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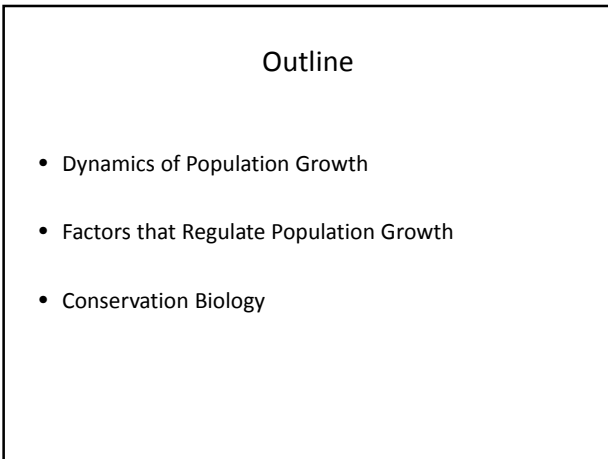
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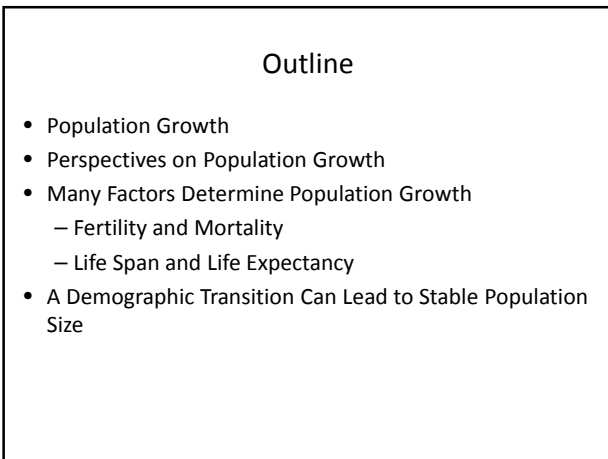
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**Population Terminology**

- **Carrying capacity (K)** – the population of a species that can be supported in a specific area without depleting the available resources.
- **Overshoot** – when a population exceeds the carrying capacity of the environment and deaths result from a scarcity of resources.
- **Population crash** – a rapid dieback in the population to a level below the carrying capacity.
- **Boom and bust** – when a population undergoes repeated cycles of overshoots followed by crashes.

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**Describing Population Growth Mathematically**

- (N) **Population** – total number of all the members of a single species living in a specific area at the same time.
- (r) **Rate**—This is the rate of growth; the number of individuals which can be produced per unit of time under ideal conditions (with no limits to the population’s growth).
- (t) **Time**—This is the unit of time upon which the rate is based.

**Geometric Rate of Increase**--The population size that would occur after a certain amount of time under ideal conditions is described by the formula:

$$N_t = N_0 r^t$$

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**Example of Geometric Rate of Increase**

If cockroaches reproduce 10 offspring for each adult roach per 3 month period of time, the geometric rate of increase can be calculated as follows:

<u>time</u>	<u>N</u>	<u>rate (r)</u>	<u>r x N</u>
t <sub>1</sub>	2	10	10 x 2 = 20
t <sub>2</sub>	20	10	10 x 20 = 200
t <sub>3</sub>	200	10	10 x 200 = 2000
t <sub>4</sub>	2000	10	10 x 2000 = 20,000

*Conclusion: 1 pair of roaches can produce a population of 20,000 roaches in 1 year!*

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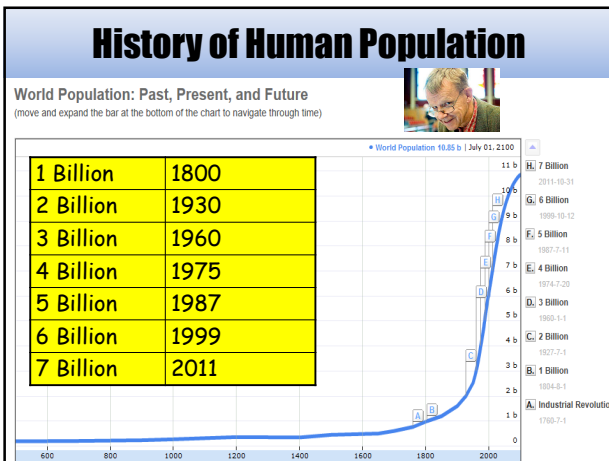
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### Exponential Growth

#### Describes Continuous Change

- The previous example projects growth at specific time periods, but in reality, growth in cockroaches under ideal conditions occurs continuously.
- Such change can be described by modifying our previous formula to:  $dN/dt=rN$
- The d is for delta which represents change.
- Thus the formula would read: “the change in the population (dN) per change in time (dt) is equal to the rate of change (r) times the population size (N).”
- This is a simple mathematical model of population showing **Exponential Growth**.

