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Population Ecology

Models of Population Growth and Change

Dr. Brian M. Napoletano

University of Detroit Mercy
Department of Biology
Biology 1030

26 September 2011

SUSTAINABILITY FORUM on the Population Factor

<http://goo.gl/7Qw7Z>

- ▶ 74 million (40%) of 184 million pregnancies in the South unintended
 - ▶ 48% end in abortions
 - ▶ 40% end in unintended births
 - ▶ 12% end in miscarriages
- ▶ 215 million women lack access to desired contraception
- ▶ Additional \$3.6 billion needed
- ▶ Could prevent (per annum)
 - ▶ 53 million unwanted pregnancies
 - ▶ 150,000 maternal deaths
 - ▶ 25 million abortions
- ▶ USAID considering reintroducing sterilization incentives instead

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Preparations for Exam One

- ▶ Study sheets will be ready and posted today
- ▶ Review session on Wed, 28 Sep, at 6:00 pm?

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Basics

Population Number of individuals of a given species in a given area

Population density Number of individuals per areal unit in a given area

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Change in a population with continuous growth

$$\begin{aligned}N_{t+1} &= N_t + B - D + I - E \\ \Delta N &= r = B - D + I - E\end{aligned}$$

- ▶ N_t = No. individuals at time t
- ▶ B = No. births
- ▶ D = No. deaths
- ▶ I = No. immigrants
- ▶ E = No. emigrants

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Exponential population growth

$$\frac{dN}{dt} = rN \quad (1)$$

$$N_t = N_0 e^{rt} \quad (2)$$

After Gotelli (1998)

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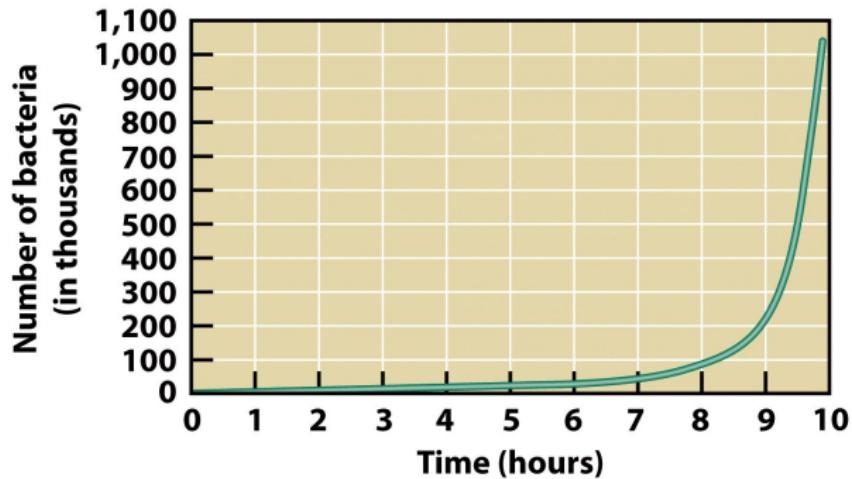
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Exponential population growth



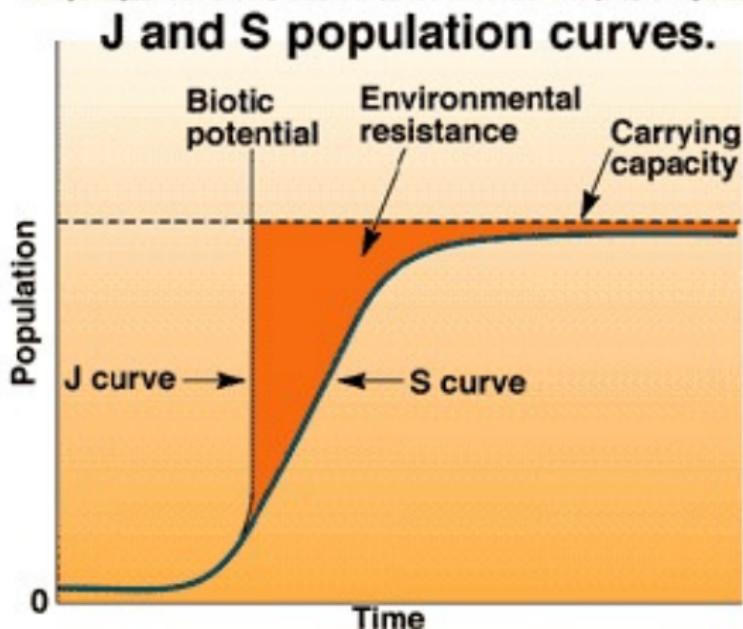
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Environmental resistance

