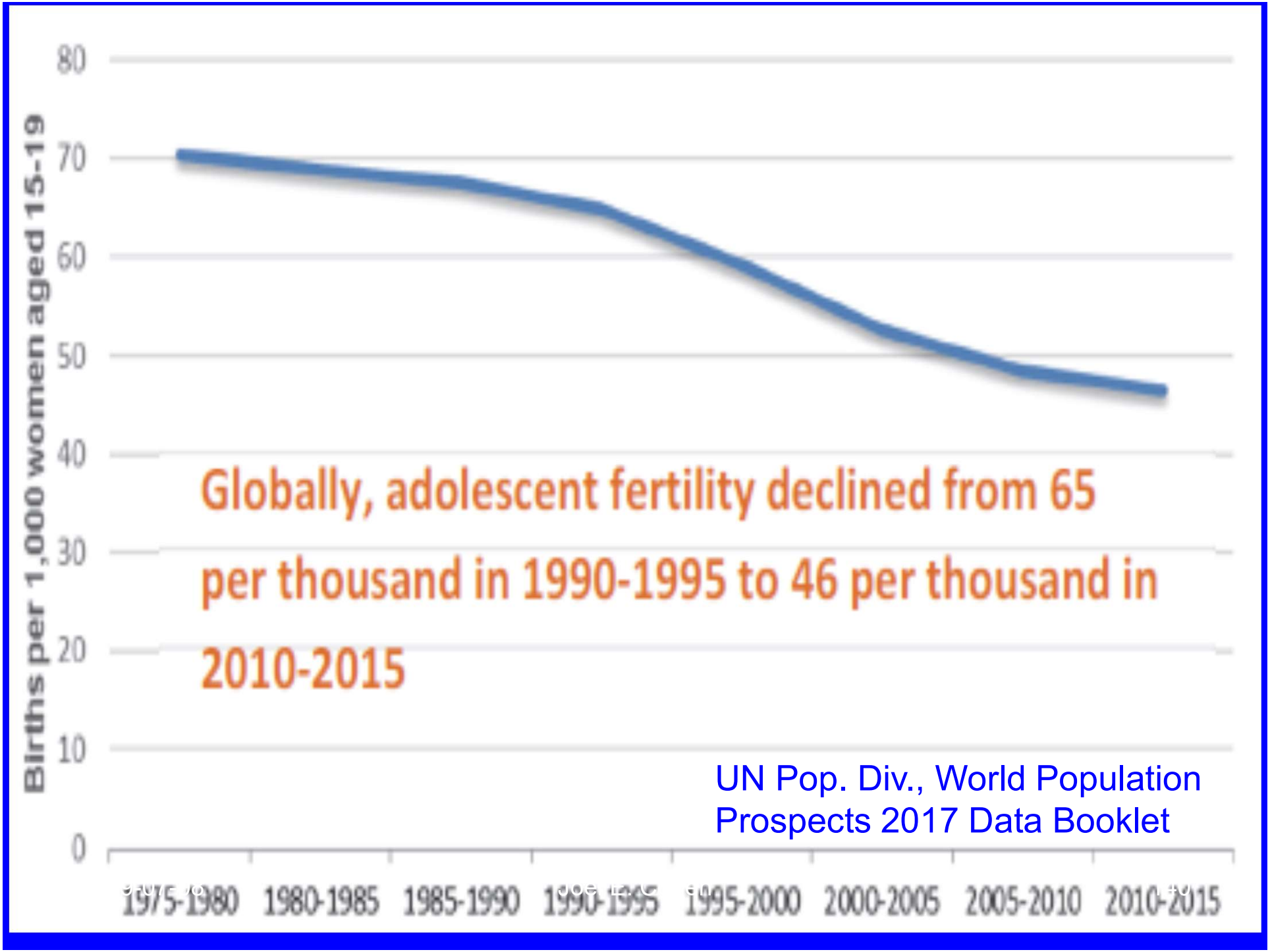
JEC Chicago
2014-05-13

Adolescent birth rate is births/1000 women aged 15-19.

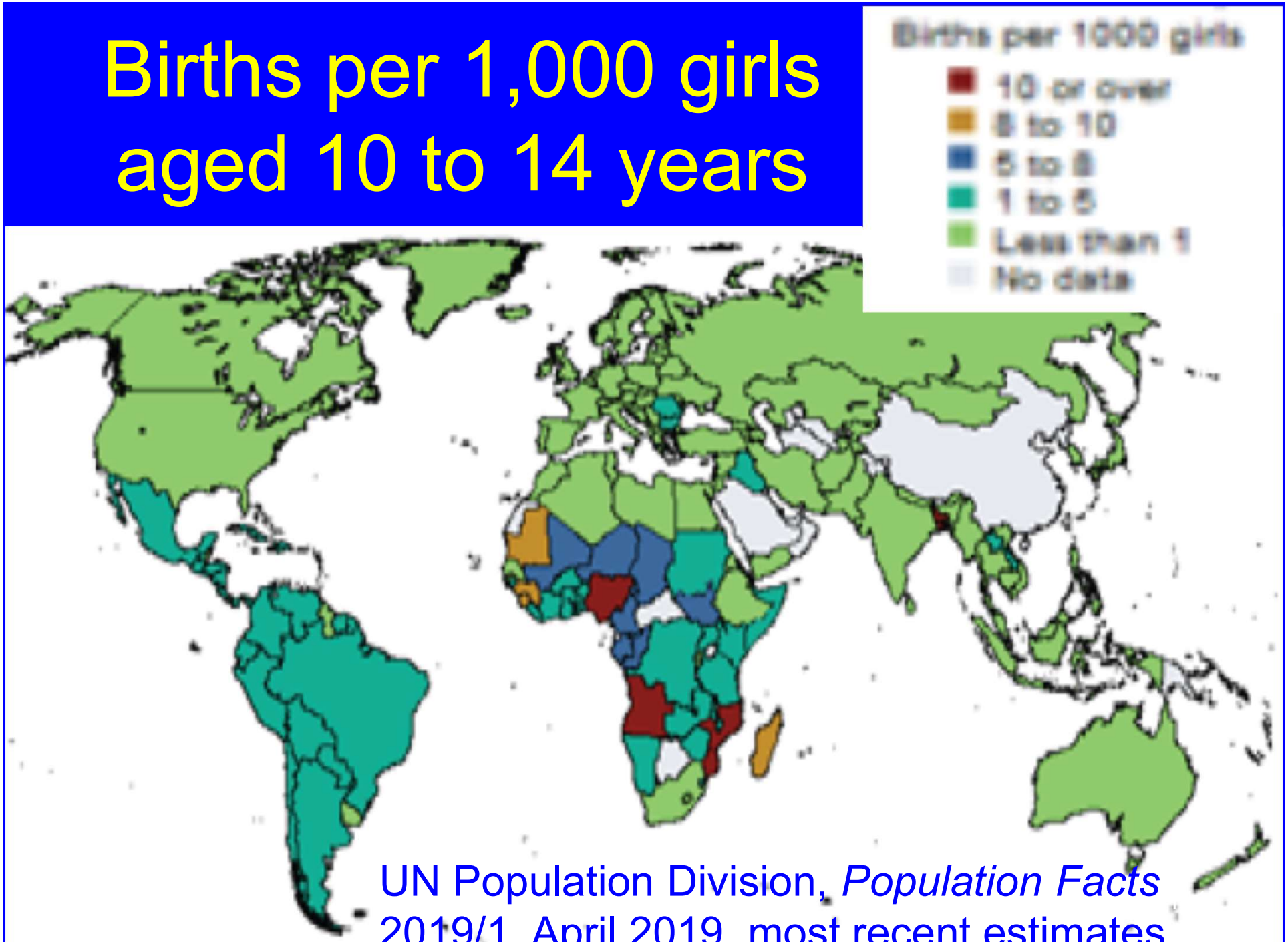


46 births/1000 adolescent women in 2010-15

UN, World Fertility Patterns 2015

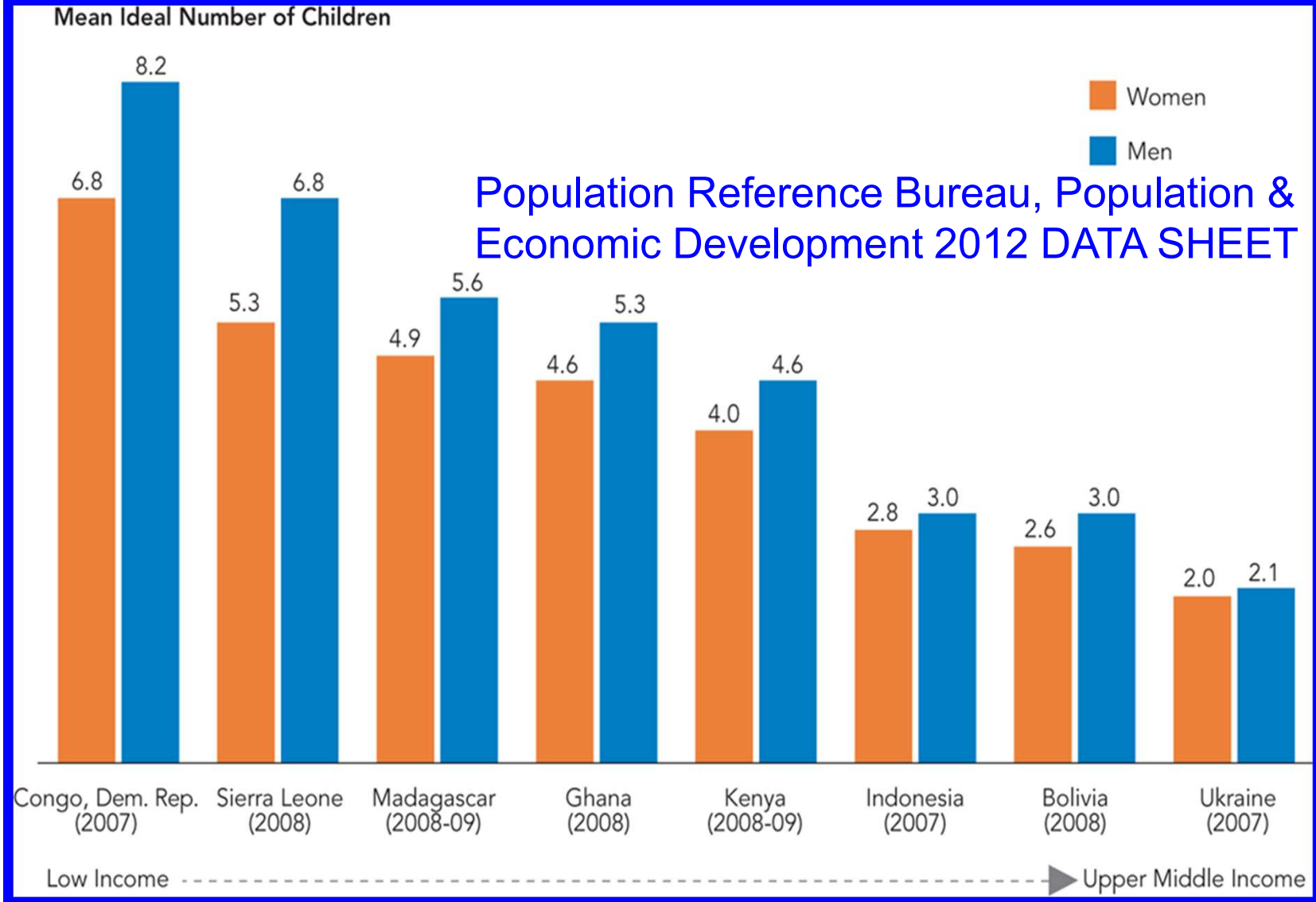

Births per 1,000 women aged 15-19
80
70
60
50
40
30
20
10
0
1975-1980
1980-1985
1985-1990
1990-1995
1995-2000
2000-2005
2005-2010
2010-2015
Globally, adolescent fertility declined from 65 per thousand in 1990-1995 to 46 per thousand in 2010-2015
UN Pop. Div., World Population Prospects 2017 Data Booklet

Births per 1,000 girls aged 10 to 14 years



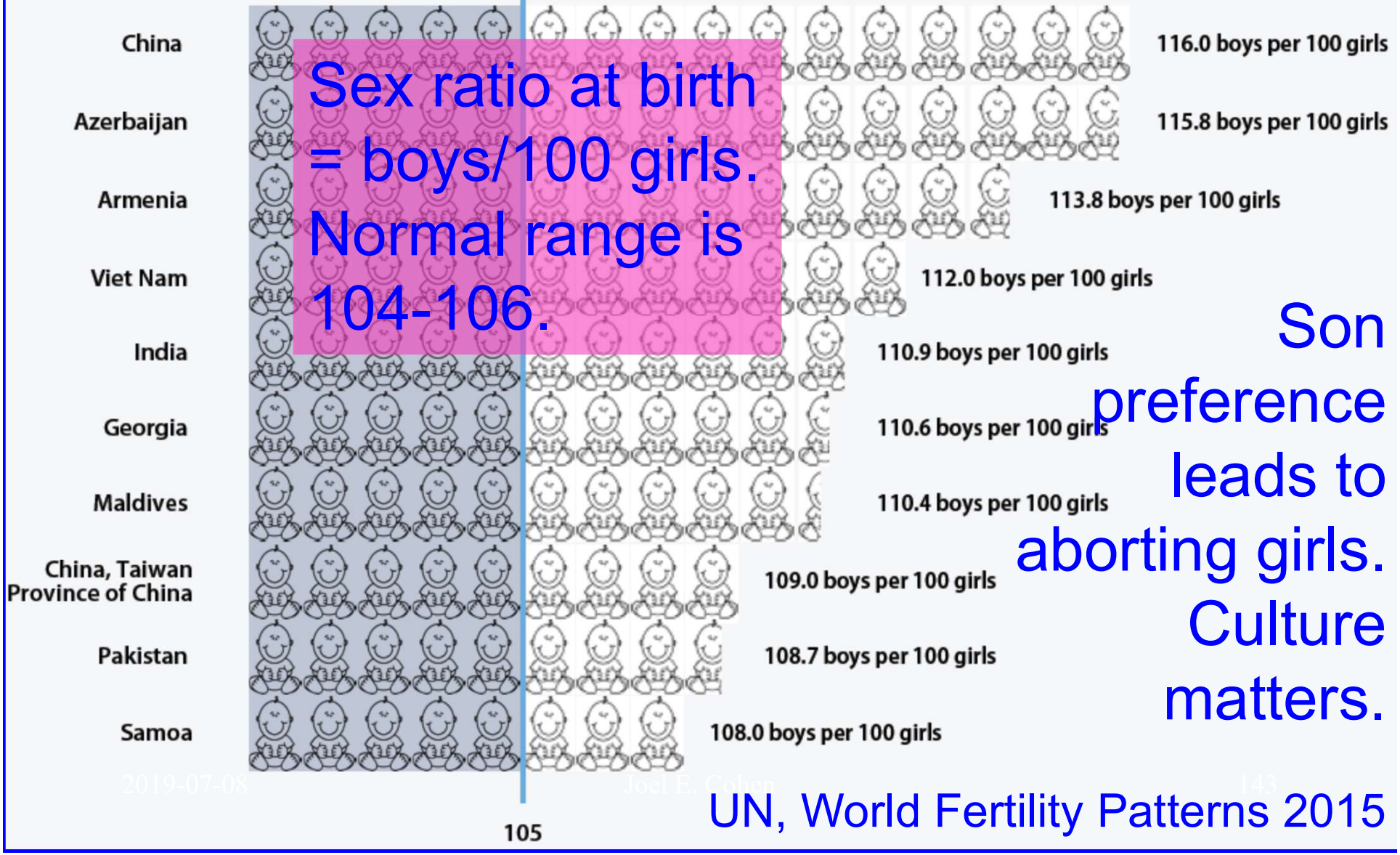
UN Population Division, *Population Facts* 2019/1, April 2019, most recent estimates

Men's ideal number of children exceeds women's.



ICF Macro, Demographic and Health Surveys; and World Bank, World Development Indicators Database

Sex ratio at birth is high especially in Asia (2010-15).



Sex ratio at birth = boys/100 girls. Normal range is 104-106.

Son preference leads to aborting girls. Culture matters.

UN, World Fertility Patterns 2015

Optional stopping & sex ratio

Suppose couples stop having children after having a boy, or after they have 4 girls, whichever comes first.

How many boys & how many girls will be born to an average couple?

What will be the average fraction of girls/children per couple?

Can optional stopping explain a great excess of boys among children? (No!)

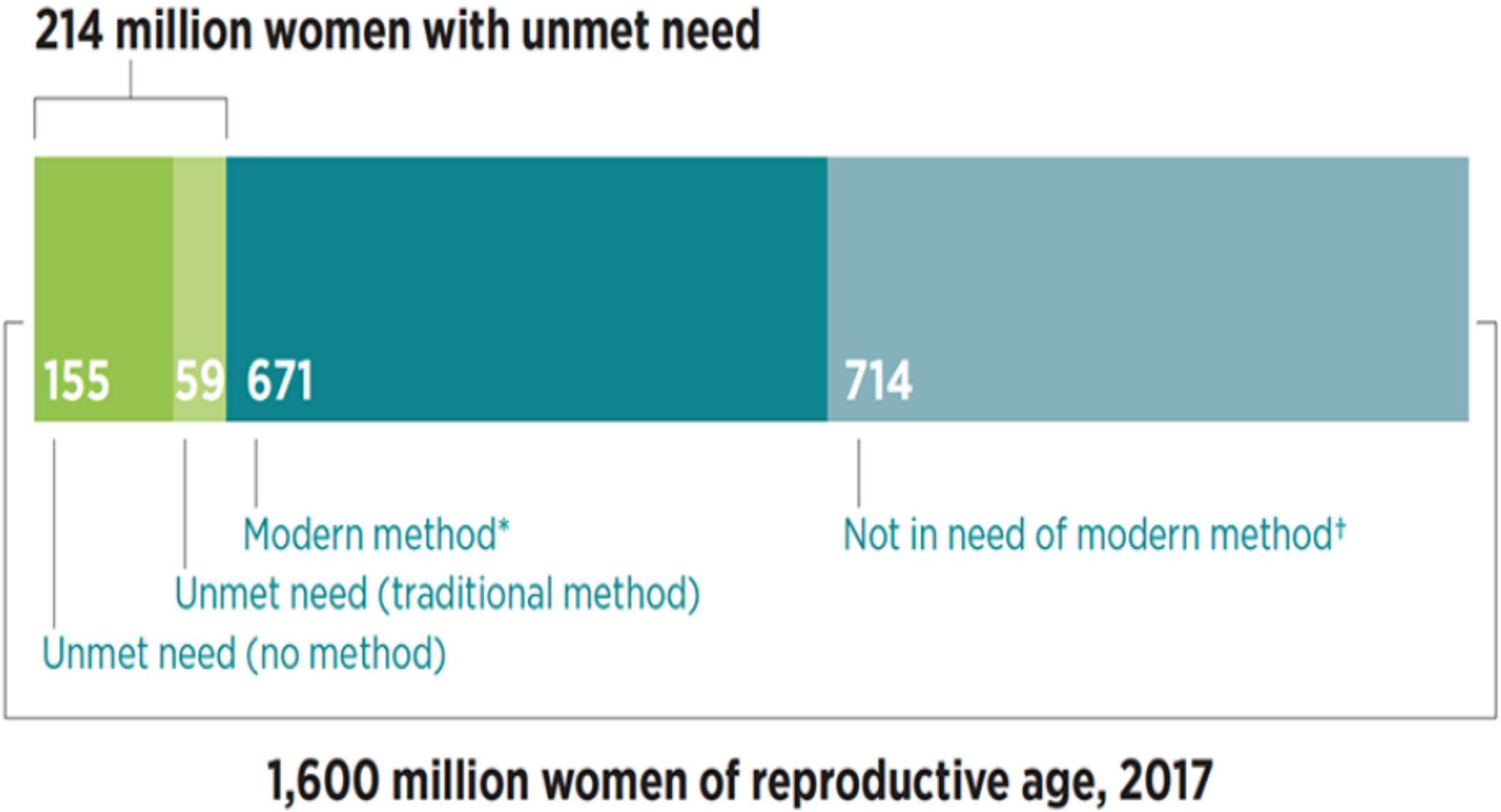
Optional stopping & sex ratio

Assume birth probability of either sex = 1/2.

Births	Proba-bility	Boys	Girls	Children	Boys/ Children	Girls/ Children
B	0.5	1	0	1	1	0
GB	0.25	1	1	2	0.5	0.5
GGB	0.125	1	2	3	0.33333	0.66667
GGGB	0.0625	1	3	4	0.25	0.75
GGGG	0.0625	0	4	4	0	1
	Average	0.9375	0.9375	1.875	0.68229	0.31771

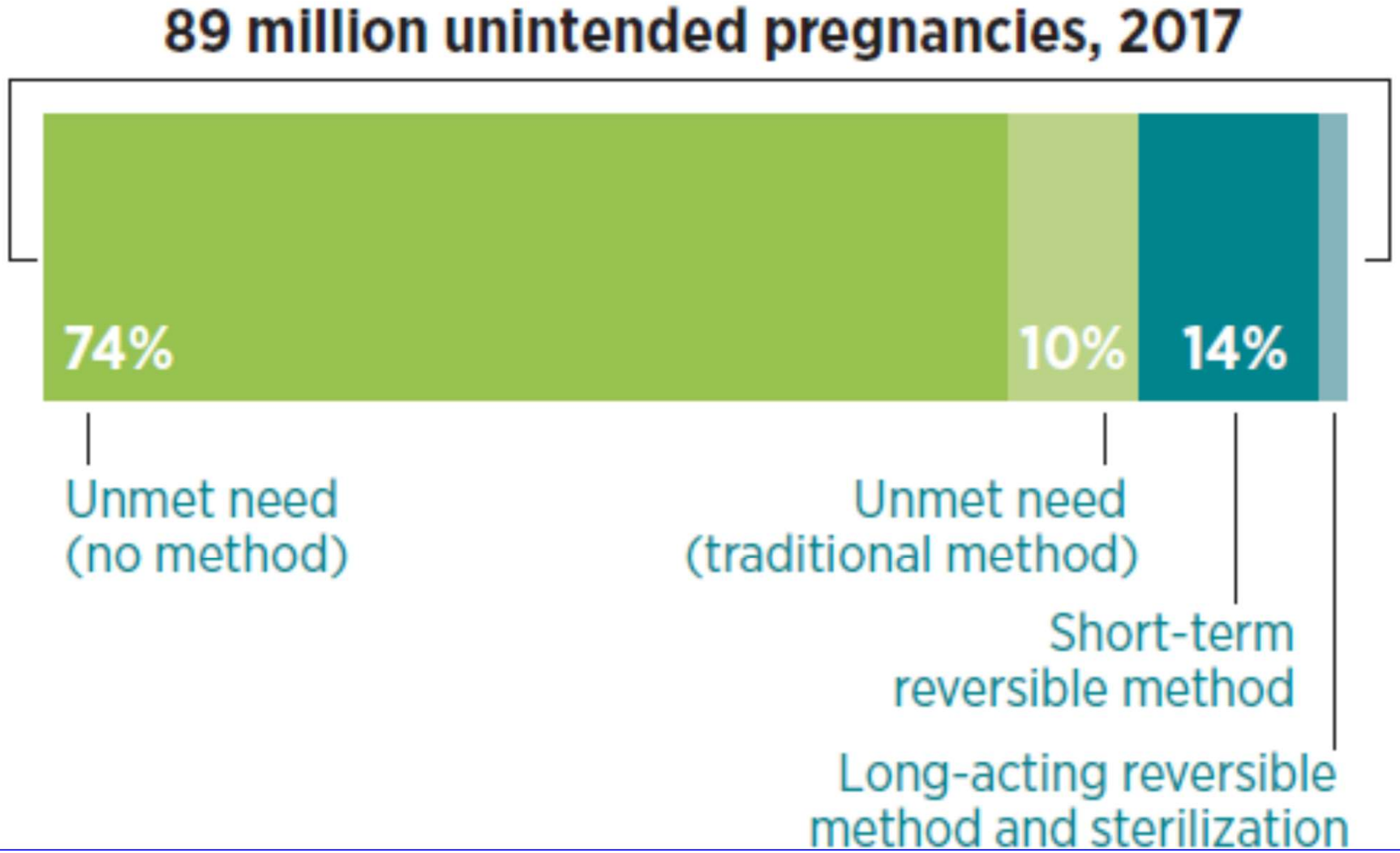
In developing regions, 214 million women want to prevent pregnancy but are not using modern contraception.

Gantmacher Institute, Adding It Up, December 2017

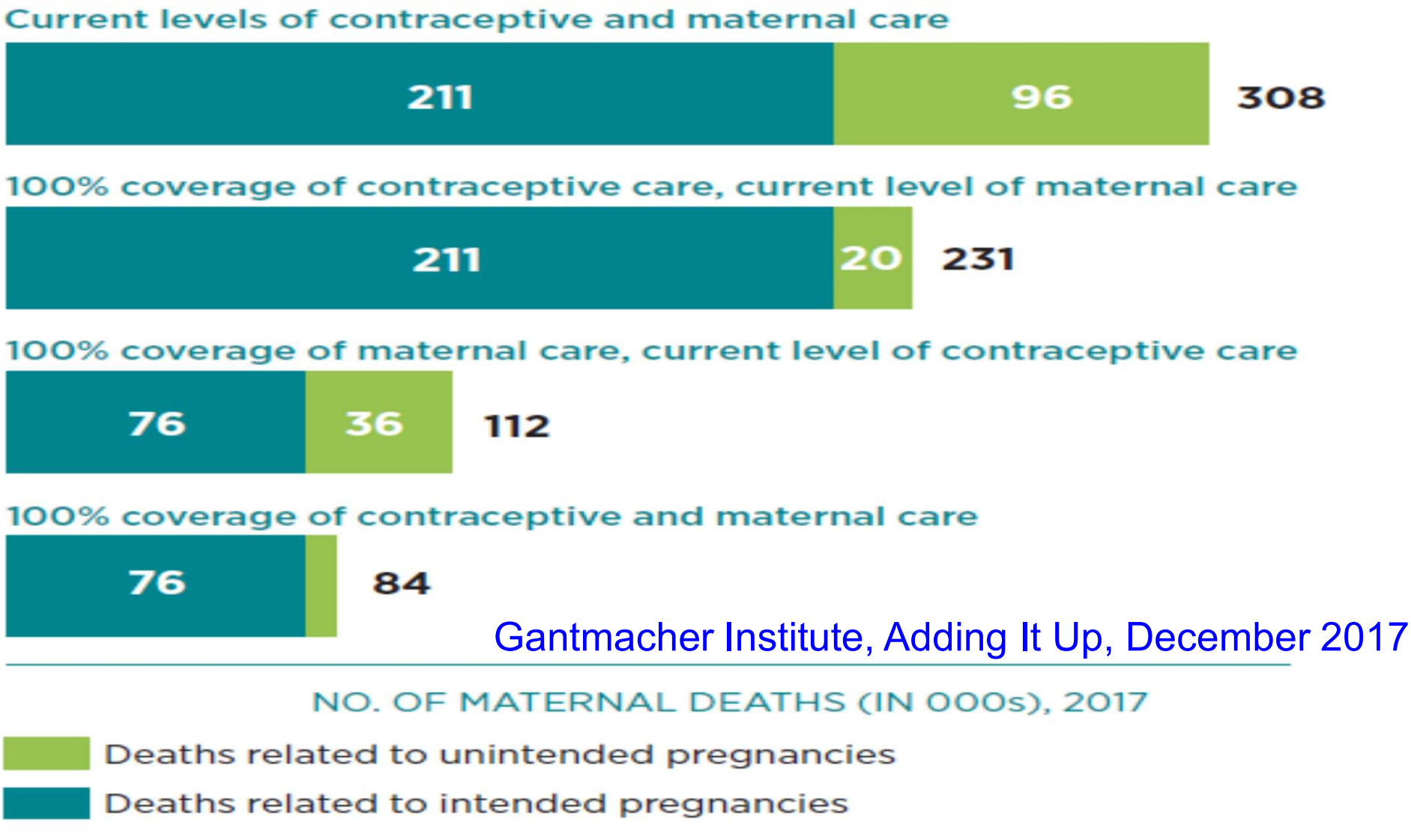


Women with unmet need for modern contraceptive methods account for 84% of unintended pregnancies.

Gantmacher Institute, Adding It Up, December 2017

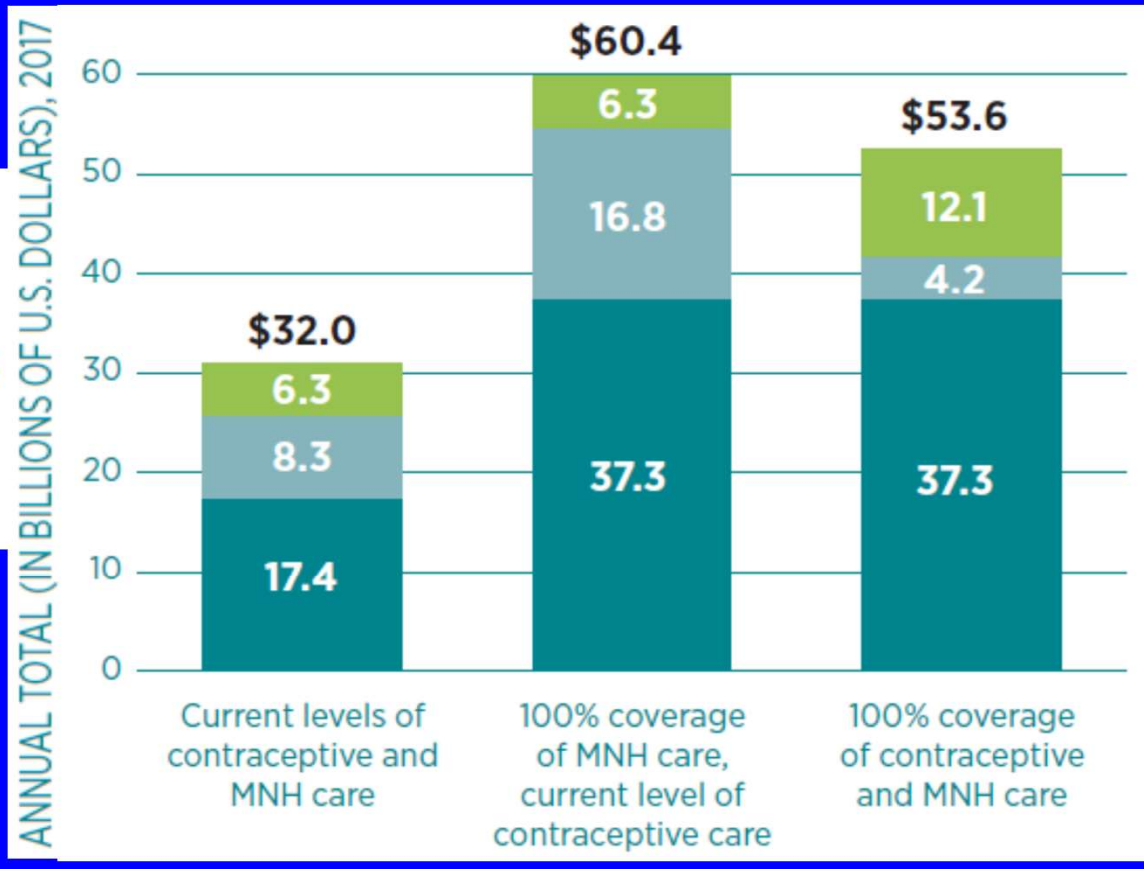


224,000 maternal deaths/year could be prevented.



Gantmacher Institute, Adding It Up, December 2017

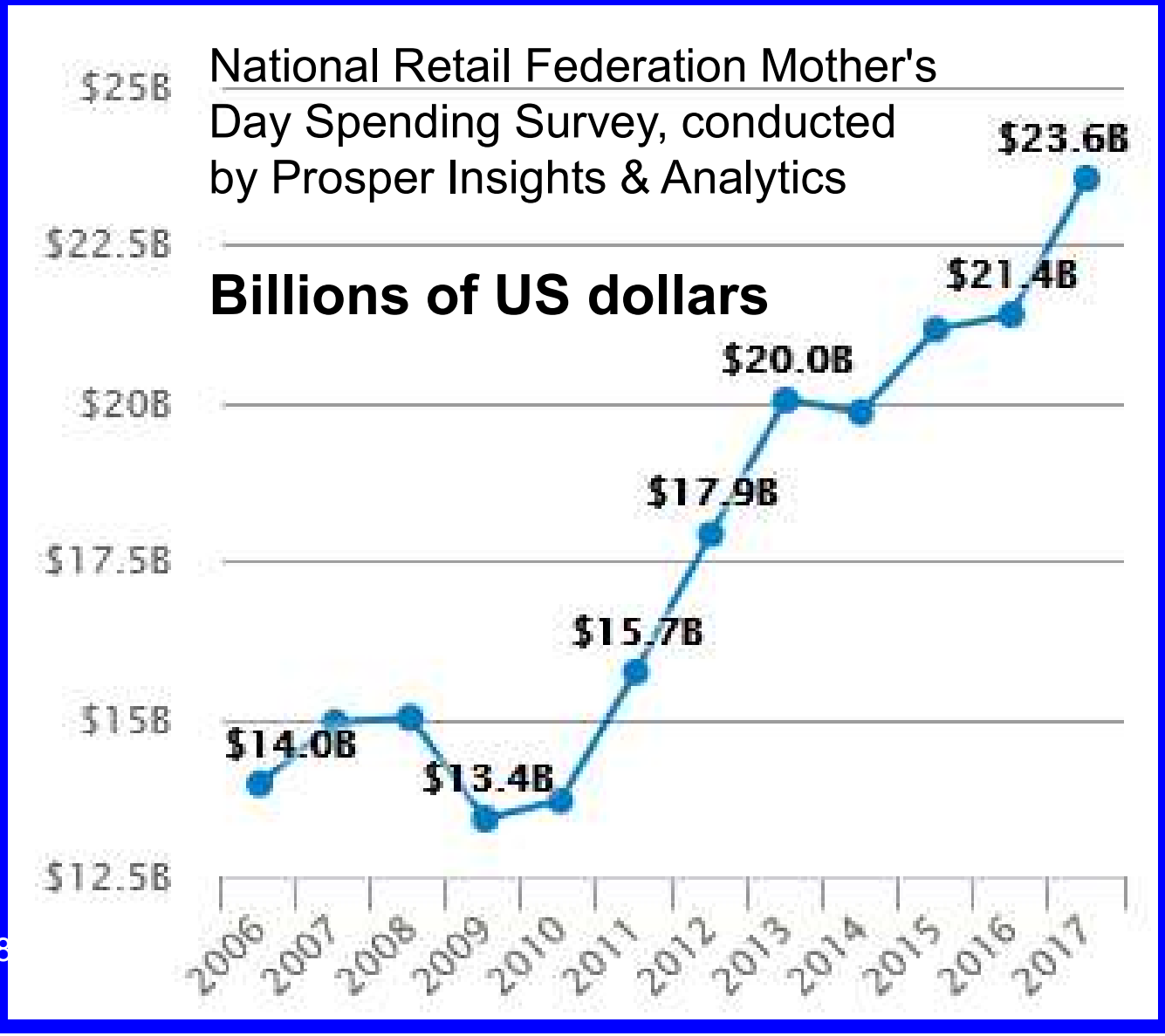
Contraceptive & maternal & newborn health (MNH) coverage for all would cost $21.6 billion more per year than current levels of care.

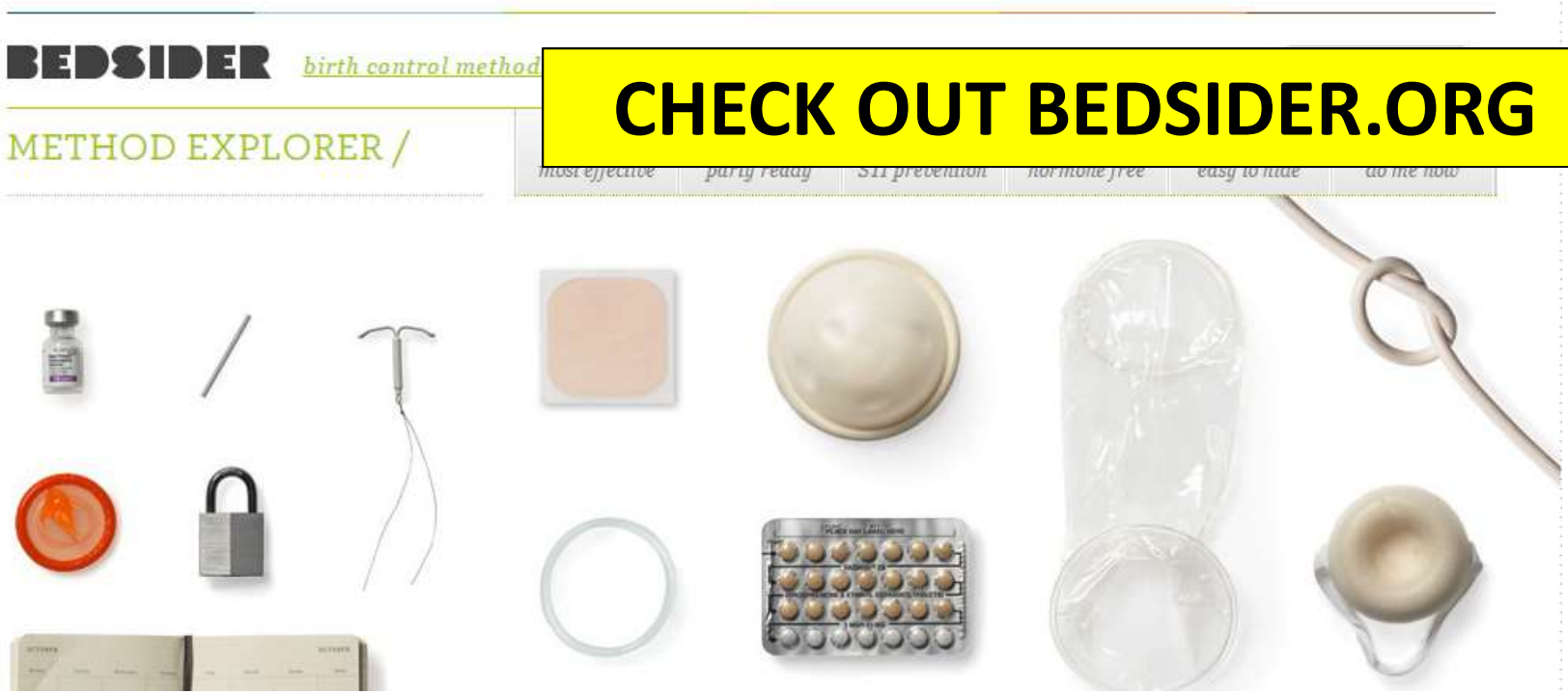


Gantmacher Institute, Adding It Up, December 2017

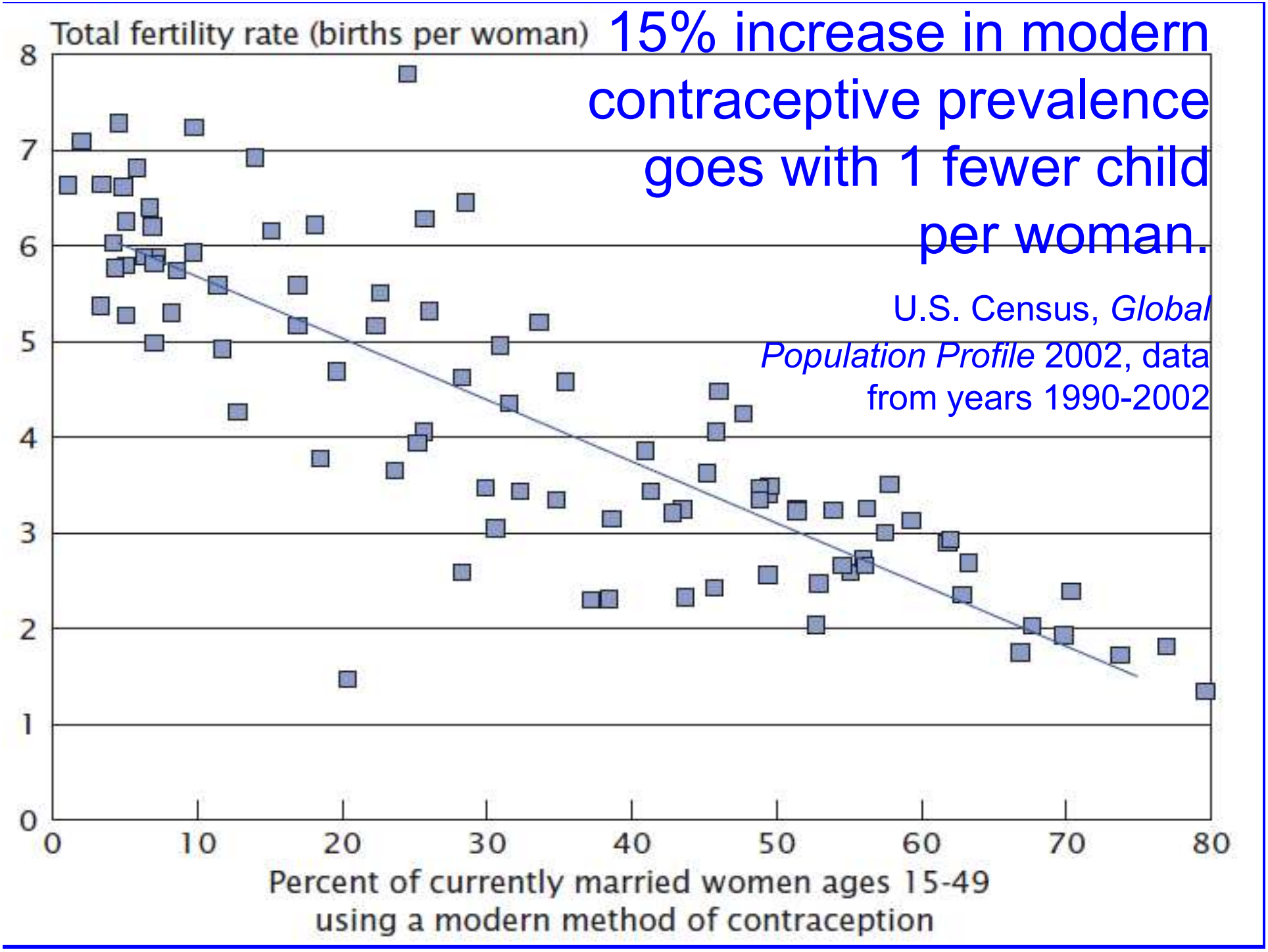
2019-07-08

Planned US Mother's Day spending reached $23.6B in 2017.