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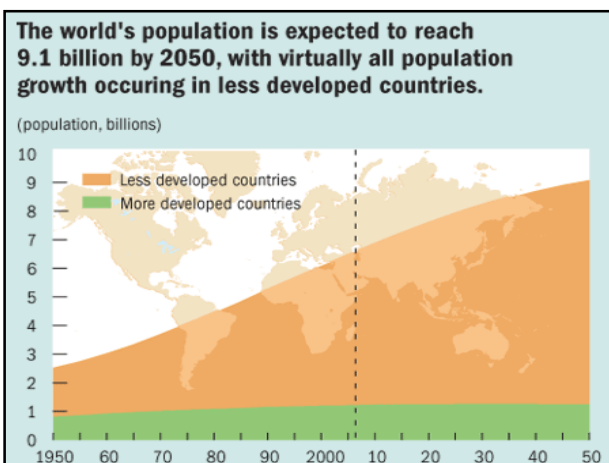
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## Exponential Growth

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$$\frac{dN}{dt} = rN$$

Rate of increase ( $r$ ) times number

Change in number ( $N$ )  
per change in time ( $t$ )

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### Exponential Growth Always Has Limits

- Exponential growth only can be maintained by a population as long as nothing limits its growth.
- In the real world there are limits to growth that each population will encounter.
- Eventually, shortages of food or other resources lead to a reduction in the population size.

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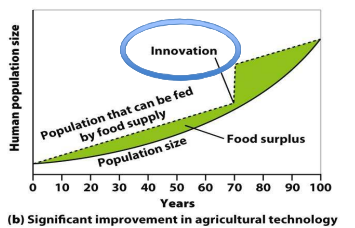
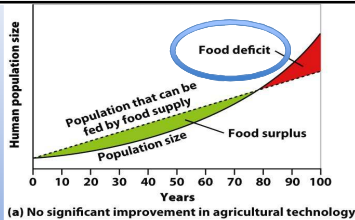
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## Can A Population Increase Be Supported?

- Disagreement on Carrying Capacity
- Technological Advancements (NPK fertilizer)




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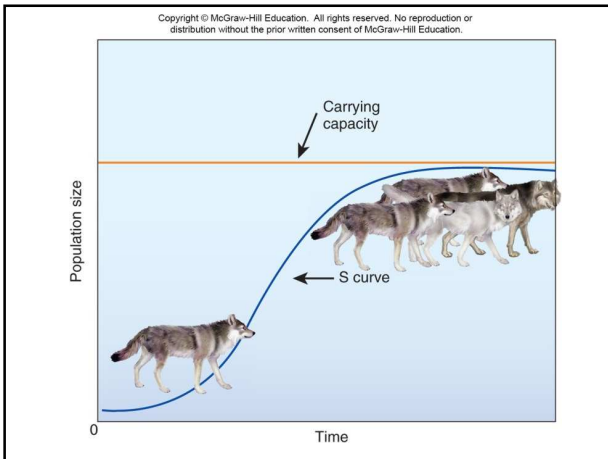
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### S-Curve or Logistic Growth

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$$\frac{dN}{dt} = rN \left( 1 - \frac{N}{K} \right)$$

Population size as a proportion of carrying capacity

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### Factors Affecting Population Growth

- Logistic Growth is **density-dependent** which means that the growth rate *depends* on the population density.
- Many density-dependent factors can influence a population including: disease, physiological stress and predation.
- Density-dependent factors intensify as population size increases.
- **Density independent factors** may also affect populations. These may include drought, fire, or other habitat destruction that affects an ecosystem.

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### r and K Selected Species

- **r-selected species** rely upon a high reproductive rate to overcome the high mortality of offspring with little or no parental care. For example: a clam can release a million eggs in a lifetime, with few surviving to maturity.
- **K-selected species** have few offspring, slower growth as they near carrying capacity and exercise more parental care. For example: an elephant produces one offspring every 4 or 5 years, but nurturing by a herd increases the likelihood of it surviving to maturity.

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### Reproductive Strategies

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r-Selected Species	K-Selected Species
1. Short life	1. Long life
2. Rapid growth	2. Slower growth
3. Early maturity	3. Late maturity
4. Many small offspring	4. Few, large offspring
5. Little parental care or protection	5. High parental care or protection
6. Little investment in individual offspring	6. High investment in individual offspring
7. Adapted to unstable environment	7. Adapted to stable environment
8. Pioneers, colonizers	8. Later stages of succession
9. Niche generalists	9. Niche specialists
10. Prey	10. Predators
11. Regulated mainly by extrinsic factors	11. Regulated mainly by intrinsic factors
12. Low trophic level	12. High trophic level

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### Factors That Affect Growth Rates

Four factors affect growth rate: Births, Immigration, Deaths and Emigration. ( $r=B+I-D-E$ )

- **Births** - the number of births that occur in the population at any give time; rate of births vary by species and also with stress and food availability.
- **Immigration** - the number of organisms that move into the population from another population.
- **Deaths** - mortality, or the number of deaths that occur in the population at any given time, vary by species and with environmental factors.
- **Emigration** - the number of organisms that move out of the population to another population.

