TOPICS 3.6 TO 3.8
AGE STRUCTURE DIAGRAMS, TOTAL FERTILITY, AND HUMAN POPULATION DYNAMICS

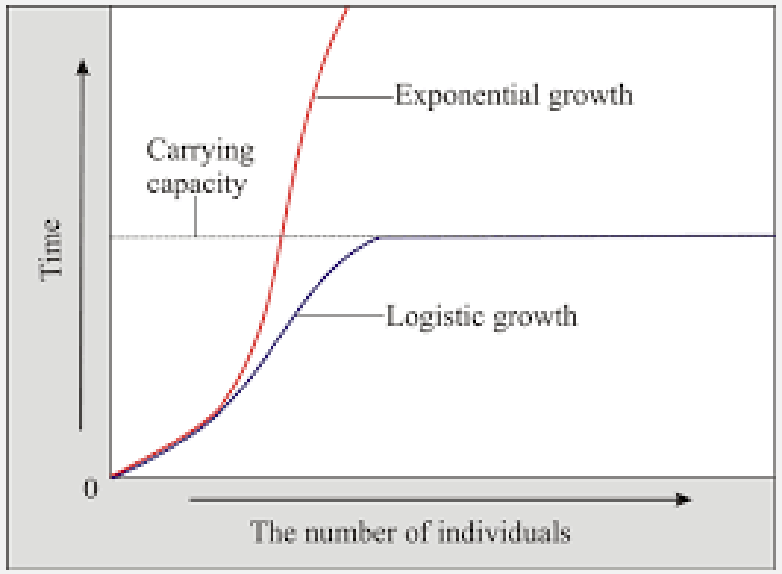
Enduring Understanding: Human populations change in response to a variety of factors, including social and cultural factors.

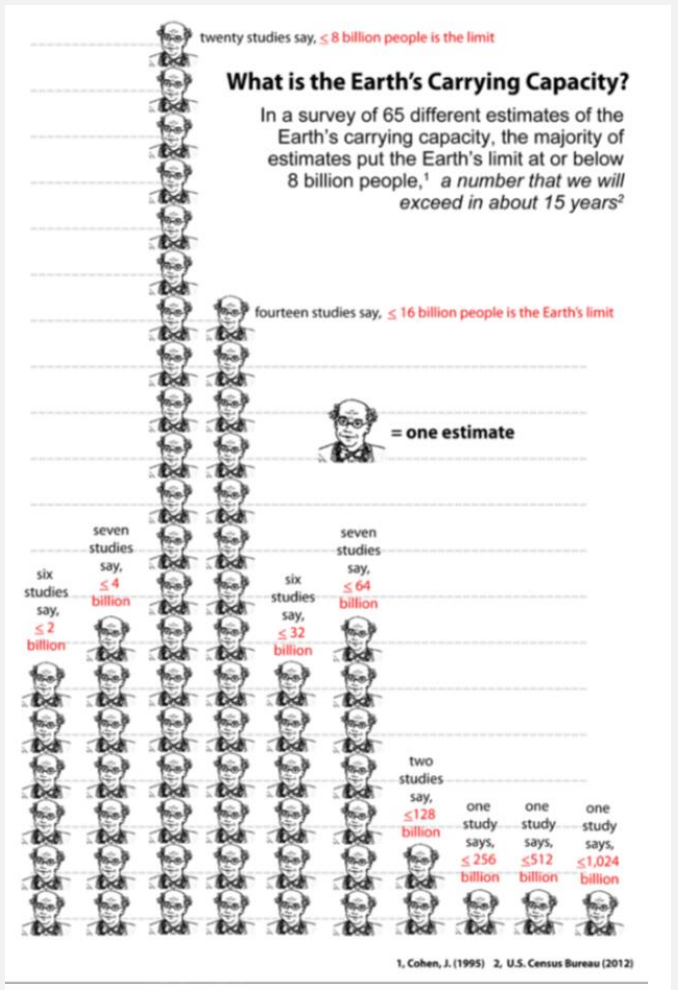
Learning Objectives: Explain age structure diagrams; Explain factors that affect total fertility rate in human populations; Explain how human populations experience growth and decline.

Related Readings: pg. 188 – 210 "Environment; The Science Behind the Stories" Withgott, Jay and Laposatea, Matthew

IS CONTINUED POPULATION GROWTH A PROBLEM?

- Population principles apply to humans too.
  - Humans populations are subject to the density-dependent and density-independent limiting factors.
    - Resource shortages, climate change, wars; something will eventually limit our growth.
    - There is a carrying capacity for all species, even humans
- What will that carrying capacity be?
- Can we change that carrying capacity through technology?





1 billion – 2 billion: living prosperously in a healthy environment

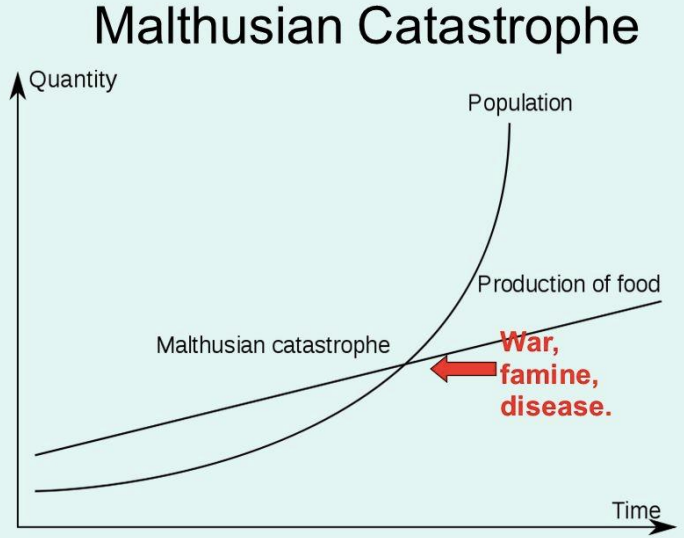
10 -12 billion (World Bank estimate): Extrapolation of current growth trends and assuming logistic growth

Up to 33 billion: living in poverty with no natural spaces

Carrying Capacity Estimates

IS POPULATION GROWTH A PROBLEM?