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Density dependence in limited populations

Density-dependent factors Vary in significance with population density—e.g. predation, disease, competition

Density-independent factors Do not vary in response to population density—e.g. weather events, volcanic eruptions, collision with an extra-terrestrial body

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Logistic population growth

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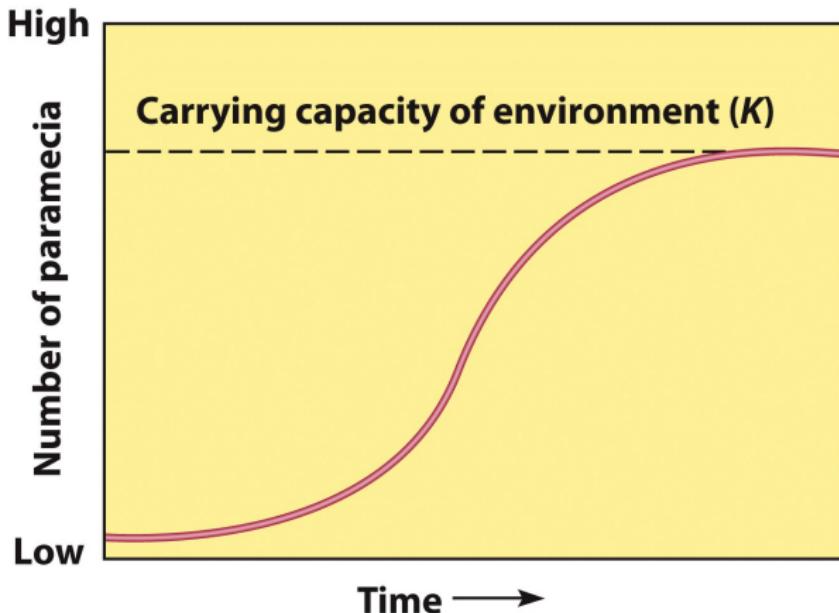
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$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right) \quad (3)$$

$$N_t = \frac{K}{1 + \left[\frac{(K-N_0)}{N_0}\right]e^{-rt}} \quad (4)$$

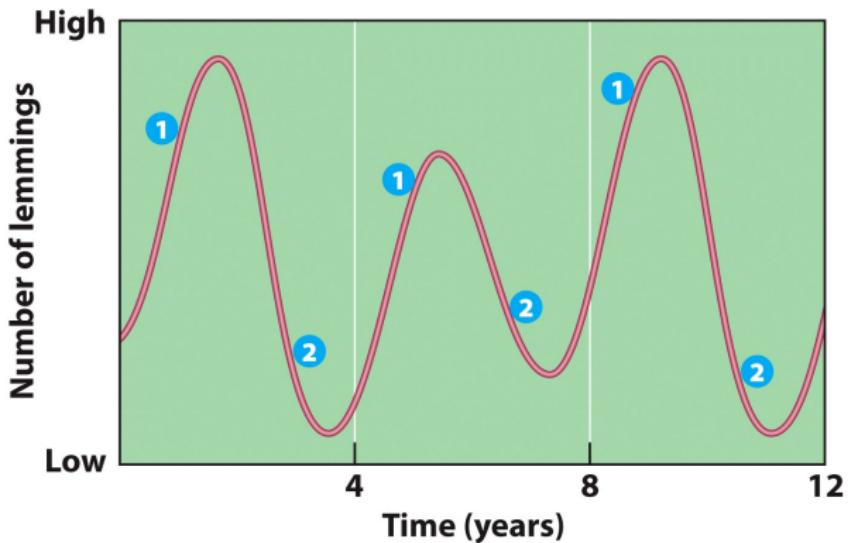
After Gotelli (1998)