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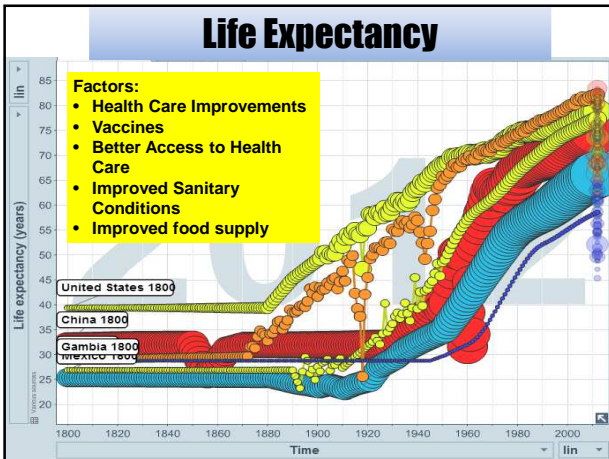
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### Survivorship Curves Vary by Species

There are three general patterns:

- Full physiological life span if organism survives childhood
  - Example : elephants and bears
- Probability of death unrelated to age
  - Example : gulls and mice
- Mortality peaks early in life.
  - Examples: trees and fish

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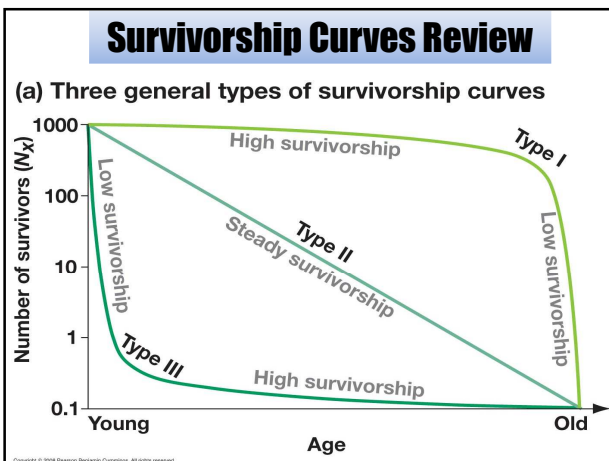
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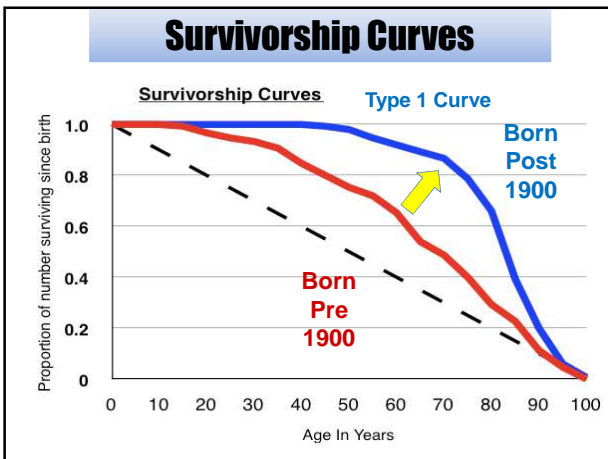
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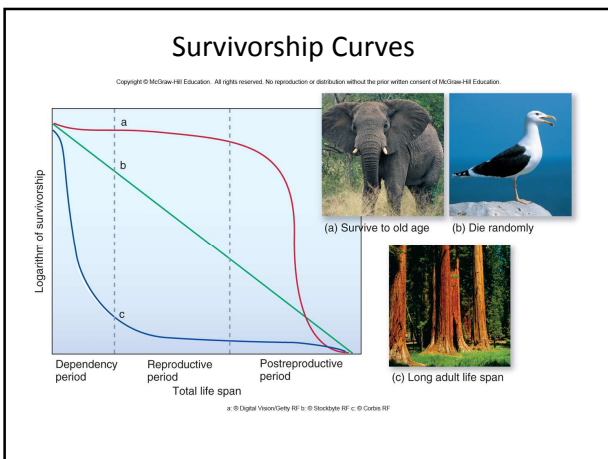
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### Factors that Regulate Population Growth

- **Intrinsic factors** - operate within or between individual organisms in the same species
- **Extrinsic factors** - imposed from outside the population
- **Biotic factors** - caused by living organisms. Tend to be density dependent.
- **Abiotic factors** - caused by non-living environmental components. Tend to be density independent, and do not really regulate population, although they may be important in increasing or decreasing numbers.  
Example: Rainfall, storms

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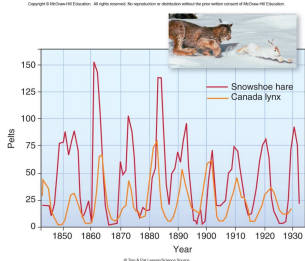
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### Density Dependent Factors

- Reduce population size by decreasing natality or increasing mortality.
- Interspecific Interactions (between species)
  - Predator-Prey oscillations




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### Density Dependent Factors

- Intraspecific Interactions - competition for resources by individuals within a population
  - As population density approaches the carrying capacity, one or more resources becomes limiting.
  - Control of access to resources by territoriality; owners of territory defend it and its resources against rivals.
  - Stress-related diseases occur in some species when conditions become overcrowded.

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### Total Fertility Rate

- **Total fertility rate (TFR)** - average # of children per woman during a lifetime
- **Replacement level fertility** - level of fertility at which a population exactly replaces itself .
- 2.1 Children/Couple on average.




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### Population Growth

- Every second 4 or 5 children are born while only 2 people die. There is a net gain of roughly 2.5 persons per second.
- Current world population is greater than 7 billion and growing at 1.13% per year.
- Global population will double in 62 years if conditions remain unchanged.
- Ecologists are concerned that overpopulation will cause environmental degradation that will threaten the ecological life-support systems on which we depend.