- **Thomas Malthus's** *An Essay on the Principles of Population* (1798) warned of rapidly increasing population
  - Although there was enough food then (1798), growth of food production was mostly linear, but population growth was exponential
  - Warned that humans will outstrip food supplies and other resources. Predicted disease, starvation, and conflicts (wars) over resources would soon reduce population size.
  - Paul Erlich wrote "The Population Bomb" which expressed Neo-Malthusian ideas in 1968, when there were only 3.5 billion people on Earth.
- **Cornucopians** argue that we will continue to find new resources and technology to support people
  - Supply of intellect is growing as well – innovation and creativity
  - Technological advances can increase carrying capacity



INCREASING AFFLUENCE COMPOUNDS THE PROBLEMS OF GROWING POPULATIONS

The **IPAT model**:

$I = P \times A \times T \times S$

I = Total impact

P = population

A = Affluence

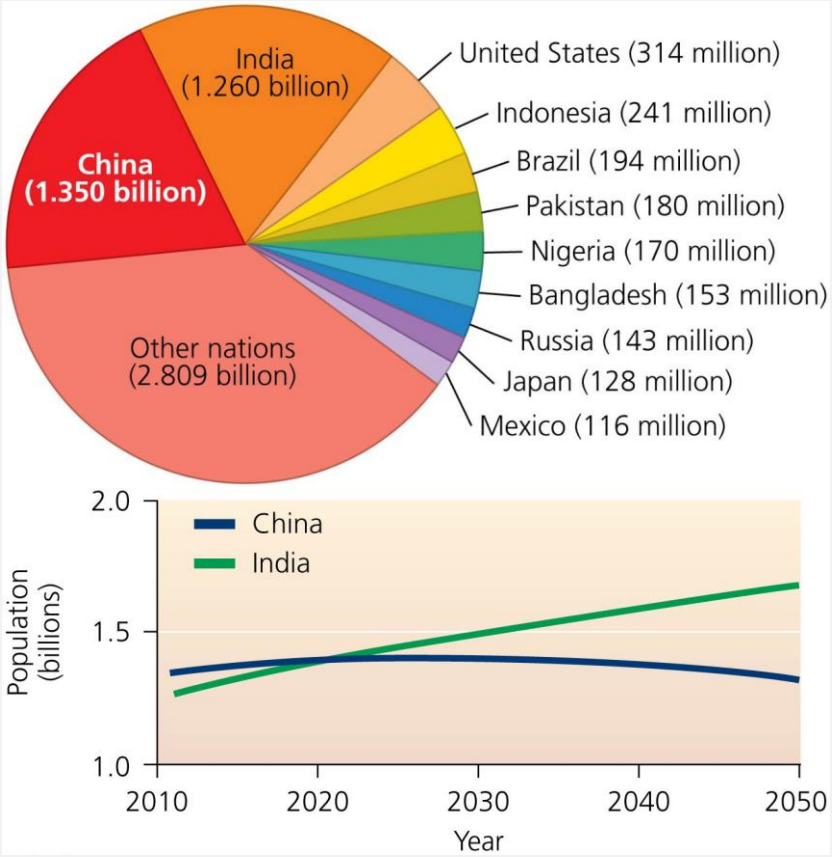
T = Technology

S = Sensitivity

- **Impact** equates to pollution, resource consumption, and reduction of ecosystem services
  - Humans use 25% of Earth's net primary production for our own needs
- Increasing **population** increases the strain on resources and increases the amounts of wastes and pollution
  - Each person requires resources and produces waste
- **Technology** has increased efficiency and reduced our strain on resources, resulting in further population growth
  - For example, increased agricultural production
- Increasing **affluence** is causing:
  - Increased resource consumption
  - Farmland erosion, depleted aquifers, urban pollution
- Some areas are more sensitive to pollution or have more limited resources to begin with

OUR WORLD AT ~~6.5~~ ~~7~~ ~~7.5~~ 7+ BILLION

- Populations continue to rise in many countries
  - Growing fastest in poverty-stricken developing nations



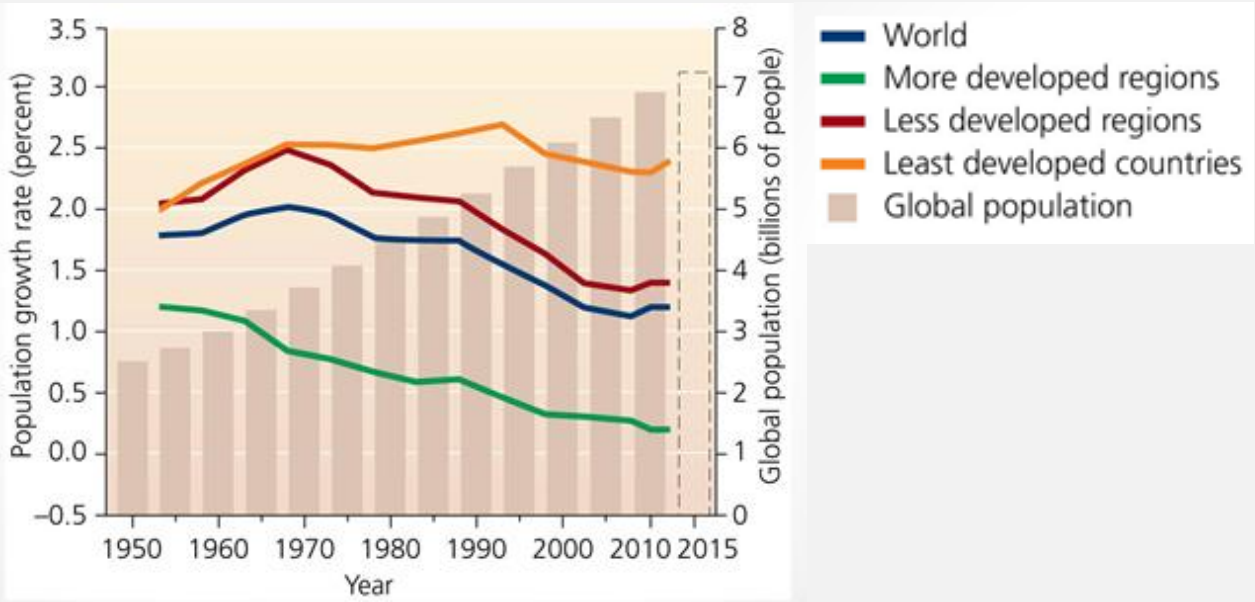
- The global population (≈7.7 billion) is growing exponentially
  - Our global population grew by 84 million people last year. (230,000 births per day)
  - It took until 1800 to reach 1 billion
  - In 1930 (130 years later) we reached 2 billion
  - We added the most recent billion in just 12 years
  - A positive feedback cycle
- Growth rates (r) vary from country to country
  - Some countries r > 5%, many countries are over r > 2%, and other country's populations are shrinking ($r \leq -2.3\%$)
- The current world average growth rate is r = +1.2%
  - At this rate, the human population of the planet will double in approximately 58 years