Logistic population growth



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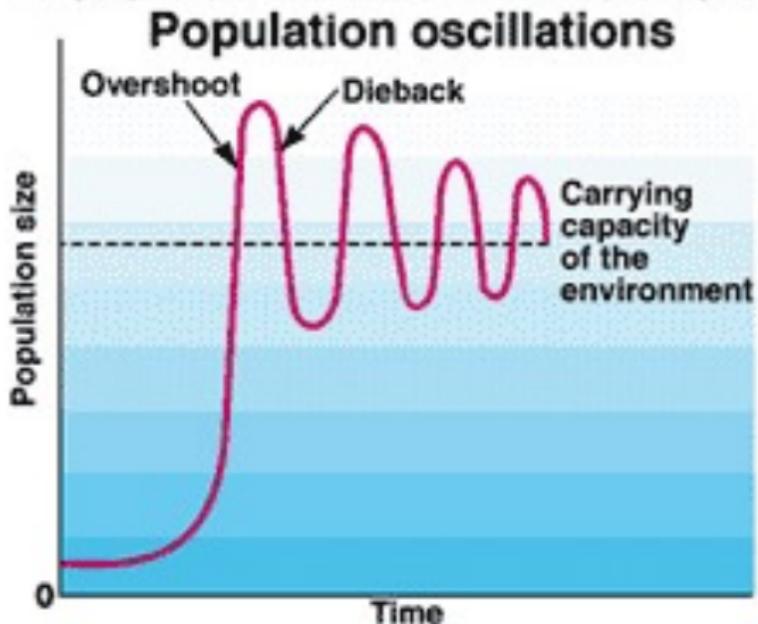
Oscillating population



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Oscillating population

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Age-structured population

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$$\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ \vdots \\ n_x \end{pmatrix}_{(t+1)} = \begin{pmatrix} f_1 & f_2 & f_3 & \cdots & f_x \\ p_1 & 0 & 0 & \cdots & 0 \\ 0 & p_2 & 0 & \cdots & 0 \\ \vdots & \ddots & \ddots & \cdots & \vdots \\ 0 & 0 & \cdots & p_{x-1} & 0 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ \vdots \\ n_x \end{pmatrix}_{(t)} \quad (5)$$

Called the Leslie matrix after Leslie (1945), see also Coulson and Godfray (2007)

Predator-prey interactions

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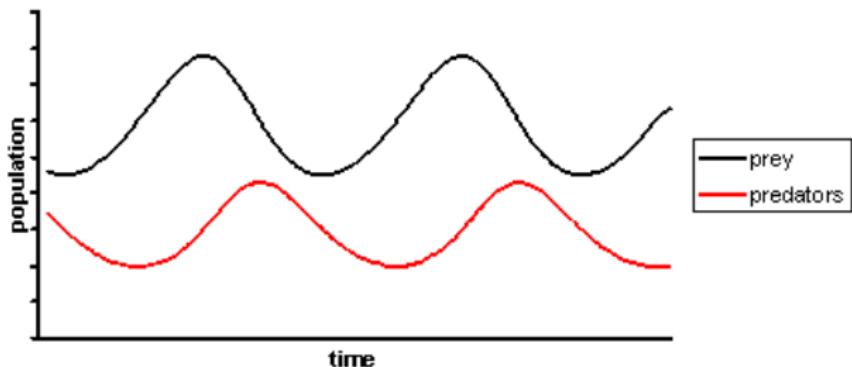
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$$\frac{dV}{dt} = rV - \alpha VP \quad (6)$$

$$\frac{dP}{dt} = \beta VP - qP \quad (7)$$

Derived independently by Lotka (1925) and Volterra (1928)

Predator-prey interactions



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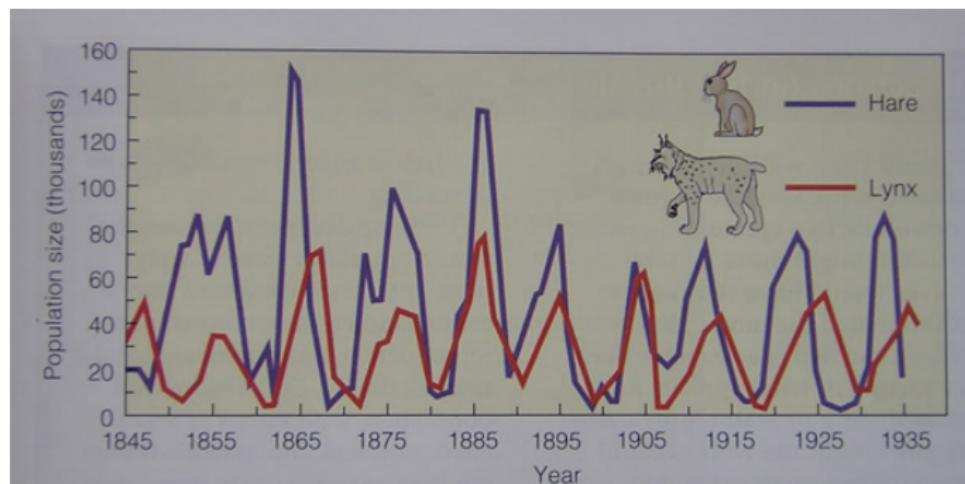
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Hare-lynx interactions