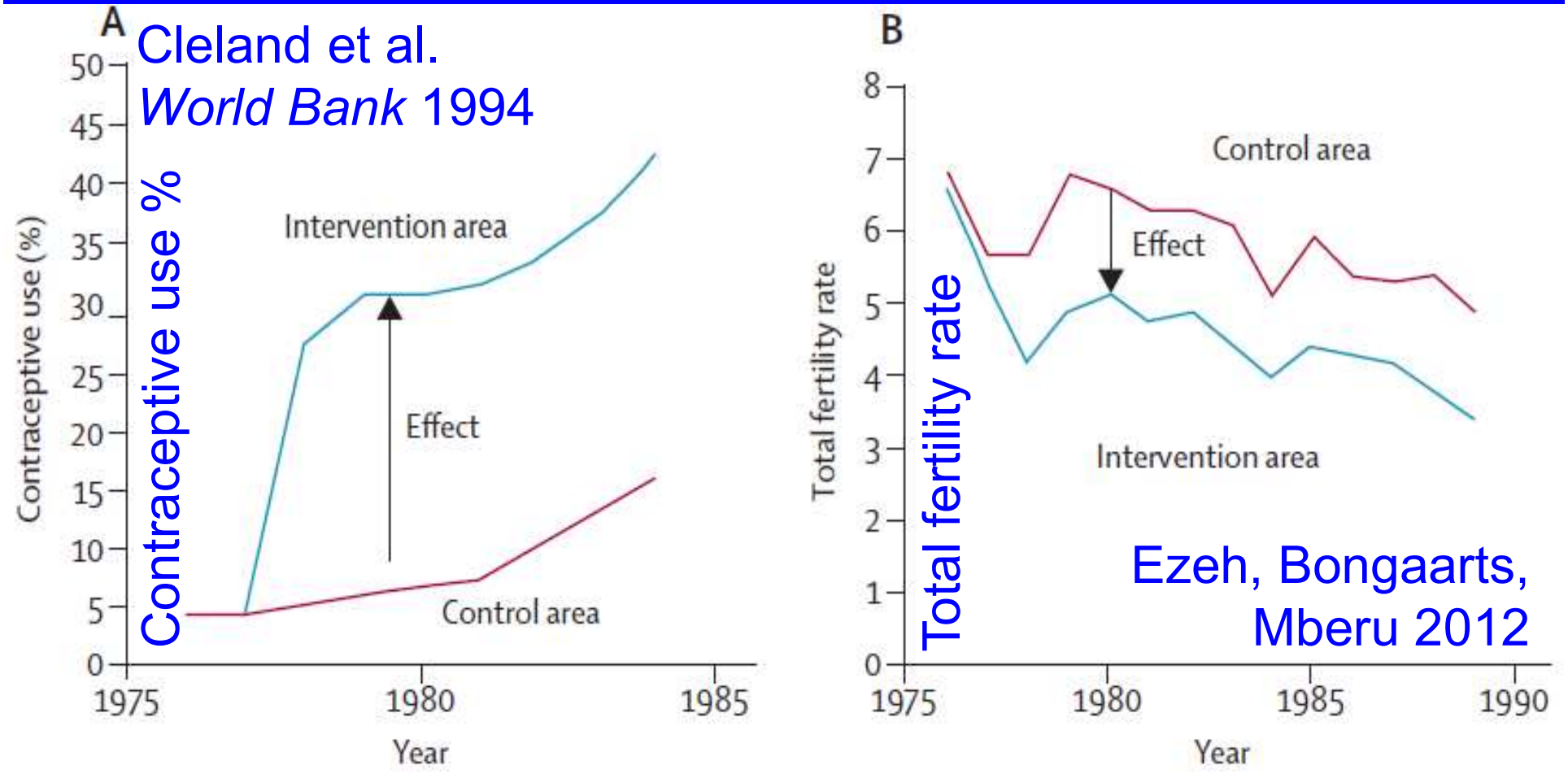
- Random assignment to Bedsider vs. control group found women in Bedsider group less likely to have a pregnancy scare, an unintended pregnancy, or unprotected sex as compared to the control group (Antonishak et al. 2015)



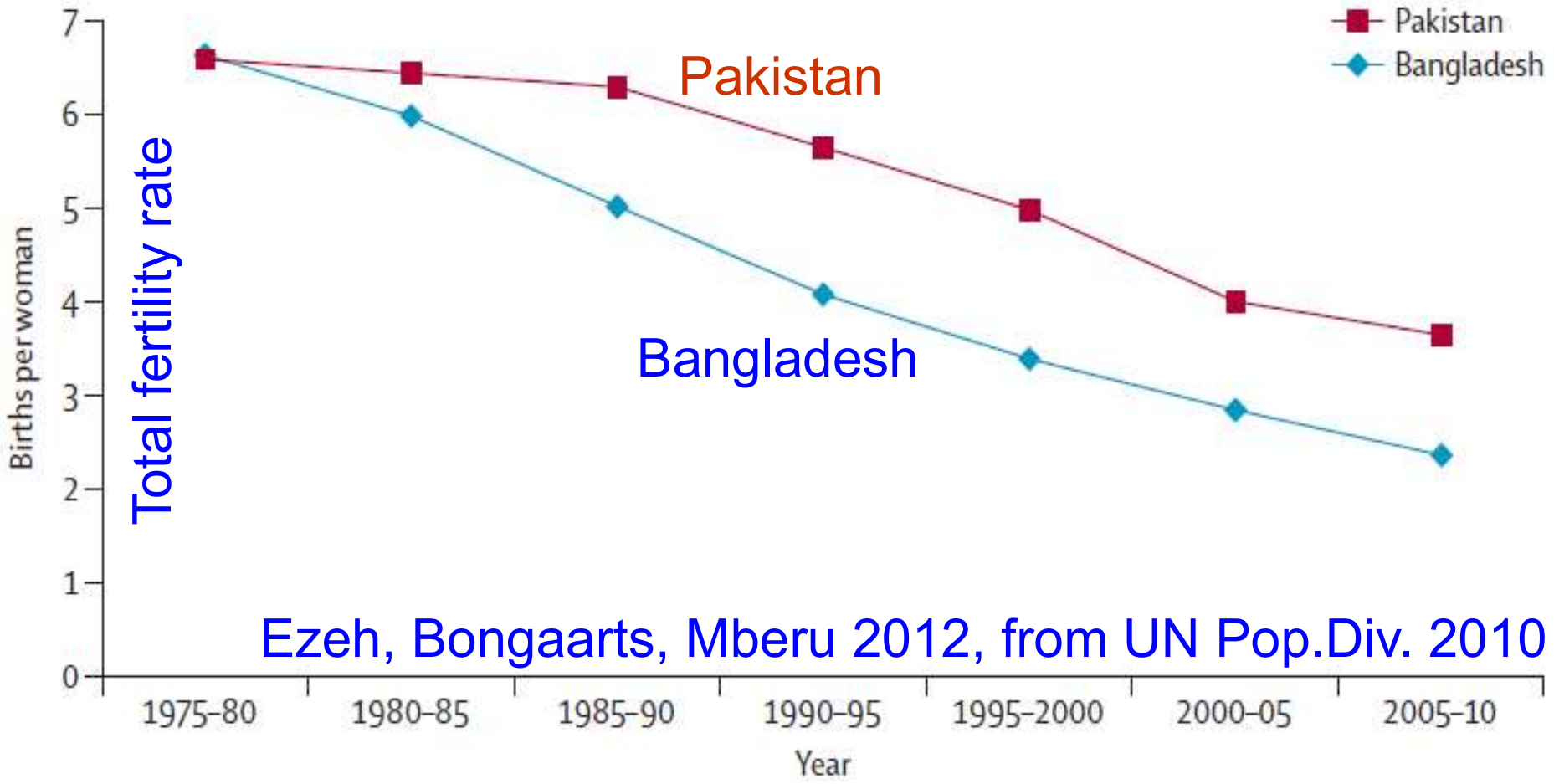
15% increase in modern contraceptive prevalence goes with 1 fewer child per woman.

U.S. Census, *Global Population Profile* 2002, data from years 1990-2002

Contraceptive use lowered fertility in Matlab, Bangladesh.

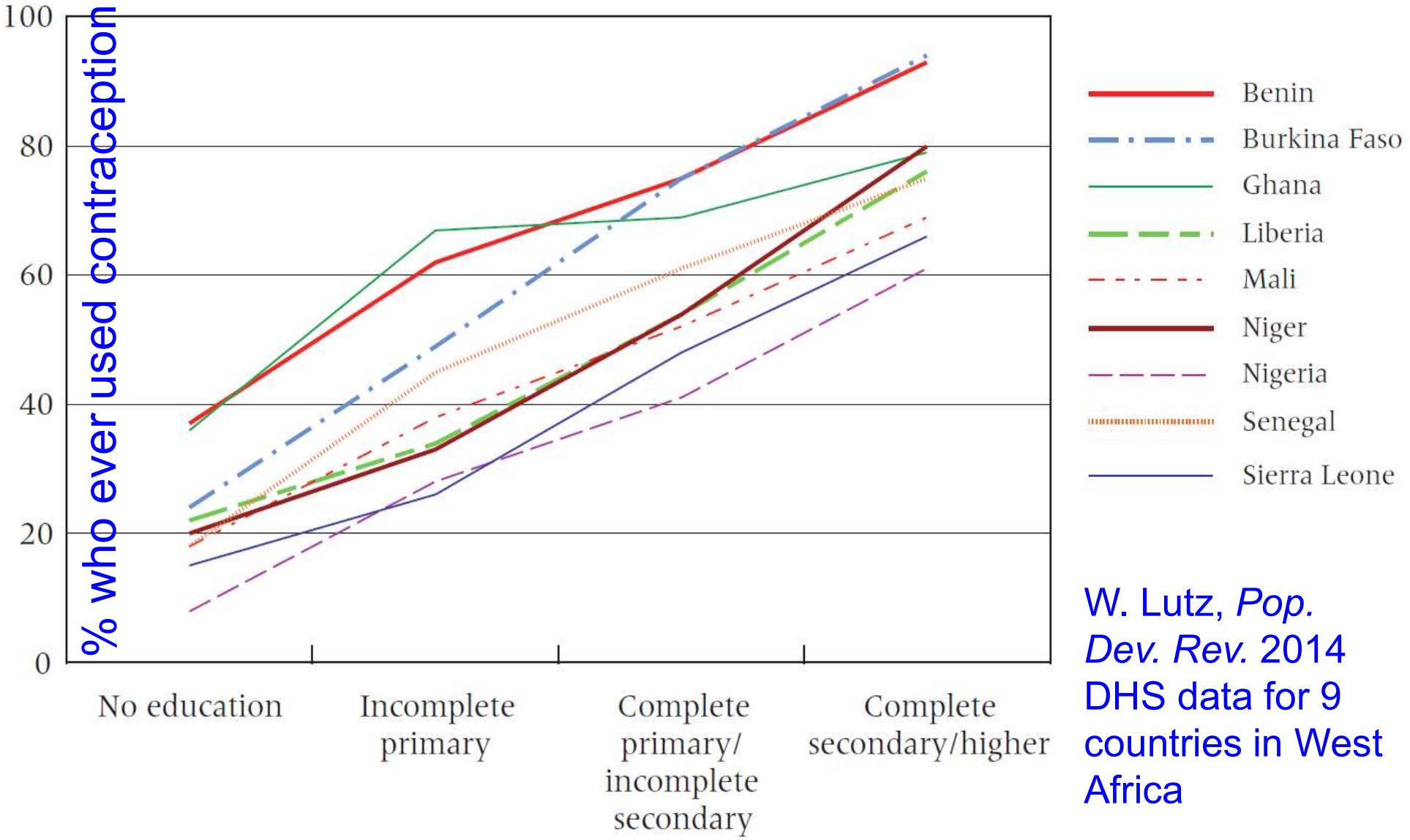


National policy affected fertility.



Ezeh, Bongaarts, Mberu 2012, from UN Pop.Div. 2010

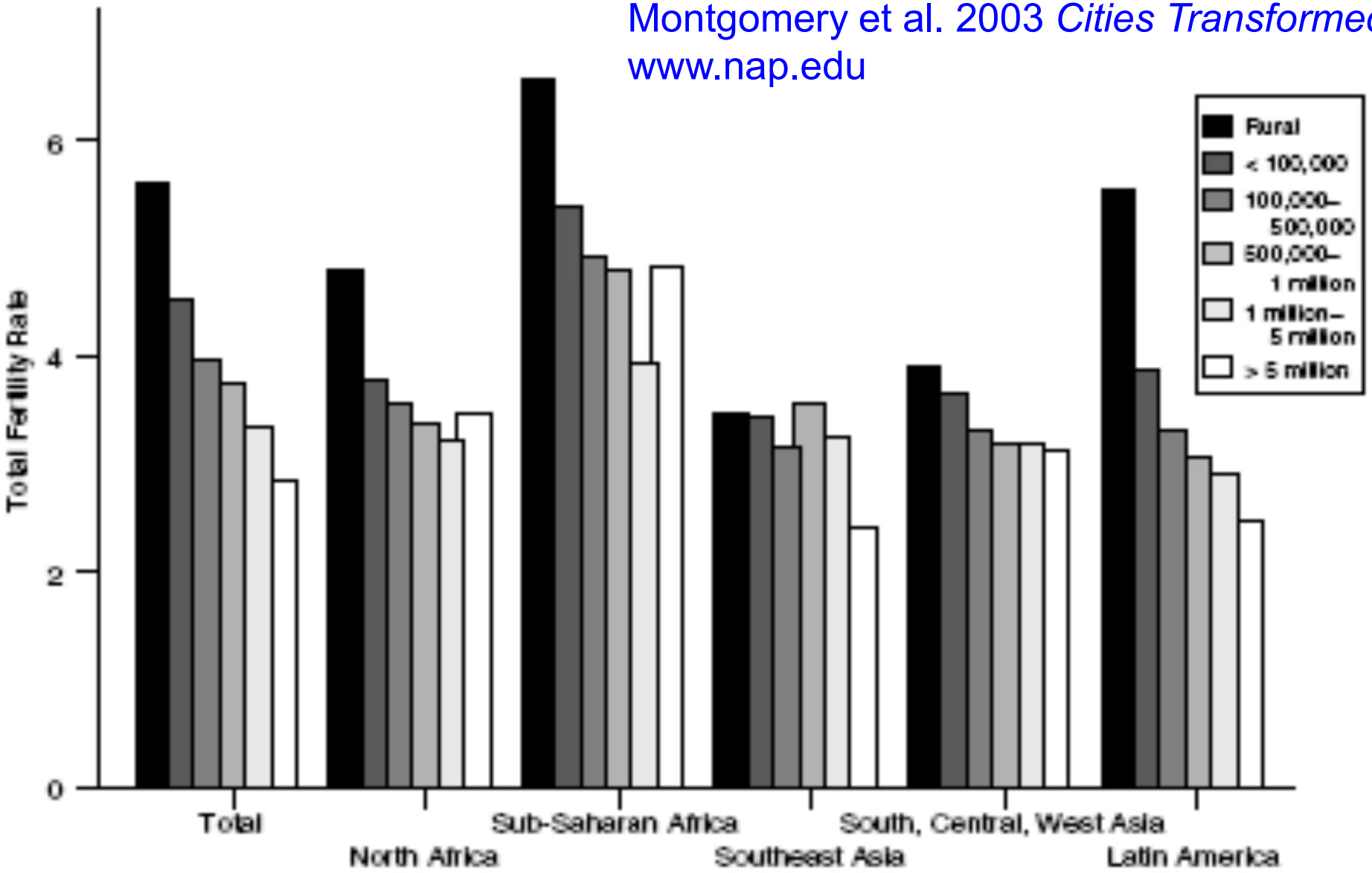
More educated women use contraception more.



W. Lutz, *Pop. Dev. Rev.* 2014 DHS data for 9 countries in West Africa

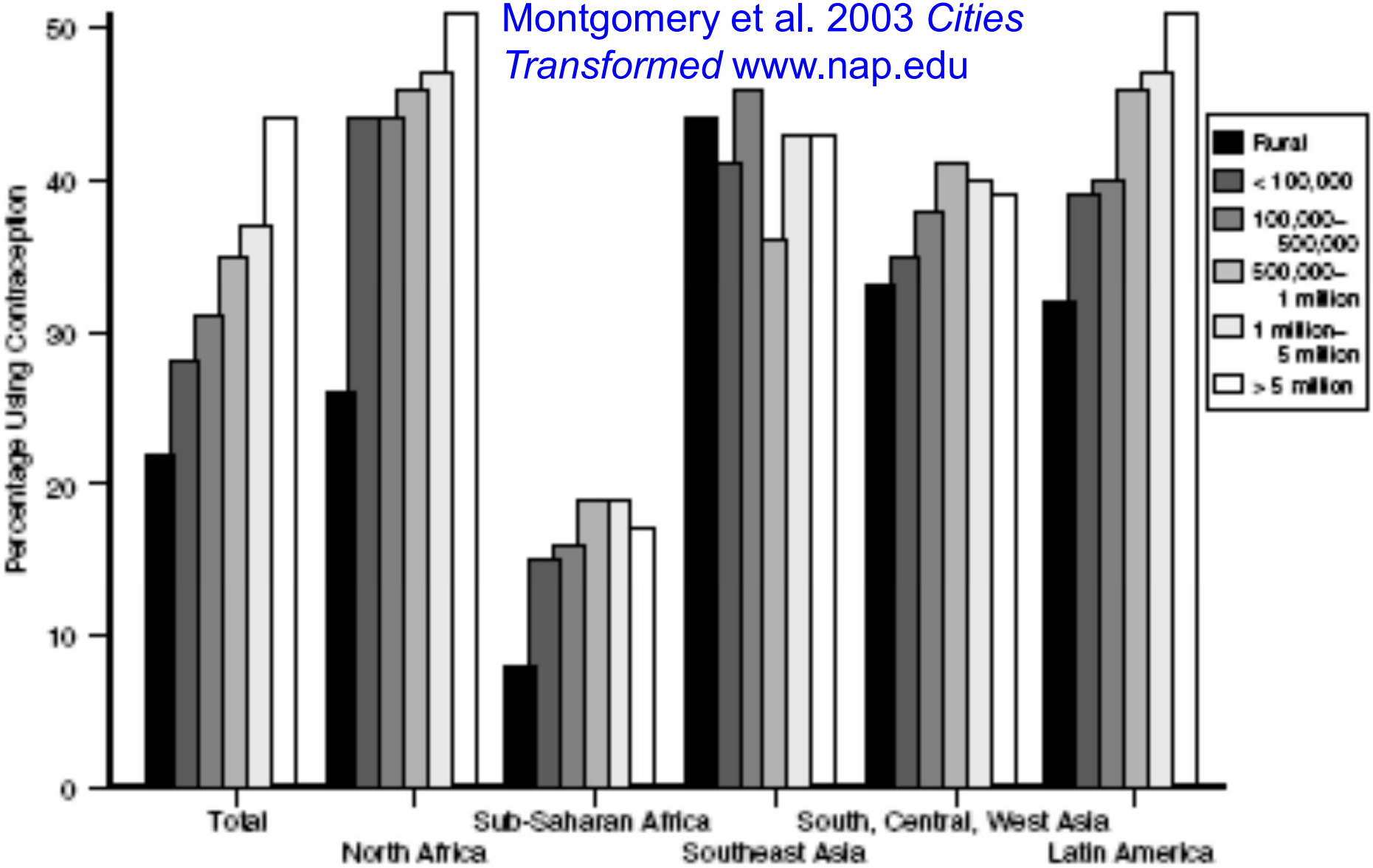
Total fertility rates decline from rural to urban areas.

Montgomery et al. 2003 *Cities Transformed*
www.nap.edu



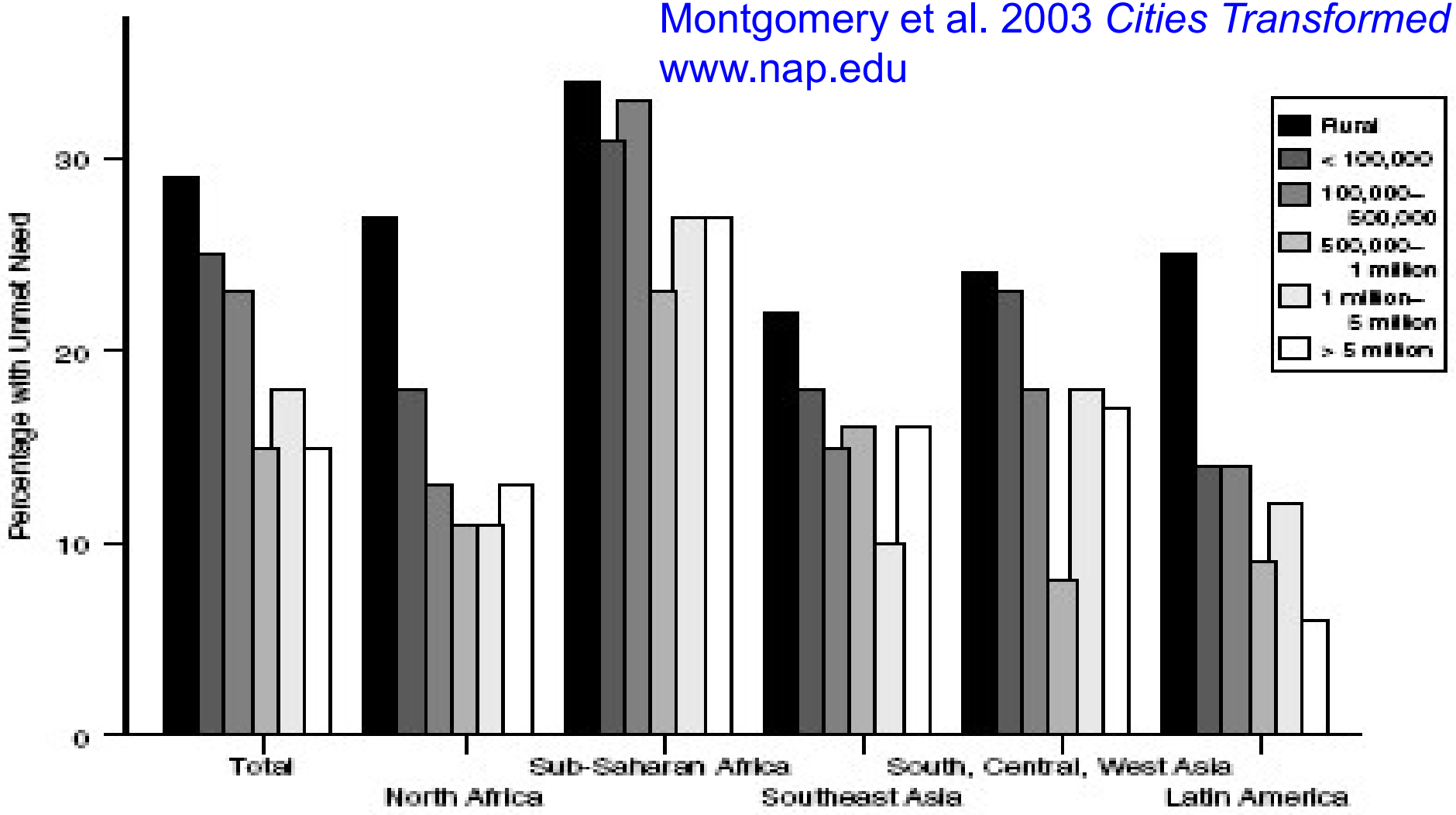
Modern contraceptive use increases from rural to urban areas in most regions.

Montgomery et al. 2003 *Cities Transformed* www.nap.edu

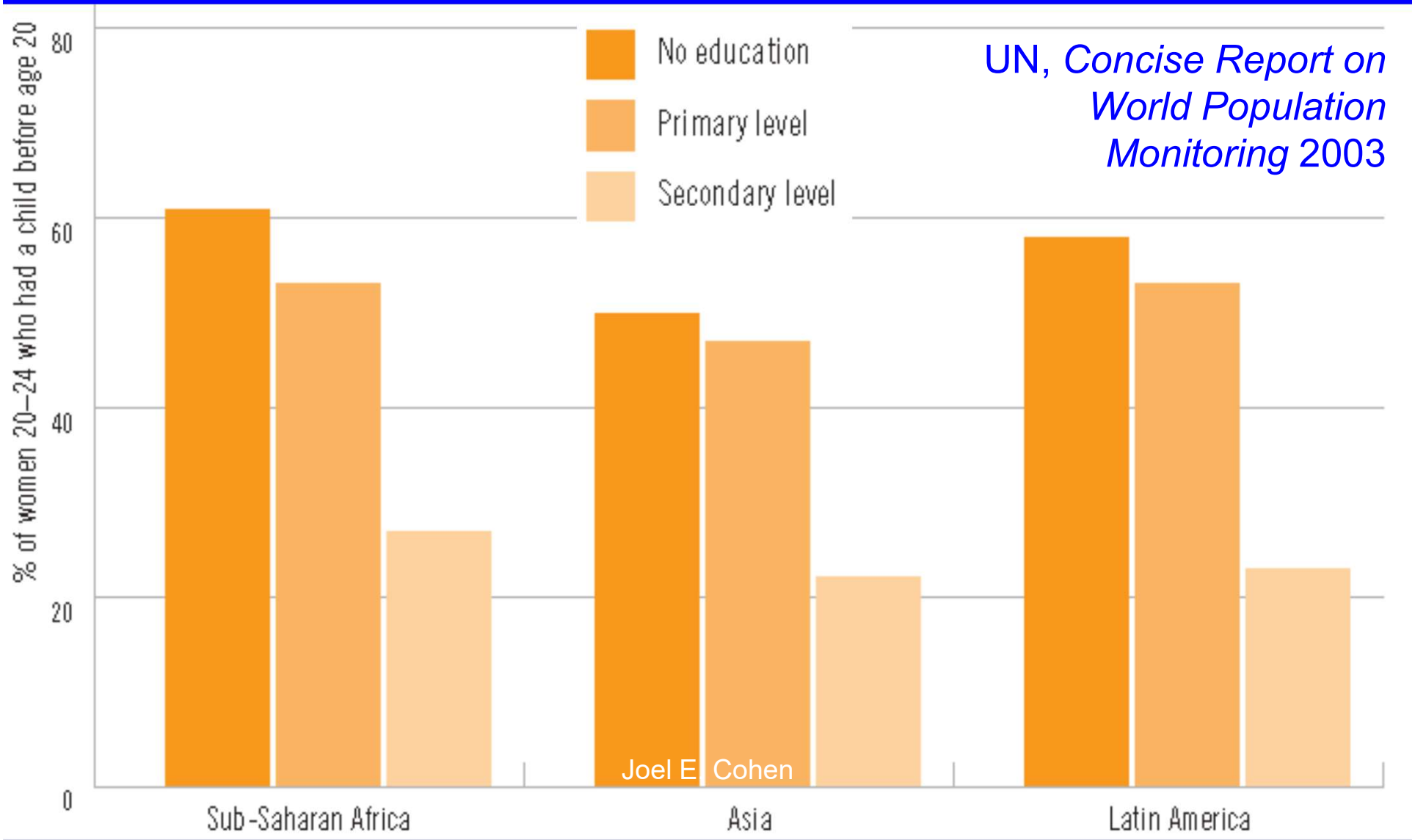


Unmet need for contraception is greatest in rural & small urban areas.

Montgomery et al. 2003 *Cities Transformed*
www.nap.edu

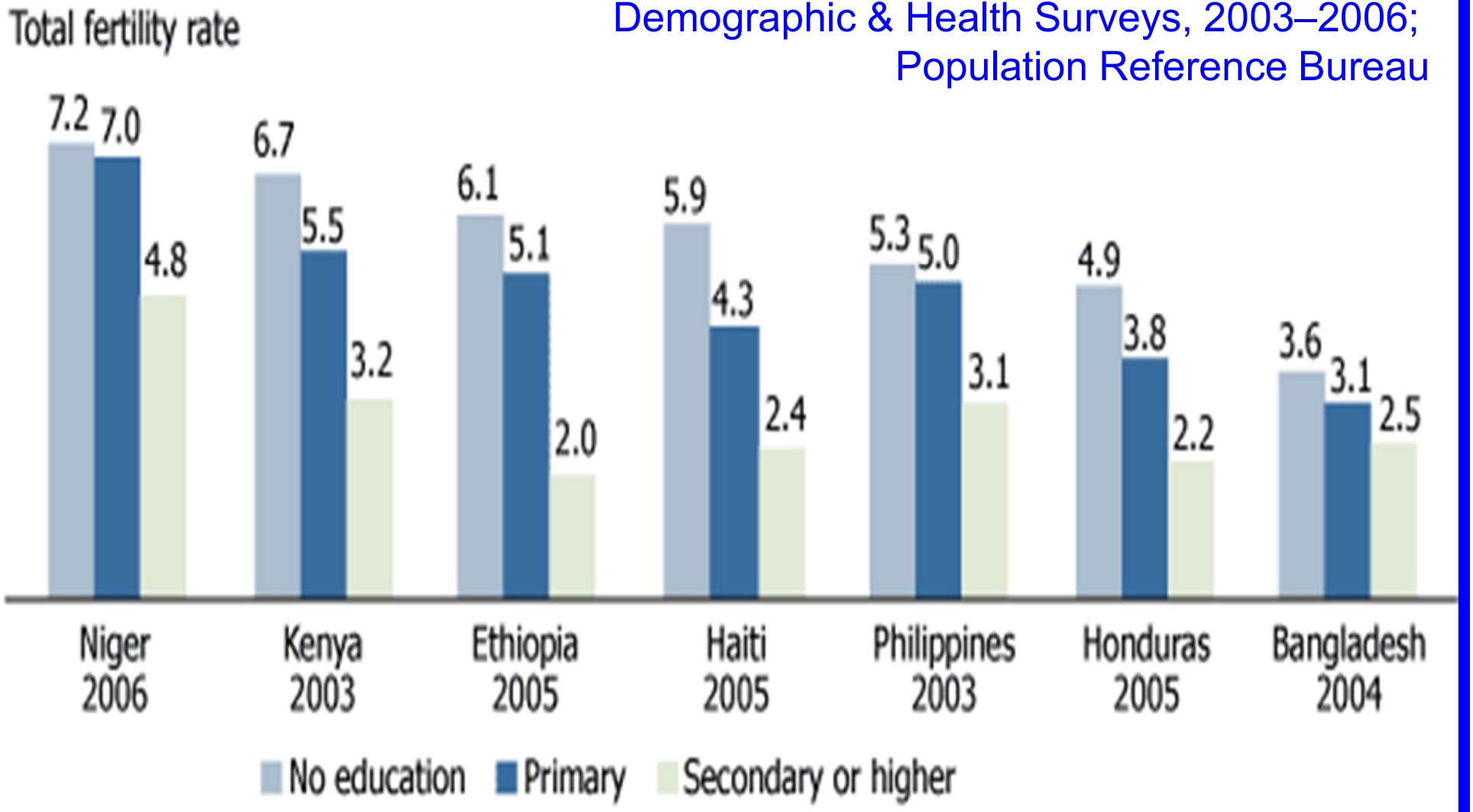


Women with more education are less likely to have children before age 20.

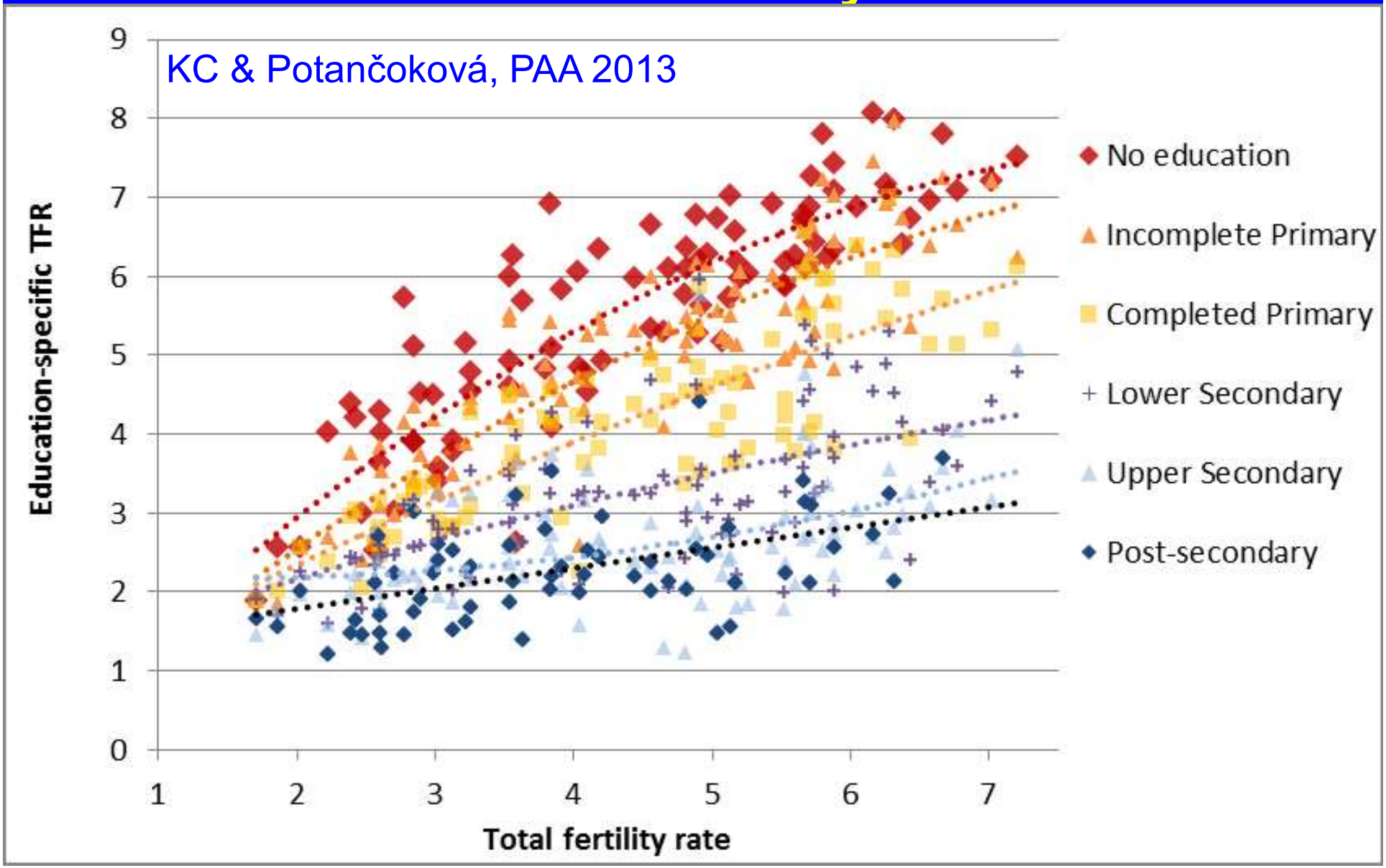


UN, *Concise Report on World Population Monitoring* 2003

More educated women have fewer children almost everywhere.



The lower a country's overall TFR, the closer its TFRs by education.



Fertility decline has many effects.

In future,

1. fewer individuals;

2. smaller household size, so for given population size, more households.

Montpellier, France

Is low fertility really a problem? Population aging, dependency, and consumption

Montgomery et al. 2003 *Cities Transformed*

Montgomery et al. 2003 *Cities Transformed*

www.nap.edu

www.nap.edu

Ronald Lee,[1]* Andrew Mason,[2,3]* members of the NTA Network†

Longer lives and fertility far below the replacement level of 2.1 births per woman are leading to rapid population aging in many countries. Many observers are concerned that aging will adversely affect public finances and standards of living. Analysis of newly available National Transfer Accounts data for 40 countries shows that fertility well above replacement would typically be most beneficial for government budgets. However, fertility near replacement would be most beneficial for standards of living when the analysis includes the effects of age structure on families as well as governments. And fertility below replacement would maximize per capita consumption when the cost of providing capital for a growing labor force is taken into account. Although low fertility will indeed challenge government programs and very low fertility undermines living standards, we find that moderately low fertility and population decline favor the broader material standard of living.

Science sciencemag.org 2014-10-10 346(6206):229-234

Survival, mortality, age

Concepts of chronological age & lifespan

1. One person

In Gregorian (Western) calendar, people are born at age 0. Age increases by 1 year on each anniversary of birthday.

In traditions of China, Japan, Korea, child is born at age 1 (ordinal number of first year of life), & age is increased by 1 at each following lunar new year.