EXPONENTIAL GROWTH AND DOUBLING TIMES

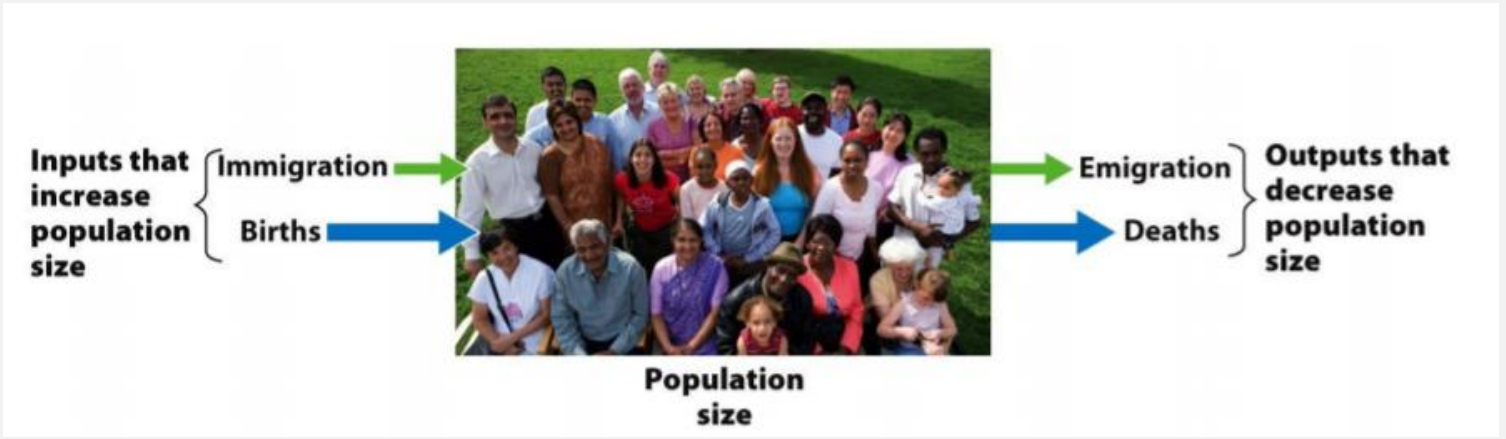
- The doubling time (t_{double}) for an exponentially growing population is the time required for a population to double in size.
- The equation for exponential growth is $N_t = N_0e^{rt}$
- For a population that is doubling in size, $N_t = 2N_0$
  - Therefore $2N_0 = N_0e^{rt}$ so….
  - $2 = e^{rt}$, and ….
  - $\ln 2 = rt$, and ….
  - $t = .693 / r$
- If r is expressed as a percent, not as a decimal then

$$t_{double} = 70/r.$$

- Small changes in growth rate (r) have a big impact on overall population size.
  - Bahrain has a growth rate of $r \approx 5\%$
  - Argentina has a growth rate $r \approx 1\%$
  - The population of Bahrain (regardless of how large it is) will double in 14 years, while it will take the population of Argentina 70 years to double
  - Small changes in growth rate have large effects on population growth.



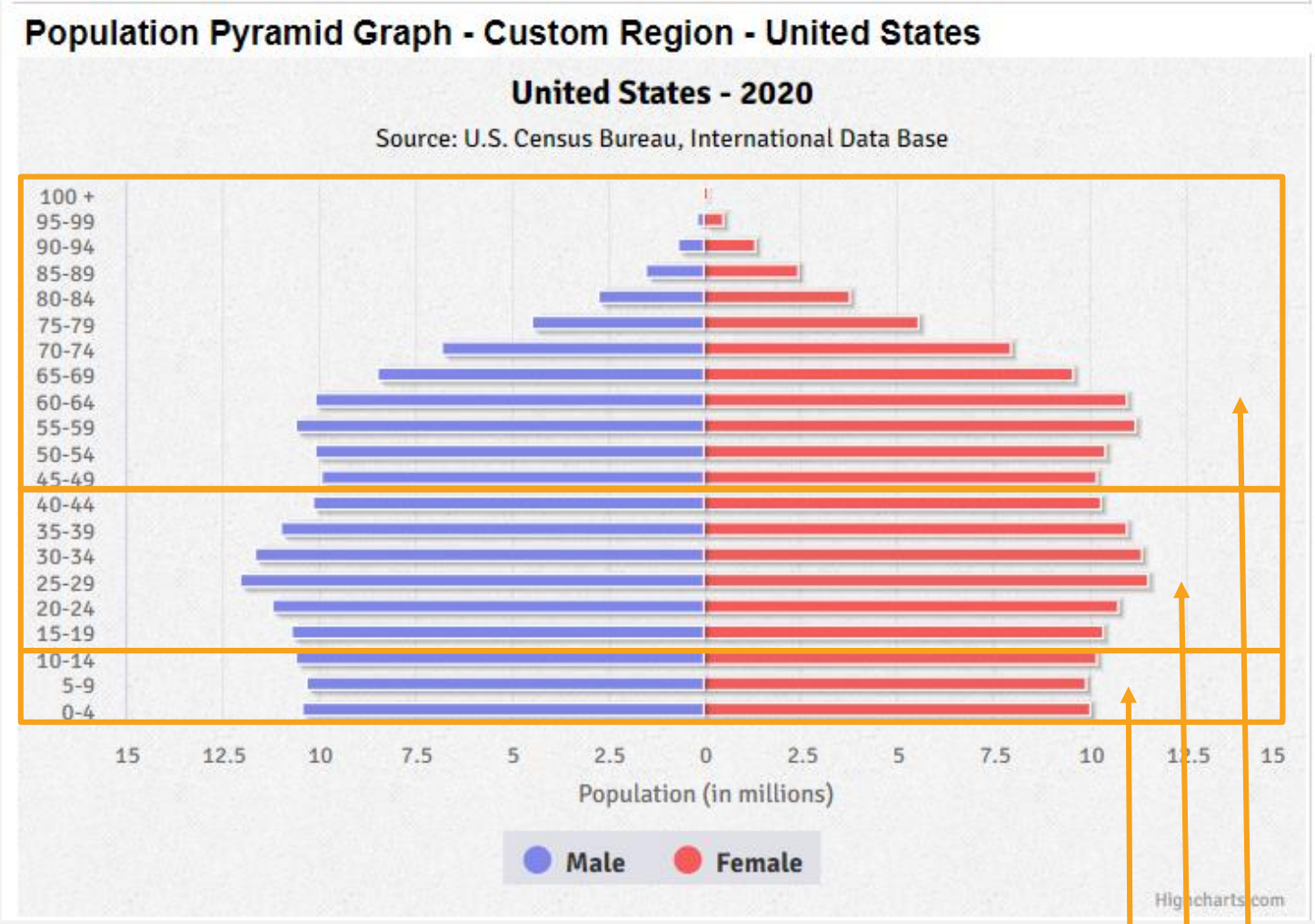
MORE POPULATION MATH



- Birth and immigration add individuals. Death and emigration remove individuals
  - **b = (B/N) x 100**
  - **d = (D/N) x 100**
  - **$\Delta P = B\text{-}D$ or $\Delta P = (B - D) + (I - E)$**
  - b = birth rate
  - d = death rate
  - B = Number of births
  - D = number of deaths
  - I = Number of immigrants
  - E = Number of emigrants
- Formulas for population growth rate (r,% change)
  - **r = b – d**
  - **r = (b-d) + (i – e)**
  - **r = (B – D) /N**
  - **r = [(B – D) + (I – E)] / N**
- Migration has an increasingly significant effect on population change.
  - War, civil strife, and environmental degradation cause people to flee their homes and seek new ones
  - Yet College Board usually ignores it in calculation problems and tends to ask about the "Rate of Natural Increase"