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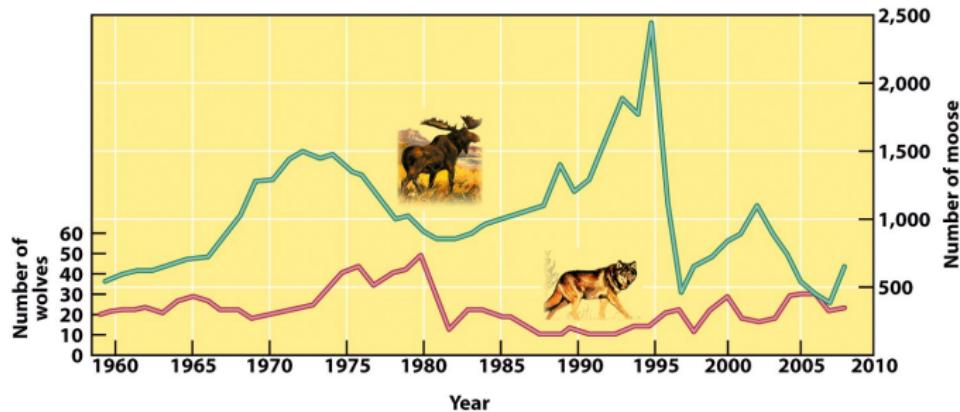
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Wolf-moose interactions on Isle Royale



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Reproductive strategies

r-selected species Large numbers of offspring with little parental care and small proportion of offspring expected to survive

K-selected species Small numbers of offspring with substantial parental care and large proportion of offspring expected to survive

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Survivorship types

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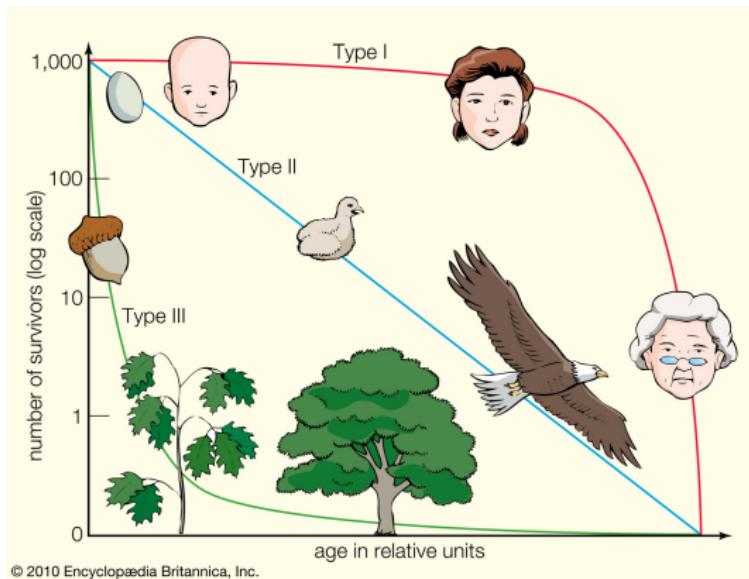
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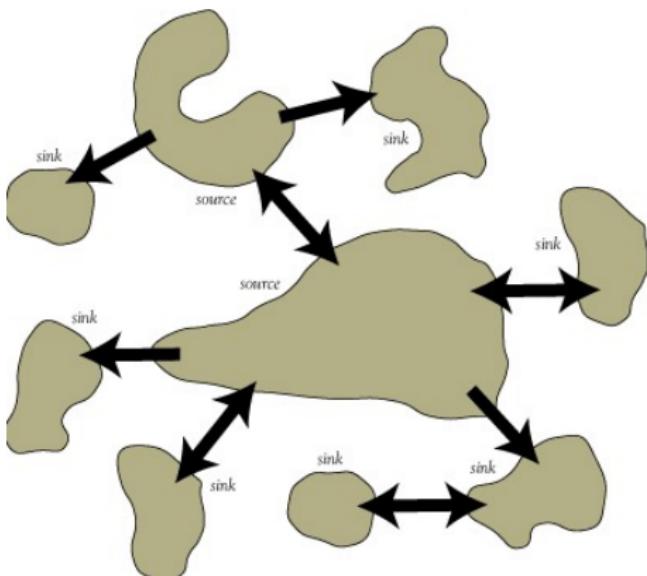
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Metapopulations



