Population Ecology

Chapter 55

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Environmental Challenge

- **Ecology:** the study of how organisms relate to one another and to their environments
- **Abiotic:** non-living; wind, temperature
- Key elements of the environment:
  - Temperature
  - Water
  - Sunlight
  - Soil

Environmental Challenge

- **Homeostasis**: a steady-state internal environment regardless of external environment
- Beetle is catching water to help live in a dry environment

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Environmental Challenge

- **Conformers:** conform to the environment in which they live, their bodies adopting the temperature, salinity and other aspects of their surroundings
- Short and long term
- Coping with a range of living conditions
  - Physiological, morphological and behavioral coping mechanisms

Environmental Challenge

- Physiological responses
  - Sweat: evaporative heat loss
  - High altitudes: lower oxygen; adaptations

TABLE 55.1 Physiological Changes at High Elevation
Increased rate of breathing
Increased erythrocyte production, raising the amount of hemoglobin in the blood
Decreased binding capacity of hemoglobin, increasing the rate at which oxygen is unloaded in body tissues
Increased density of mitochondria, capillaries, and muscle myoglobin

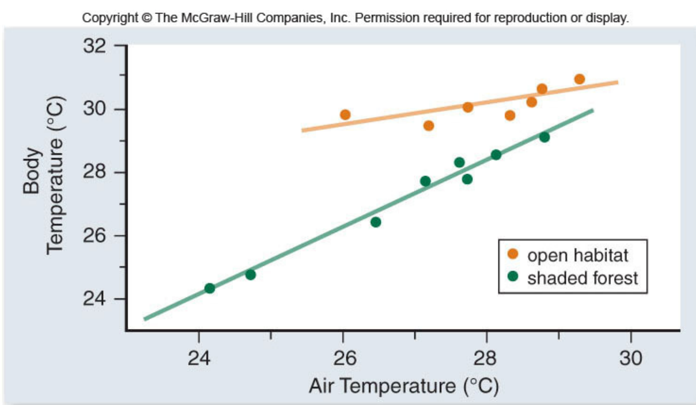
Environmental Challenge

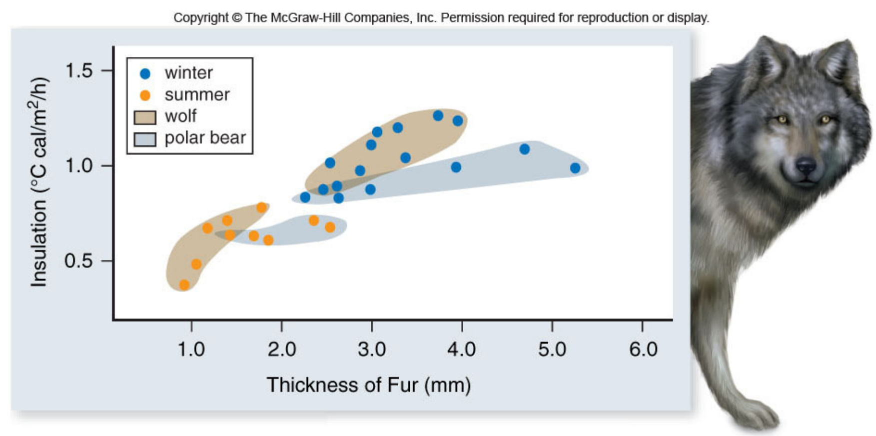
- Morphological capabilities
- Endotherms: maintain constant internal temperature
  - Adaptations that minimize energy expenditure
    - Thick coats during the winter
    - Wolf’s fur 3xs thicker in winter for insulation purposes