AGE STRUCTURE DIAGRAMS HELP PREDICT POPULATION DYNAMICS

- ***Age structure diagrams*** are graphs that show population size by age (usually for entire countries)
  - X-axis is population size or percentage of population.
  - Y-axis is age (usually 5-year age classes).
  - They are divided vertically to show the number of males and the number of females of each age group.
- Age structure diagrams make it easy to see the portions of the populations that fall into each of the ***reproductive cohorts*** (groups):
  - Pre-reproductive (0-14 years old)
  - Reproductive (15-44 years old)
  - Post-Reproductive (45+)

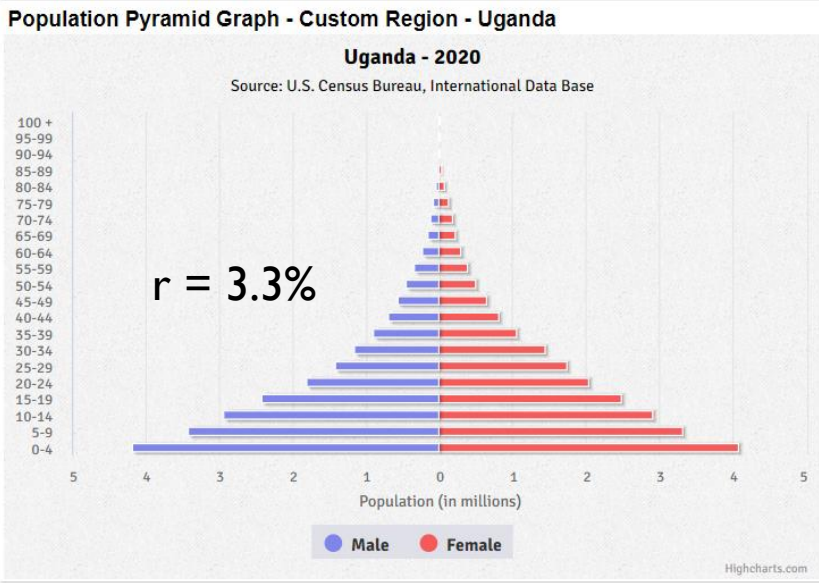


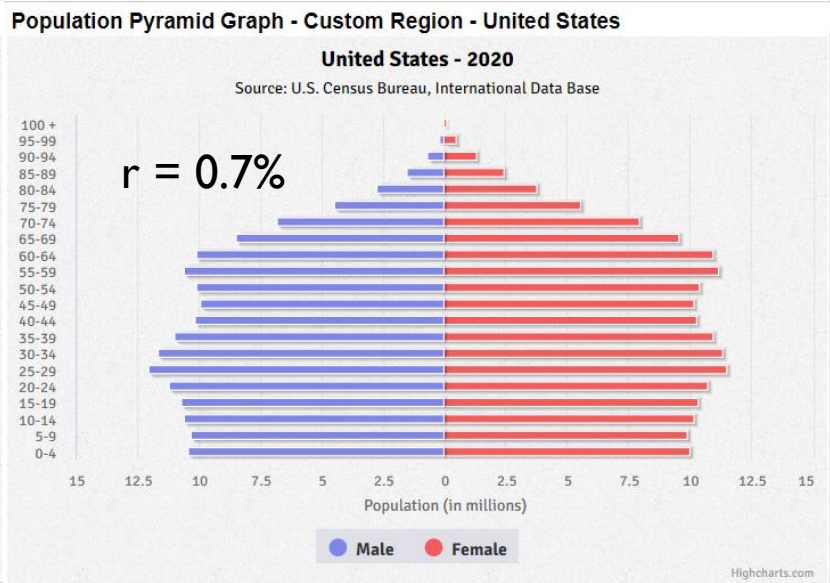
Pre-reproductive Cohort (0-14)

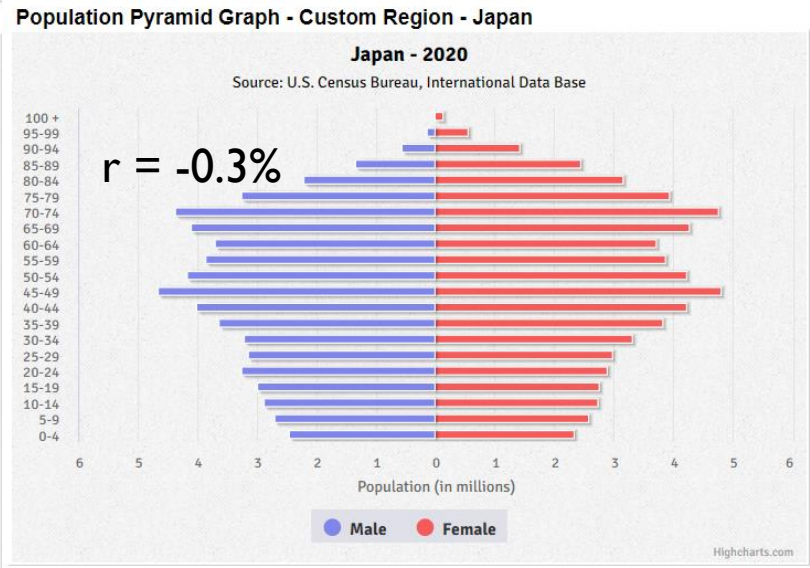
Reproductive Cohort (15-45)

Post-Reproductive Cohort(45+)