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### Population Growth

- Economists often disagree with ecologists, arguing that economic and technological growth will enable us to solve these problems.
- Social justice advocates argue that the root cause of the problem is inequitable distribution of the Earth's resources.

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### Population Growth is a Recent Event

- Until the invention of agriculture 10,000 years ago, the human population was a few million people.
- Populations were held in check by diseases, famine and war.
- Early societies regulated their population through cultural taboos, abstinence and infanticide.
- Human population began to increase rapidly after 1600 due to agricultural developments, better sources of power, and better health care and hygiene.

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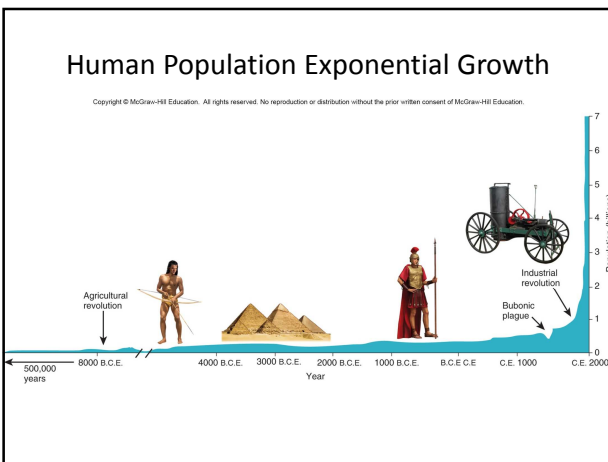
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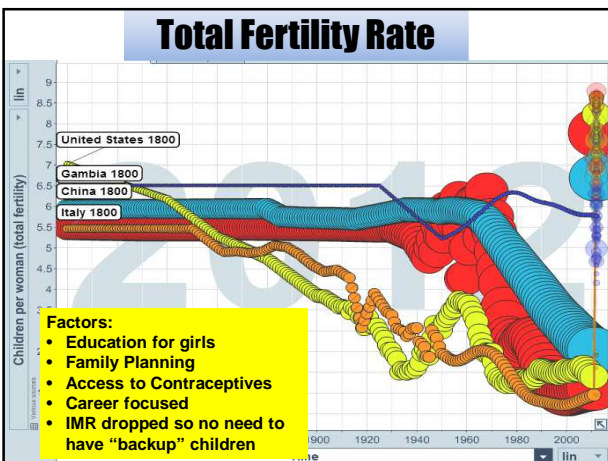
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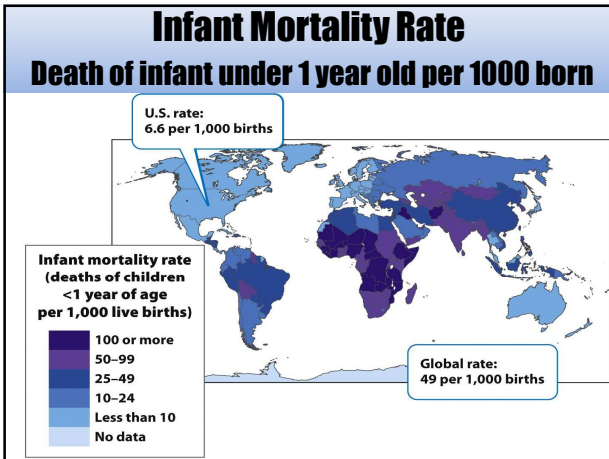
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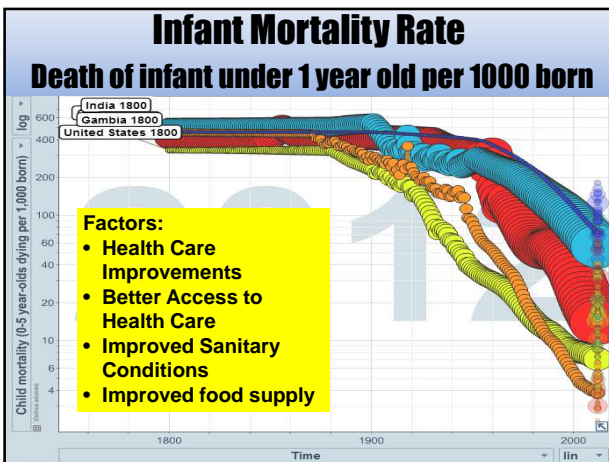
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	Developed	Moderately Developed	Less Developed
<b>Example Countries</b>			
<b>Growth Rate</b>			
<b>Life Expectancy</b>			
<b>Fertility Rates (per 1000)</b>			
<b>Infant Mortality (per 1000)</b>			
<b>Net Migration (per 1000)</b>			
<b>Per Capita GDP</b>			

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**Table 7.1 World Population Growth and Doubling Times**

Date	Population	Doubling Time
5000 B.C.E.	50 million	?
800 B.C.E.	100 million	4,200 years
200 B.C.E.	200 million	600 years
1200 C.E.	400 million	1,400 years
1700 C.E.	800 million	500 years
1900 C.E.	1,600 million	200 years
1965 C.E.	3,200 million	65 years
2000 C.E.	6,100 million	51 years
2050 C.E. (estimate)	8,920 million	215 years