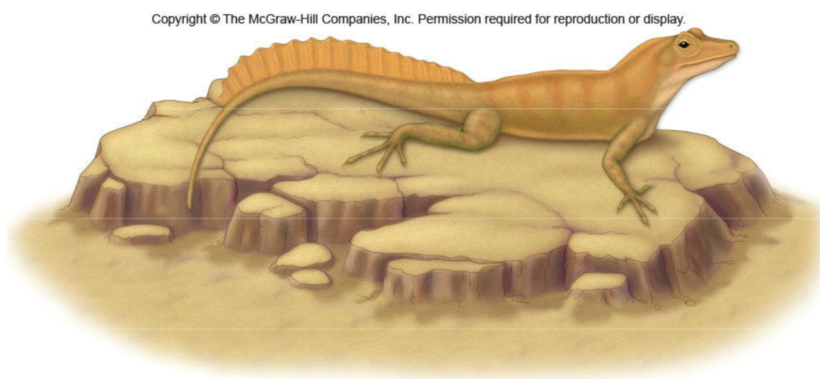
Environmental Challenge

- Behavioral responses
  - Moving from one habitat to another
  - Maintain body temperature
    - Going into the sun when cold
    - Going into the shade when hot
  - Spadefoot toads
    - Burrow down in the sand to avoid the heat

Environmental Challenge







Morphological and Behavioral Adaptations

Environmental Challenge

- Natural selection leads to evolutionary adaptation to environmental conditions
  - Compare closely related species that live in different environments
  - **Allen's rule** of reduced surface area: Mammals from colder climates have shorter ears and limbs
  - Desert frogs: evolved a greatly reduced rate of water loss through their skin

Populations

- Populations: groups of individuals of the same species in one place
- 3 characteristics of population ecology
  - Population range: area throughout which a population occurs
  - Pattern of spacing of individuals
  - How population changes in size through time

Populations

- Range
  - Most species have limited geographic range
    - Devil's hole pupfish lives in a single spring in southern Nevada