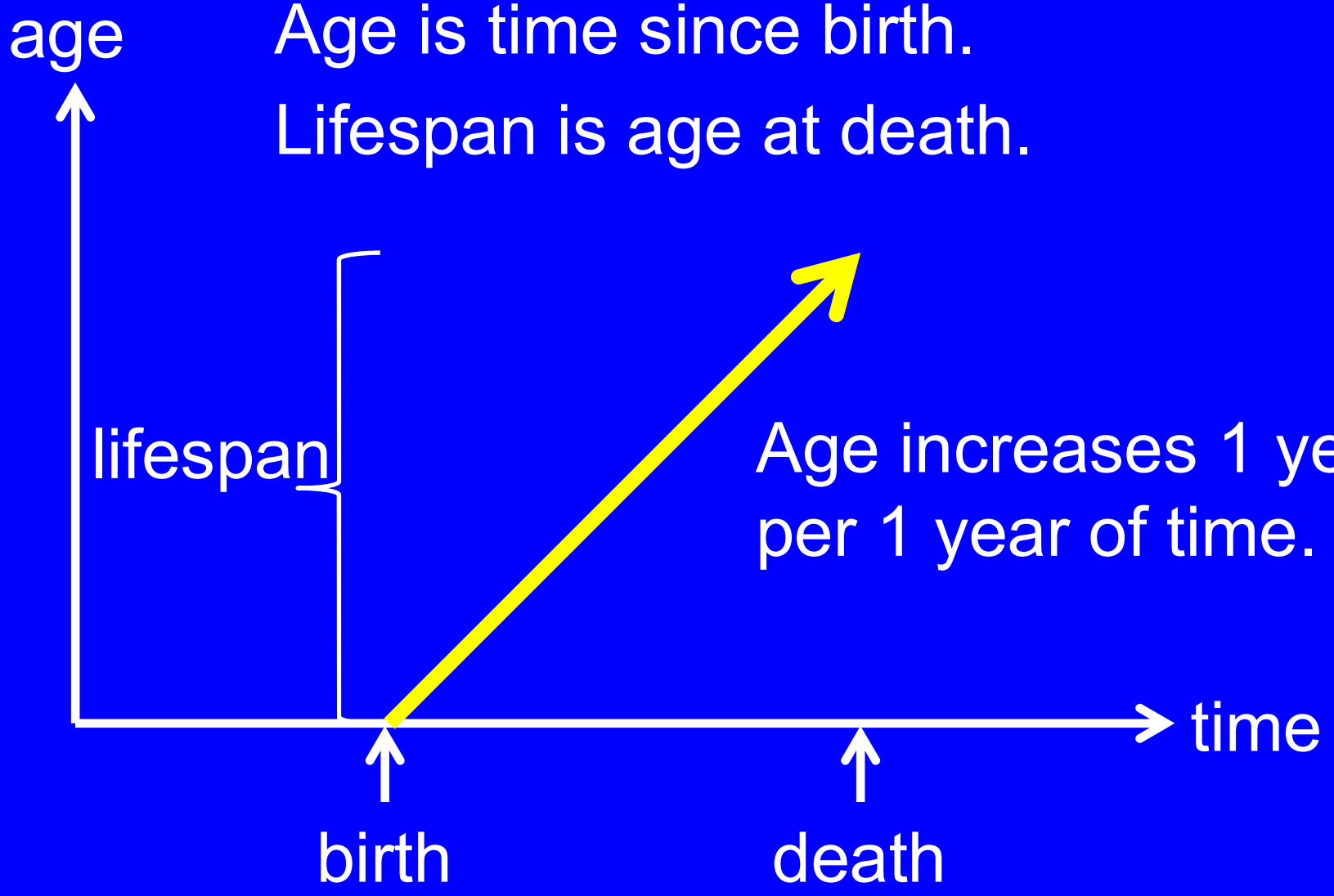
Concepts of chronological age & lifespan

1. One person
2. Cohort population: group of people *born* in a time interval, followed through time
3. Period population: group of people *alive* in a time interval, during that interval only
4. Population: group of people, over time, increasing by births & immigration, decreasing by deaths & emigration

One person

Age is time since birth.

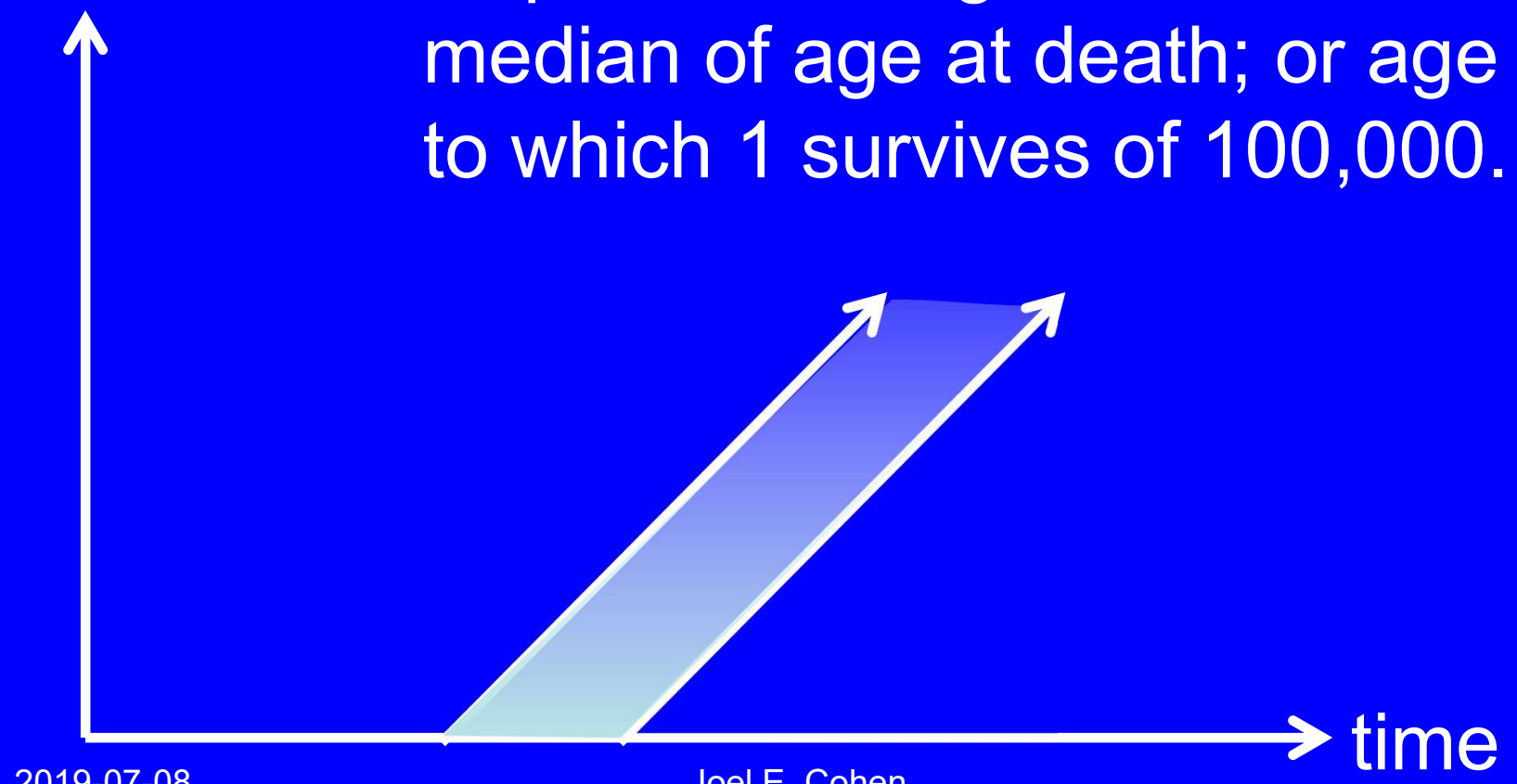
Lifespan is age at death.



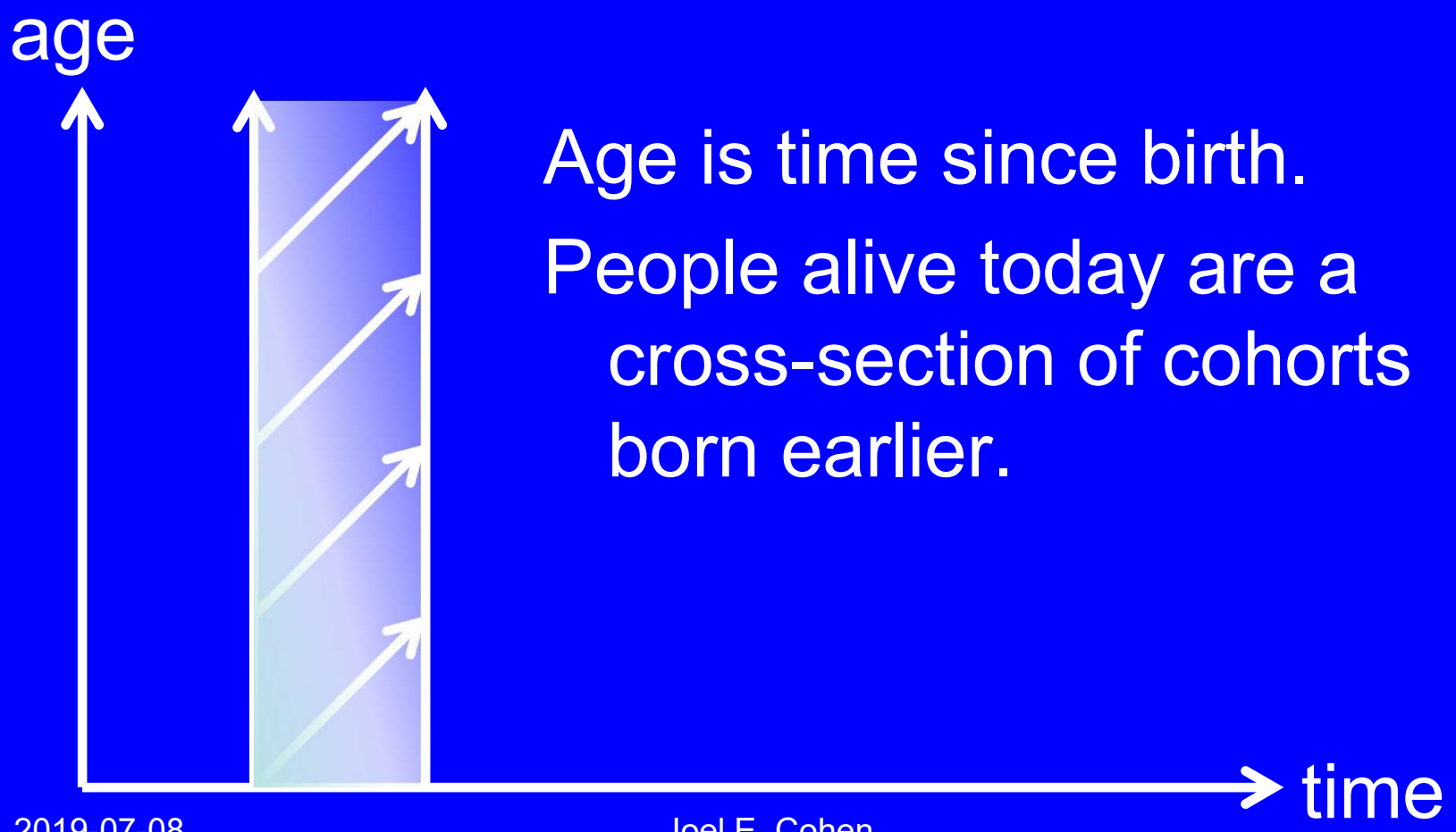
Cohort population: people *born* in a time interval

Age is time since birth.

Lifespan is average, mode, or median of age at death; or age to which 1 survives of 100,000.



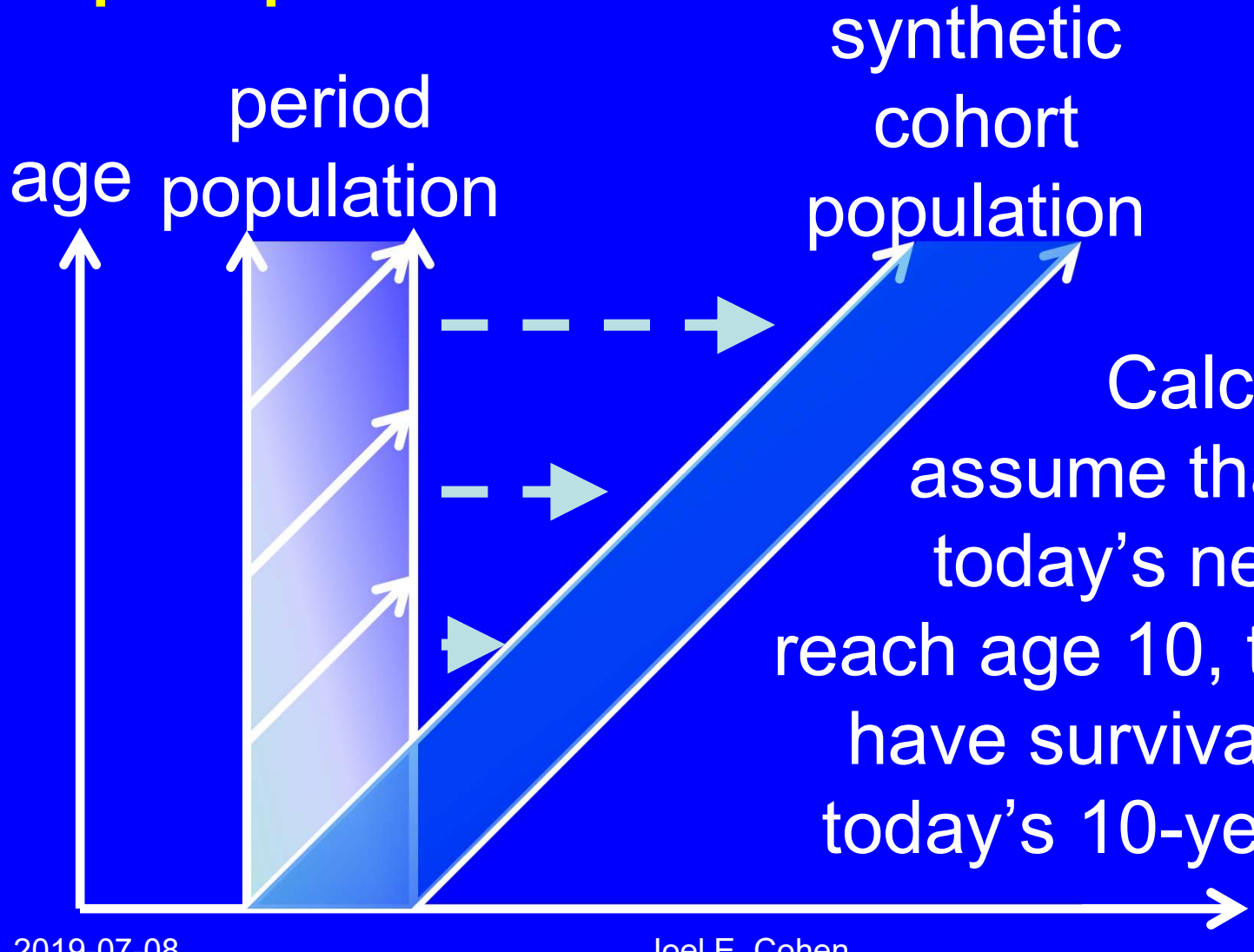
Period population: people *alive* in a time interval



Age is time since birth.

People alive today are a cross-section of cohorts born earlier.

Period population: people *alive* in a time interval



Calculations assume that when today's newborns reach age 10, they will have survival rate of today's 10-year-olds.

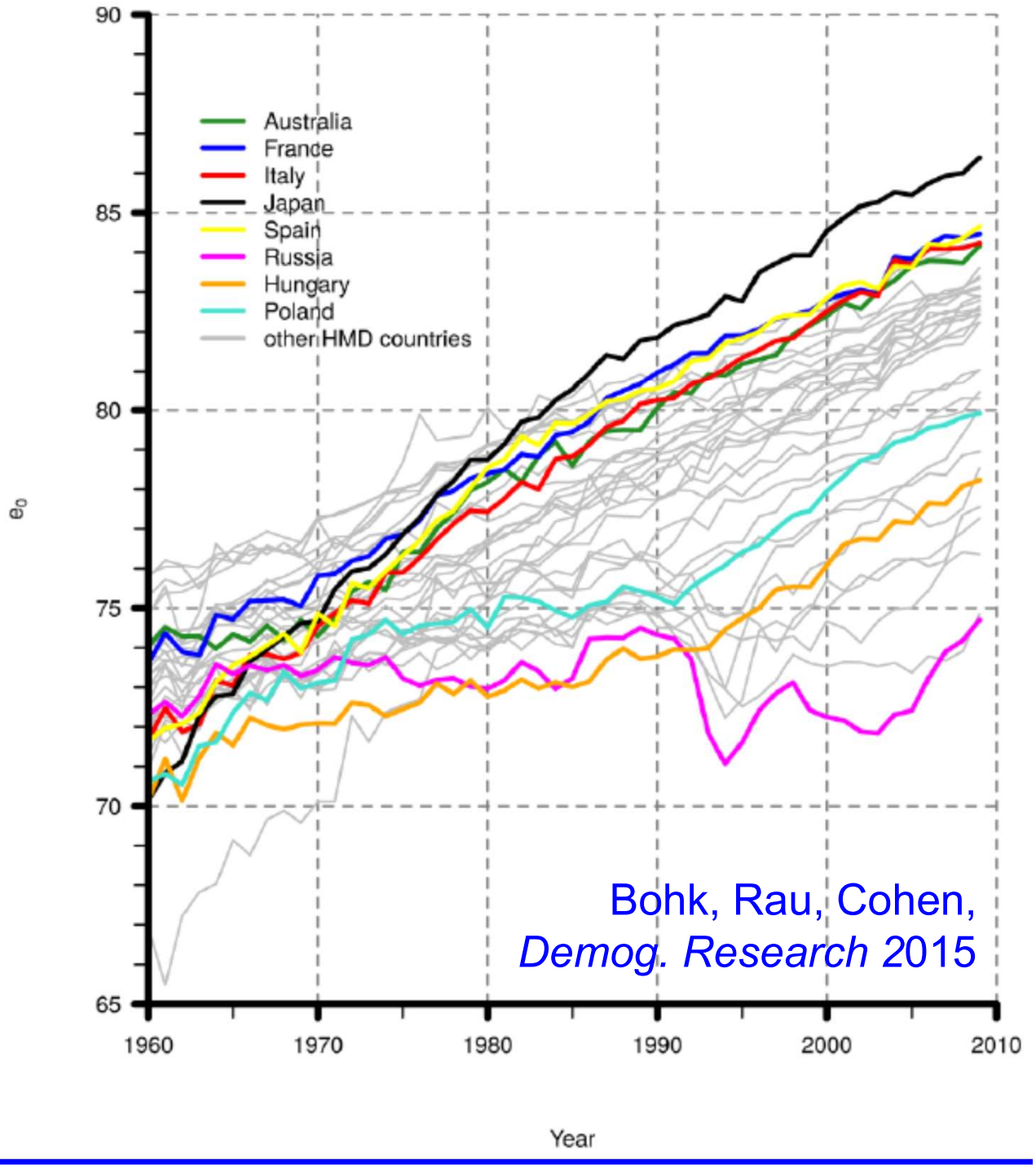
Period life expectancy

Period life expectancy at birth is a summary of present age-specific rates of survival, like the reading on a car's speedometer.

Period life expectancy at birth is NOT a prediction of the average remaining life length of a person alive today. Survival may improve or worsen in the future.

A speedometer reading of 100 km/hour does NOT mean you will be 100 km ahead after one hour.

Period life expectancy at birth for women of countries in Human Mortality Database (2014), 1960-2009



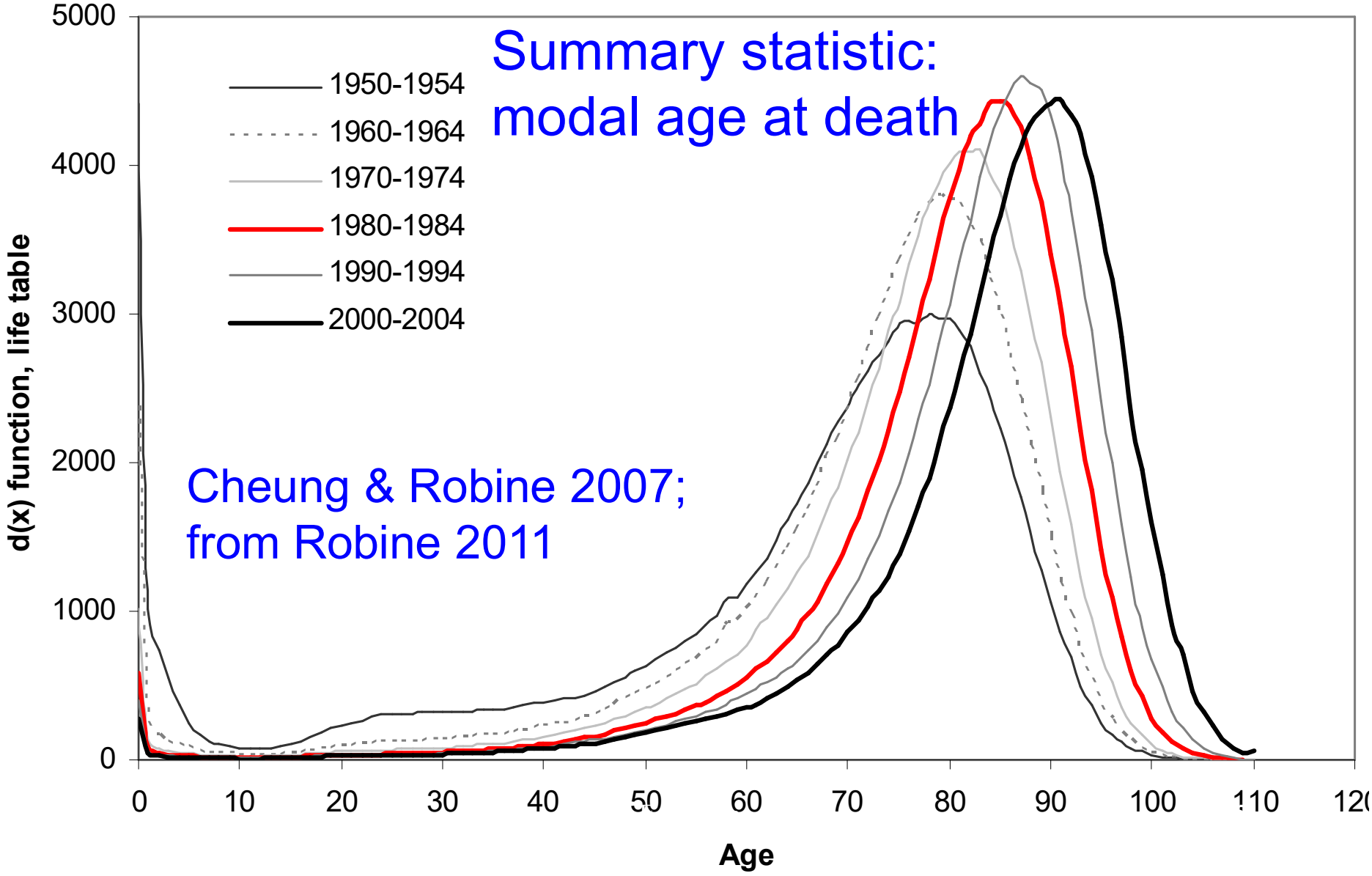
Population lifespan

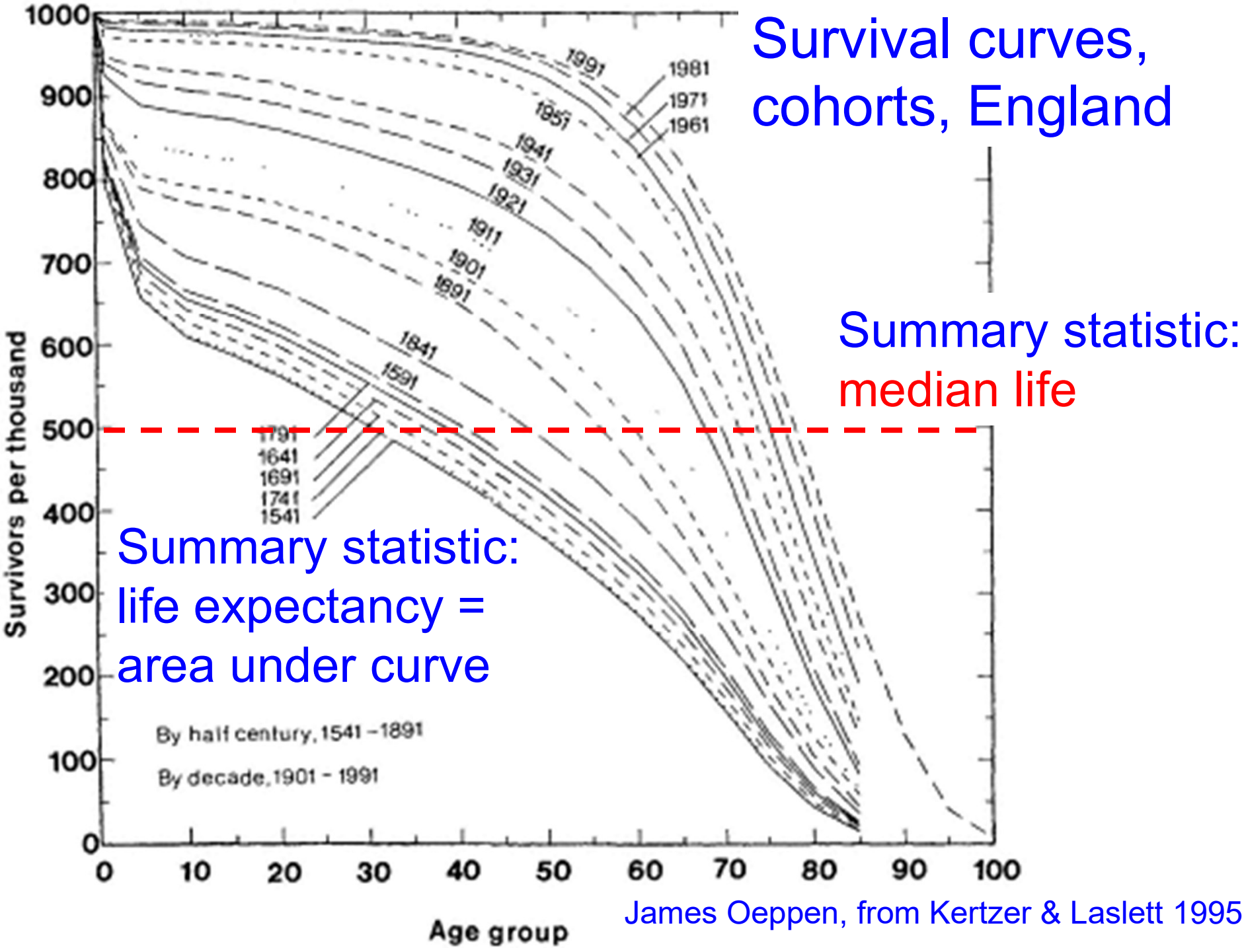
"Lifespan" of a population may be generations, centuries or millennia.

How to describe mortality in a (cohort or period) population?

1. Distribution of length of life
   = distribution of age at death
   (probability density function)
2. Life table, or survival curve
   (1 – cumulative distribution function)

Distribution of ages at death, women in Japan, 1950-54 to 2000-2004





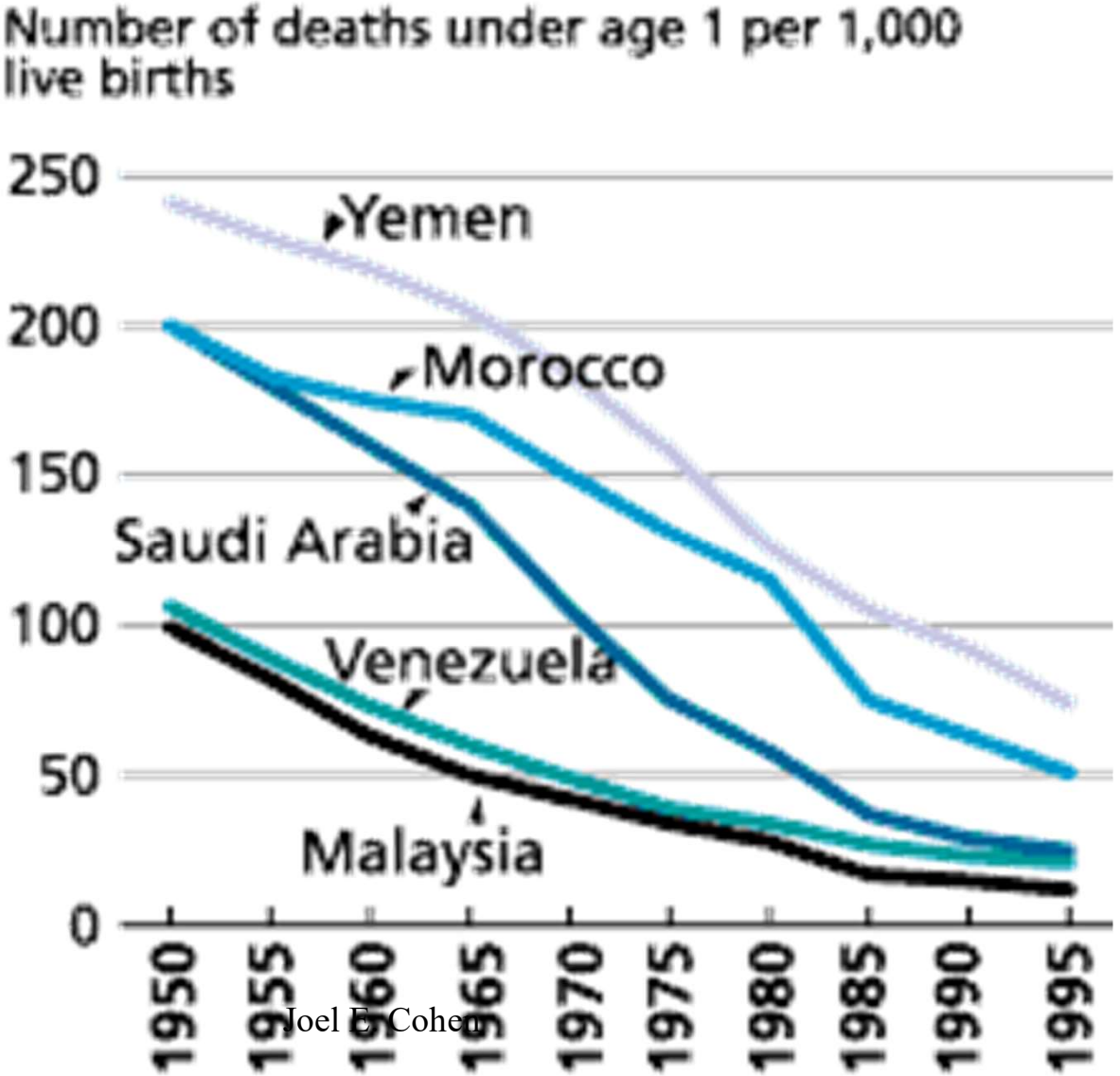
Survival curves, cohorts, England

Summary statistic: median life

Summary statistic: life expectancy = area under curve

James Oeppen, from Kertzer & Laslett 1995

Infant mortality rates fell.



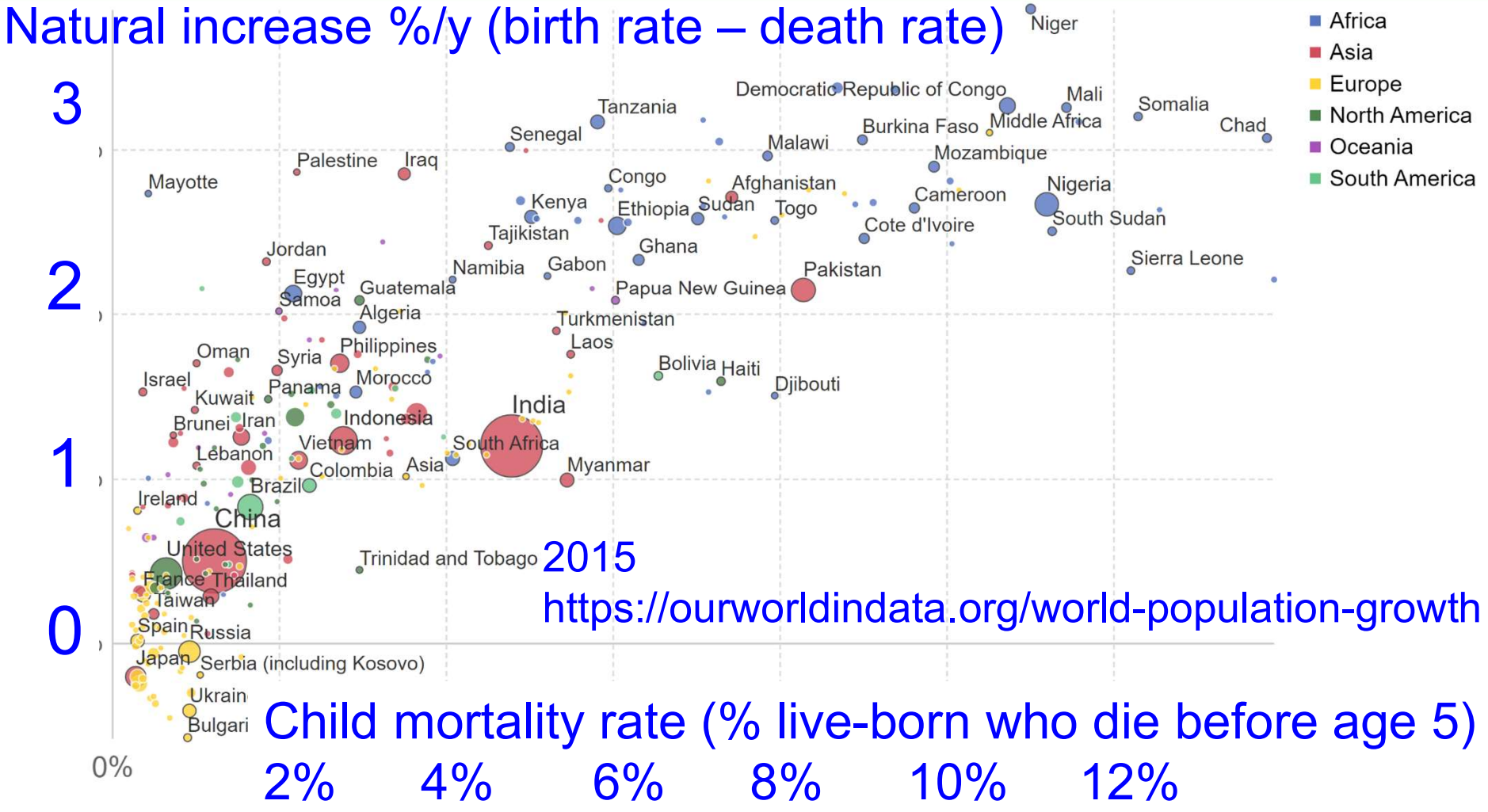
Deaths of children under 5 fell from 9% of live births in 1990 to 4.6% in 2013.

"All regions except Sub-Saharan Africa and Oceania have reduced the rate by 52 percent or more. The global under-five mortality rate is falling faster than at any other time during the past two decades."

"About half of under-five deaths occur in only five countries: India, Nigeria, Pakistan, Democratic Republic of the Congo and China."

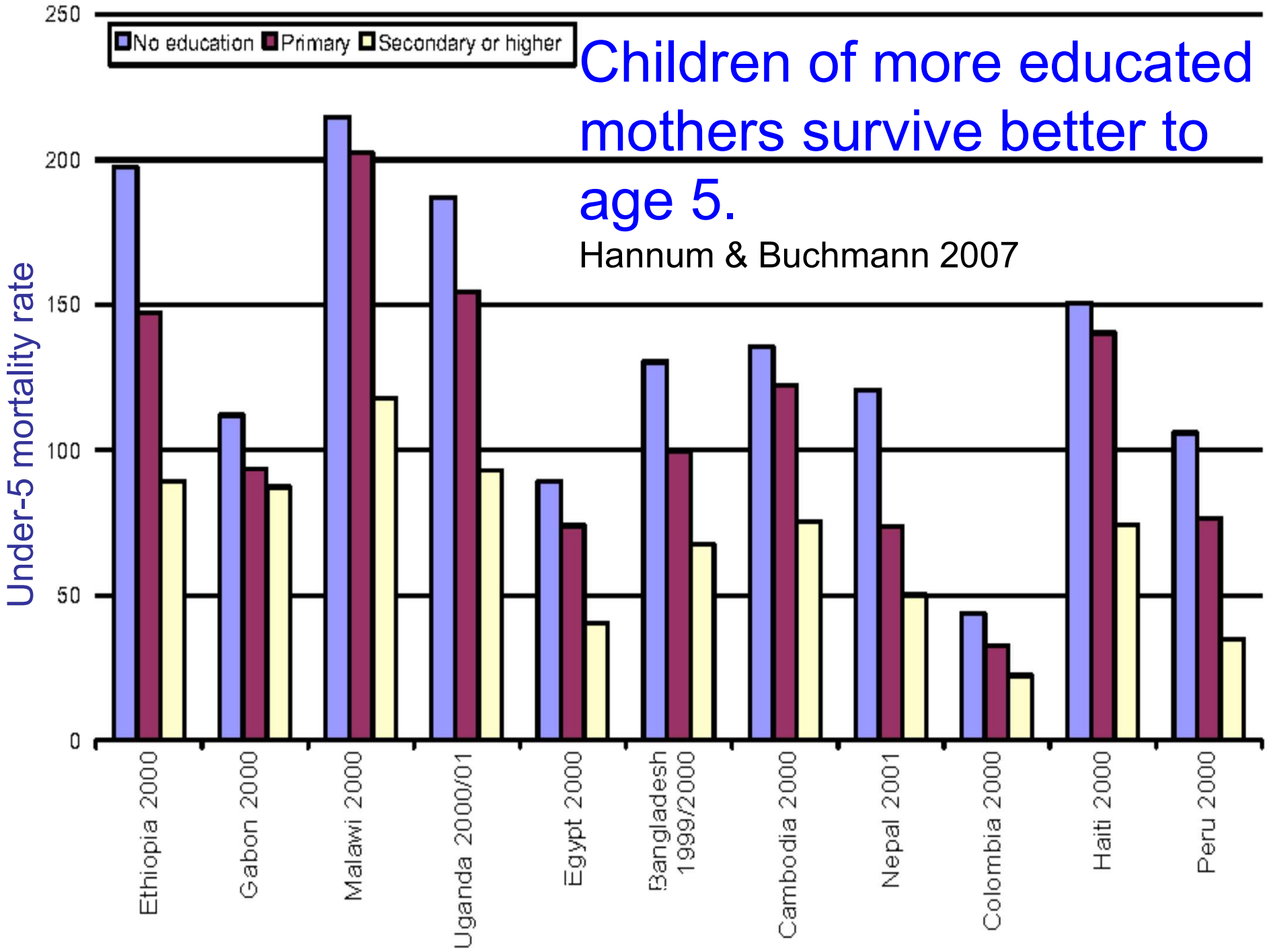
UNICEF, Child Mortality Report 2014

Higher natural increase goes with much higher child mortality rate.