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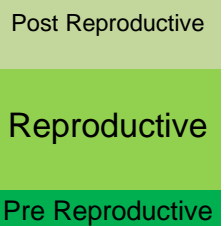
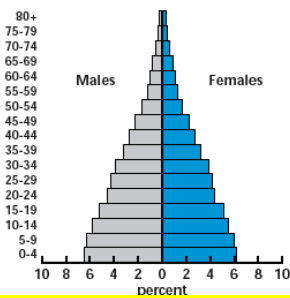
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**POPULATION BY AGE AND SEX**

**Venezuela**



Shows Rapid Growth because a large percentage of the population is Pre-Reproductive and Reproductive

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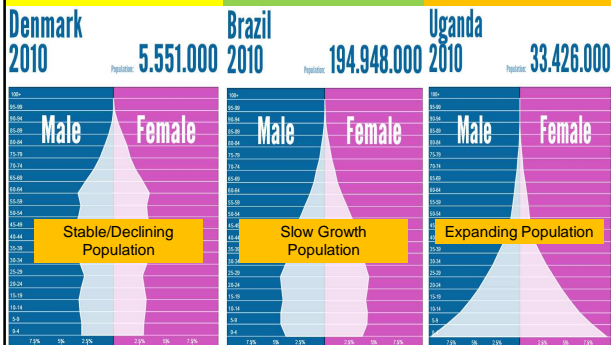
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**Age Structure Diagrams**

**DEVELOPED**

**MODERATELY**

**LESS**




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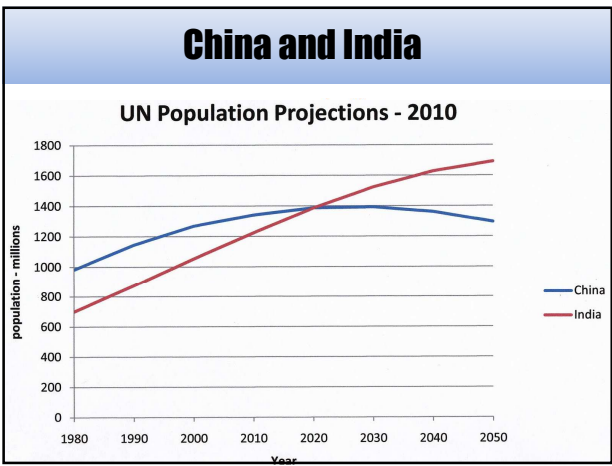
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### China's One Child Policy [CLICK HERE](#)

**China 1970** Population: **812,260,000**

**1979 – one child per family**

**Positive:**

- Reduced 400 million births since 1980

**Negative:**

- Forced Abortions
- Forced Sterilization
- Infanticide (typically females)
- 120 men per 100 women
- Overburdened Orphanages
- Starvation in Orphanages

**Nov 2013:**

- allow couples in which one of the parents was an only child to have a second child.

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### Baby Boom

USA, Canada, Australia

**of America** 6,297,000

**Male** **Female**

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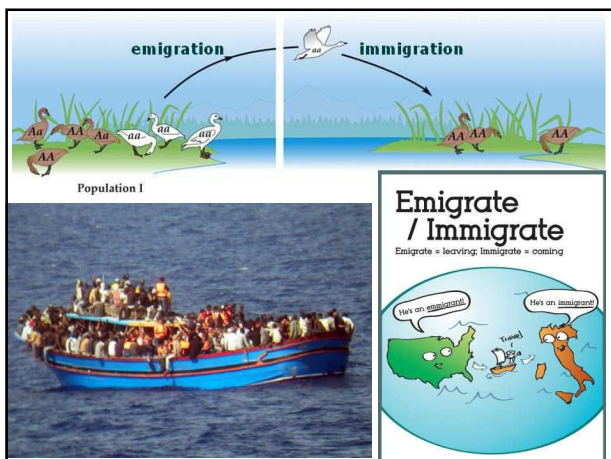
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### Perspectives on Growth

- **Thomas Malthus** (1798) wrote *An Essay on the Principle of Population* in which he showed that human populations increase exponentially.
- Population growth is checked by famine, disease, and cultural factors (e.g., late marriage).
- Debate about whether human population growth *causes* environmental degradation (Malthus) or whether human population growth *results from* poverty and resource depletion (Karl Marx).
- These two viewpoints are still debated today.

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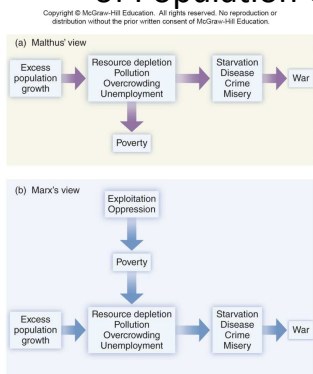
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### Views of Malthus vs. Marx on the Effects of Population Growth




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### Technology Can Increase Carrying Capacity

- Technology can boost carrying capacity as we make progress in agriculture, engineering, commerce and medicine. These achievements make it possible to support many more people per unit area.
- However, much of our growth has been based upon cheap, abundant fossil fuels. Will rising fuel prices constrain food production and distribution?