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Metapopulations

- ▶ Source: Number of births higher than number of deaths
- ▶ Sink: Numbers of deaths higher than number of births
- ▶ See Levins and Culver (1971)

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Are there too many people?

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Thomas Malthus

- ▶ Population increases exponentially, but food production can only increase linearly
- ▶ Poverty is the result of irresponsible breeding by the poor
- ▶ Contraception is unacceptable, as the poor become lazy if they aren't forced by necessity to work
- ▶ The only way to prevent universal famine is to starve the poor
- ▶ See Malthus (1798); Harvey (1974)

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Garrett Hardin

- ▶ Human reproduction continues until carrying capacity reached
- ▶ Poverty and famine in poor countries primarily due to irresponsible governments and citizens
- ▶ Allowing families (and by extension women) to control their own fertility is “intolerable”
- ▶ “Lifeboat ethic” (i.e. “Every man for himself, and the Devil take the hindmost”)
- ▶ Food aid causes the poor to breed, and eventually leads to famine
- ▶ Privatize natural resources or have the State restrict access to prevent overexploitation
- ▶ See Hardin (1968, 1974b,a, 1986, 1998)

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“Cairo consensus”

- ▶ Switch from coercive to individual-based approach
- ▶ Emphasis on women's rights and empowerment, sexual health, contraception availability, family planning
- ▶ Partnerships with NGOs and human rights organizations
- ▶ “Sustained economic growth,” social justice, and ecological sustainability are mutually obtainable goals
- ▶ See ICPD (1994); UNFPA (2004)

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Karl Marx

- ▶ Human reproduction is linked to social mode of production and reproduction
- ▶ Poverty due to wealth accumulation (intra-nationally) and imperial exploitation (inter-nationally)
- ▶ Surplus population produced by land appropriation and replacement of workers with machines
- ▶ Population stabilization much more feasible when wealth and power are shared
- ▶ See Marx (1857, 1867); Meek (1971)