POPULATION GROWTH AND AGE STRUCTURE





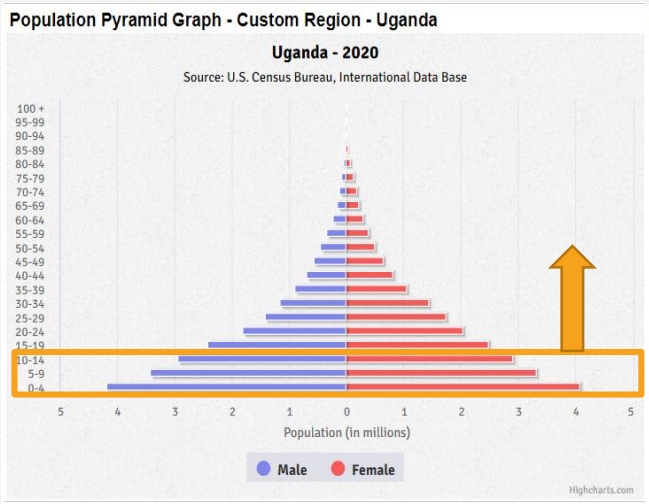


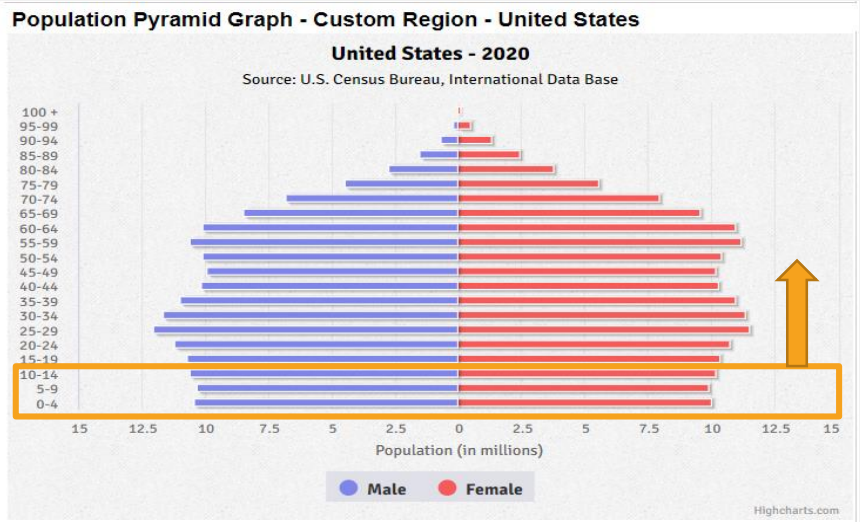
- Pre-reproductive cohort of Uganda is large compared to the reproductive cohort (wide base)
- As people in the pre-reproductive cohort age into the reproductive cohort, further increase in population size is likely
- Birth rate > death rate

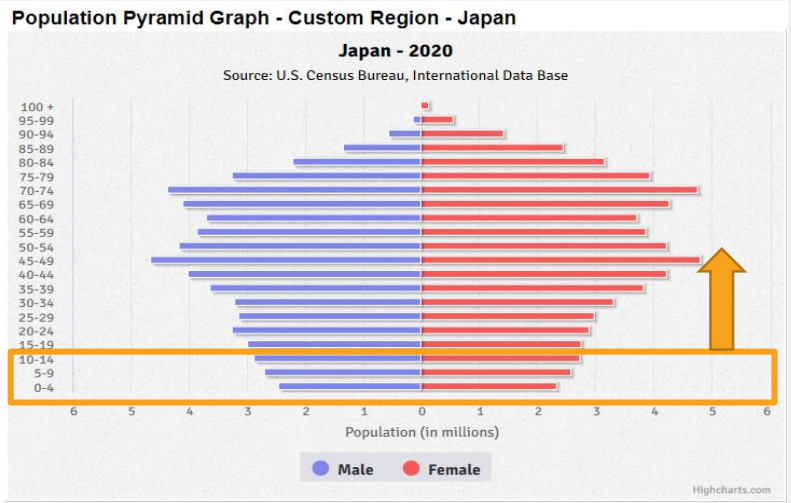
- The pre-reproductive cohort of the U.S. is similar in size to the reproductive cohort (≈rectangular)
- As people in the pre-reproductive cohort age into the reproductive cohort, a slow increase or no increase in population size is likely
- Birth Rate ≈ Death rate

- The pre-reproductive cohort of Japan is noticeably smaller than the reproductive cohort. (narrow base)
- As people in the pre-reproductive cohort age into the reproductive cohort, a a reduction in population size is likely
- Birth rate < Death rate

AGE STRUCTURE AND POPULATION MOMENTUM







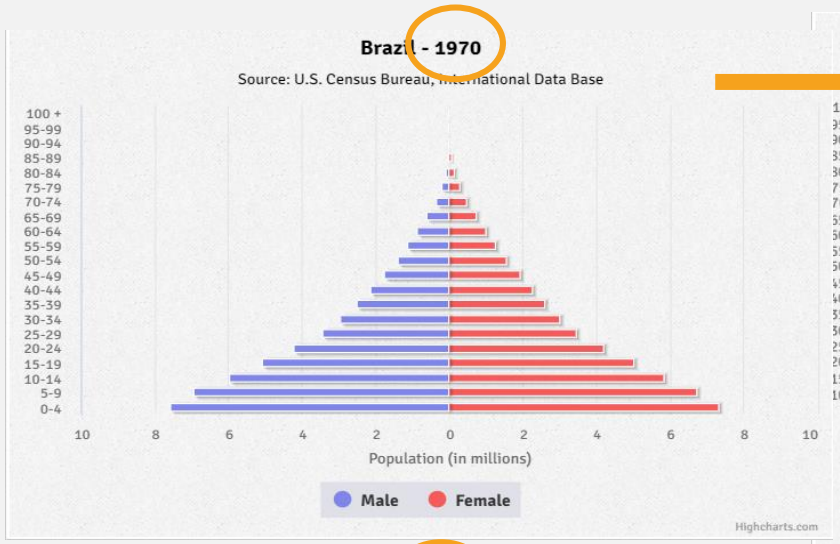
- ***Population Momentum:*** The potential of a countries population to continue to grow, even after reducing their ***fertility rate***. Population momentums results from a larger number of people in the pre-reproductive cohort than in the reproductive cohort.
  - If more people move into the reproductive cohort, than move out, the population can continue to grow despite falling fertility rates.

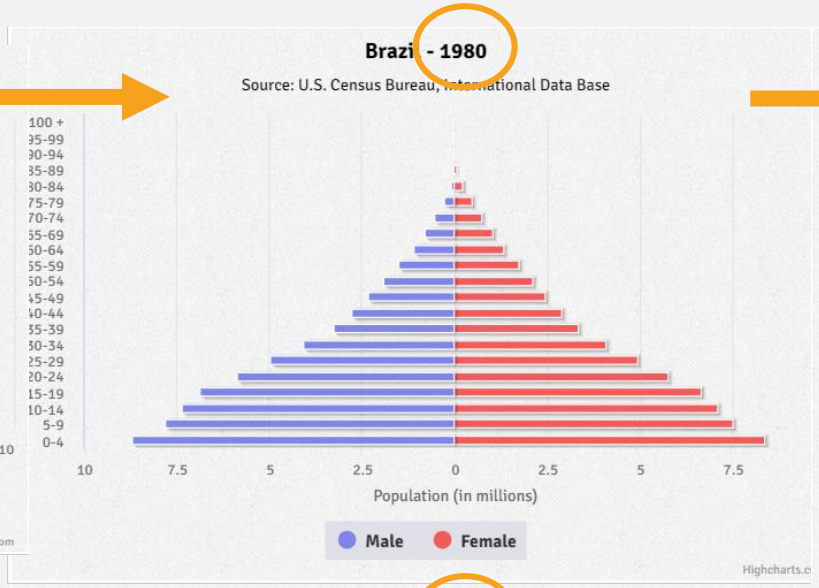
Malaysia is a great example. At just over 30 million people, this Southeast Asian nation reached replacement level fertility around the year 2000 (down from a 6-child average in the 1950s). Yet, with 25 percent of its population under age 15, Malaysia is expected to grow until 2070 (according to UN projections), at which time the country's under-15 cohort will have dropped to 15 percent of the population.