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### Environmental Effects of Population

- Effects of population on the environment are not due to numbers alone.

$$I = PAT$$

I = environmental impact

P = population size

A = affluence

T = technology

A single American living an affluent lifestyle produces more pollution than an entire village of farmers in Africa.

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### Can More People be Beneficial?

- More people mean larger markets, more workers, and increased efficiency due to mass production.
- Greater numbers also provide more intelligence and enterprise to overcome problems.
  - Economist Julian Simon believes that human ingenuity will be able to solve the problems associated with population growth.

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### Two Demographic Worlds

- First is poor, young, and rapidly growing.
  - Less-developed countries
    - Found in Africa, Asia, Latin America
    - Contain 80% of world population, and will account for 90% of projected growth
- Second is wealthy, old, and mostly shrinking.
  - In North America, Western Europe, Japan
    - Average age is about 40
    - Populations expected to stabilize or decline

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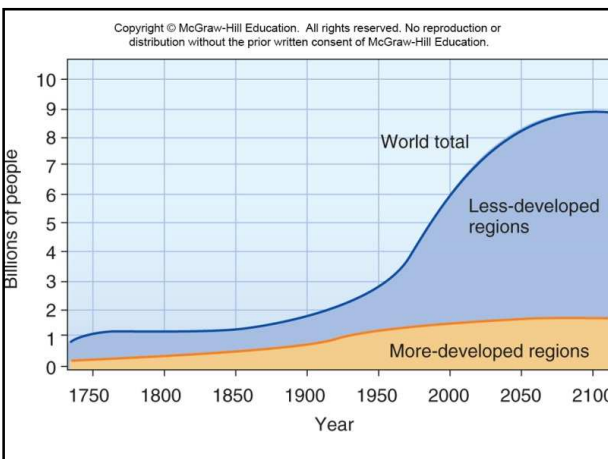
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### Population of World's Largest Countries

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2013		2050*	
Country	Population (millions)	Country	Population (millions)
China	1,344	India	1,692
India	1,206	China	1,295
United States	314	United States	403
Indonesia	249	Nigeria	390
Brazil	204	Indonesia	293
Pakistan	191	Pakistan	275
Bangladesh	162	Brazil	223
Nigeria	171	Bangladesh	194
Russia	128	Philippines	155
Japan	127	Dem. Rep. of Congo	149

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### Declining Populations

- Europe and Japan—birth rates are declining due to couples choosing to have fewer or no children.
- Russia - The end of the Soviet Union caused economic collapse. Death rates have risen dramatically and the birth rate is among the lowest in the world.
- Africa - the AIDS epidemic has hit Africa the hardest. In Zimbabwe, Botswana, Zambia and Namibia, up to 39% of the population is HIV positive. More than 2/3 of the 15 yr. olds now living will die of AIDS before age 50. Life expectancy in Botswana has dropped to 31.6 years.

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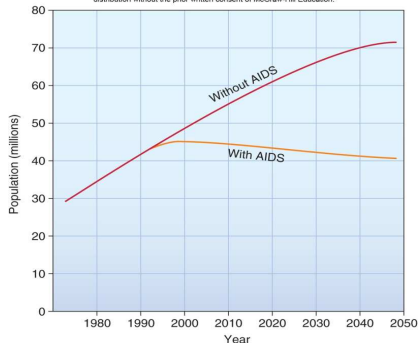
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### AIDS in South Africa

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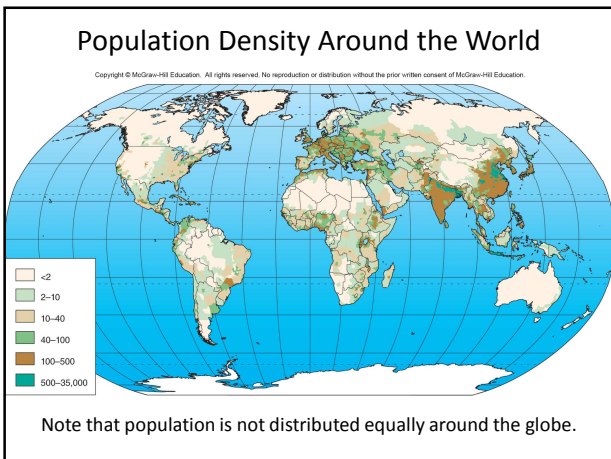
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### Fertility and Birth Rates

- **Crude Birth Rate** - Number of births in a year per thousand. (Not adjusted for population characteristics such as number of women of childbearing age.)
- **Total Fertility Rate** - number of children born to an average woman in a population during her life
- **Zero Population Growth** - Occurs when births plus immigration in a population equal deaths plus emigration. ZPG is a rate of 2.1 children per couple, not 2.0, because some people do not have children and some children do not survive to reproductive age.

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### Decline in Fertility Rates Worldwide

- Fertility rates have declined everywhere except in Africa.
- China's one child policy has decreased the fertility rate from 6 in 1970 to 1.54 in 2010.
  - May cause social problems
  - May result in the gender balance being altered

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### Mortality and Death Rates

- **Crude Death Rate** - number of deaths per thousand persons in a given year
  - Poor countries average about 20 while wealthier countries average about 10.
  - Some rapidly growing countries have very low crude death rates due to a high proportion of young people.
- **Natural Increase** - crude birth rate minus crude death rate
- **Total growth rate** includes immigration, emigration, births and deaths.