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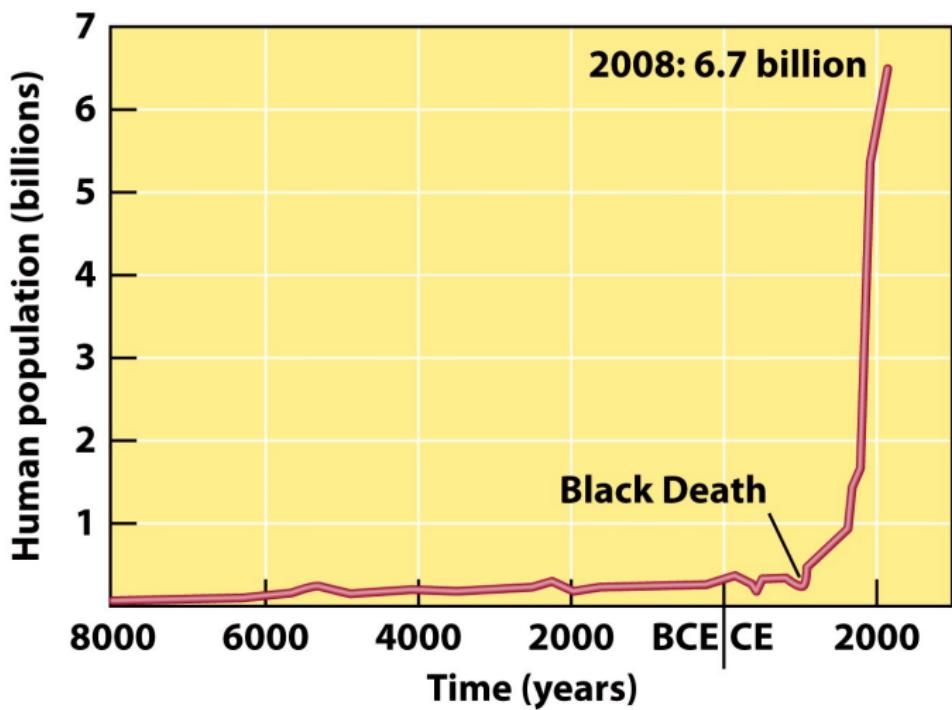
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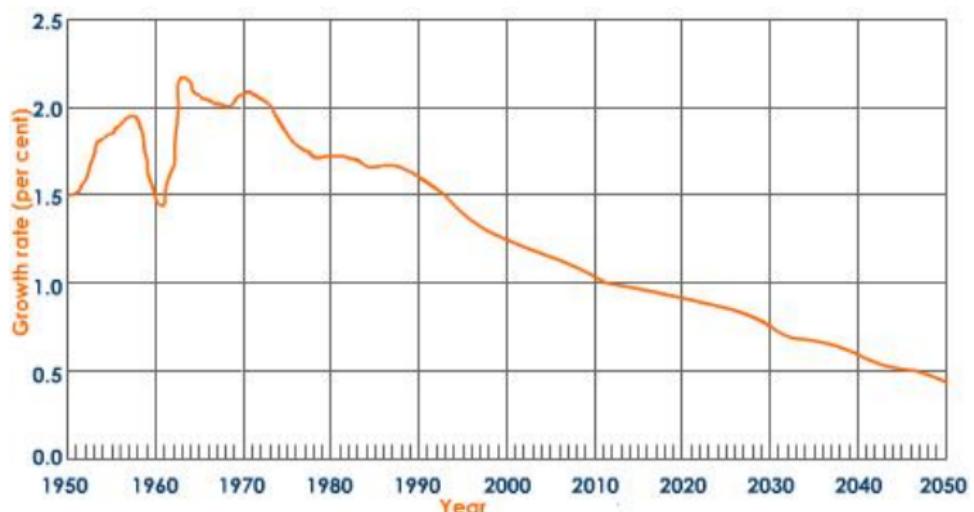
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Anomalous human population growth



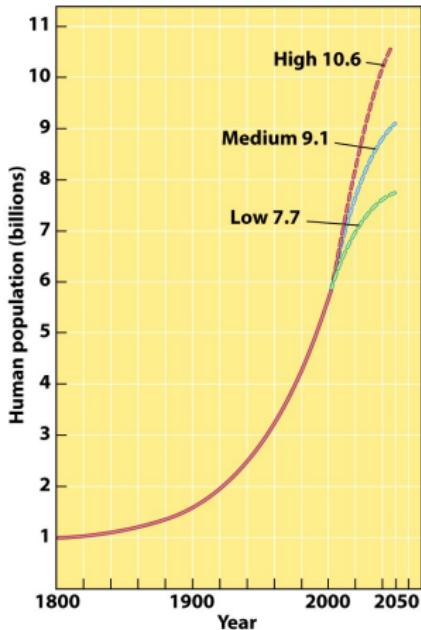
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Human population growth rate



Projected World Population Growth Rate between 1950 and 2050
(Based on United States Census Bureau, International Data)