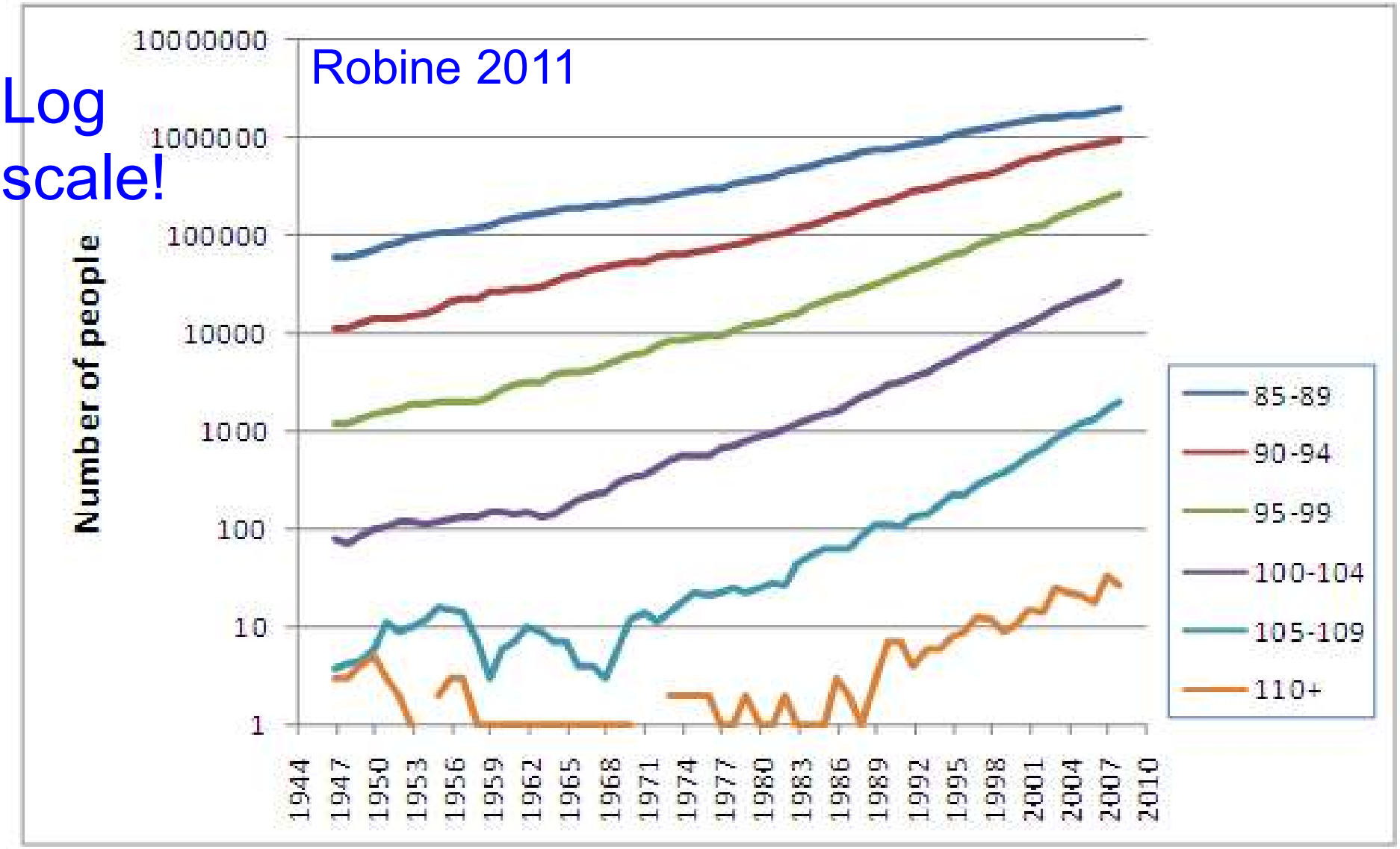


Children of more educated mothers survive better to age 5.

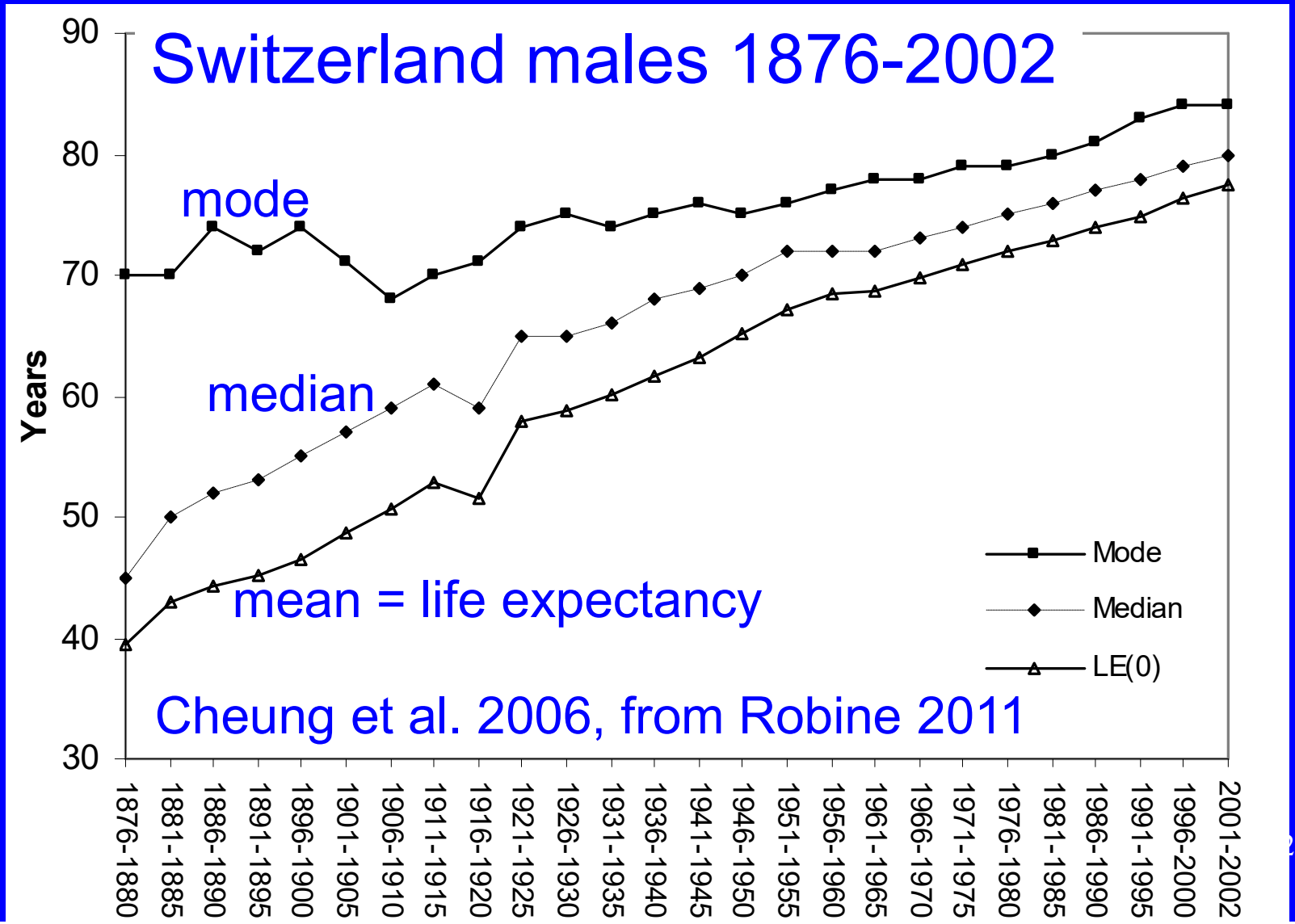
Hannum & Buchmann 2007



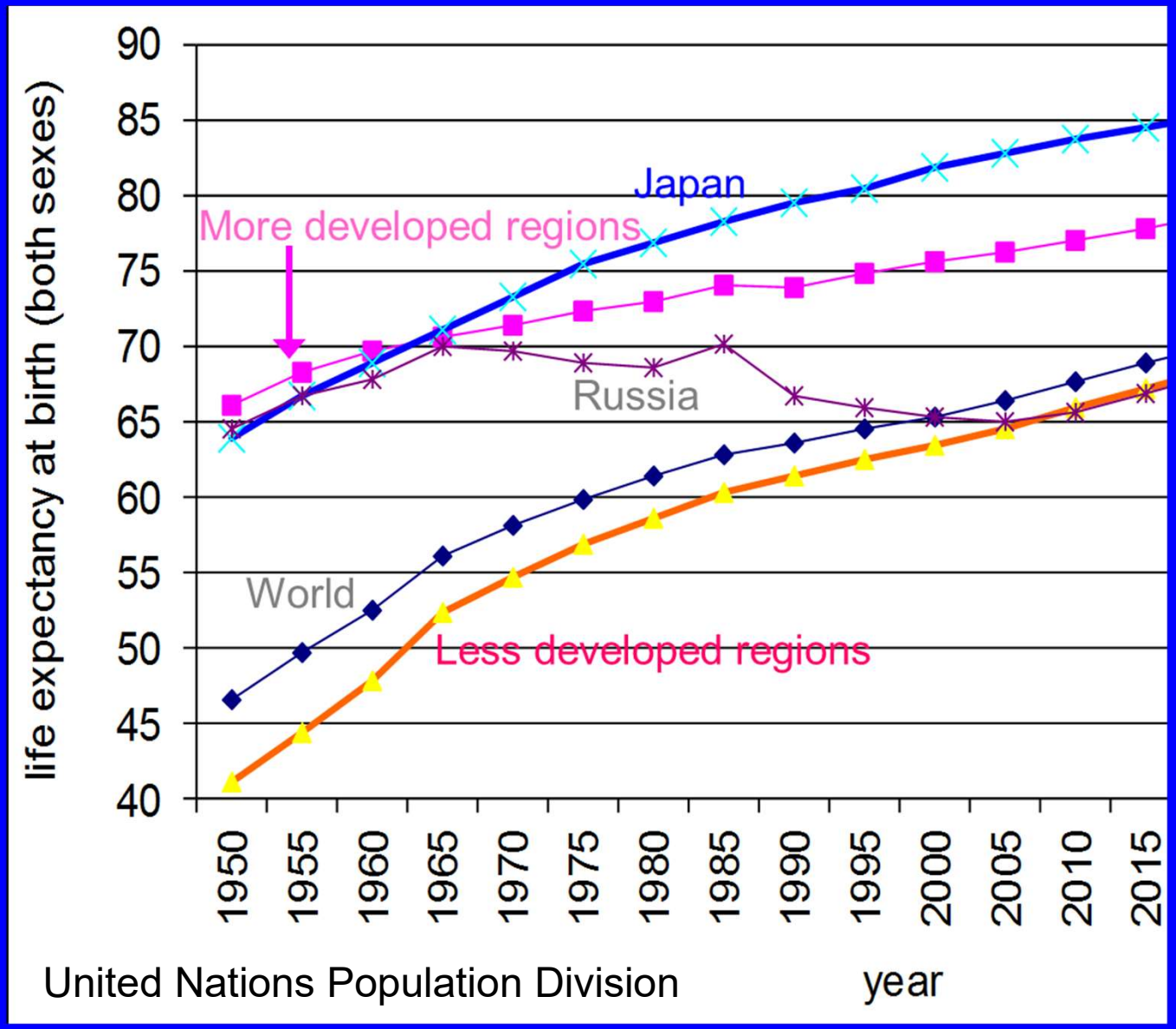
Oldest old people in Japan



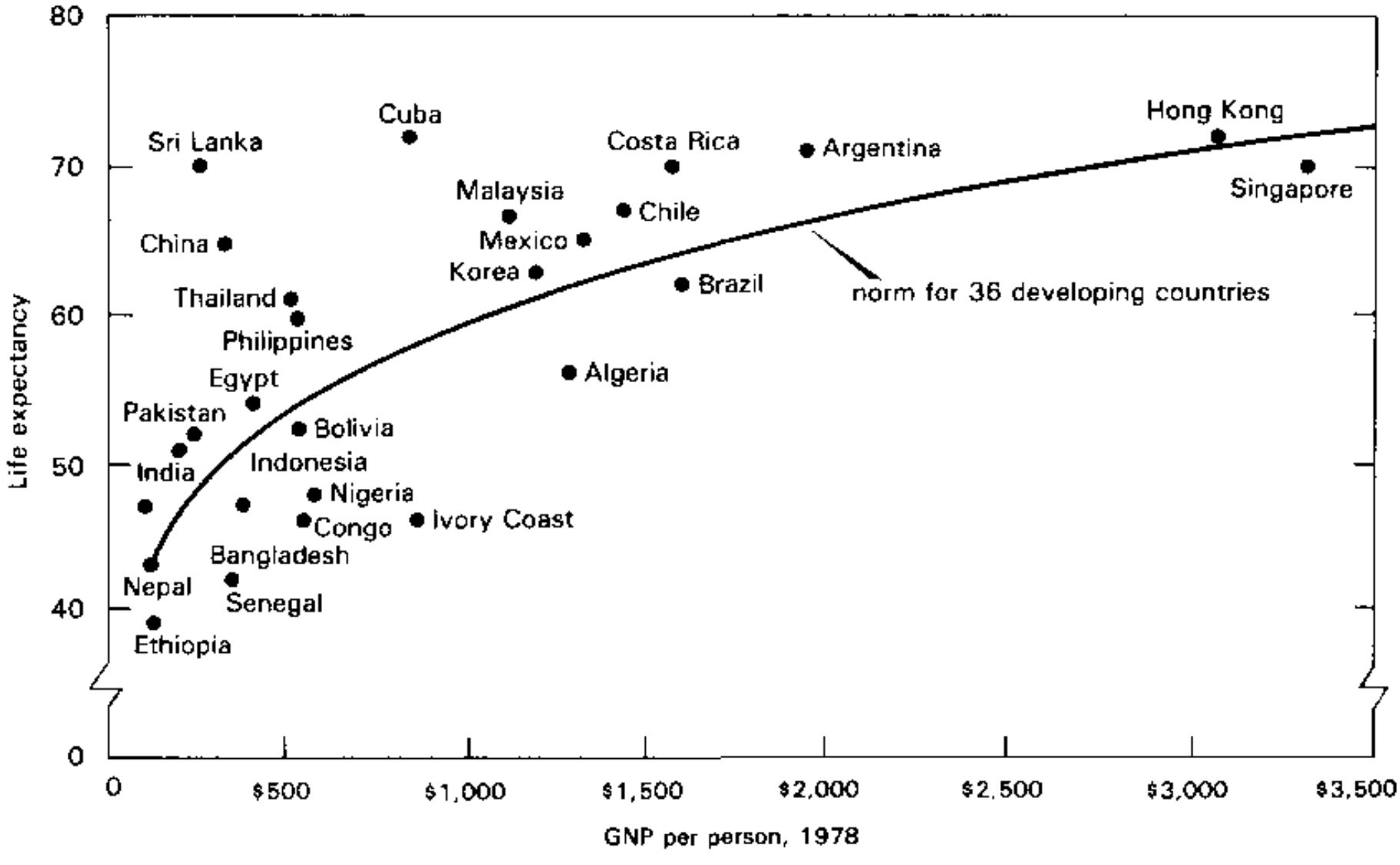
Modal age at death, median life, & life expectancy (average life) grew together.



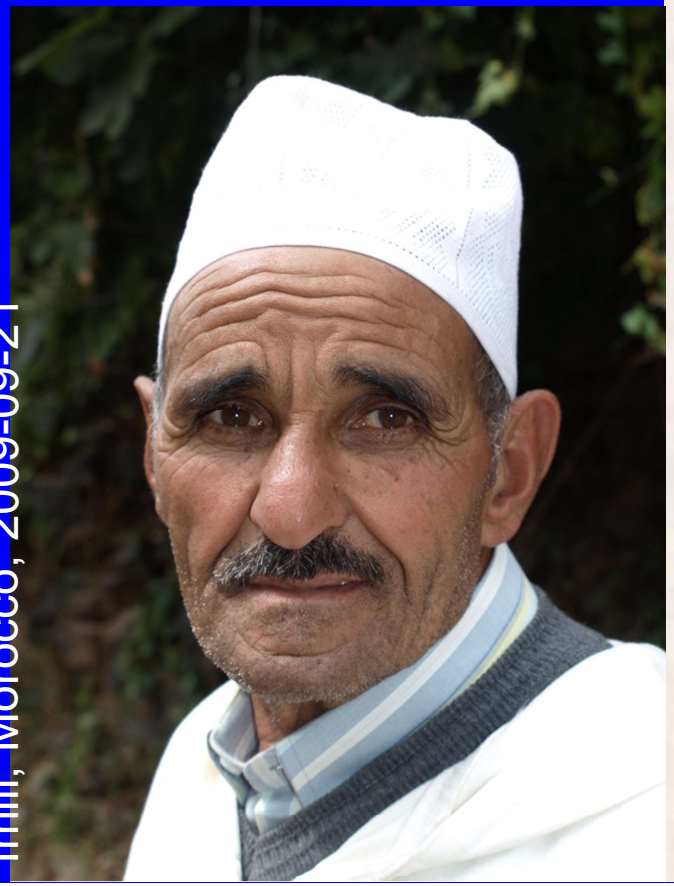
Life expectancy mostly increased.



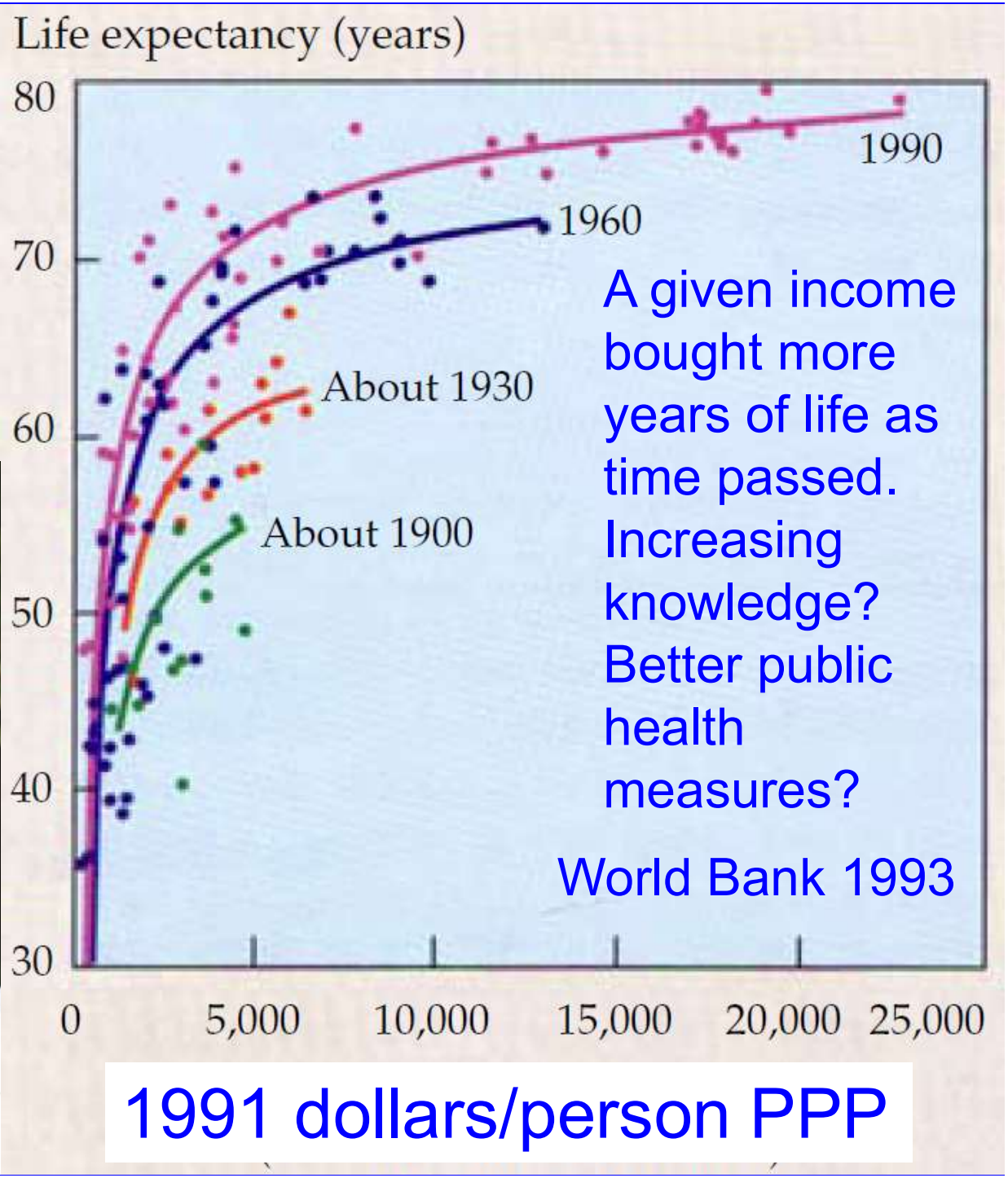
Life expectancy rises with GNP per person in developing countries.

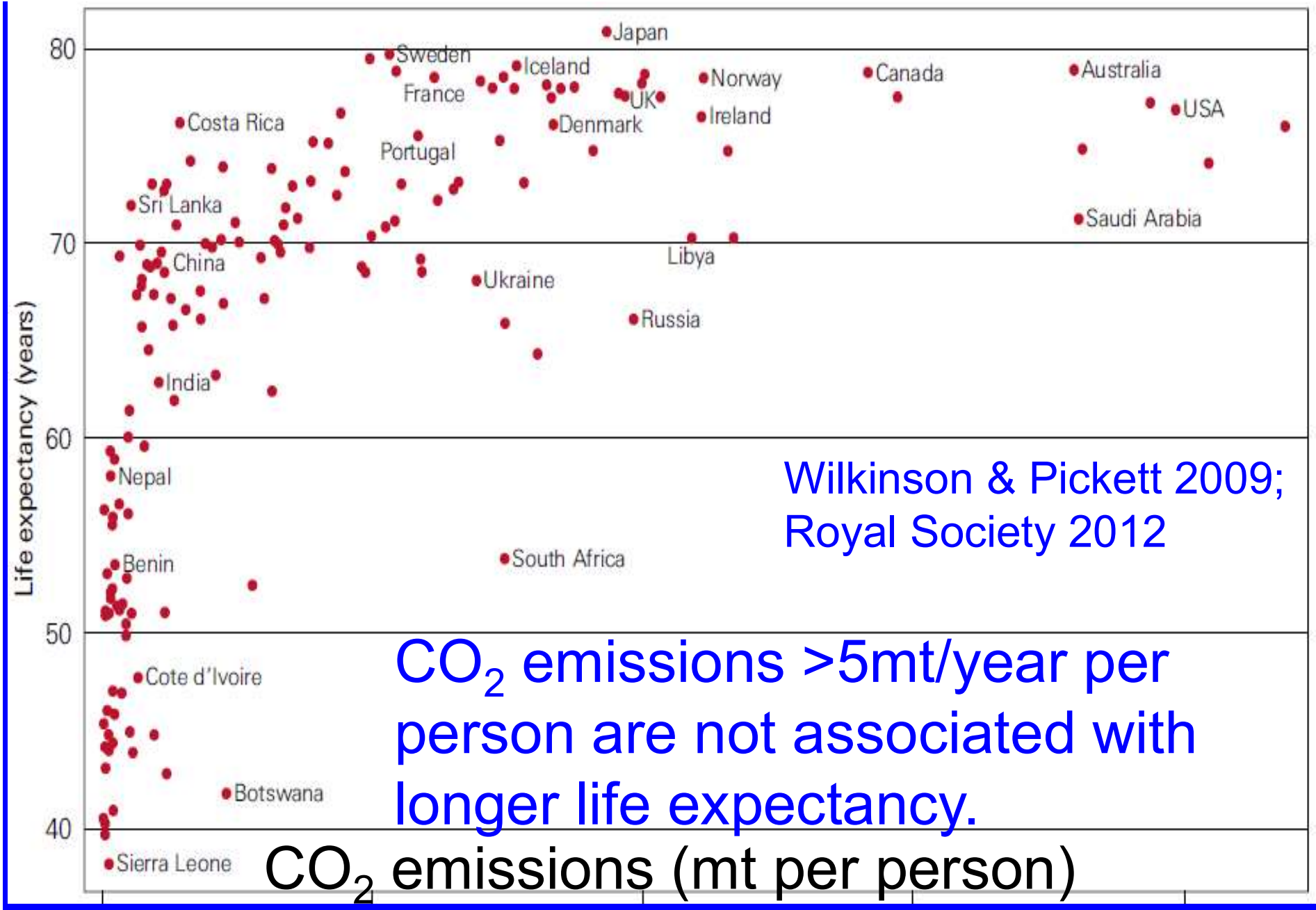


Life expectancy at birth rises with income, & shifts upward over time.



Imlil, Morocco, 2009-09-21





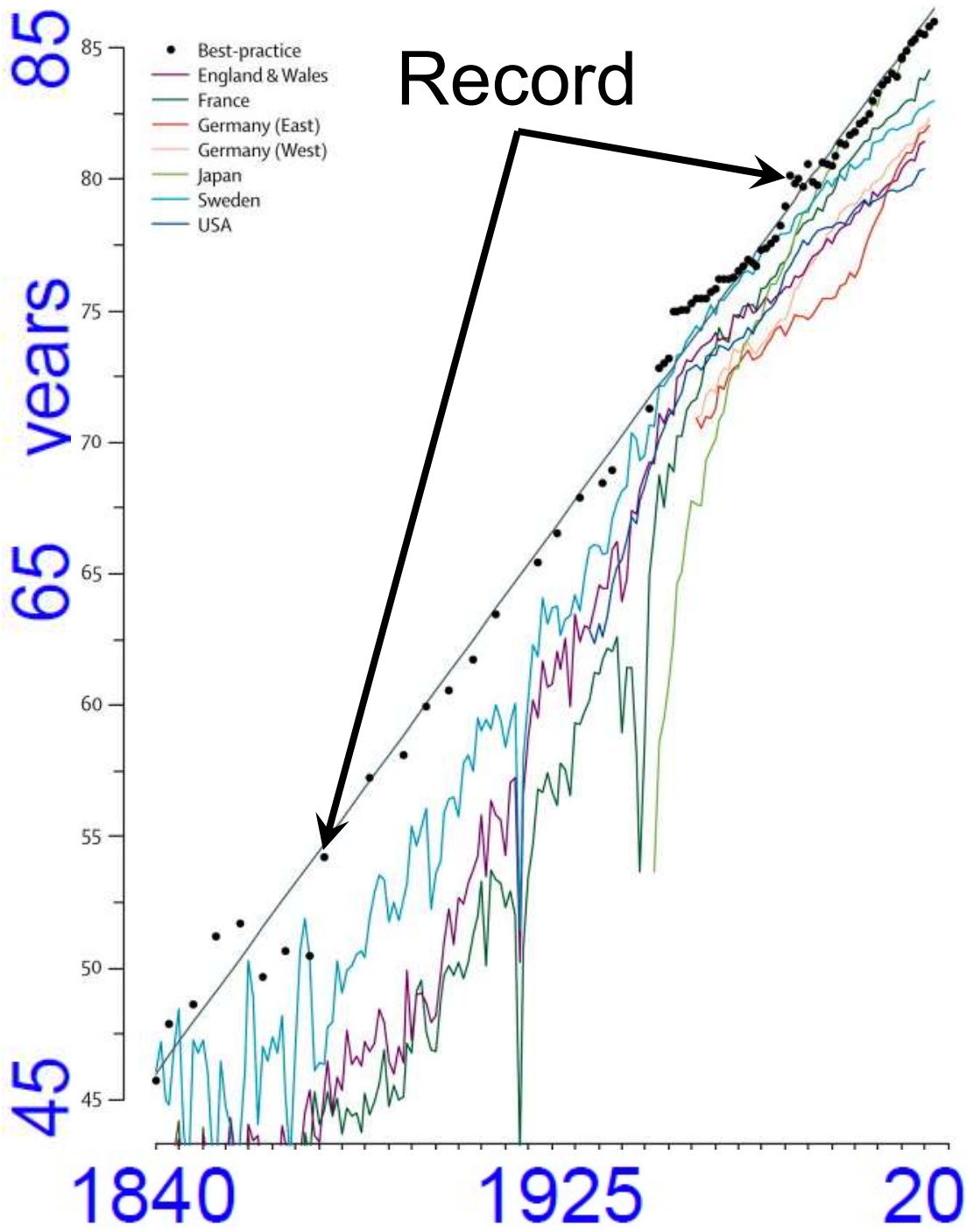
Wilkinson & Pickett 2009; Royal Society 2012

CO_2 emissions >5mt/year per person are not associated with longer life expectancy.

Rise in world-record life expectancy is not slowing down.

"if life expectancy were close to a maximum, then the increase in the record expectation of life should be slowing. It is not."

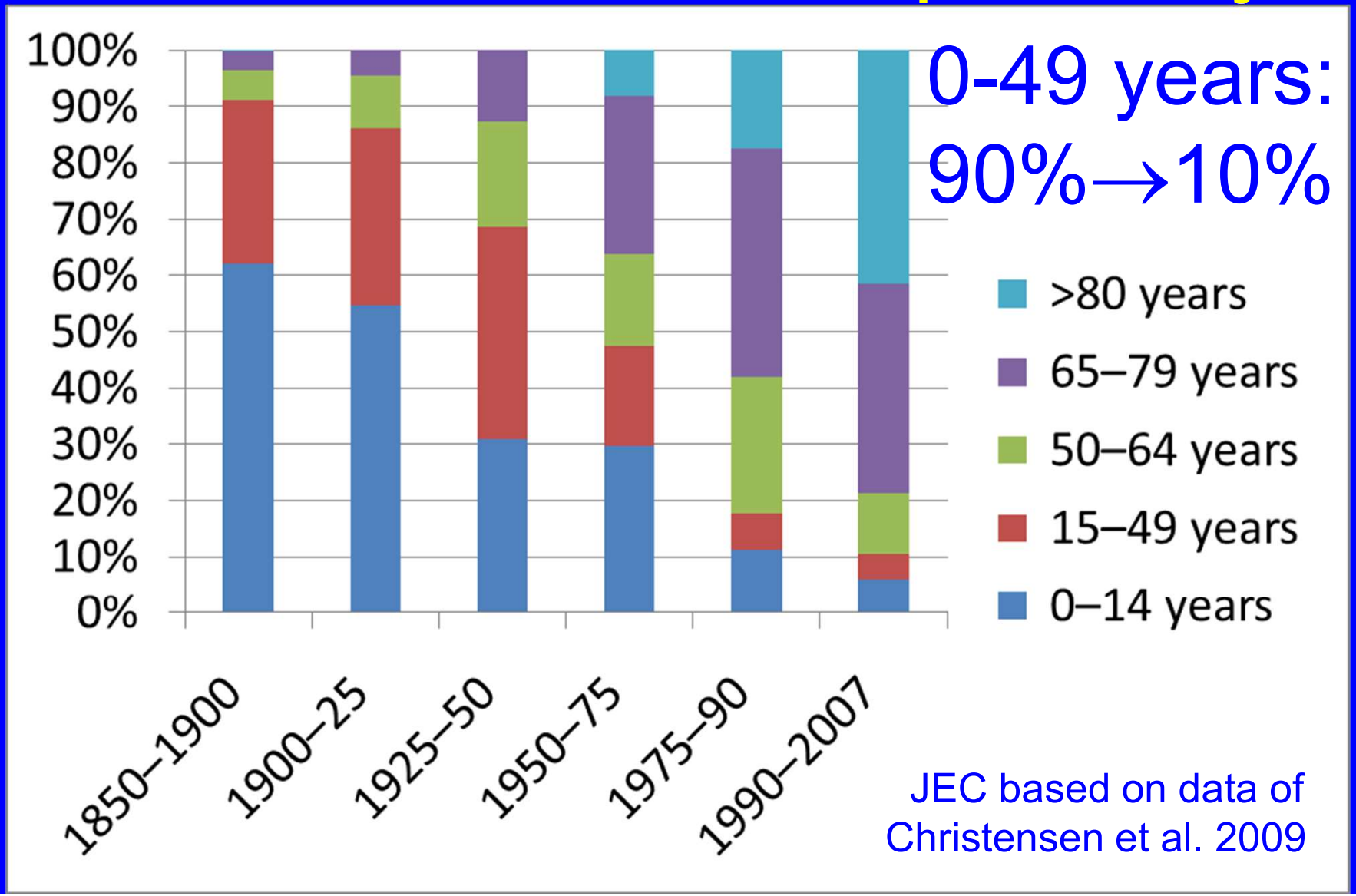
Jim Oeppen & James Vaupel 2002



Record national period female life expectancy at birth rose 0.24 years of life per calendar year, 1840-2007.

Oeppen & Vaupel, *Science* 2002, Christensen et al. *Lancet* 2009

Which age groups contributed to rise in record life expectancy?

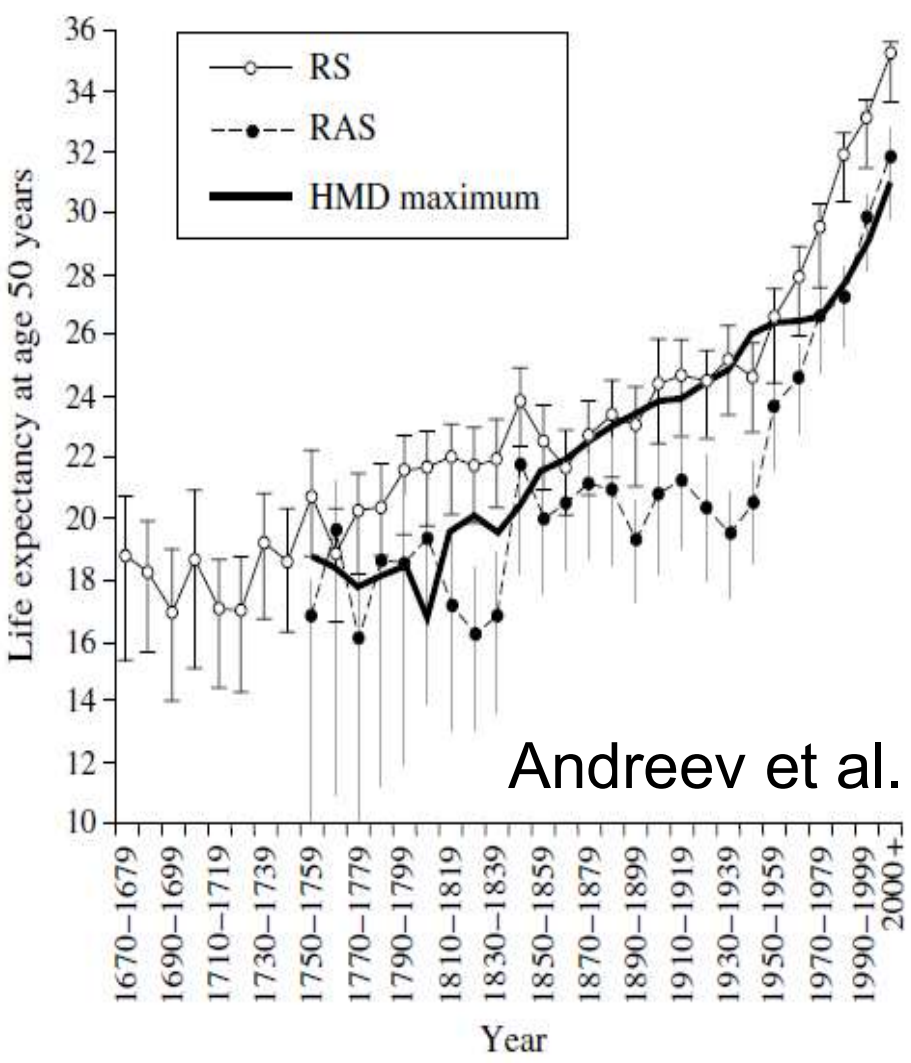


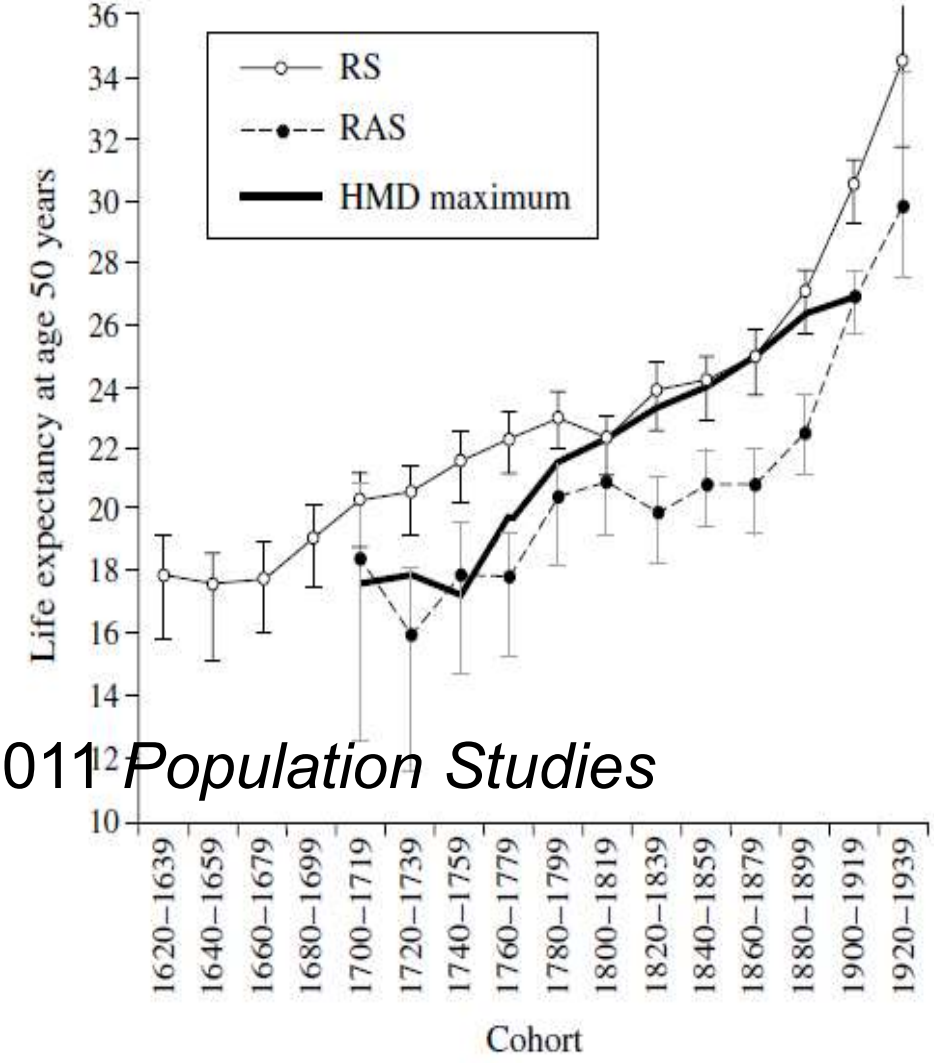
USA's oldest survivors live longer.

In period tables, the age at which 1 in 100,000 survives "for males increased from 104.4 years in 1900 to 109.8 years in 2001, while for females it increased from 104.9 years to 112.0 years. … This trend runs counter to the widely held belief that the age attained by the oldest survivors in the population has risen little, if at all, during the twentieth century."