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### Life Span and Life Expectancy

- **Life Span** is the oldest age to which members of the species survive.
- **Life Expectancy** - average age a newborn can expect to attain in any given society
  - Declining mortality is the primary cause of most population growth in last 300 years.
  - Worldwide, the average has risen from 30 to 68 over the past century. The greatest progress has been in developing countries
  - Longer life expectancy is not due to medicine, but rather improved nutrition, sanitation, and education.

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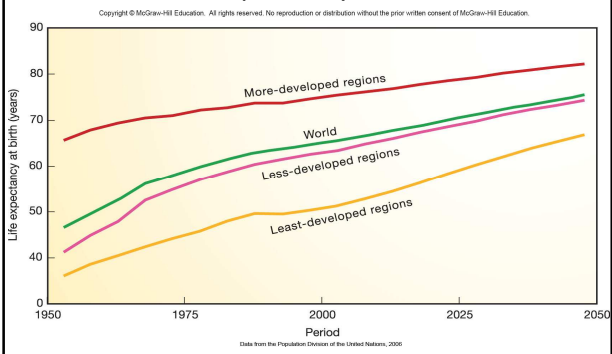
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### Life Expectancy At Birth




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## Life Expectancy for Selected Countries

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**Table 7.3 Life Expectancy at Birth for Selected Countries in 1900 and 2009**

Country	1900		2009	
	Males	Females	Males	Females
India	23	23	67	73
Russia	31	33	59	73
United States	46	48	76	81
Sweden	57	60	79	83
Japan	42	44	79	86

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## Demographic Implications of Living Longer

- A population growing rapidly due to natural increase has more young people than does a stationary population.
  - Even if total fertility rates were to fall, the population would continue growing as young people enter reproductive age (**population momentum**).
- Some countries now have a stable population with the same number of people in each age group.
- Declining populations have more old people than young people.

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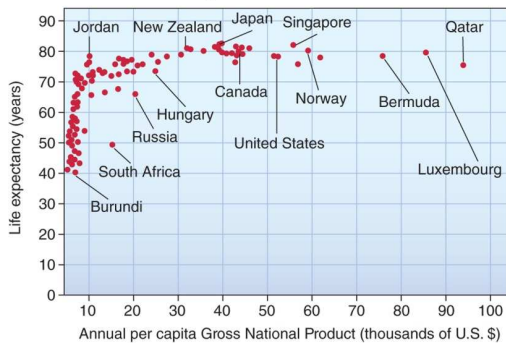
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## Life Expectancy vs. Income

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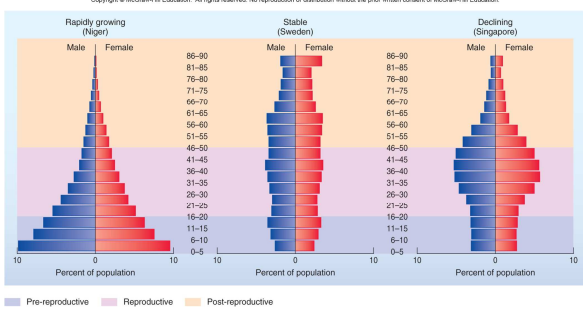
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### Age Structure




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### Living Longer has Implications

- Both rapidly and slowly growing countries can have a problem with **dependency ratio**.
  - The number of non-working compared to working individuals in a population.
  - In the U.S., fewer working age people will have to support many more retired people, and this is a problem for the Social Security system.
  - Similar problems are developing in other countries around the world causing countries to rethink their population policies.

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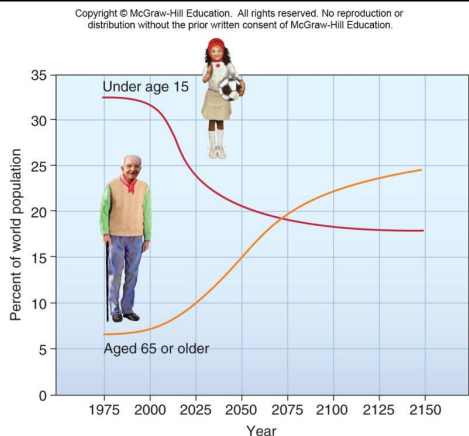
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### Emigration and Immigration

- Emigration and immigration play a large role in human population dynamics.
  - Developed regions expect 2 million immigrants a year for next 50 years.
  - Immigration is a controversial issue. “Guest workers” often perform dangerous or disagreeable work, while being paid low wages with few rights.
  - Locals complain immigrants take away jobs and overload social services.

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### Ideal Family Size

- **Pronatalist Pressures**
  - Factors that increase the desire for children
    - Source of pleasure, pride, comfort
    - Source of support for elderly parents
    - Current source of family income and labor
    - Social status
    - Replace members in society as they die

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### Pronatalist Pressure (continued)

- Society’s need to replace its members may be codified into cultural or religious values.
  - Families with few children are pitied.
  - Controlling fertility may be taboo.
  - In some cultures, boys are valued more than girls because they carry on the family name and often are expected to financially support parents in old age.
  - Couples may have more children than they really want in order to have a boy.
  - Having a large family in some cultures is a source of male pride.