Human population projections



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Demographic transition

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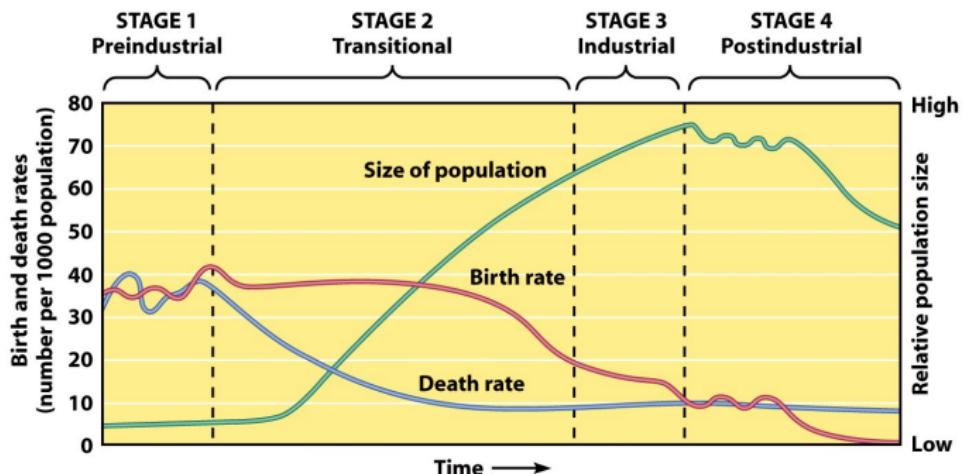
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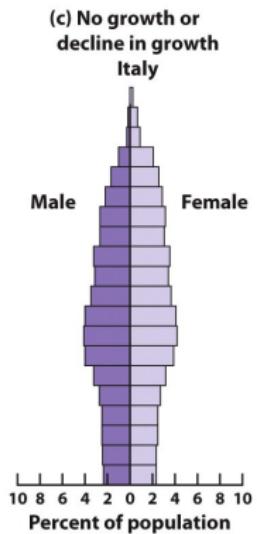
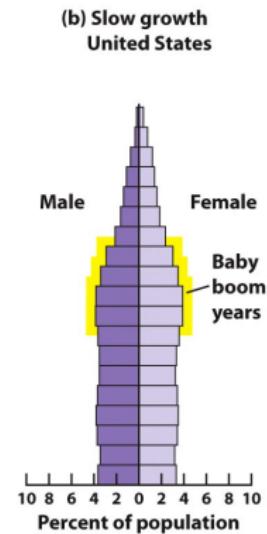
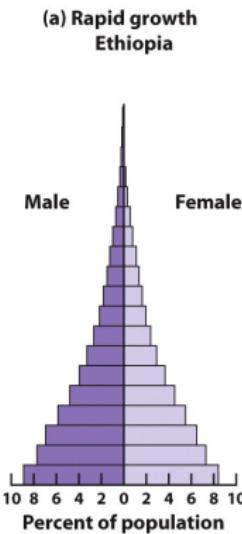
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National population structures

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World population structure

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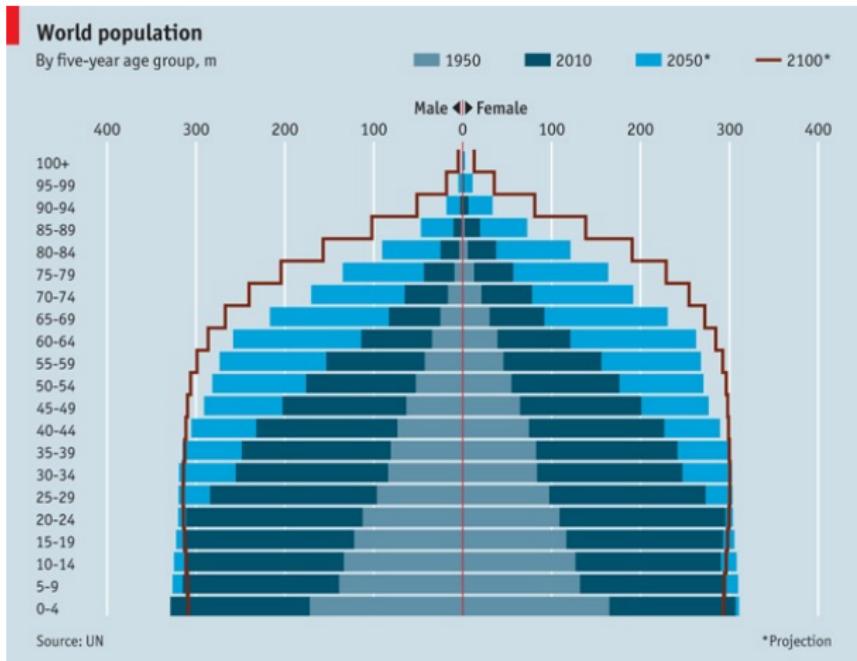
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What is humanity's carrying capacity?

- ▶ Distribution of wealth and commodities
- ▶ Average level of wealth or consumption
- ▶ Role of technology
- ▶ Types of global and national political institutions
- ▶ Demographic structure and distribution
- ▶ Desired environmental quality and levels of biodiversity
- ▶ Whether total population should be stabilized or allowed to oscillate
- ▶ Acceptable levels of risk (e.g. Should floodplains be developed?)
- ▶ The time-frame being considered

After Cohen (1995)

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