Bell & Miller, Social Security Administration, 2005

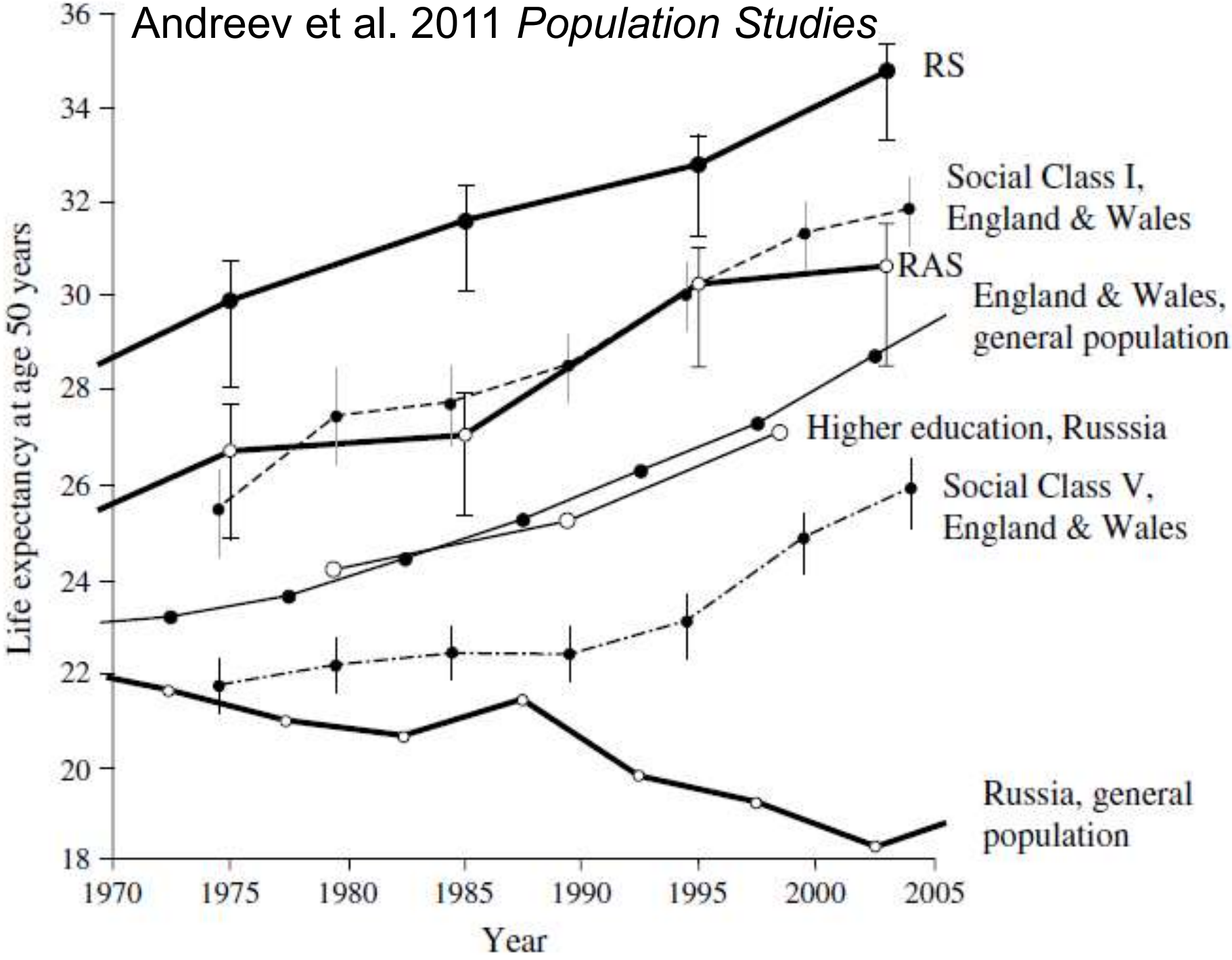
Intellectual elites (Royal Society UK, Russian Academy of Sciences) live longer.





Andreev et al. 2011 *Population Studies*

Andreev et al. 2011 *Population Studies*




50
IS THE NEW
30


60
is the new
40

40 is the new 30.

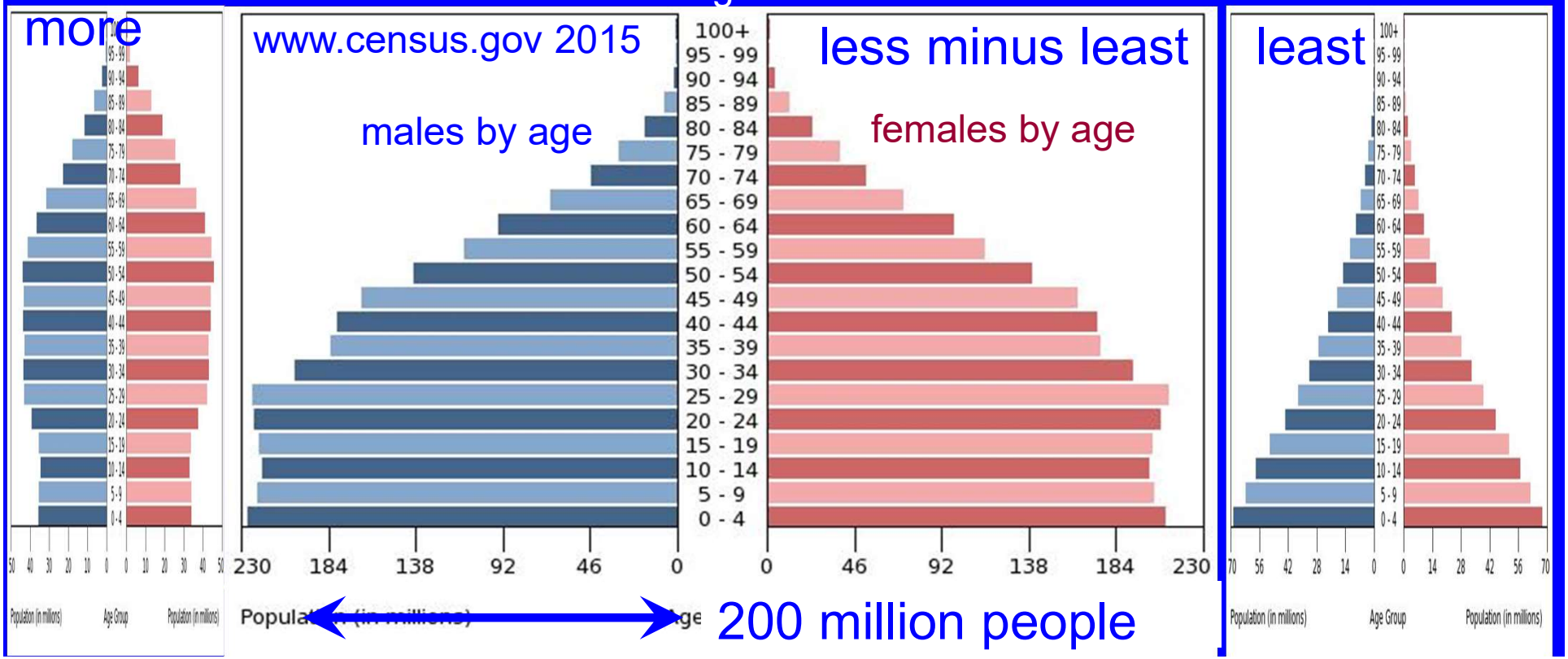
In France in 2005, women aged 40 years had remaining life expectancy of women aged 30 years in 1952. (Lutz, Butz, KC et al. 2014)

Year	Chronological age	Remaining life expectancy
1952	30	44.7
2005	30	54.4
2005	40	44.7

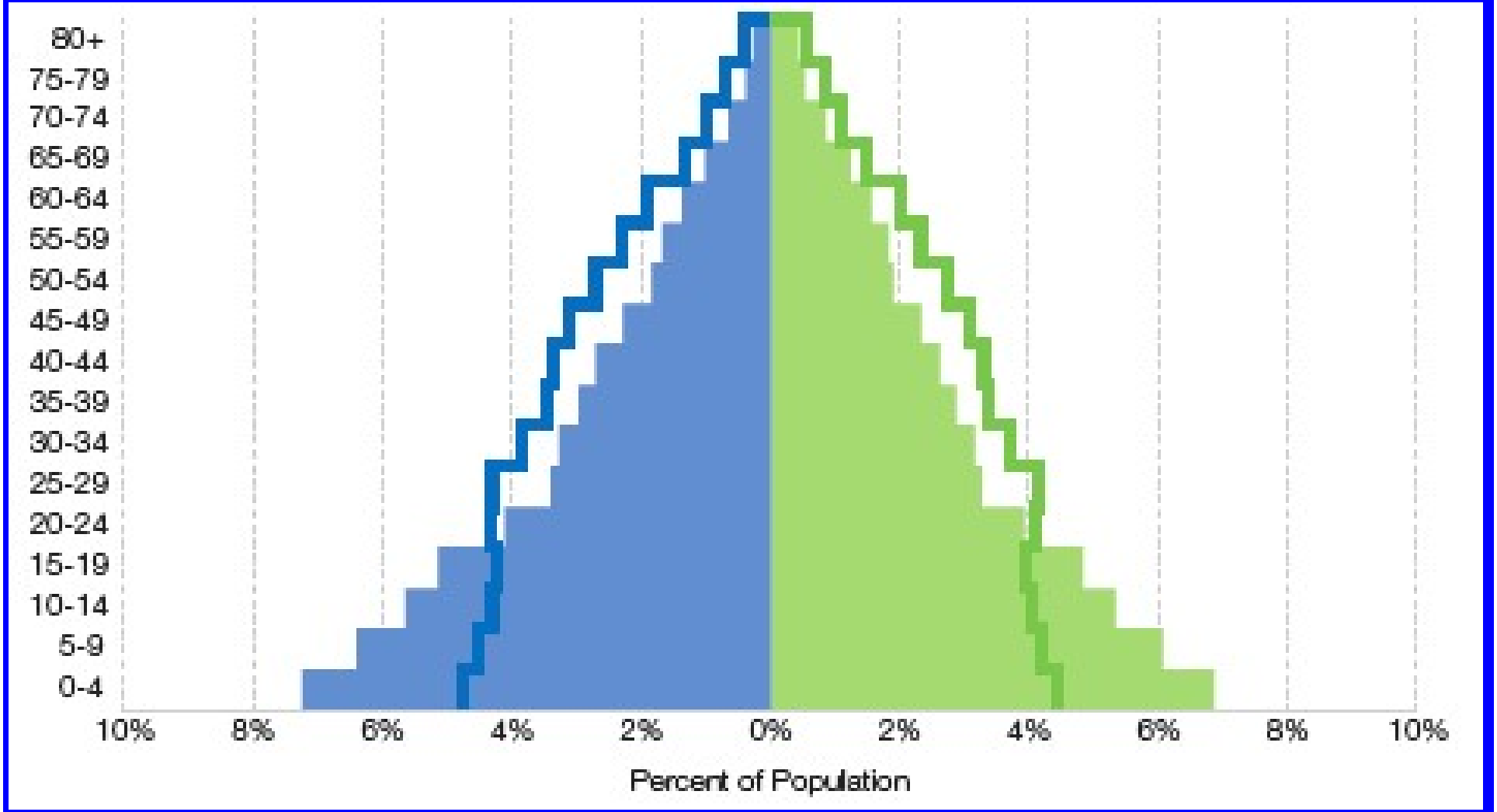
Populations, not individuals, have age structure.

Poor countries have younger, bigger, denser populations than rich countries.

1.25	billion people	5.05	0.95
25	people/km^2	83	47
40.8K	GNIpc 2014 $ PPP	9.7K	1.6K

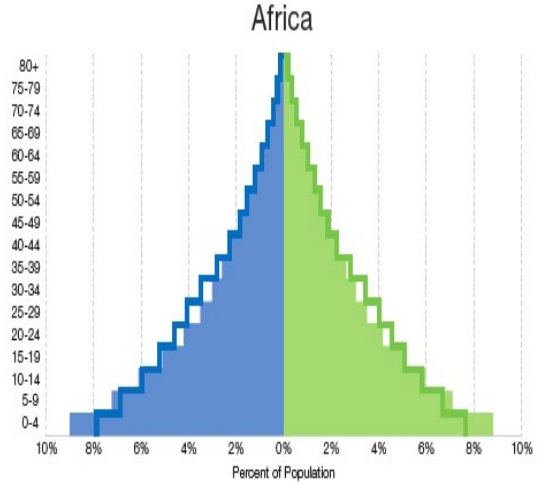


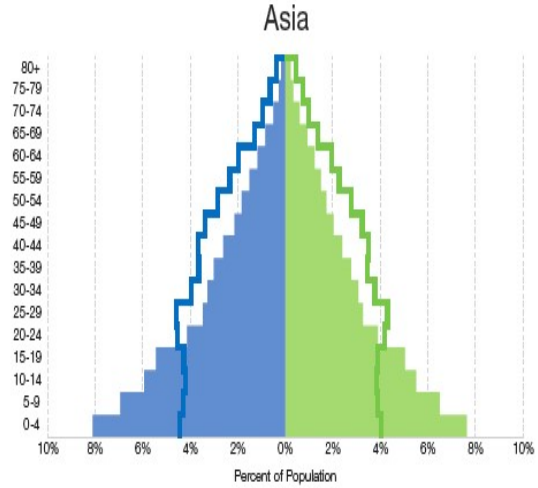
World age structure grew older 1970-2014.

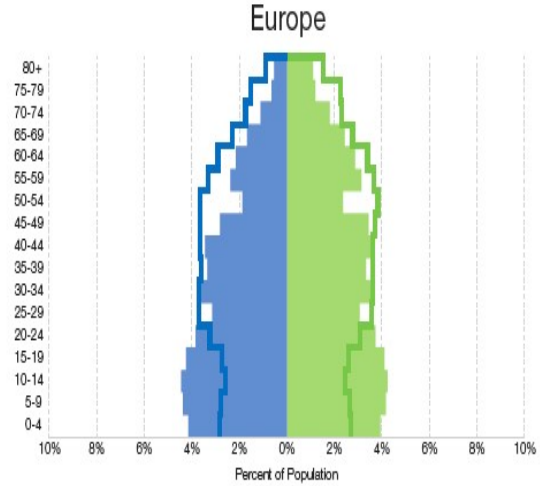


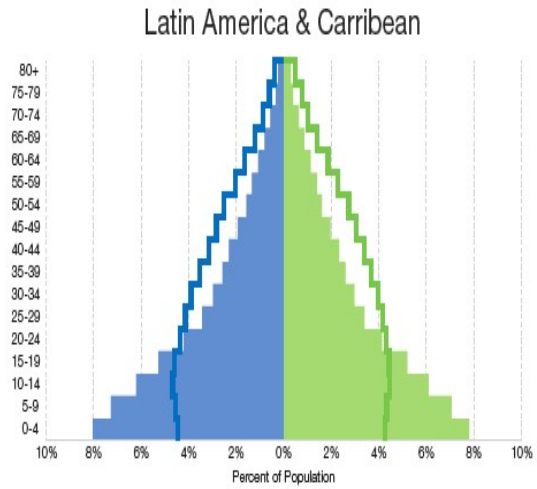
PRB, *2014 World Population Data Sheet.* UN Population Division 2013

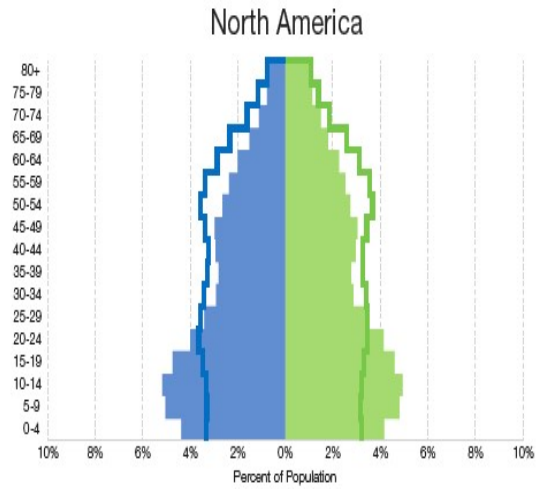
Regions changed differently 1970-2014.

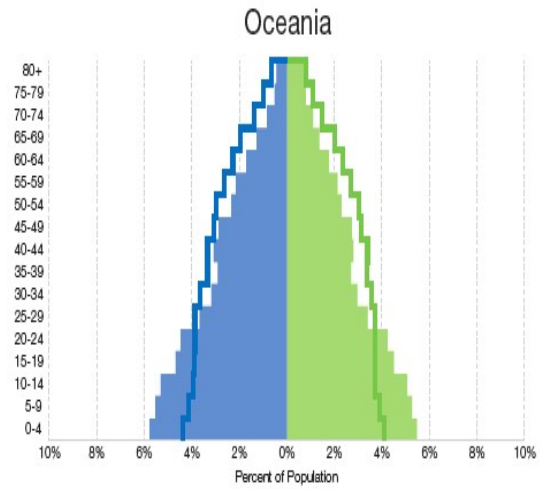






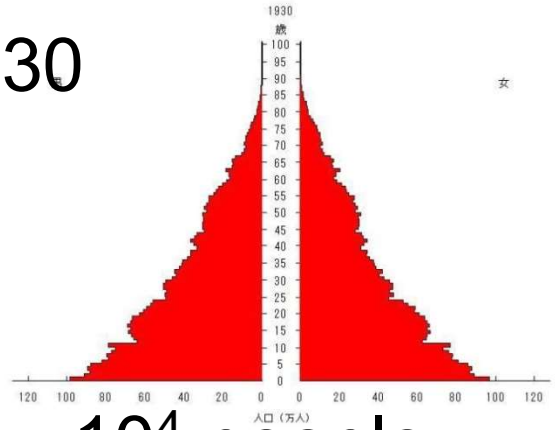






PRB, *2014 World Population Data Sheet.* UN Population Division 2013

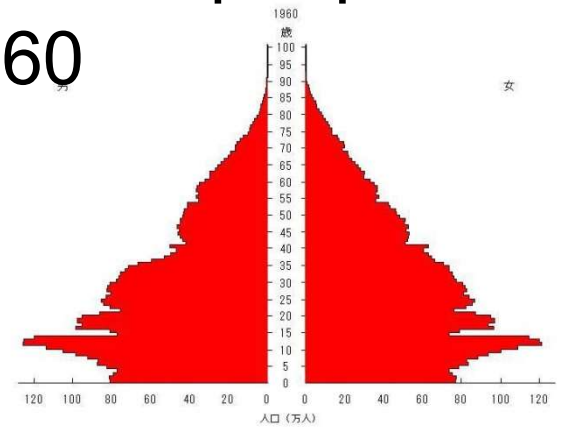
1930



10^4 people

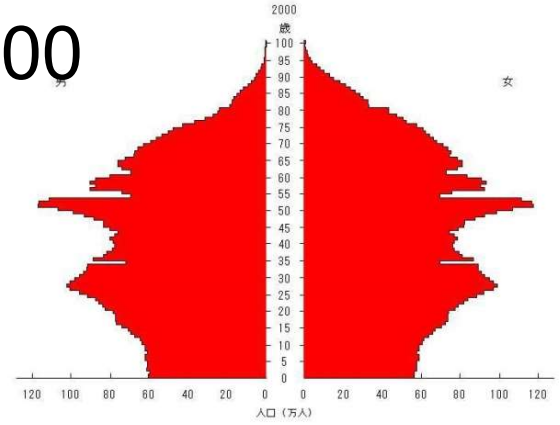
作成：国立社会保障・人口問題研究所

1960



作成：国立社会保障・人口問題研究所

2000



作成：国立社会保障・人口問題研究所

Japan's age structures reflected rapid growth of Meiji era,

deaths & deferred births during war, post-war baby boom,

improved adult survival & falling fertility.

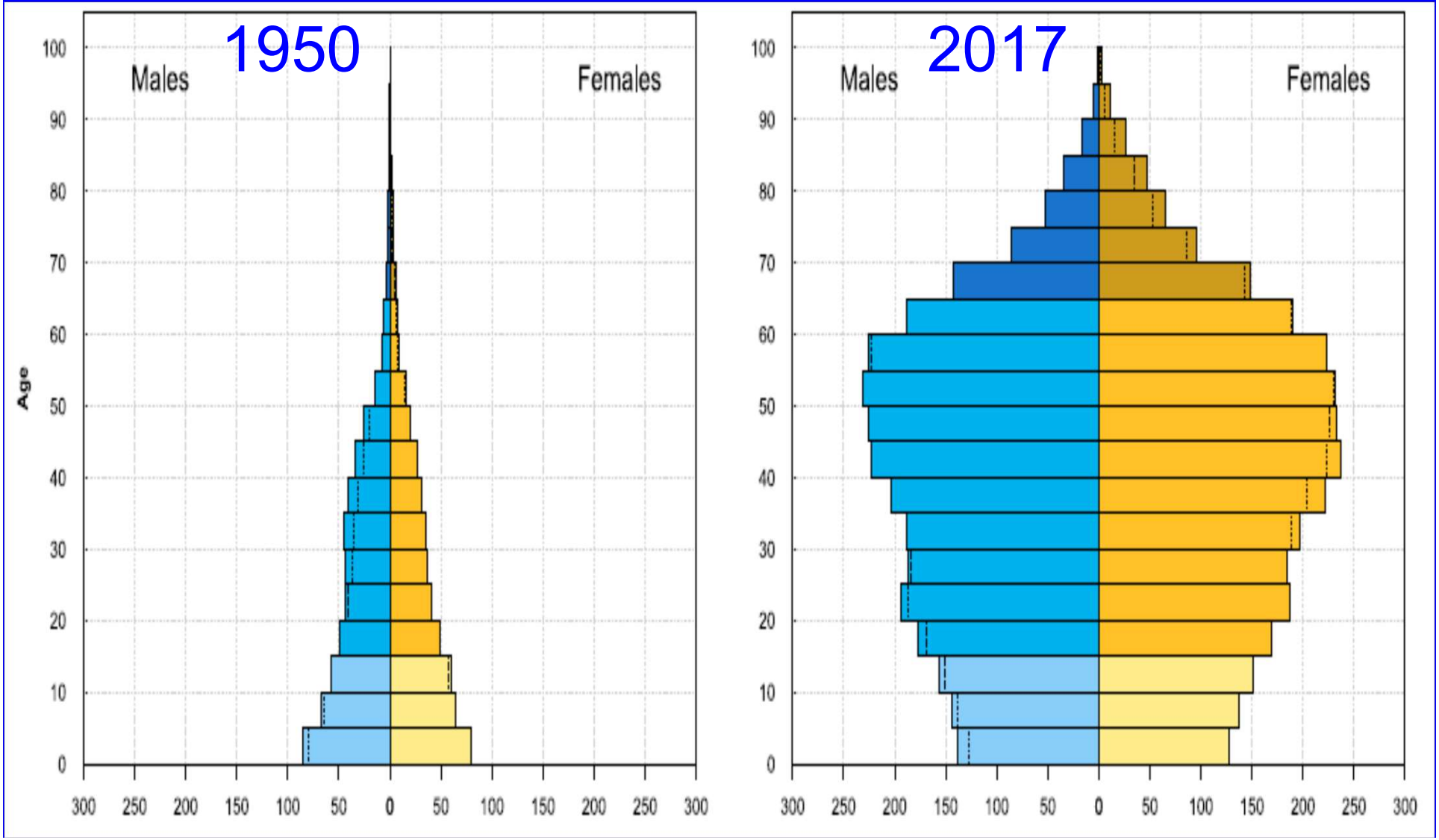
Hinoeuma – fire horse

Satoshi Shimizutani & Hiroyuki Yamada, 2014. Long-term consequences of birth in an ‘unlucky’ year: evidence from Japanese women born in 1966. Applied Economics Letters 21(16):1174-1178. https://doi.org/10.1080/13504851.2014.916377

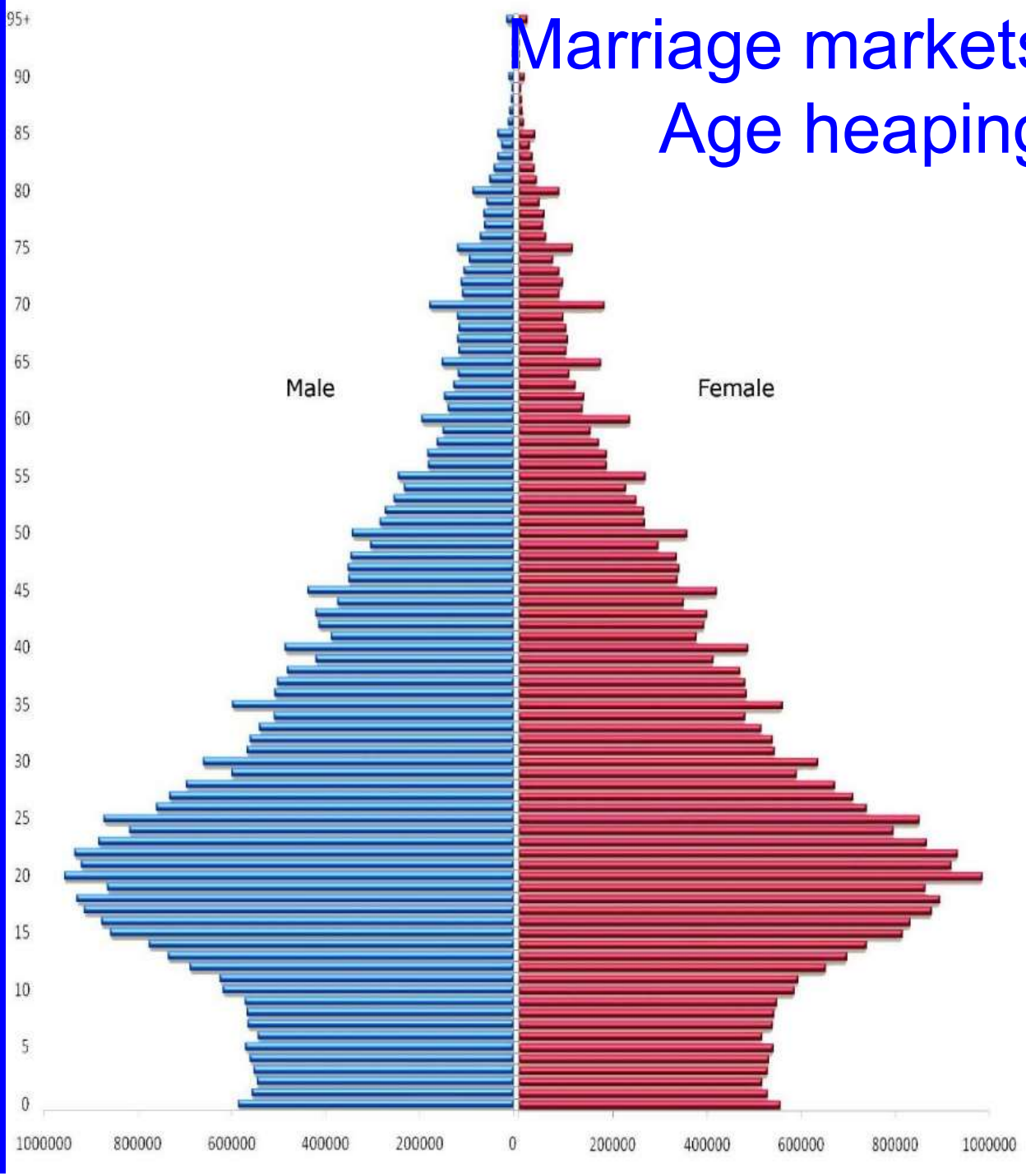
Kaku, Kanae (April 1975). Increased induced abortion rate in 1966, an aspect of a Japanese folk superstition. Annals of Human Biology 2(2):111–115. doi:10.1080/03014467500000651

Singapore

UN Population Division, *World Population Prospects: 2017 Revision, II: Demographic Profiles*



Iran's age pyramid 2006

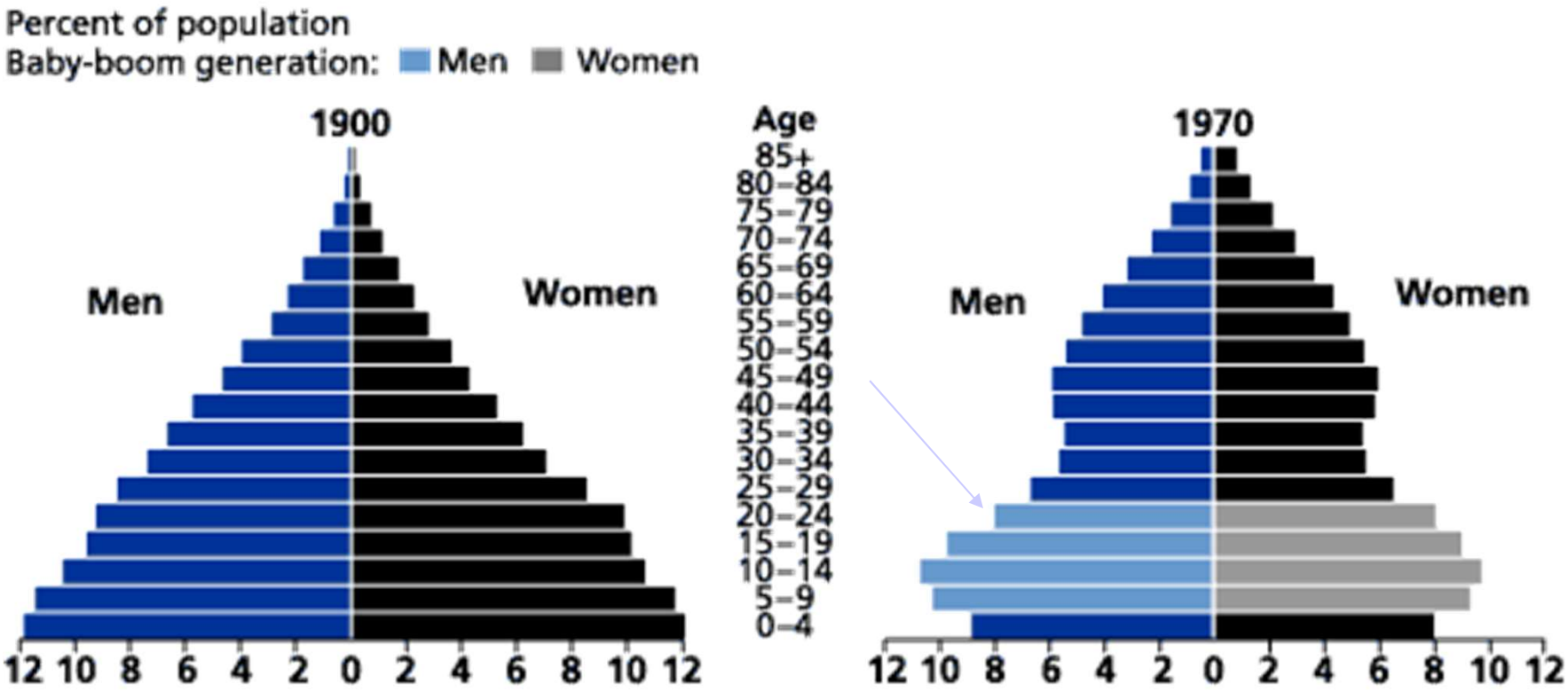


Marriage markets
Age heaping

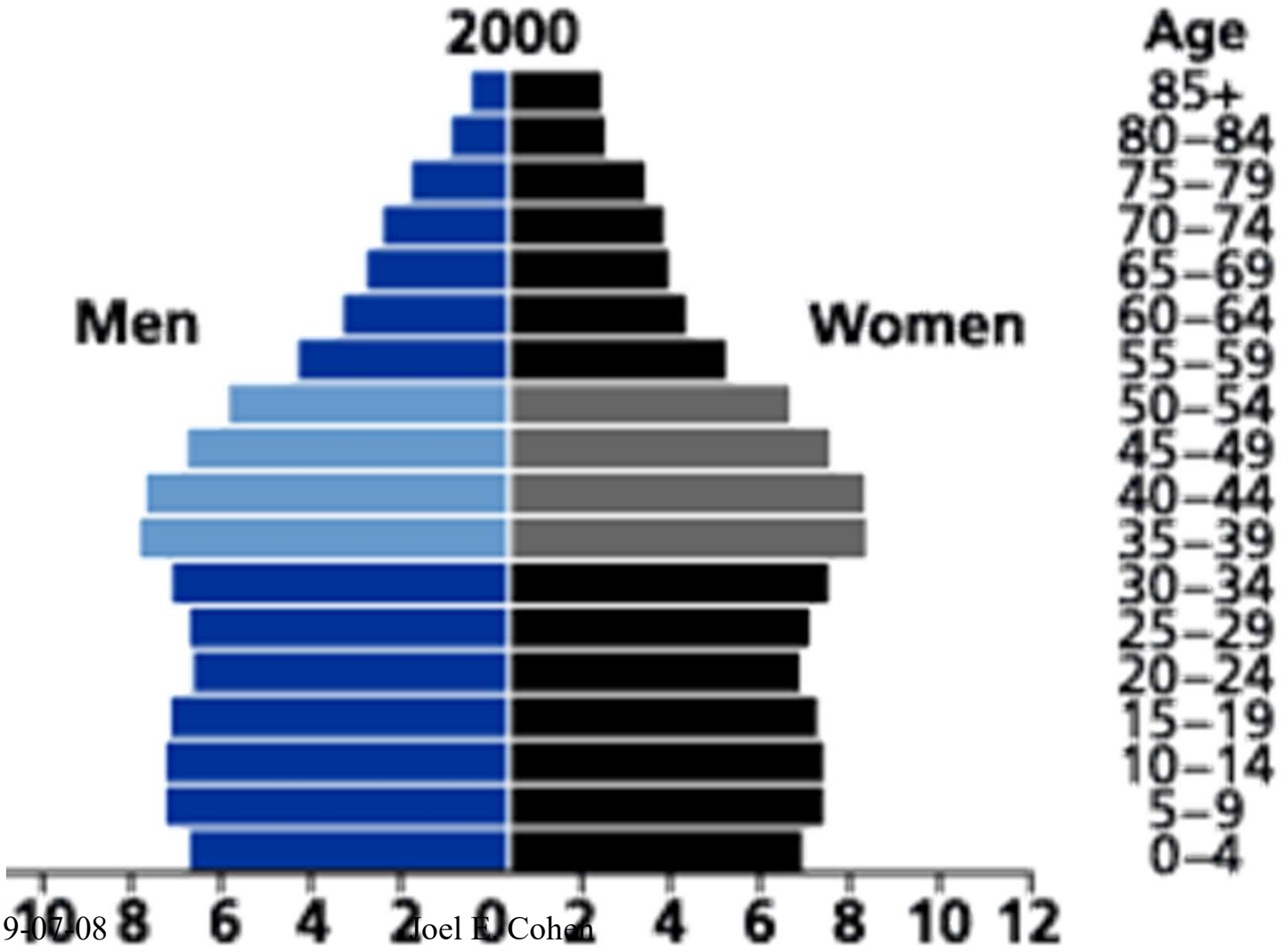
http://iran.unfpa.org/Country%20Profile.asp

2019-07-08

U.S. age structure, 1900, 1970



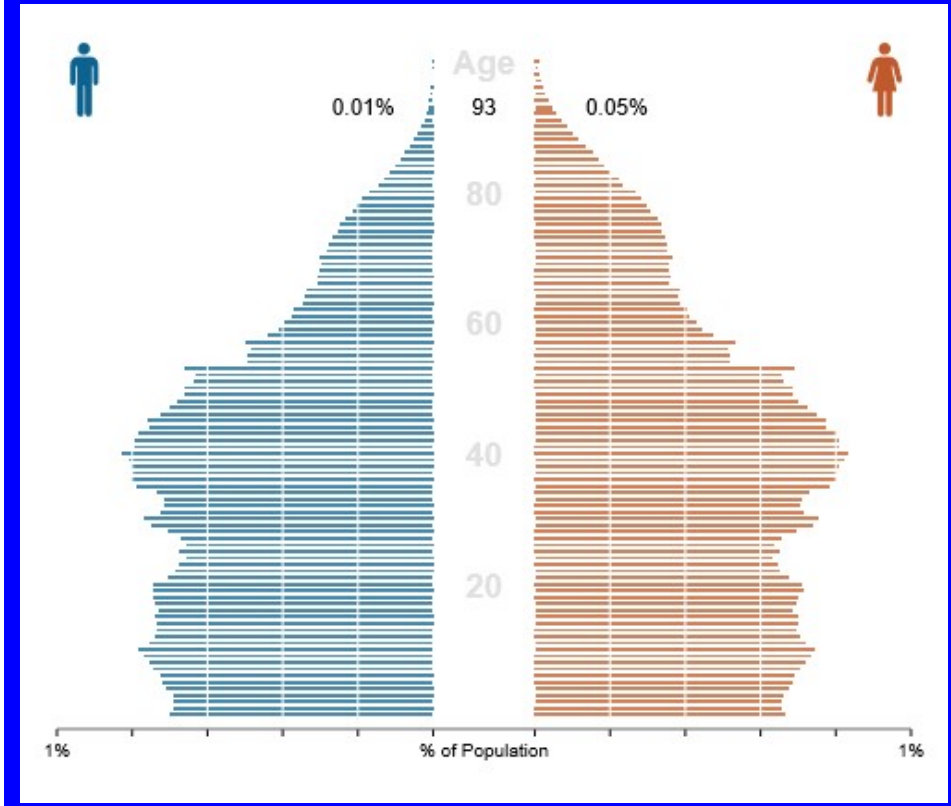
U.S. age structure 2000



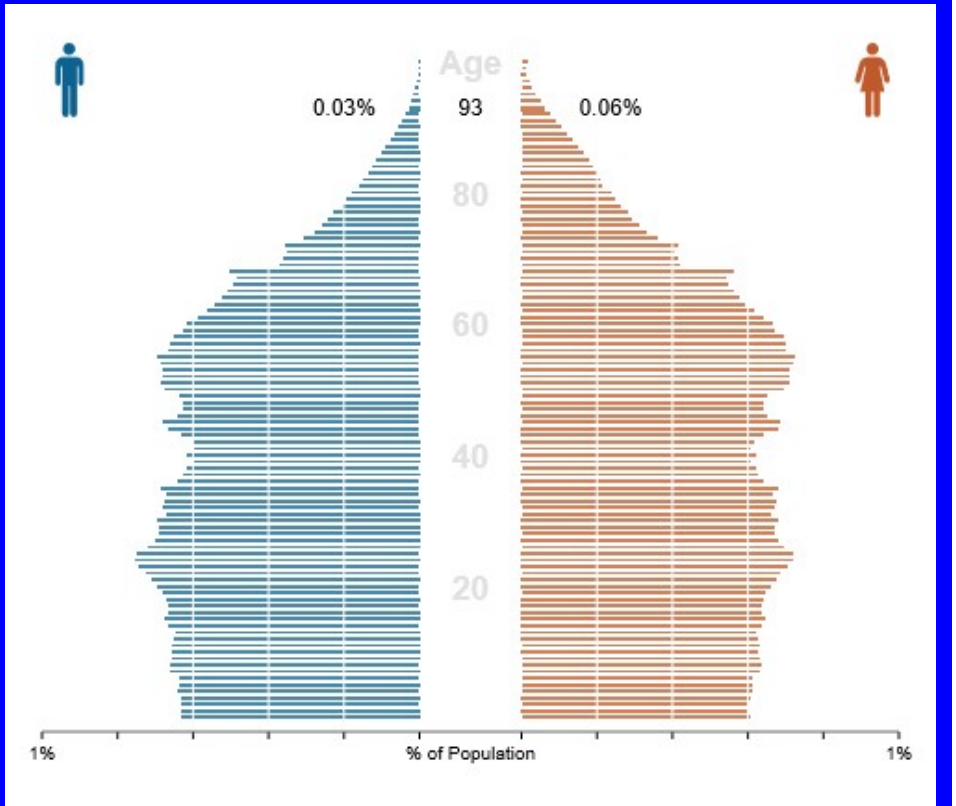
U.S. age structure 2000-2015

https://www.census.gov/popclock/

USA 2000



USA 2015



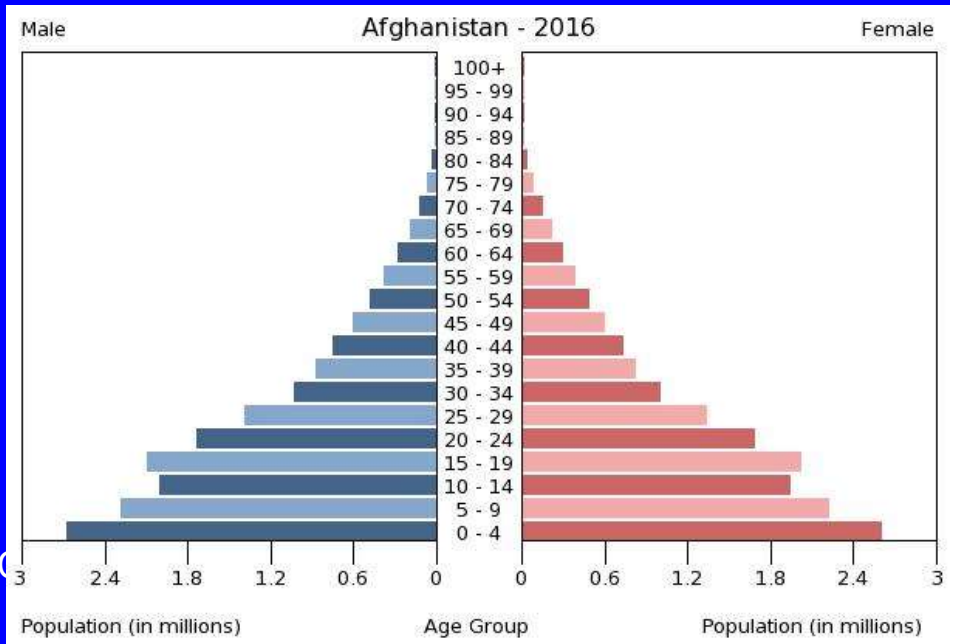
Age pyramids for every country!