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### Birth Reduction Pressures

- Higher education and personal freedom for women often result in decisions to limit childbearing.
  - When women have more opportunities to earn a salary, they are less likely to have many children.
  - Education and socioeconomic status are usually inversely related to fertility in wealthier countries.

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### Birth Reduction Pressures

- In developing countries, higher income often means families can afford more children, thus fertility often increases, rather than decreasing as it does in developed countries.
- In less-developed countries, adding another child to a family usually does not cost much, while in developed countries, raising an additional child can carry significant costs.

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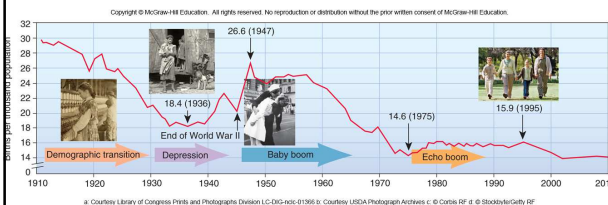
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### A Century of US Birth Rates




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### Could We Have a Birth Dearth?

- Most European countries, as well as Japan, Singapore and Taiwan, are experiencing negative growth rates.
  - There are concerns in all these countries about a lack of young people to be soldiers, workers, and taxpayers.
- One reason that birth rates may have dropped in developed countries is that toxins and endocrine disrupters that are pollutants interfere with sperm production. Sperm numbers and quality have fallen by half in the last 50 years.

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### Demographic Transition

- Pattern of falling death rates and birth rates due to improved living conditions accompanying economic development.
  - **Pre-Modern Society** - Poor conditions keep death rates high; birth rates are correspondingly high. (Stage I)
  - **Economic Development** brings better standard of living thus death rates fall. Birth rates stay constant or even rise. (Stage II)

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### Demographic Transition (continued)

- **In a mature industrial economy**, birth rates begin to fall as people see that most of their children survive. (Stage III)
  - Populations continue to grow due to population momentum.
- **Developed Countries** - Transition is complete and both death and birth rates are low and population is in equilibrium. (Stage IV)

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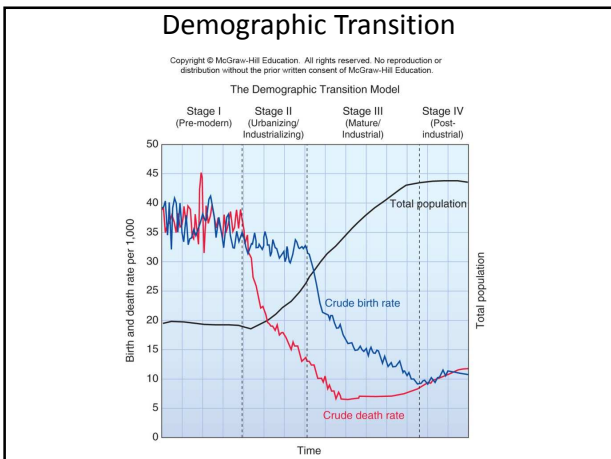
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### Demographic Transition Happening Now?

- Four conditions necessary for demographic transition:
  - improved standard of living
  - confidence that children will survive
  - improved status of women
  - availability and use of birth control
- Some demographers think that a demographic transition is taking place now in developing nations.

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### Demographic Transition Now?

- Others take a more pessimistic view. Lester Brown warns that poorer countries may be caught in a demographic trap.
- The population is growing so rapidly that there are not enough resources to complete modernization and enter stage IV.
- People who take this view urge birth control, education, and national policies that limit population growth.

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### Social Justice

- Still other demographers believe that in order for the demographic transition model to work, resources must be distributed more equitably.
  - They believe that the world has enough natural resources, but inequitable social and economic systems cause maldistribution.
  - Many rich countries, when they were colonial powers, extracted the wealth from countries that were their colonies. Some of the world's poorest countries had rich resources and adequate food supplies before they were impoverished by colonialism.

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### Other Rights

- We should consider the rights of other species.
- Perhaps, rather than asking what is the maximum number of people that Earth can hold, we should instead ask what is the optimum number of people at which we can provide a fair and decent life for all humans while causing the minimum impact on other species.

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### Women's Rights and Fertility

- Education and job opportunities for women reduce fertility rates.
- When child mortality is high, parents tend to have high numbers of children to ensure that at least some survive. Improving child survival would reduce the number of births.
- Land reform, political rights, job opportunities for women, and improved health for women translate into better survival for children and therefore lower fertility.

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### Family Planning

- **Family Planning** - allows couples to determine the number and spacing of their children
  
- **Birth Control** - any method used to reduce births
  - **Traditional Methods**
    - Long breast-feeding (suppresses ovulation), taboos against intercourse while breast-feeding, celibacy, folk medicines, abortion, infanticide

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### Factors that Complicate Family Planning

- Often, societal changes must first take place before family planning programs will be successful.
  - Improved education and economic status for women
  - Improved status for children
  - Increased sense of social responsibility
  - Financial and political stability
  - Effective and acceptable birth control methods

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