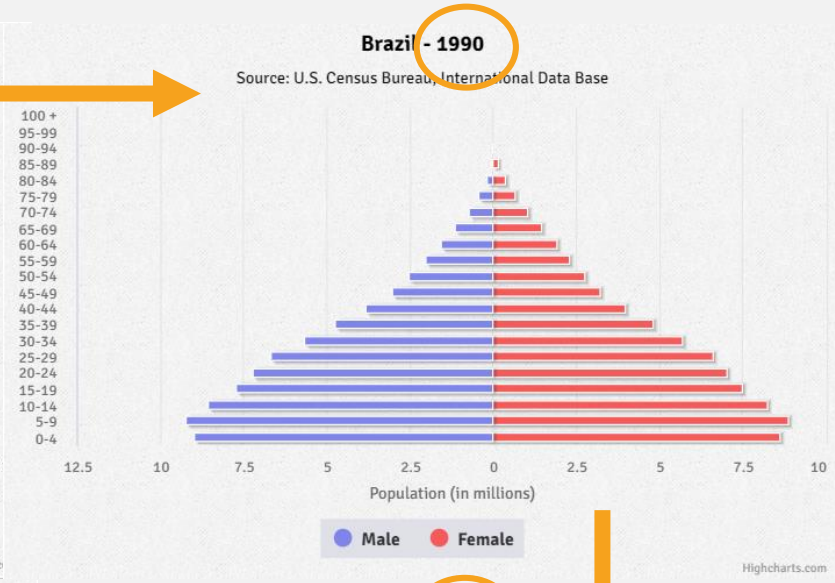
TOTAL FERTILITY RATES (TFR)

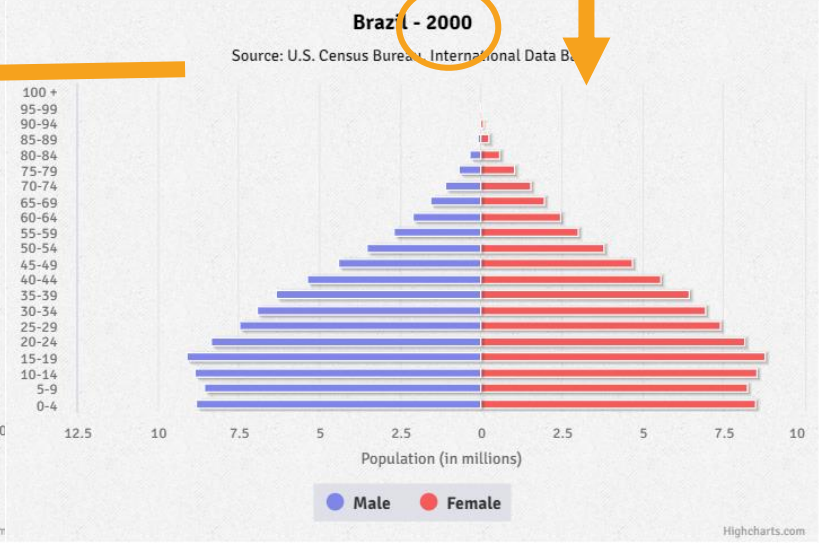
- **Total fertility rate** (TFR) is the average number of children born to each female in a population during her lifetime
  - 7.1 in Niger
  - 1.3 in Singapore
  - In Europe as a whole, TFR is now 1.6
  - 1.8 in the United States
- **Replacement level fertility rate**
  - the fertility rate (TFR) that will keep population size constant.
  - A TFR should be 2.0 in order to replace each couple in the population.
  - Replacement level fertility actually occurs when TFR = 2.1
    - Due to infant mortality preventing some from reaching their reproductive years.