https://www.cia.gov/library/publications/the-world-factbook/

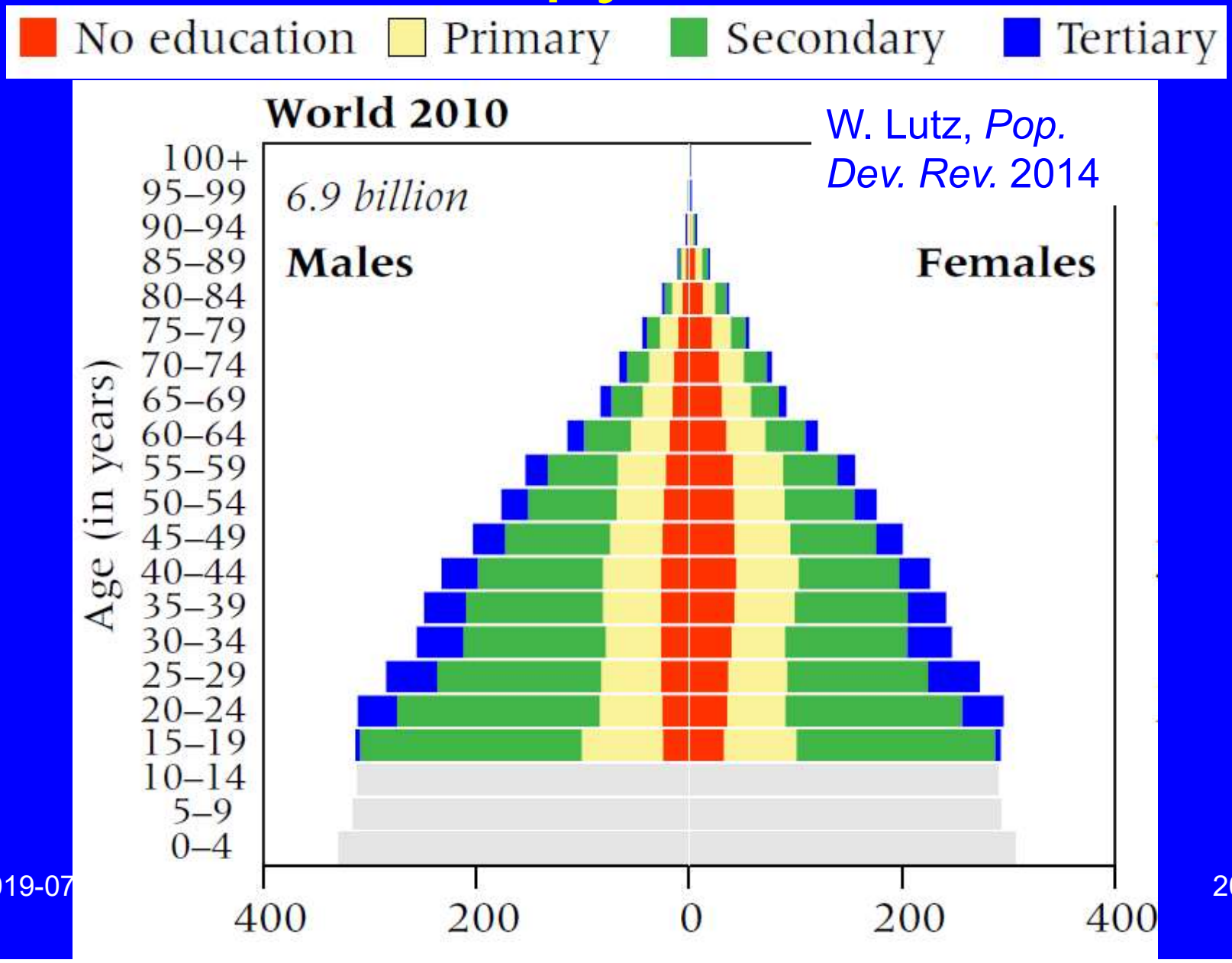
Select a country (or “World”)

Select “People and Society”

Under “Age structure”, at bottom, click on “population pyramid”



Education pyramid, 2010



W. Lutz, *Pop. Dev. Rev.* 2014

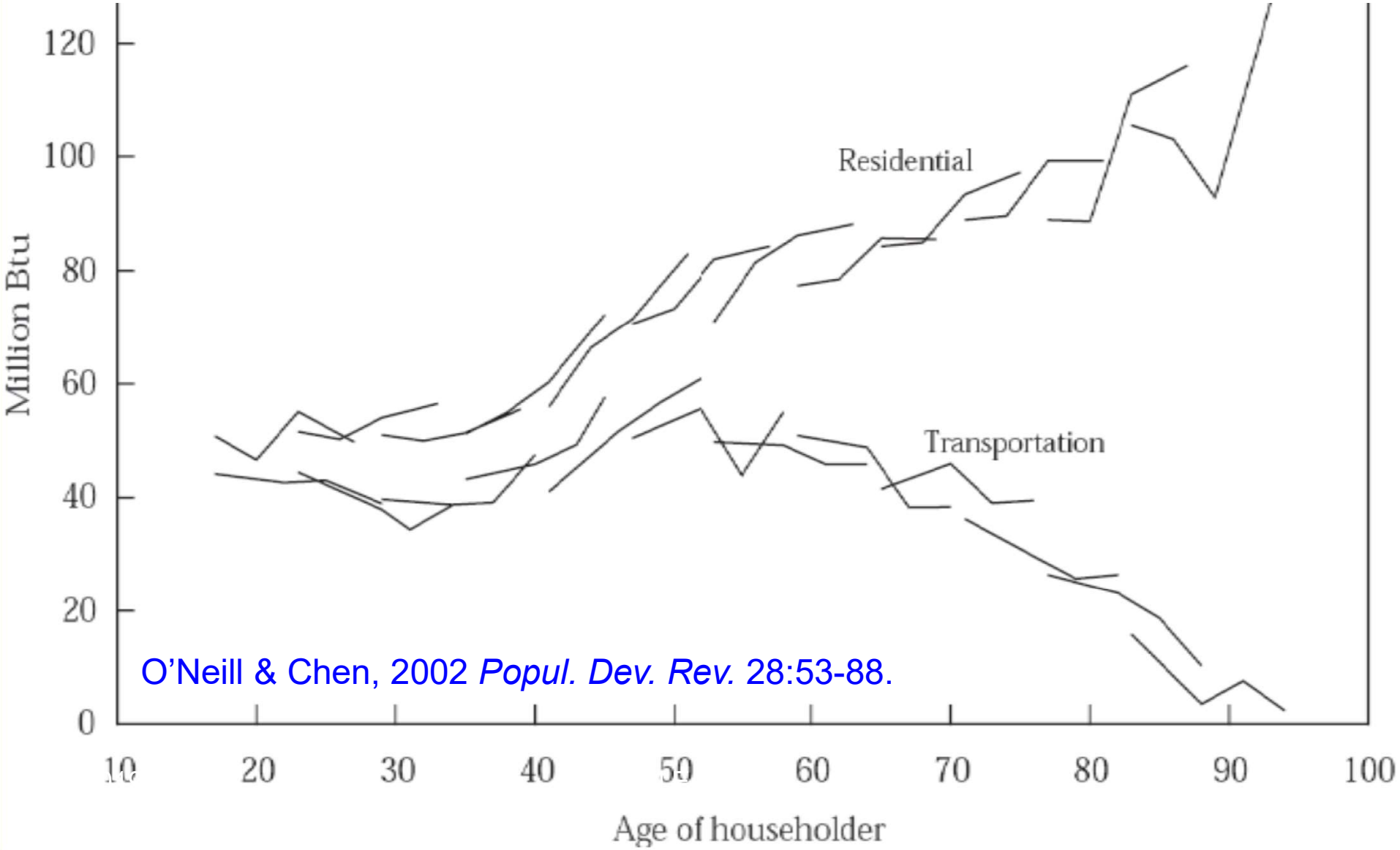
Population chronological aging depends mostly on birth rates.

Birth rates control the expansion or contraction of the bottom of the age pyramid. Changes in fertility change the proportion of elderly people in the population more than comparable changes in survival or life expectancy.

Immigration cannot keep a population young because immigrants age, too.

FIGURE 2 US per capita energy use 1987–97 (residential) and 1983–94 (transportation), by cohort

Age structure affects energy consumption.

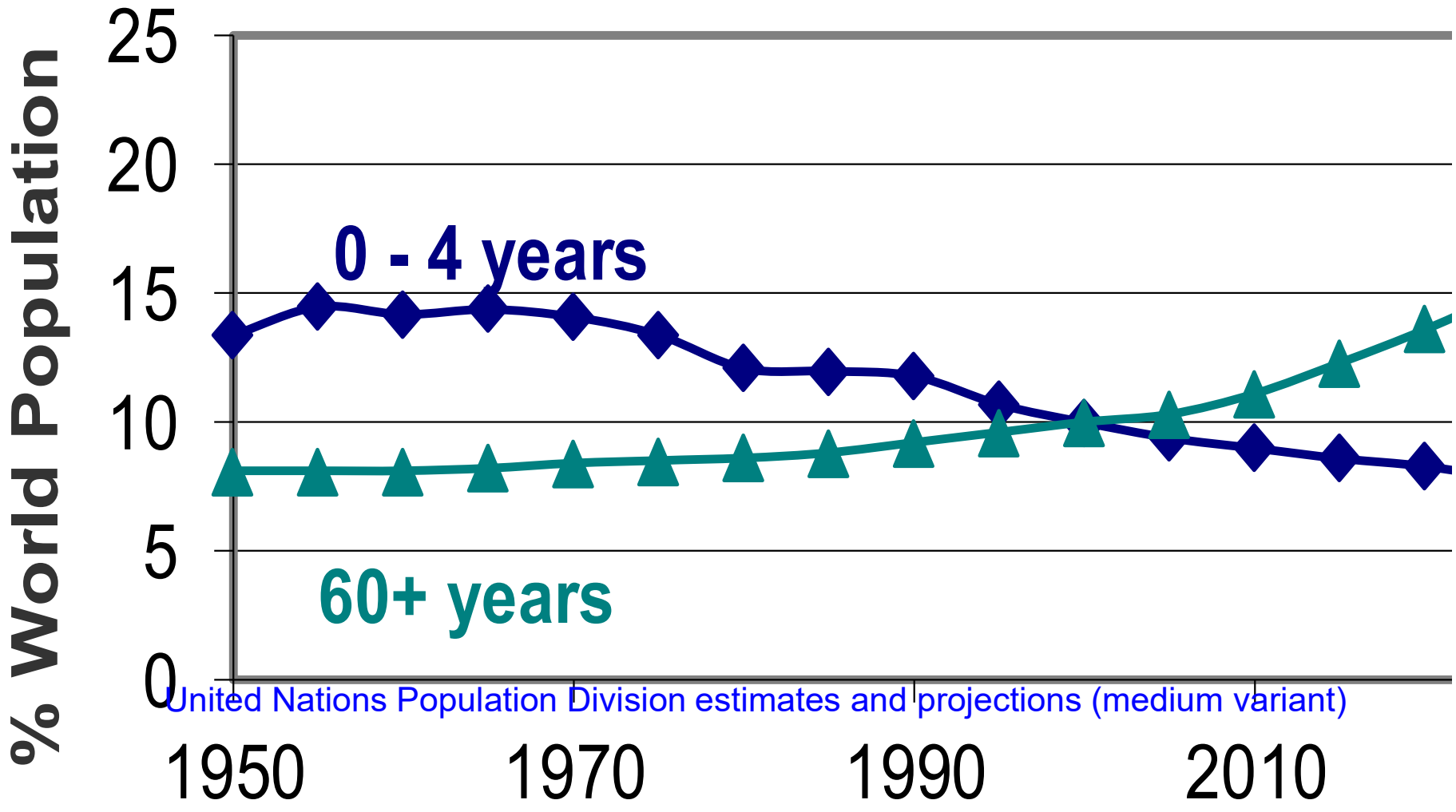


O'Neill & Chen, 2002 *Popul. Dev. Rev.* 28:53-88.

The 20th century was the last with more young than old people.

Queens, NYC
2015-01-16

People 60+ outnumber children 0-4.



United Nations Population Division estimates and projections (medium variant)

Chronological measures of population aging

Skirbekk, Staudinger, Cohen *Gerontology* 2018

Measures based on current age structure

- % of people above age 60 or 65 years
- Old-age dependency ratio
- Potential support ratio
- Age at specified percentile (oldest 15%)
- Average age
- Median age

Chronological measures of population aging

Skirbekk, Staudinger, Cohen *Gerontology* 2018

Measures based on period life table (current age-specific death rates)

- Life expectancy = average age at death
- Remaining life expectancy (RLE) at age 50
- Age with RLE of 15 years
- Age to which 5% of adults (20+) survive

Hybrid

- Population-average RLE

Economic measures of population aging

Skirbekk, Staudinger, Cohen *Gerontology* 2018

- Economic dependency ratio (EDR): ratio of number of economically inactive people to those employed (excludes housework, voluntary work)
- Ratio of number of working years to years spent in full retirement
- Real elderly dependency ratio (REDR): number of people with RLE ≤15 y divided by total number of employed people

Physical-health measures of population aging

Skirbekk, Staudinger, Cohen *Gerontology* 2018

- Healthy life expectancy HALE: average equivalent number of years of full health a person would live through life at age-specific death rates & ill-health rates in a given period & country
- Widely used by WHO, UN, Global Burden of Disease project

Functional measures of population aging

Skirbekk, Staudinger, Cohen *Gerontology* 2018

- Cognitive functioning: e.g., define people as cognitively "older" if they remembered <5 of words in a test to recall 10 words harmonized for different languages & cultures
- Cognitively intact life expectancy
- Structural & functional neuroimaging

Functional measures of population aging

Skirbekk, Staudinger, Cohen *Gerontology* 2018

Sensory functioning: hearing, vision

Functional capacity: vital (lung) capacity, gait speed (time to walk 10 m), standing balance, grip strength, chair stand test, reflex speeds

Biomarkers as potential future measures of population aging

Skirbekk, Staudinger, Cohen *Gerontology* 2018

Leonardo da Vinci: tree rings

Telomere length, algorithms applied to genome-wide DNA methylation data, algorithms combining information on multiple clinical biomarkers

"In the last 2 decades, many biomarkers of aging have been proposed, with limited success."

Is the world ageing?

By chronological measures, YES!

By economic, physical health, functional, or biomarker measures of age, nobody knows.

Migration

"A Spanish Civil Guard pulls an African migrant from a border fence, as Spanish Civil Guard officers stand underneath, during an attempt to cross into Spanish territories, between Morocco and Spain's north African enclave of Melilla." 2014-10-15 REUTERS/Jesus Blasco de Avellaneda

"A golfer hits a tee shot as African migrants sit atop a border fence during an attempt to cross into Spanish territories between Morocco and Spain's north African enclave of Melilla." 2014-10-22 REUTERS/Jose Palazon

"An African migrant grimaces while scaling a border fence during an attempt to cross into Spanish territories, between Morocco and Spain's north African enclave of Melilla." 2014-10-22
REUTERS/Jesus Blasco de Avellaneda

Migration

Migrant = person who lives outside country of birth (with intent to remain >1 year)

10 countries host half of all migrants.

USA hosts almost 20% of all migrants.

In 2015, 72% of migrants were aged 20-64, 15% under age 20, 13% aged 65+.

Total of 244 million in 2015 is 41% increase since 2000.

UN Population Division, Trends in International Migrant Stock: The 2015 Revision.

Migration

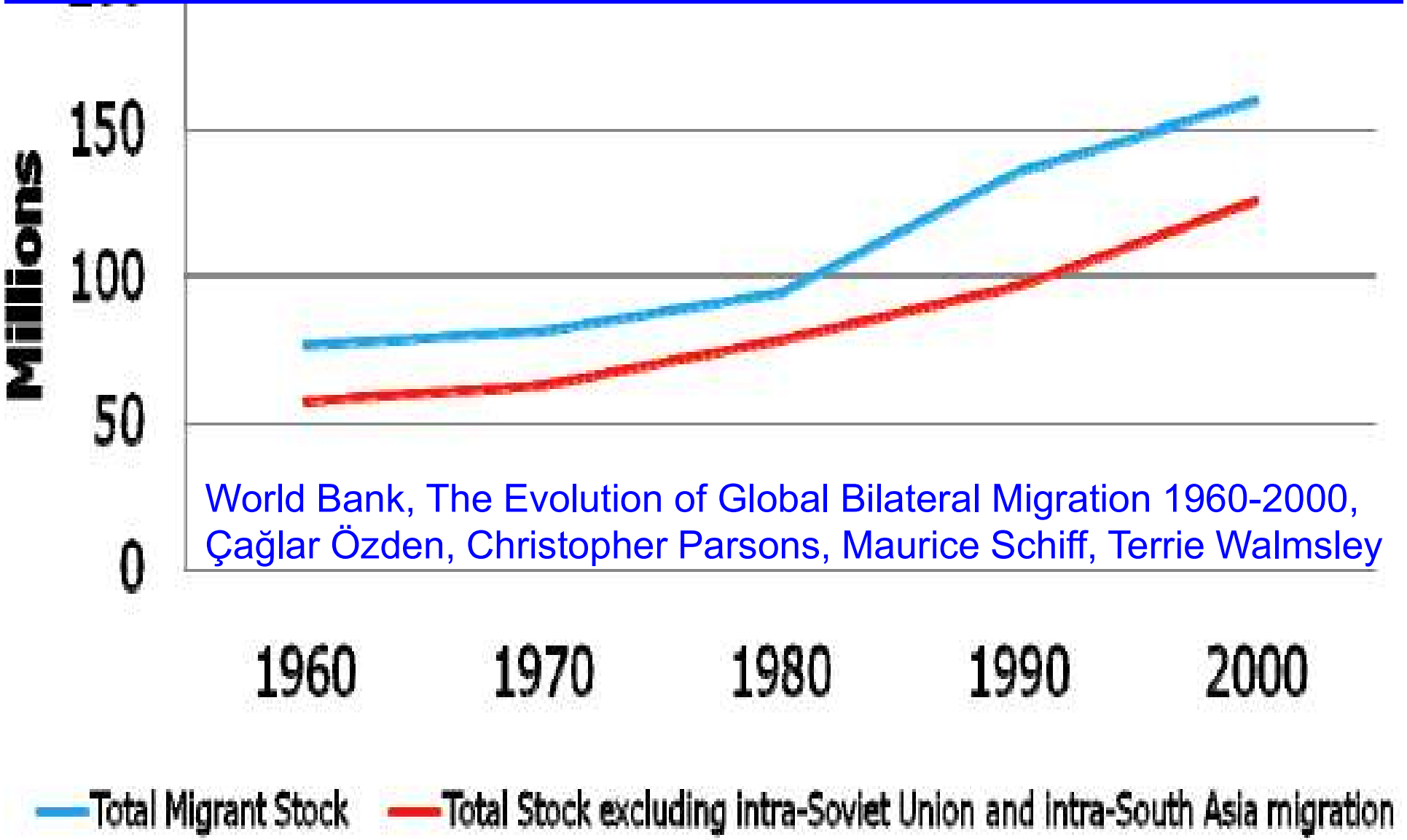
Internal migration dwarfs migration across national boundaries.

Migration between neighboring countries dwarfs interregional migration.

Migrant stocks ≠ migrant flows

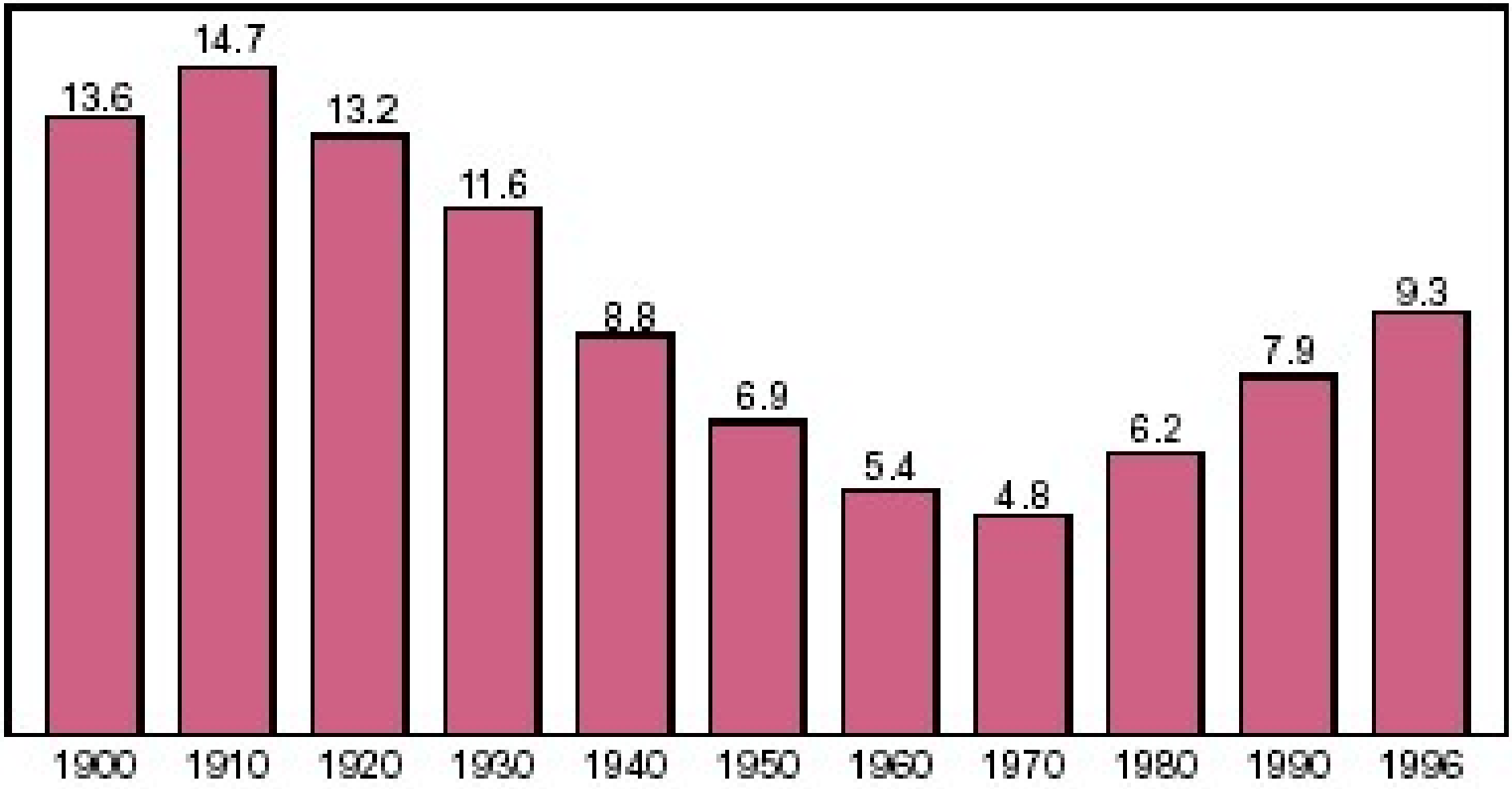
- Migrant stock is the number of people living outside country of birth (relatively easy to measure, except in USA 2010).
- Migrant flow is number of people crossing international border as "migrant" per year (difficult to measure).
- Nations have different definitions of "migrant".

Global migrant stock 1960-2000



World Bank, The Evolution of Global Bilateral Migration 1960-2000,
Çağlar Özden, Christopher Parsons, Maurice Schiff, Terrie Walmsley

% of U.S. population who were foreign-born, 1900–1996



International Migrants Stock Dataset in 2015

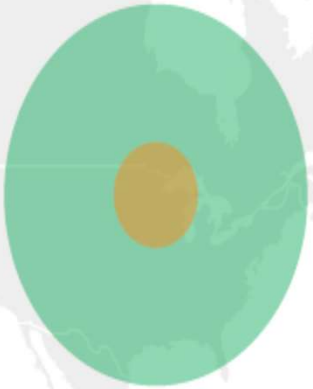
Indicates where international migrants live

Indicates where international migrants come from

The size of the circles is proportional to the number of migrants

North America

54 million | 4 million



244 million

The number of international migrants reached 244 million in 2015.

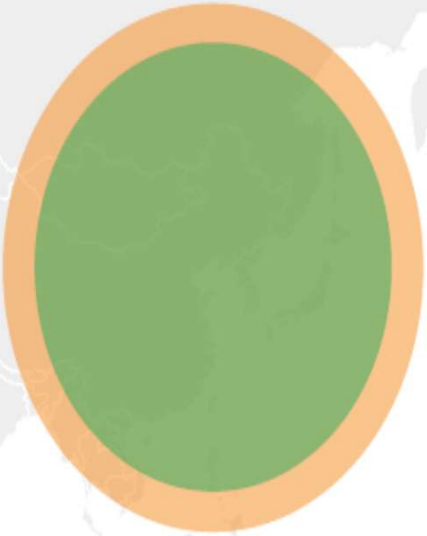
An increase of 71 million since 2000.

Europe

76 million | 62 million

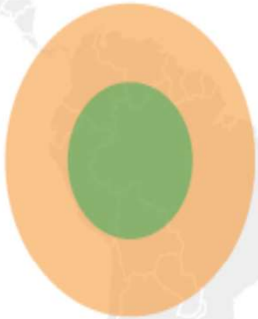
Asia

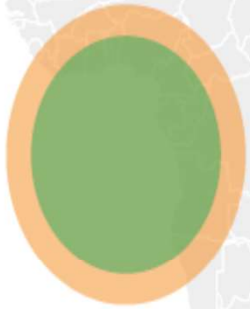
75 million | 104 million



Latin America and the Caribbean

9 million | 37 million





Africa

21 million | 34 million

Oceania

8 million | 2 million

Notes:
-All numbers are millions of people.
-Unknown residuals were redistributed proportionally to the size of groups for which data on international migrants were available by origin.

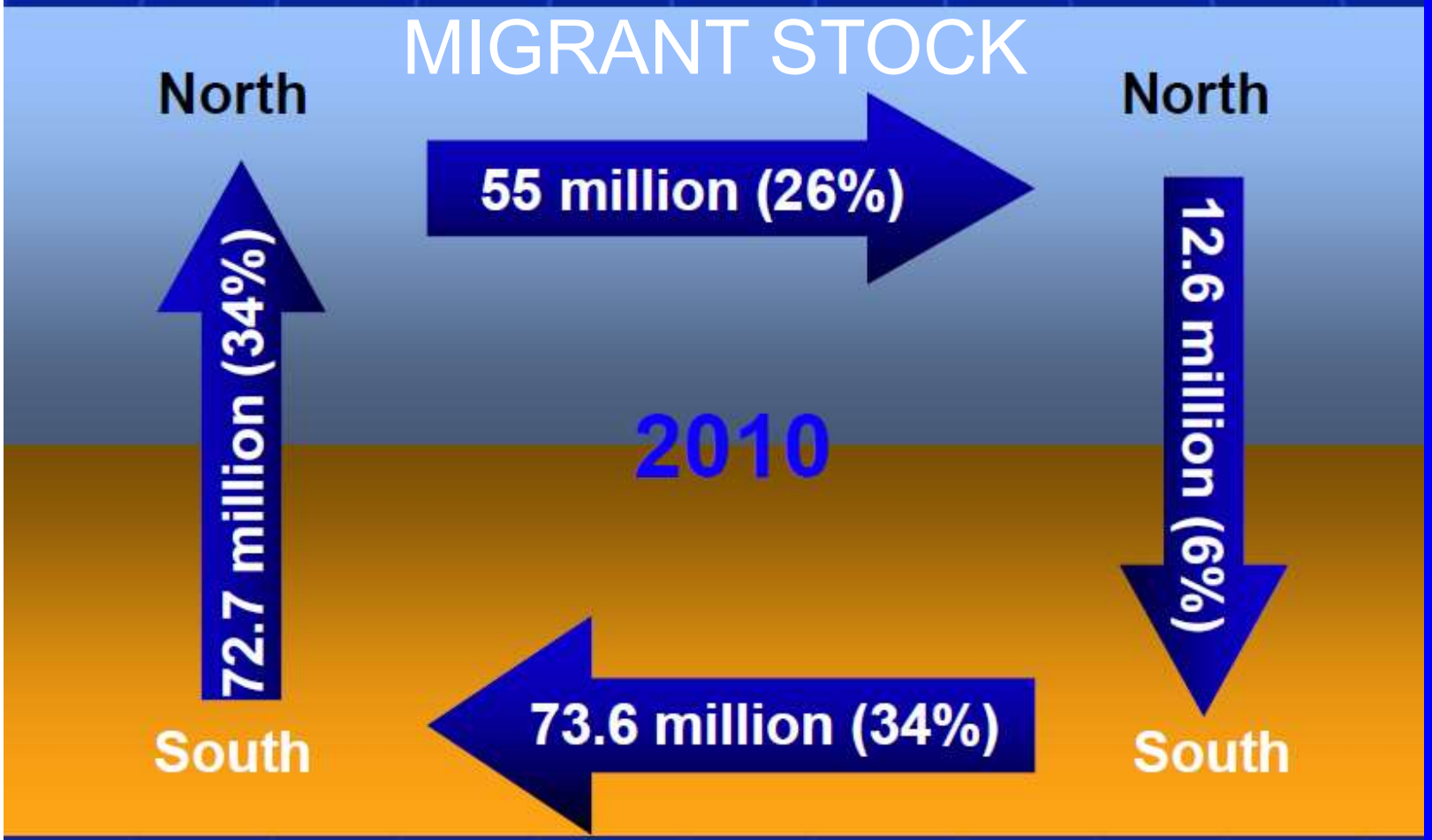
48% are women

39 median age

15% are below 20 years old

Source: United Nations, Department of Economic and Social Affairs, Population Division (2015).
Trends in International Migrant Stock: The 2015 revision.
(United Nations database, POP/DB/MIG/Stock/Rev.2015).
For more information visit: www.unmigration.org

South-South migration is as common ...



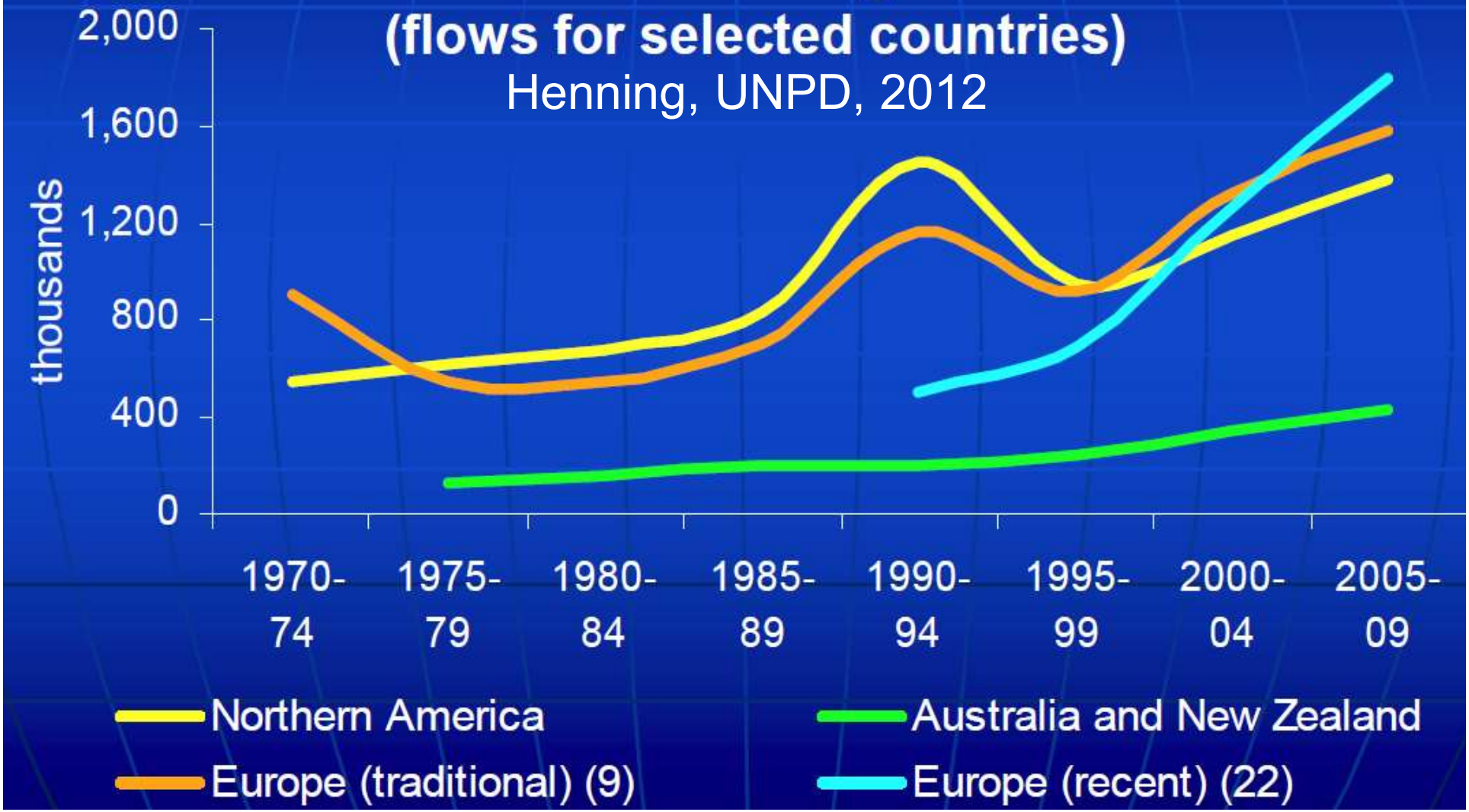
60% of international migrants

40% of international migrants

Henning, UNPD, 2012

as South-North migration

Annual average foreign immigrant inflows increased in many countries of the world starting in the 1990s



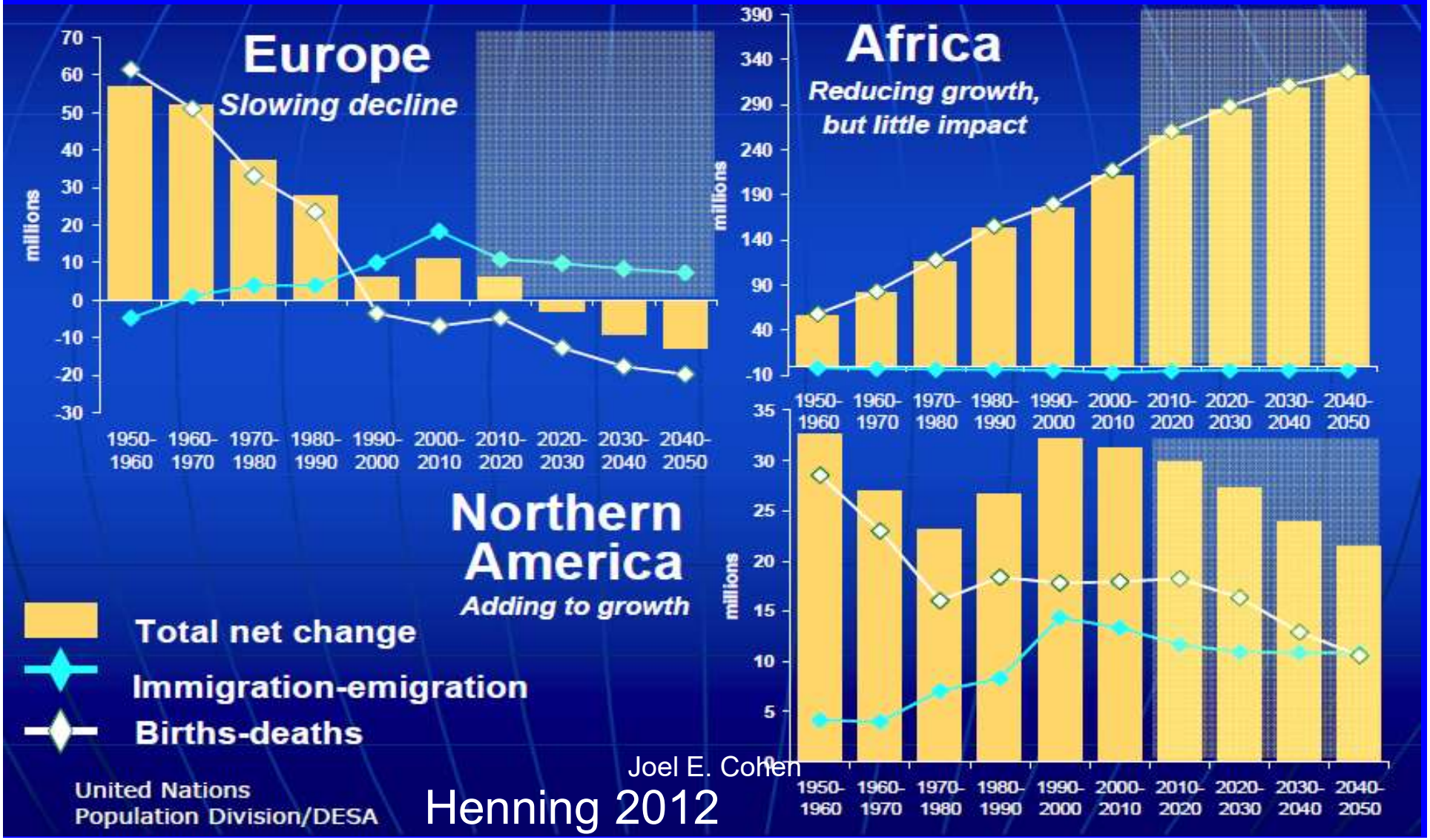
Migration relative to natural increase

Migration dominated natural increase (births minus deaths) before the demographic transition.

"Completion of the first demographic transition in many parts of the world has seen migration replace fertility and mortality as the leading agent of demographic change."

Martin Bell et al., *Pop. & Dev. Rev.* 2015

International migration affects population change differently in different regions.



Joel E. Cohen

Henning 2012

About 0.6% of people (~40 million) moved internationally 2005-2010.