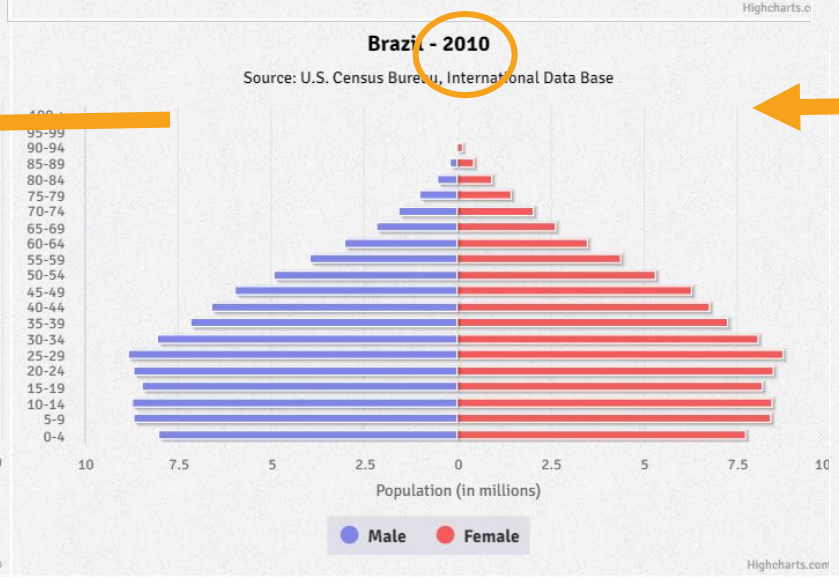
AGE STRUCTURE DIAGRAMS CAN SHOW CHANGING DEMOGRAPHICS OVER TIME

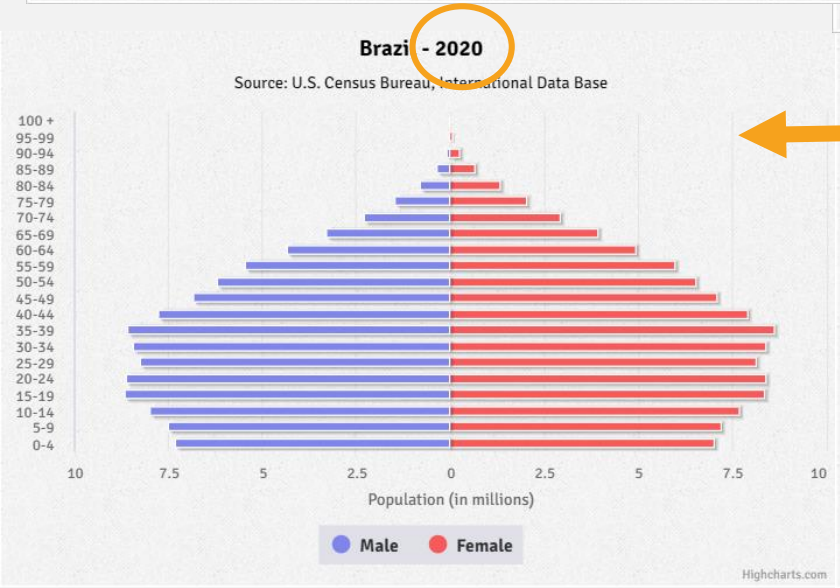




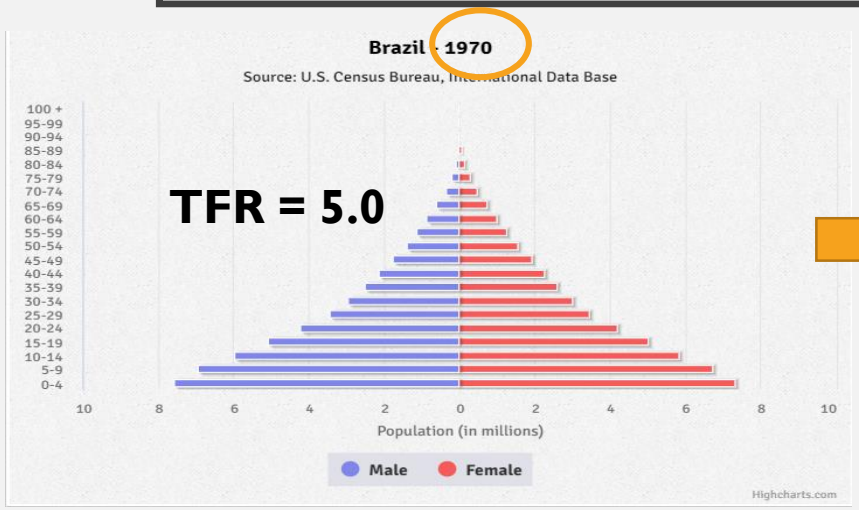


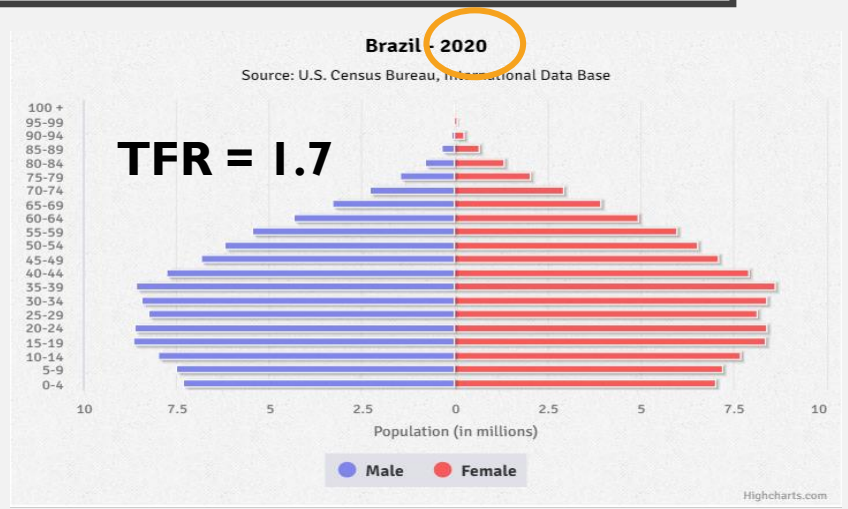






CHANGES IN AGE STRUCTURE DIAGRAMS REFLECT CHANGES IN SOCIETY

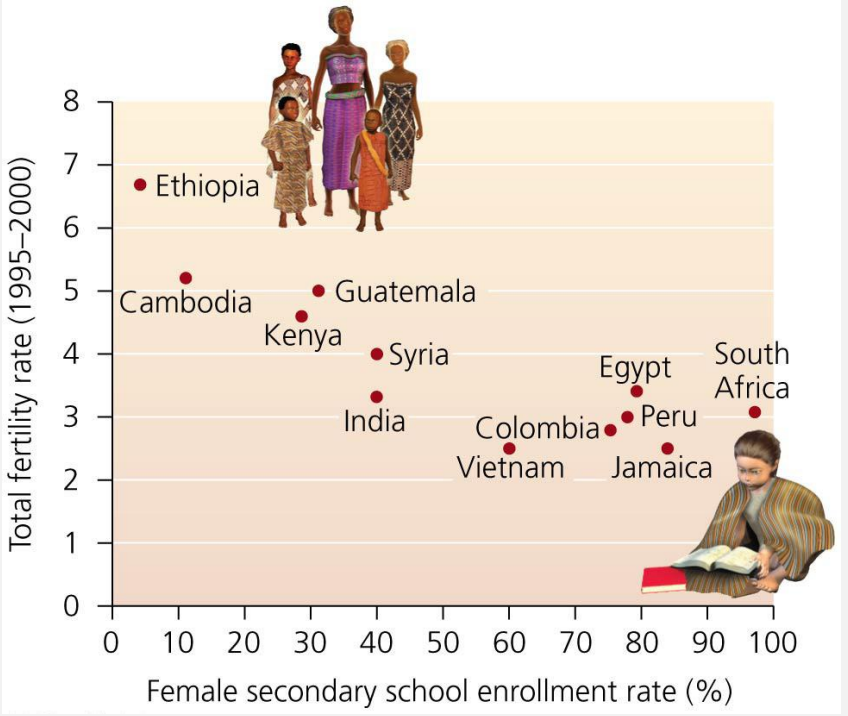


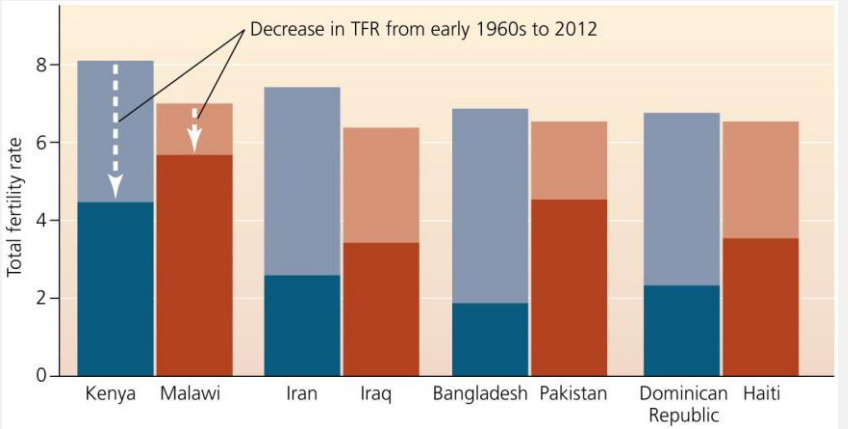


- Clearly something has changed in Brazil between 1970 and 2020.
- Changes in the age structure of a population reflect change in Total Fertility Rate (TFR)
- During this time, Brazil Industrialized and the population transitioned from rural area to urban and suburban
  - Educational opportunities increased for women → increased employment $$$ → delayed child bearing for career → fewer kids
  - Hugely popular Telenovelas showed well educated, career women, leading appealing glamorous lives without kids.