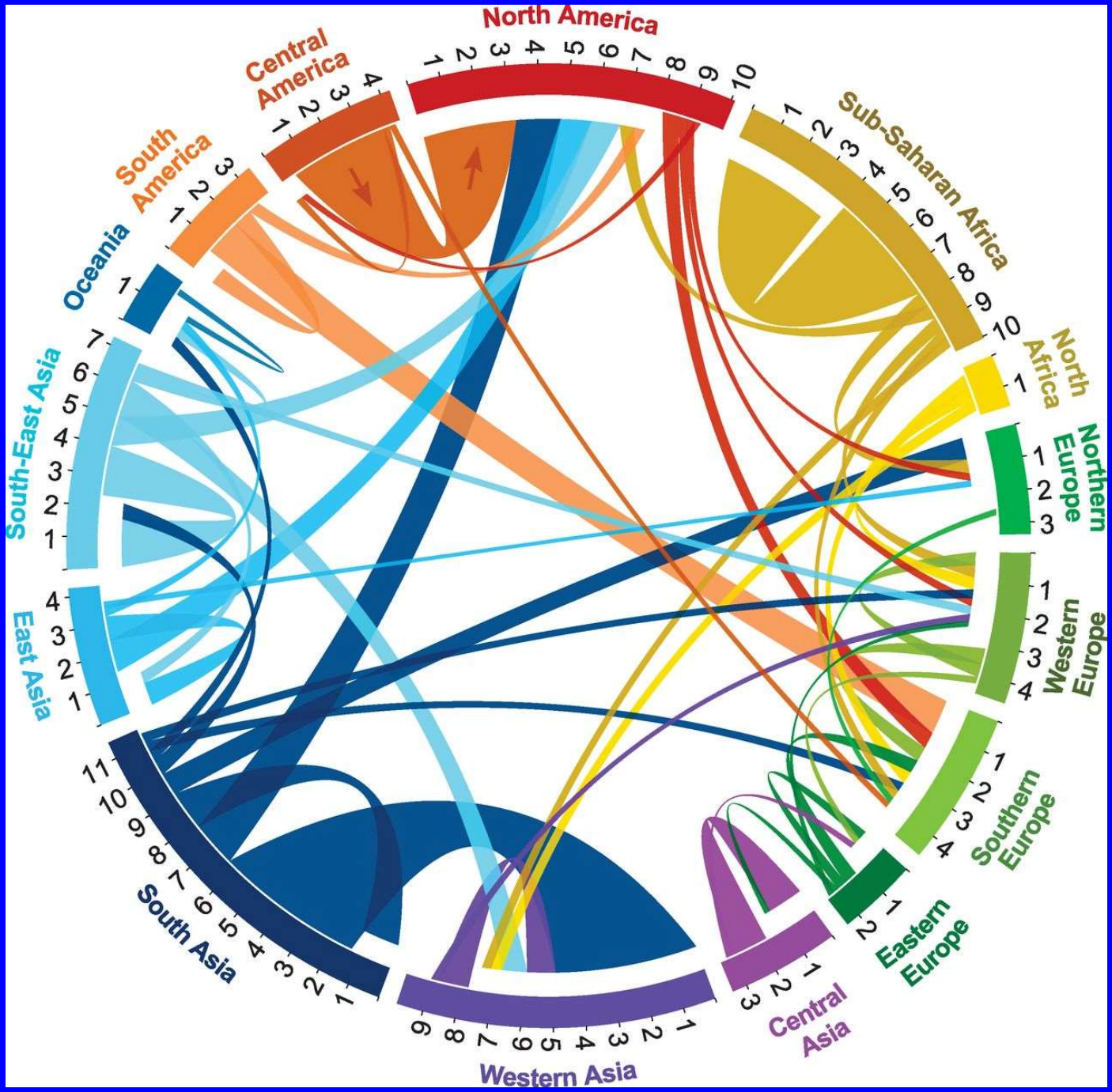
- Internal (domestic) migration dwarfs international migration.
- Migration between neighboring countries dwarfs interregional migration.
- People move: least→less developed, less→more developed, more→more developed.

Guy J. Abel & Nikola Sander, Science 2014

Migrant flows 2005-2010

G.J. Abel, N. Sander
Science 2014

Tick marks show millions of migrants (inflows & outflows).



750 million people (15% of adults) “say they would like to leave their country permanently.”

Gallup polls of 453,122 adults in 152 countries 2015-17

158 million “say they would like to move to the US” (21% of potential migrants). 16% of Americans "in 2017 … would like to move to another country … the highest measure to date." 33% of sub-Saharan African adults want to move. "In 13 countries, at least half of the adult population would like to move to another country if they had the chance." https://news.gallup.com/ December 10, 2018


Shibuya, Tokyo, 2014-10-26 JEC
Cities
CINEMAS
4

Cities are ancient.

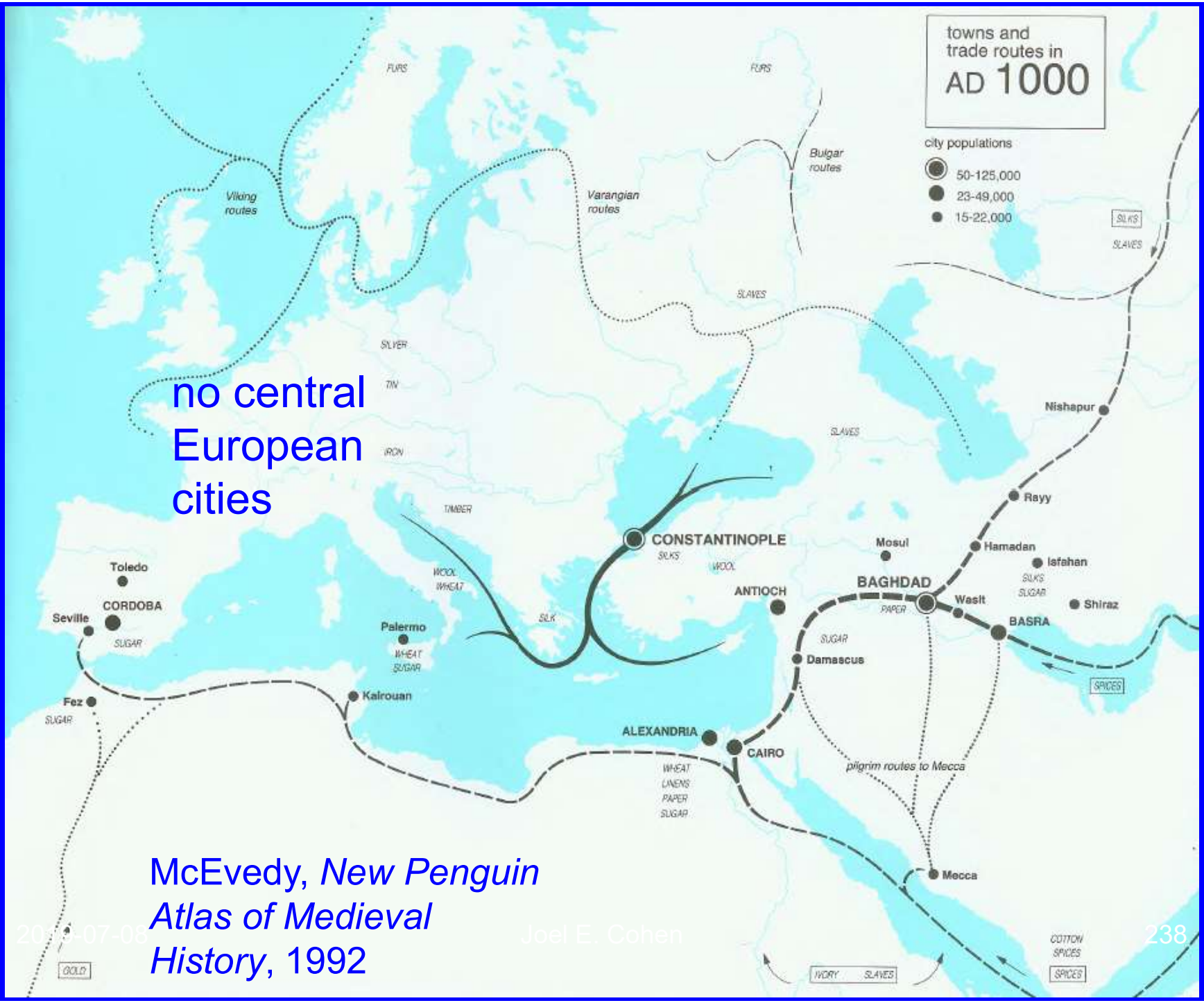
Neolithic settlements at 7000 BCE

- 'Ain Ghazal, Jordan
- Beidha, Jordan
- Çatalhöyük, Turkey
- Khirokitia, Cyprus
- Jericho, Palestinian Authority

Çatalhöyük, Verity Cridland, 2008

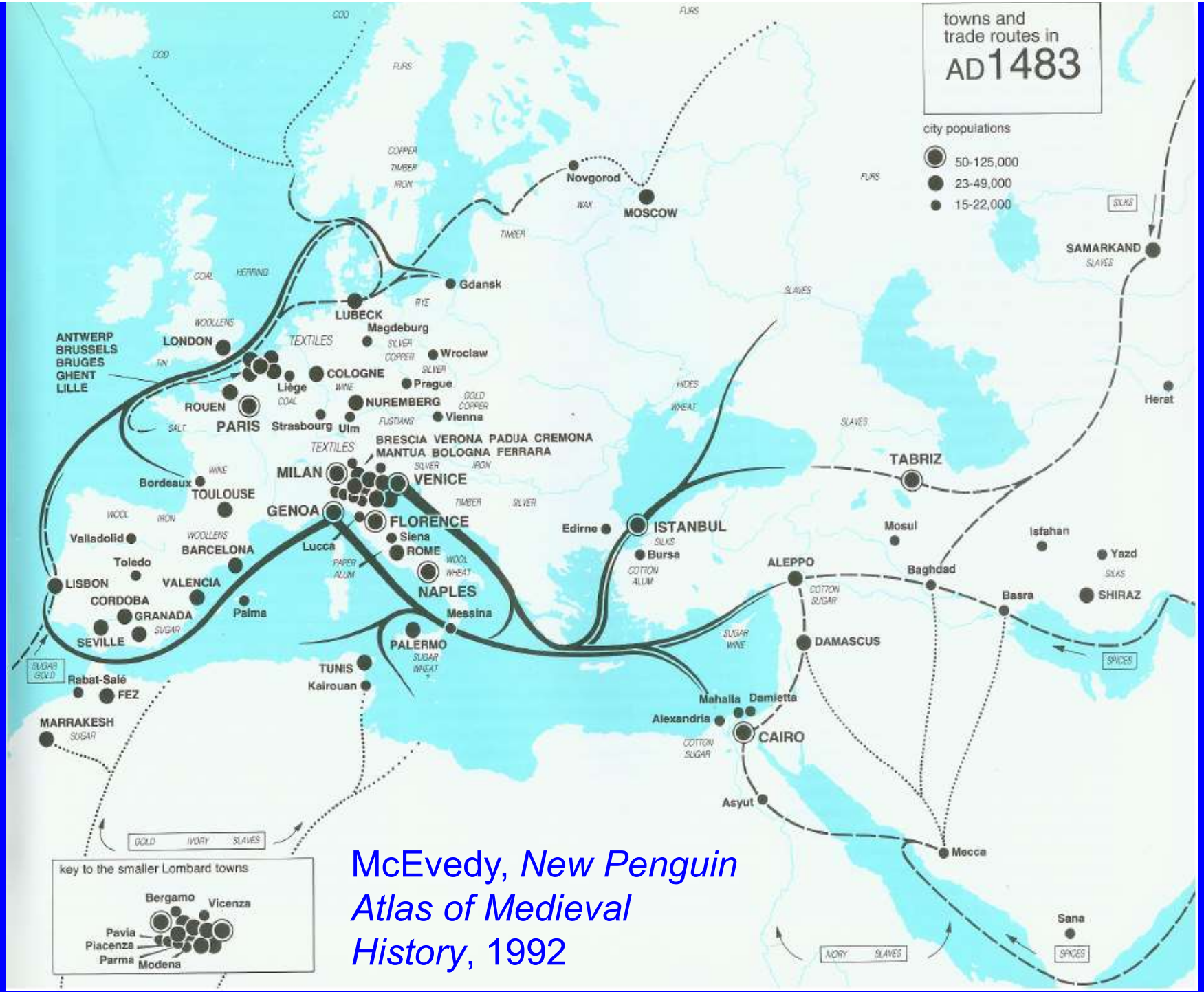
18 successive layers of buildings 7500 BCE-5600 BCE

Population 5000-7000



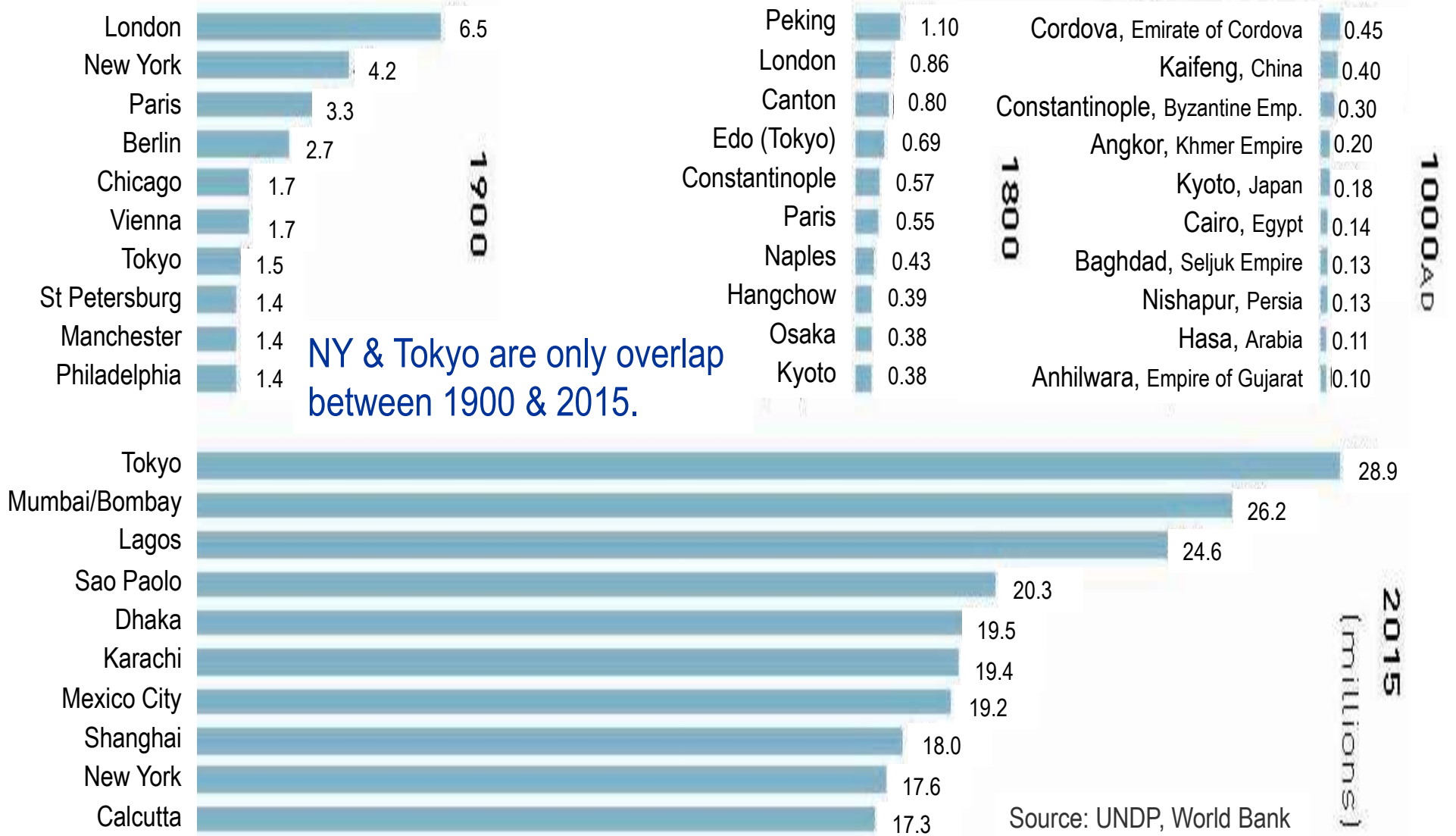
no central European cities

McEvedy, *New Penguin Atlas of Medieval History*, 1992



McEvedy, *New Penguin Atlas of Medieval History*, 1992

Top 10 cities in 1000 have no overlap with top 10 cities in 2015.



Harrison & Pearce 2000 AAAS

Cities grew in 20th century.

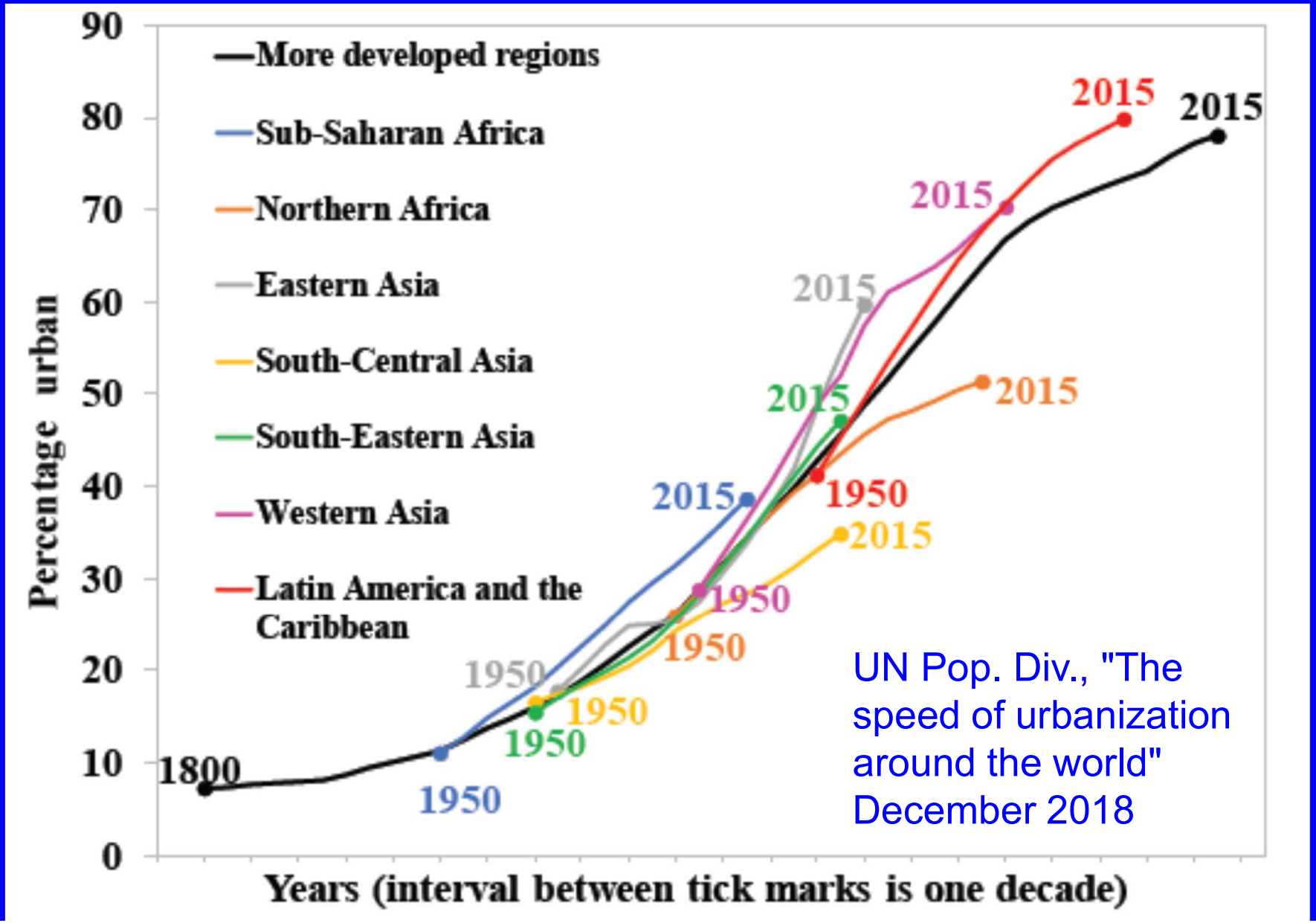
	1900	1950	2000
Urban population (billions)	0.21	0.751	2.87
% of total	13%	30%	47%
Number of cities with ≥10 million people	0	1	20
% urban pop. in cities with ≥10 million people	0	1.6	9.6

The 20th century was the last century with more rural than urban people.

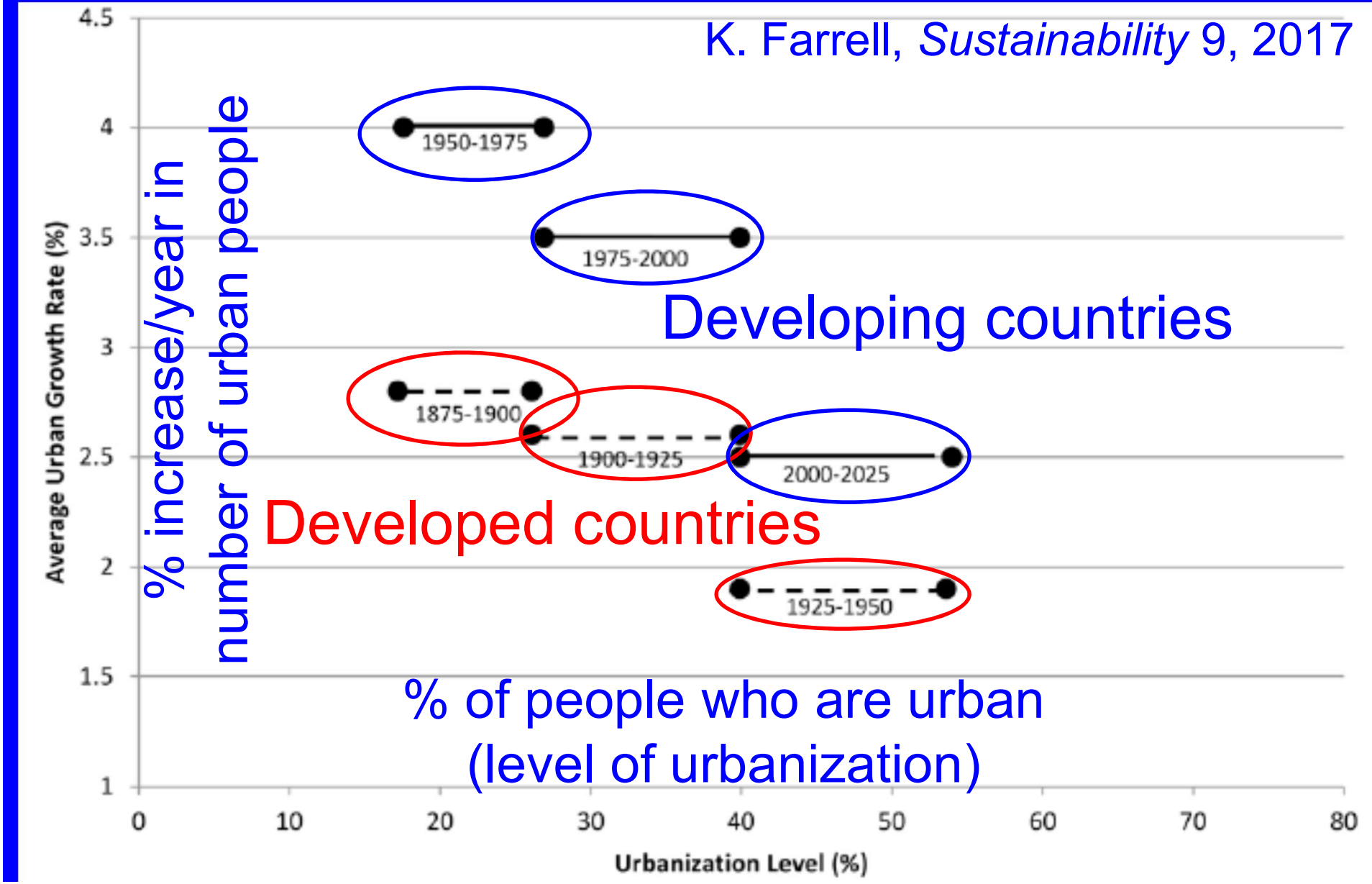
year	% urban
1950	30
2014	54
2050 (projected)	66

UN Population Division,
World Urbanization Prospects 2014

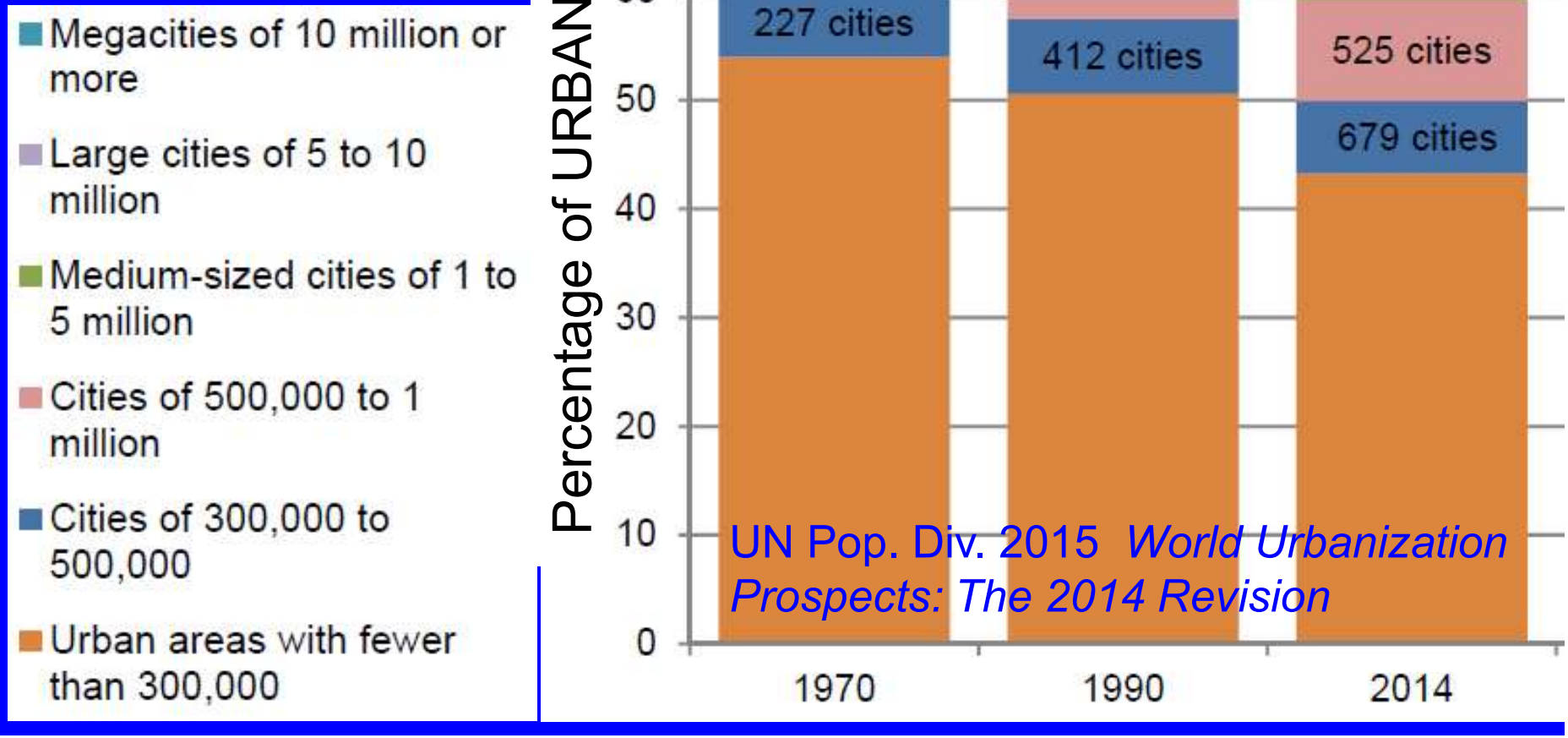
Regions urbanized at different rates.



For given level of urbanization, urban populations grew faster in developing countries.

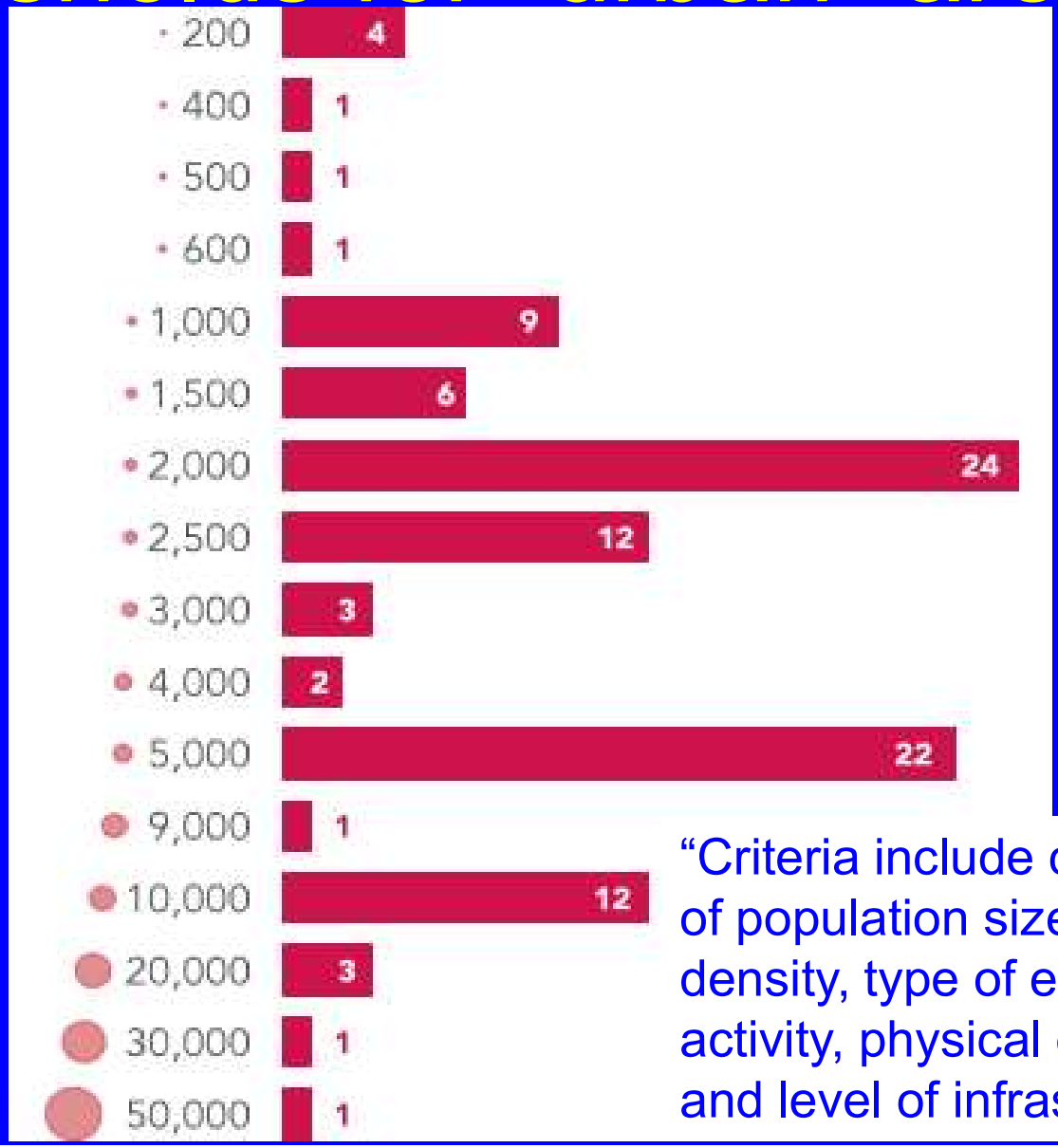


1/2 urban people live in cities <500,000.



Different countries use different thresholds for “urban” areas.

Circles show relative population sizes.



Bars show relative number of countries.

UN Pop. Div., *World Urbanization Prospects: 2014 Rev.*

World Bank, SDG Atlas

2019-07-08

“Criteria include combinations of population size, population density, type of economic activity, physical characteristics, and level of infrastructure.”

Where are people?

Least densely populated half of Earth's censused land area has <2% of people,

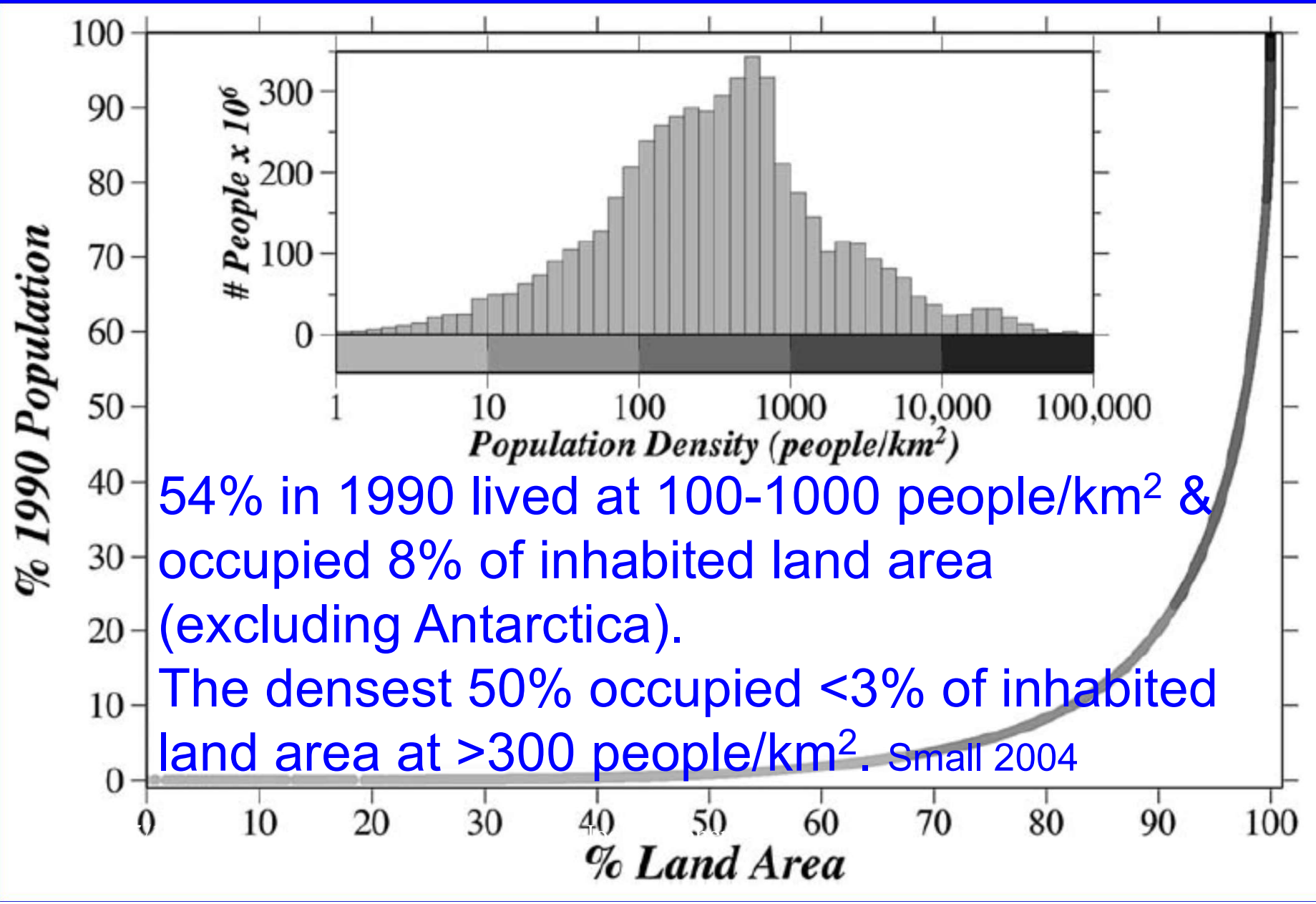
<10 people/km^2.

~½ of all people live in <3% of censused land area,

>500 people/km^2.

Cities occupy 2-3% of censused land.

Lorenz curve of people in space



54% in 1990 lived at 100-1000 people/km^2 & occupied 8% of inhabited land area (excluding Antarctica).

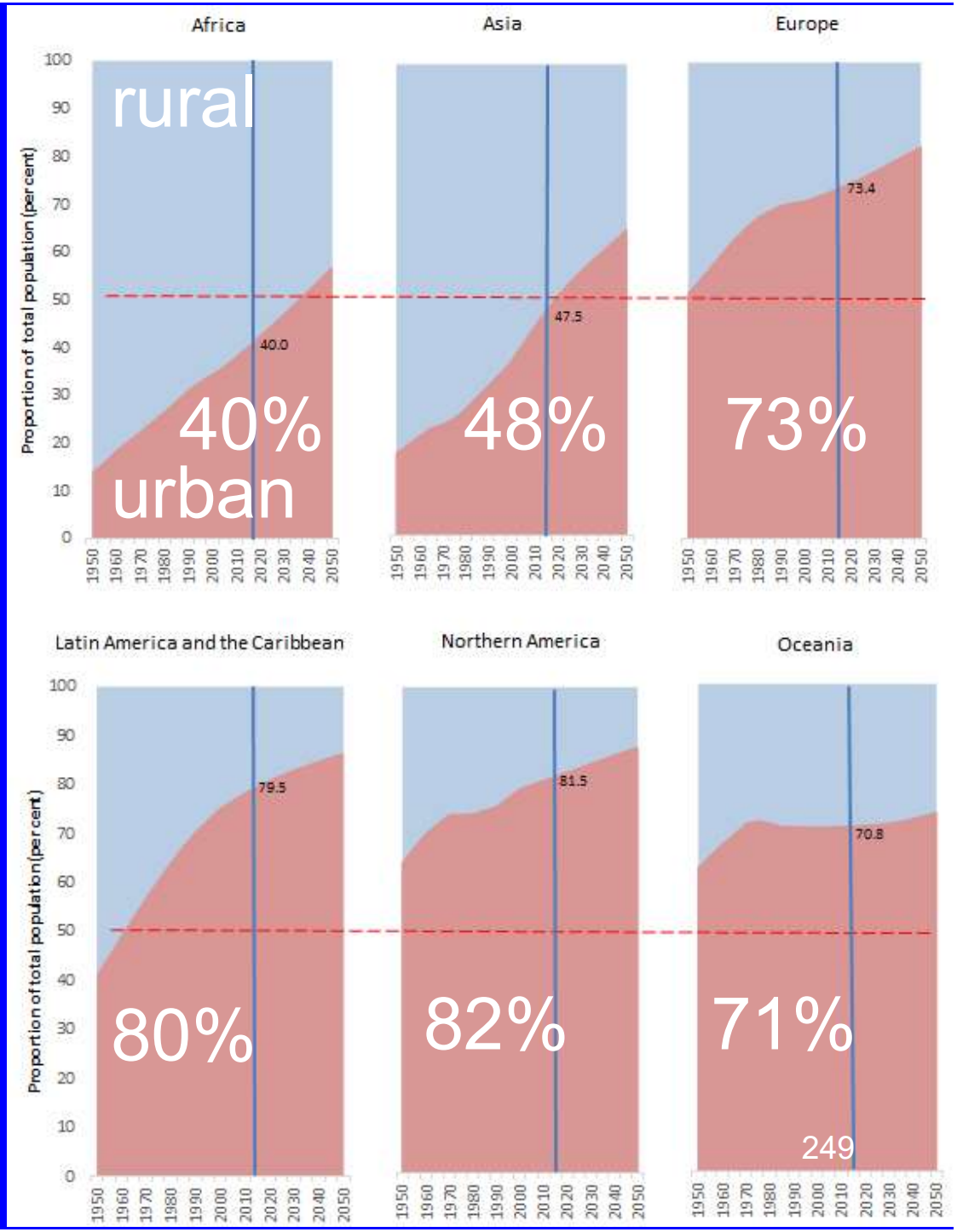
The densest 50% occupied <3% of inhabited land area at >300 people/km^2. Small 2004

% urban varies by region.