SOCIETAL CHANGES CAN LOWER TFR

- Increasing educational and employment opportunity for women lowers TFR
  - Increased $$$ reduces need to marry young, which increases a woman's age at first child birth
  - Increased career opportunities, increases a woman's age of first child birth
  - Since a woman's reproductive window is finite, delaying first child birth reduces the number of kids produced in a lifetime.
- Rural to Urban population shift
  - Kids are an important and free labor force for on subsistence farms and small family business, they are an economic liability in most urban environments
- Access to family planning
- Government policies and Legislation (Chinas one child policy)

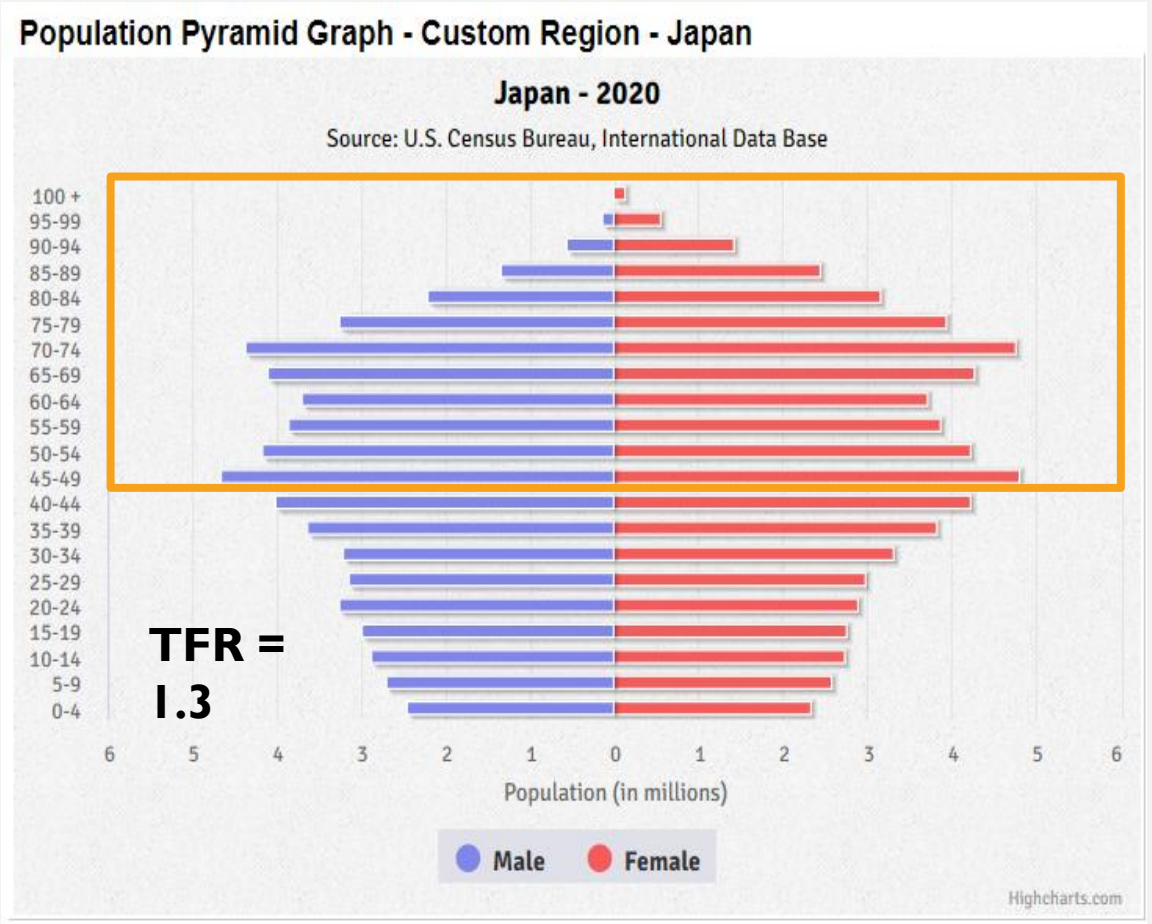




Nations in blue invested in, and promoted family planning and/or contraceptive programs. Nations in red did not.

SOME COUNTRIES NOW FEAR A FALLING POPULATION

- The population of Japan is now shrinking and the post-reproductive cohort now outnumbers the reproductive cohort.
- There are more elderly, retired people in Japan than working age citizens.
  - The retirees are pulling more money out of the Japanese social security equivalent, than workers are paying into the system.
  - Nursing homes are at capacity
- Some nations now offer incentives for more children
  - Japan, United Kingdom, France, Denmark, Italy
  - Larger population will lead to a larger work force and a more productive economy
  - 66% of European governments think their birth rate is too low.



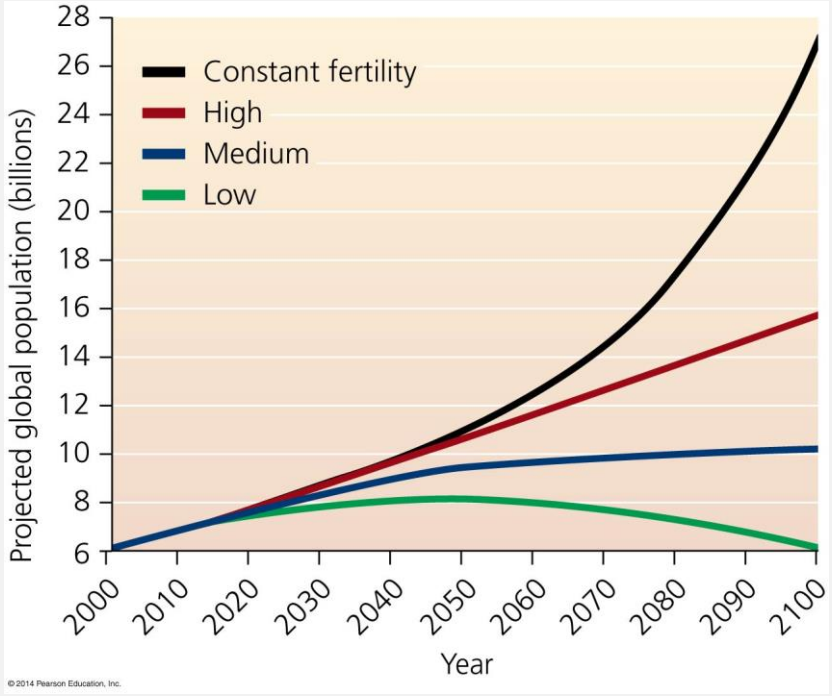
Do it for Denmark
https://www.youtube.com/watch?v=vrO3TfJc9Qw

Do it for Mom
https://www.youtube.com/watch?v=B00grl3K01g

ACHIEVING ZERO POPULATION GROWTH

- *For people to attain the material standard of living of North Americans, we would need the natural resources of four and a half more Earths*

- Reaching a stable carrying capacity and achieving ZPG requires reducing our ecological footprints AND lowering global fertility rates.
  - Or we can choose reduced standards of living and increasing mortality rates inflicted by starvation, disease and extreme weather. 😀



Projected Population Growth With Various TFR Values

Constant TFR = 2.58
High TFR = 2.4
Medium TFR = 2.1
(replacement level fertility)
Low TFR = 1.6

Generation Time (years)	Number of Children Born per Generation	Generations per 100 years	# of descendants per 100 years
35	1	2.9	≈ 3
25	2	4	28
15	3	6.7	1573

The power of extending generation times by delaying the age of first reproduction and lowering TFR