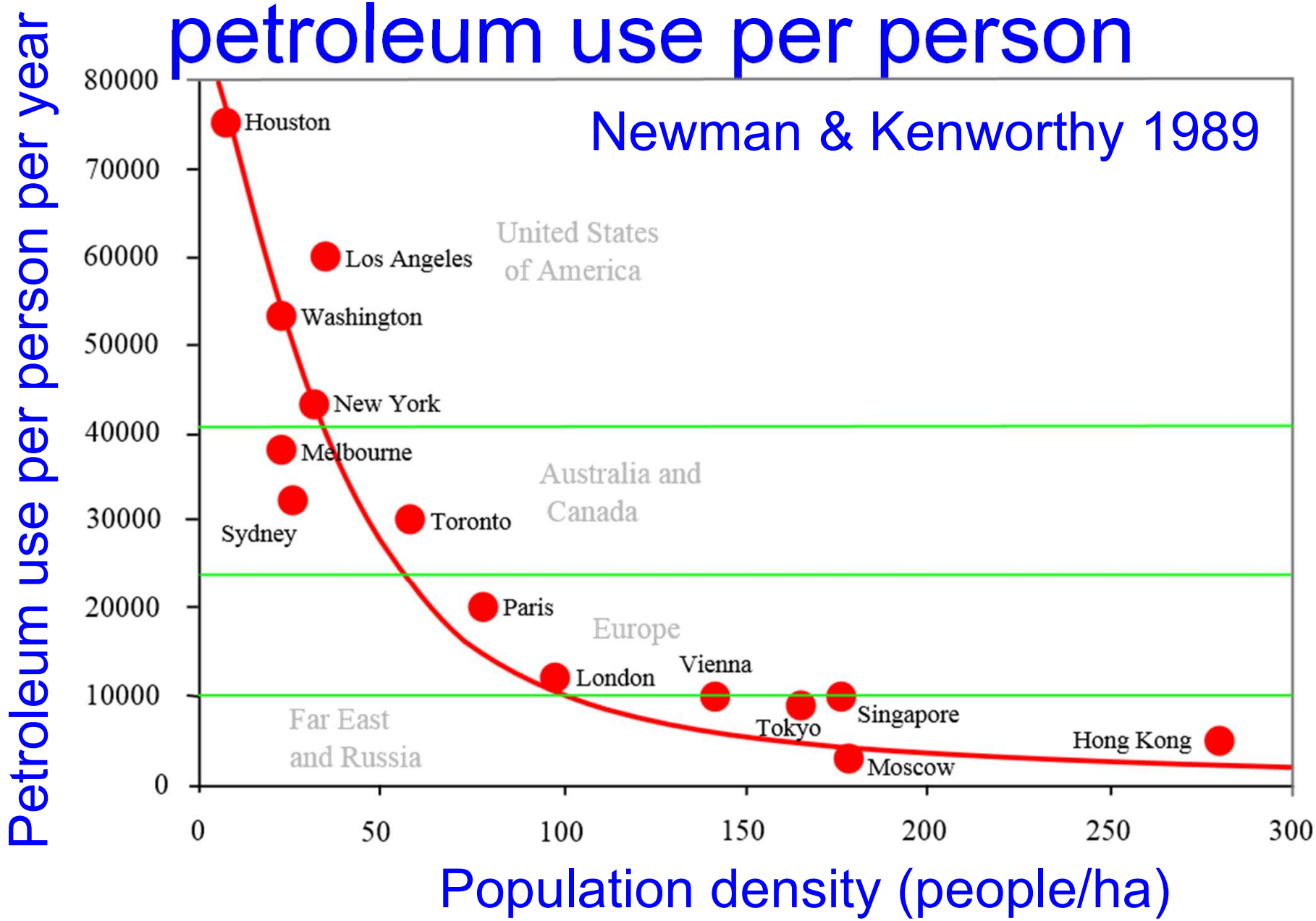
N. America > Lat.Am. & Carib. > Europe > Oceania > Asia > Africa

UN Pop. Div. 2015 *World Urbanization Prospects: The 2014 Revision*

2019-07-08

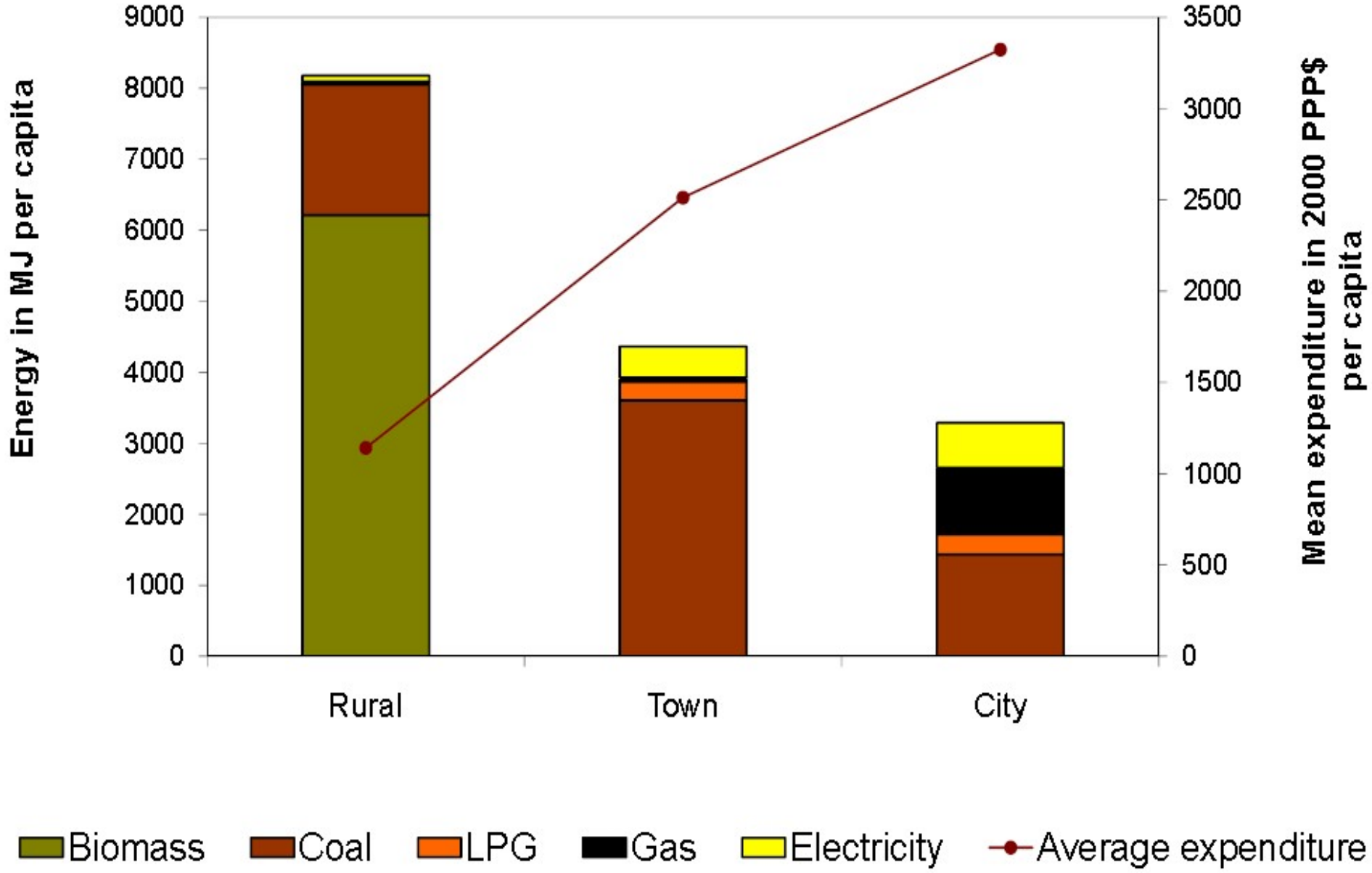


Higher urban density, lower petroleum use per person



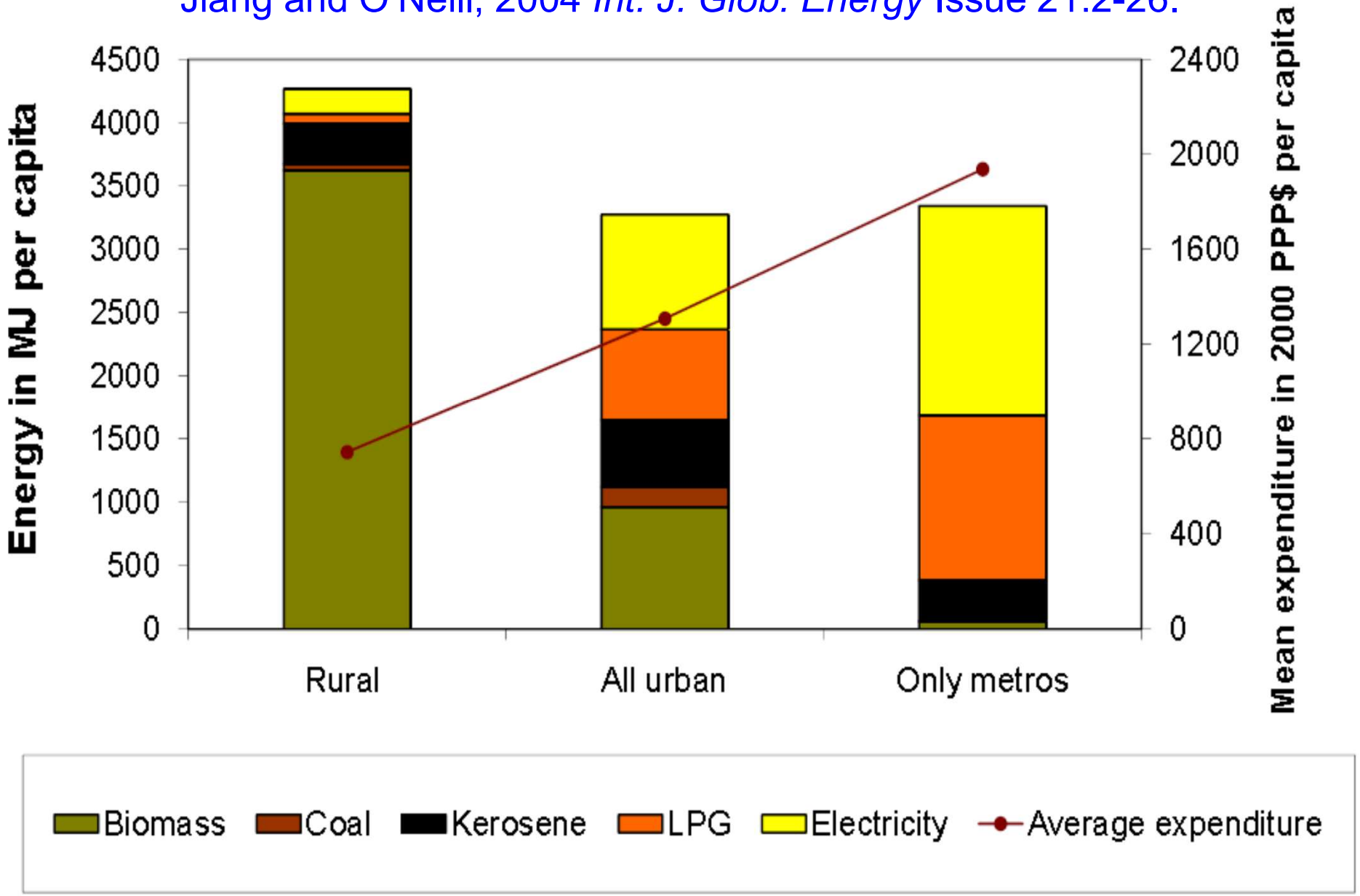
China

Jiang and O'Neill, 2004 *Int. J. Glob. Energy* Issue 21:2-26.



India

Jiang and O'Neill, 2004 *Int. J. Glob. Energy* Issue 21:2-26.



634 million people live in coastal areas at <10 m (33 ft) above sea level.

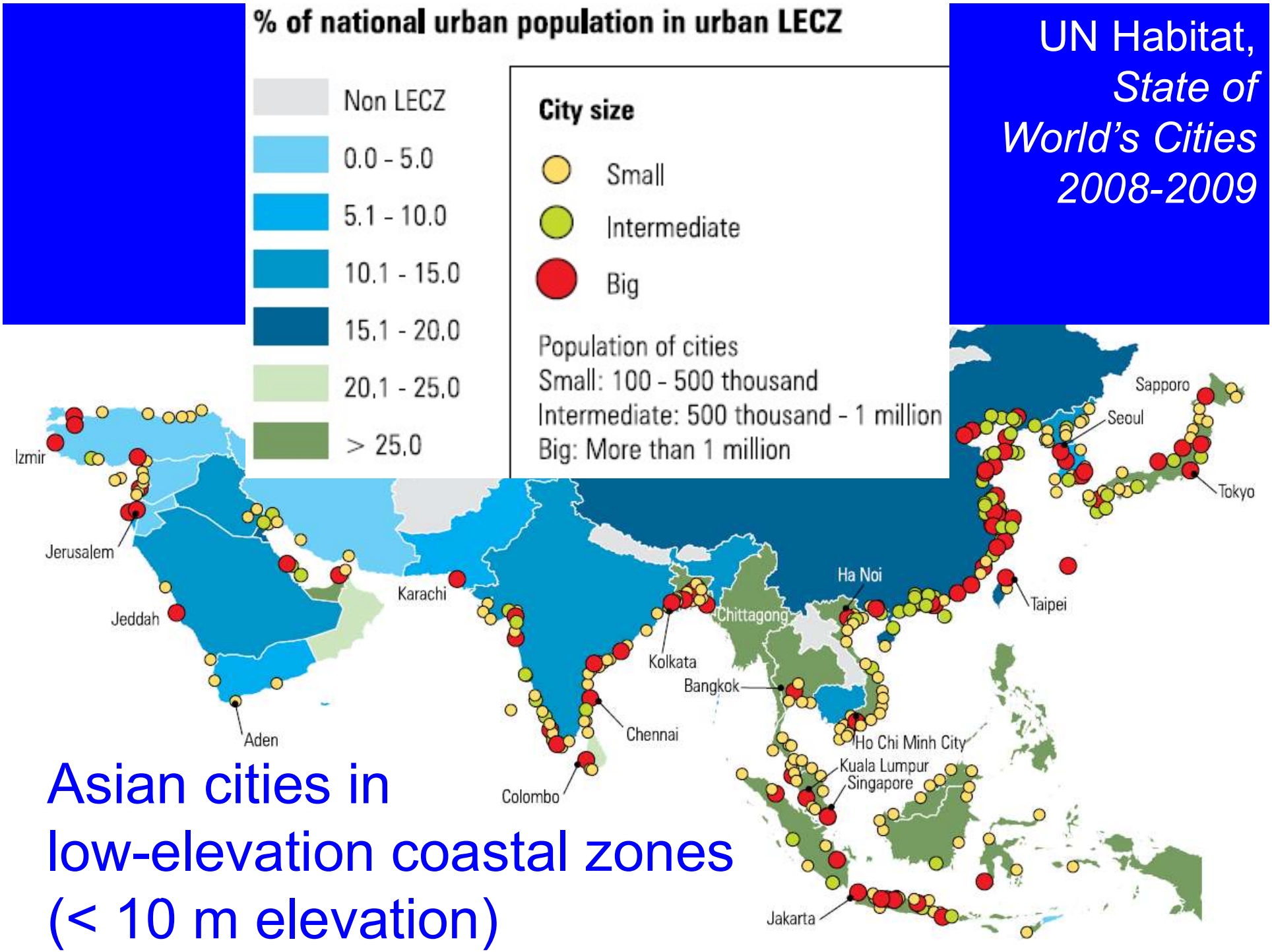
Of those 634 million, 360 million are urban.

>180 countries have people in low coastal zones.

2/3 of those countries have urban areas of more than 5 million people in low-elevation coastal zones.

McGranahan, Balk, Anderson *Environment & Urbanization* 2007

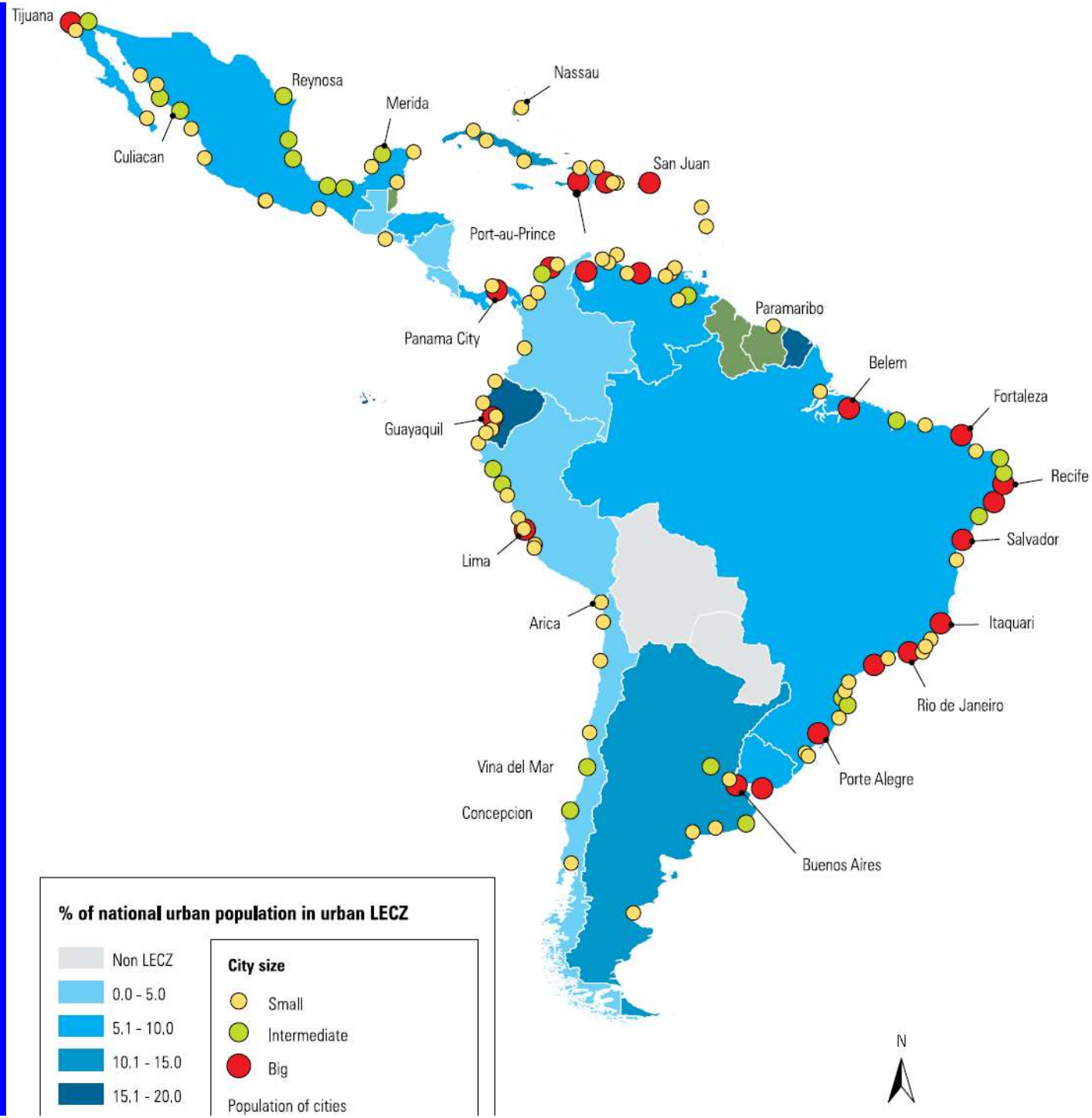
UN Habitat,
State of World's Cities 2008-2009



Asian cities in low-elevation coastal zones (< 10 m elevation)

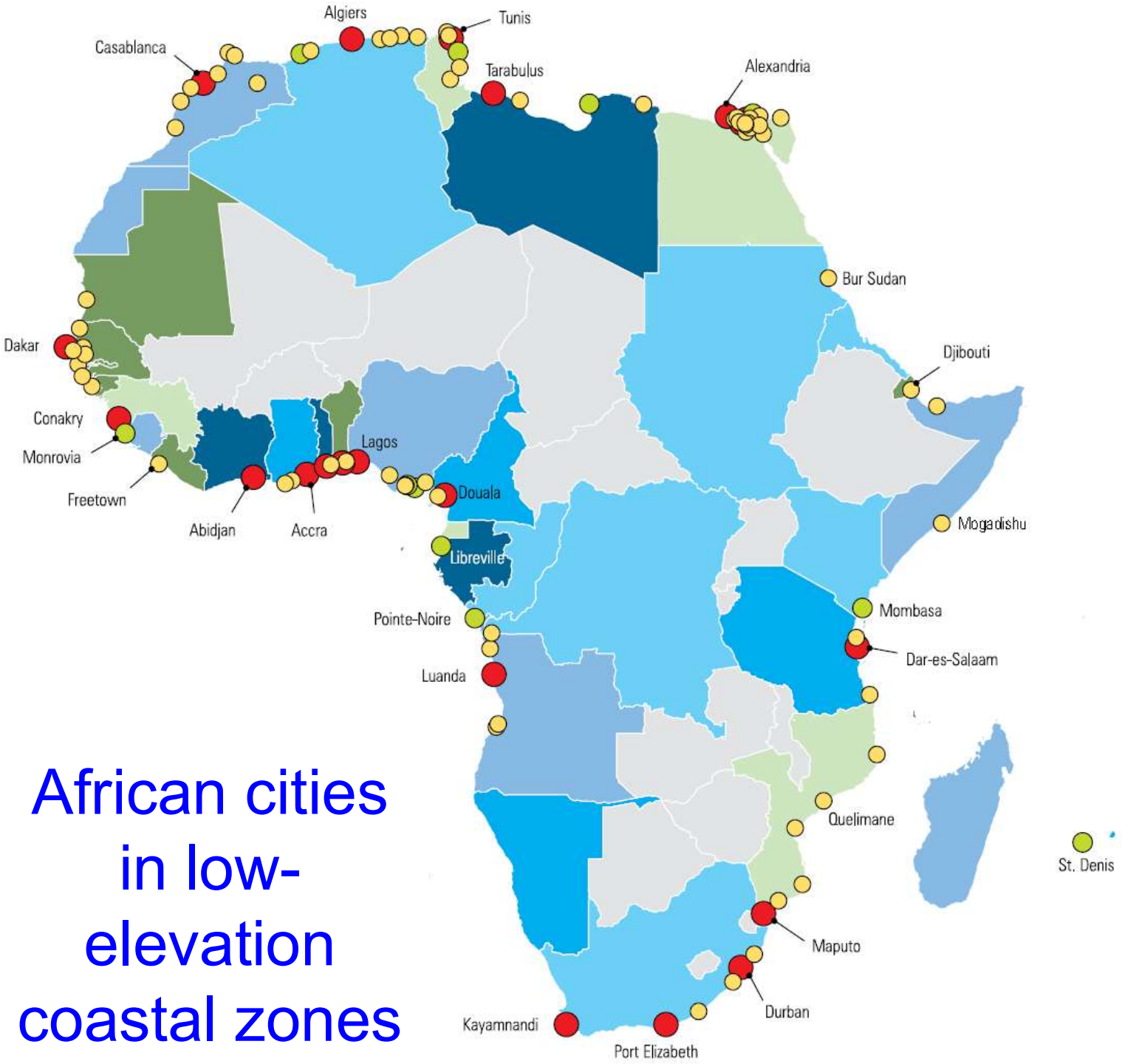
Latin American & Caribbean cities in low-elevation coastal zones

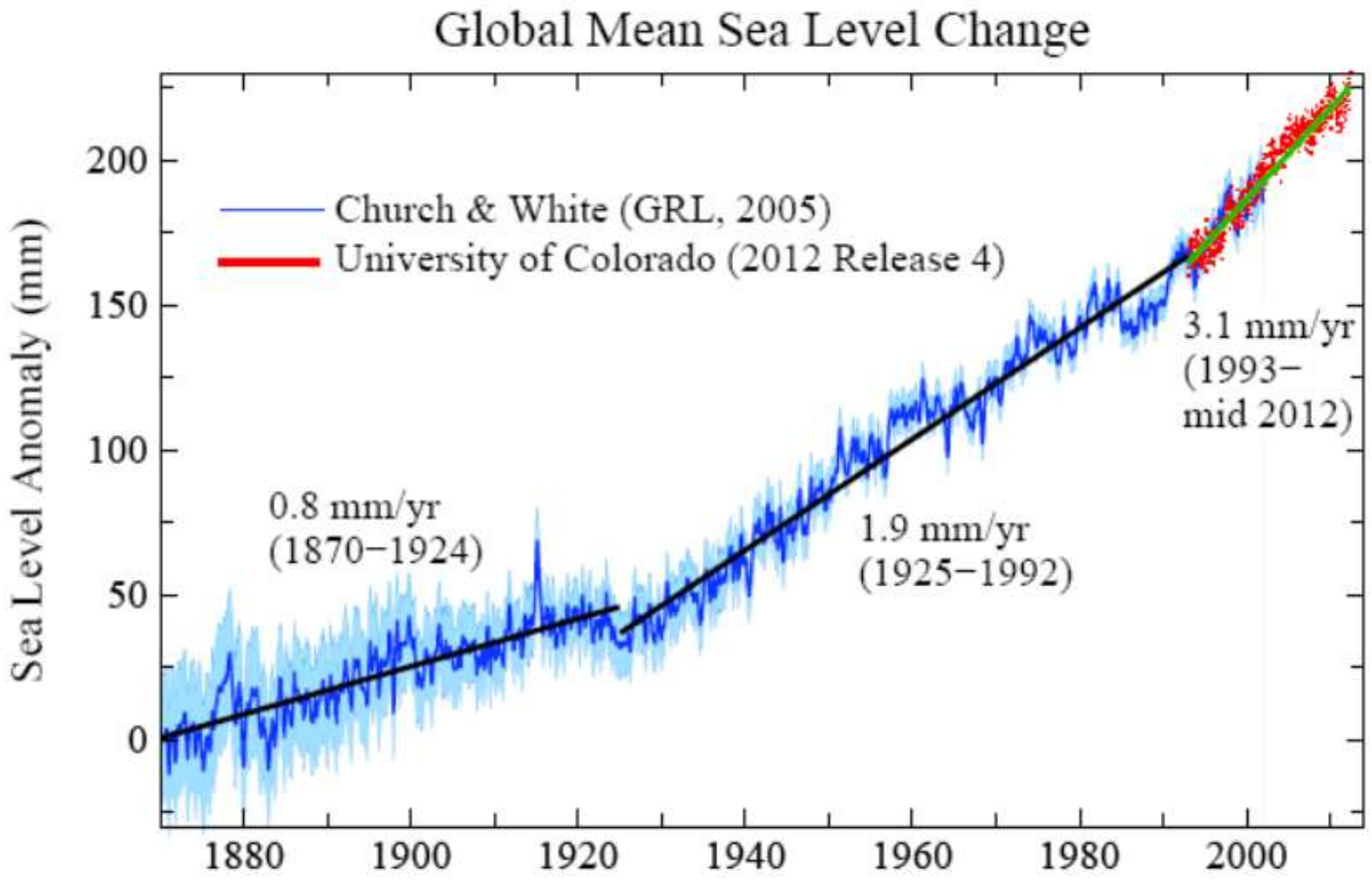
UN Habitat, *State of World's Cities 2008-2009*



UN Habitat, *State of World's Cities 2008-2009*

African cities in low-elevation coastal zones





Blue: Sea level change from tide-gauge data ***(Church J.A. and White N.J., Geophys. Res. Lett. 2006; 33: L01602)***
Red: Univ. Colorado sea level analyses in satellite era ***(http://www.columbia.edu/~mhs119/SeaLevel/)*.**

Katrina, New Orleans, 2005-08-31

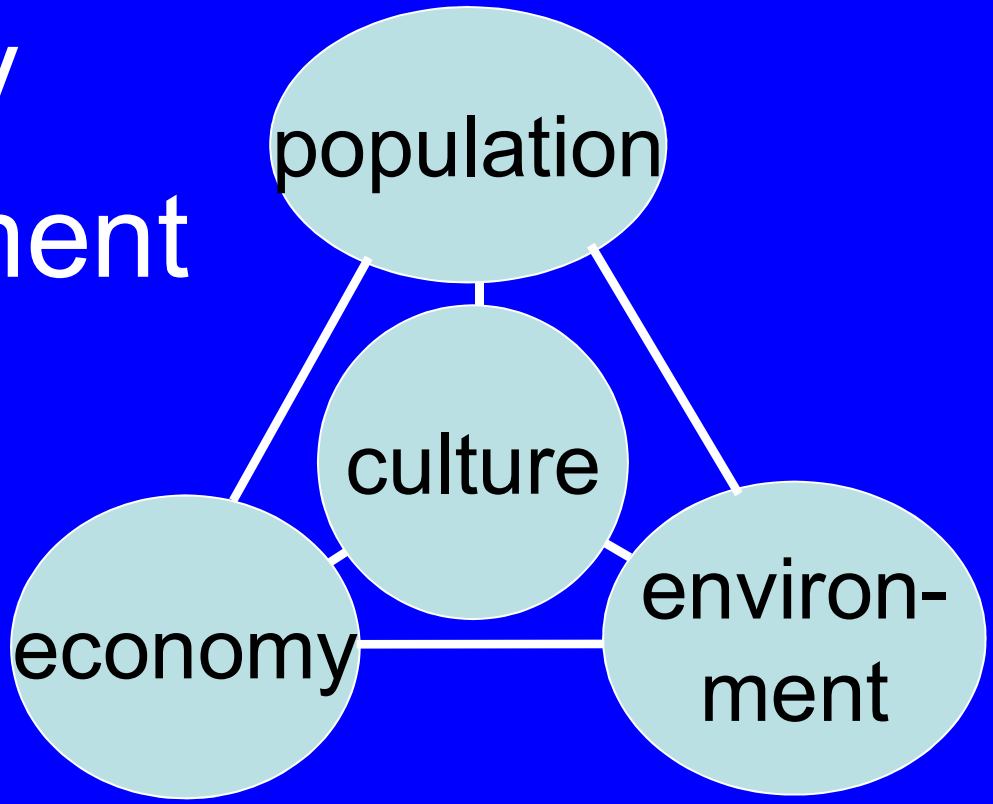
Sandy, New York City, 2012-10-28/29

"largest hurricane ever recorded in the Atlantic basin"--Wikipedia

Review of major ideas & facts

Challenges are linked.

1. Population
2. Economy
3. Environment
4. Culture



20th century was unique demographically.

1. Highest global population growth rate in history

   Only century in which global population doubled (& tripled)
2. Largest voluntary decline in fertility
3. Last century with more young people than old people
4. Last century with more rural people than urban people

Many population concepts apply across species.

Exponential growth model

Life table

Distribution of age at death

Age (or stage) structure

Cohort versus period populations

Interactions of population with environment, economics, culture

Ideas (1)

Given any statistic, ask:

How do we know the answer?

What is the uncertainty of the answer?

All humans today have African origins.

Human genetic variation is continuous, not categorical.

In exponential model (constant growth rate), doubling time (years) = 0.69 / growth rate/y.

Ideas (2)

In exponential model, plot of log(population size) as function of time is a straight line.

6/7 of population growth in last 12,000 years occurred in last 200 years.

Human population growth was super-exponential up to 1963.

Annual growth rate & annual increase peaked 1963-1990.

Annual growth rate fell from peak by half.

Ideas (3)

Rapid population growth slows economic growth. Countries that start with lower TFR grow faster economically.

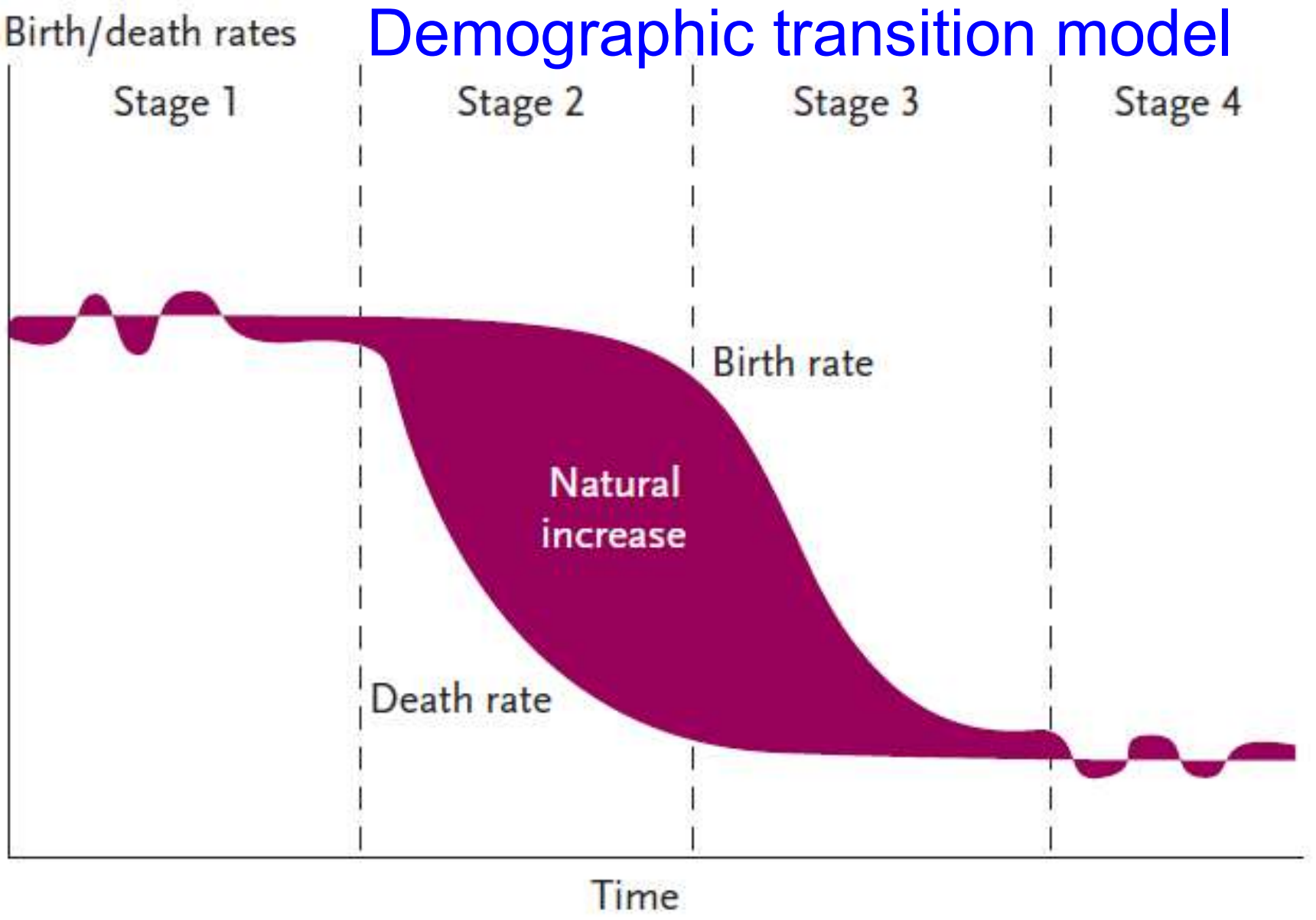
Population size changes by births (fertility), deaths (mortality), & migration (immigration, emigration).

Natural increase = births – deaths.

Net migration = immigration – emigration.

Ideas (4)

Demographic transition model



Ideas (5)

Total fertility rate (TFR) = average number of children born to 1 newborn girl at current birth rates assuming no maternal deaths.

Replacement level = 2.1-2.5 children/lifetime

Net rate of reproduction (NRR) = average number of daughters born to 1 newborn girl at current birth rates, considering maternal deaths.

Replacement level = 1 daughter/lifetime

Ideas (6)

World TFR & % increase/y fell by 1/2 since 1950.

Increased used of contraception by 15 percentage points goes with 1 fewer child per woman's lifetime (TFR reduced by 1).

Ideas (7)

Cohort population is a group of people *born* in a brief time interval (day, year, 5 years, 10 years), followed through time.

Period population is a group of people *alive* in a time interval, during that interval only.

Ideas (8)

Rapid economic growth & slow population growth go together. (Causality neutral!)

10-fold rise in income goes with reduction in TFR by half (cross-sectional data).

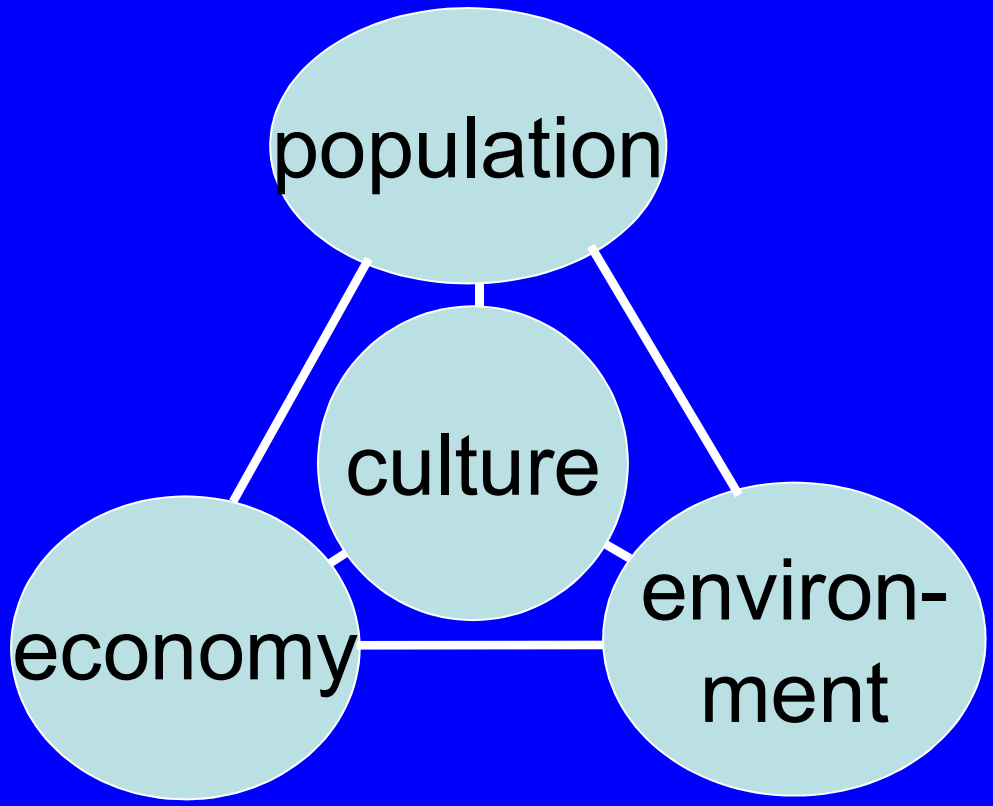
Countries that start with lower TFR grow faster economically (longitudinal data).

Educated women use more contraception, have children later, & have fewer children.

Multiple choice test

1. Over the last 2000 years, global human population size grew exponentially. T, F
2. Population size is now growing faster than ever before, as %. T, F;
   in absolute numbers added/yr. T, F
3. Average number of children per woman at current fertility rates is >3. T, F
4. ~1/2 world's women live in countries with fertility below replacement level. T, F
5. World population exceeds 10 billion. T, F;
   5 billion. T, F

Population
Economy
Environment
Culture
interact.



Thank you! Questions?