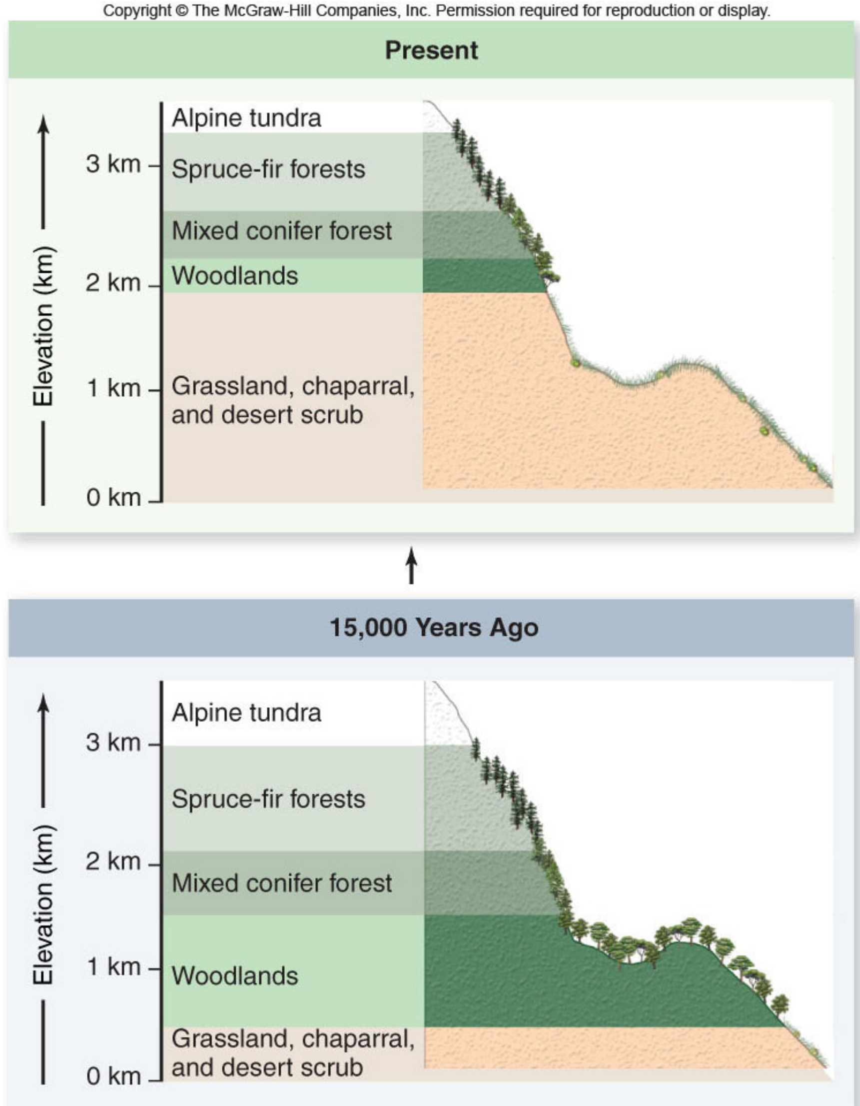
© Tom Baugh

Populations

- Organisms must be adapted for the environment in which they occur
- Each population has its own requirements
- Predators, competitors or parasites may prevent a population from occupying an area
- Ranges undergo expansion and contraction

Populations

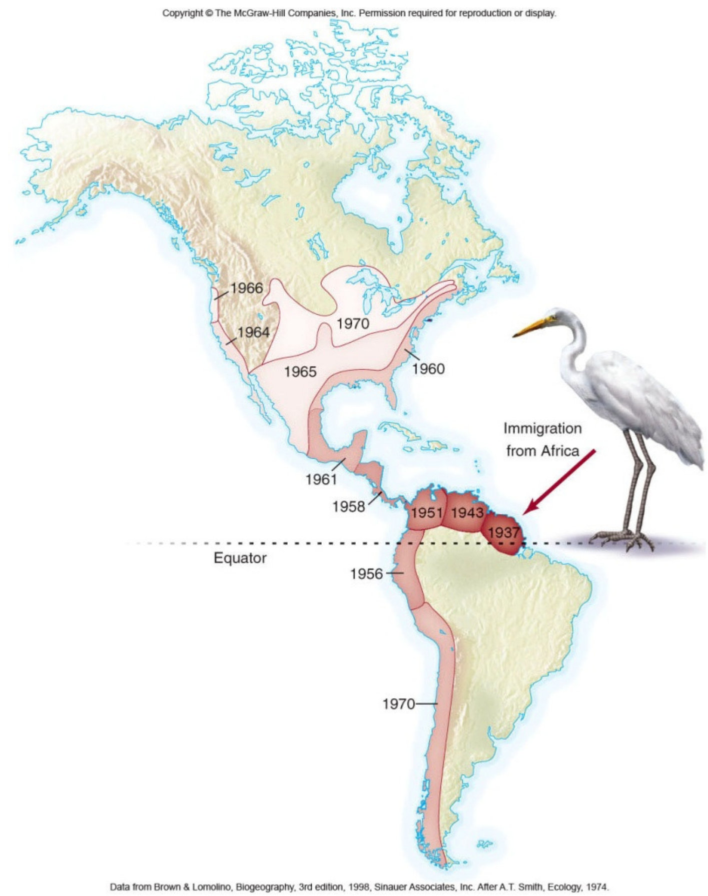
Altitude shifts in distributions of trees



Data from Brown & Lomolino, Biogeography, 3rd edition, 1998, Sinauer Associates, Inc.

Populations

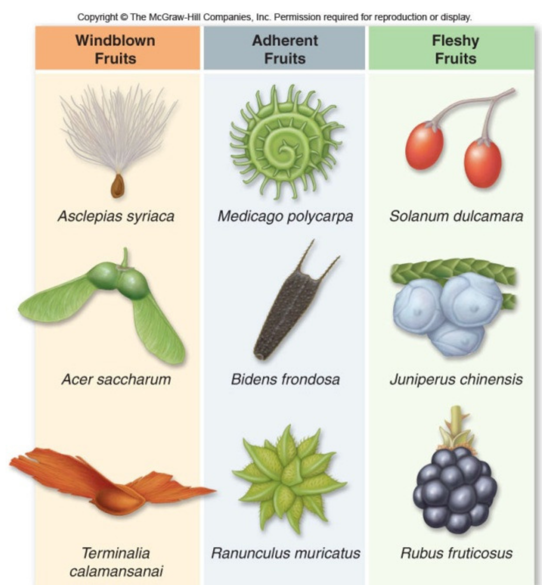
- The human effect
- Humans alter the environment and some species have altered their range to areas not previously occupied



Range expansion of the cattle egret

Populations

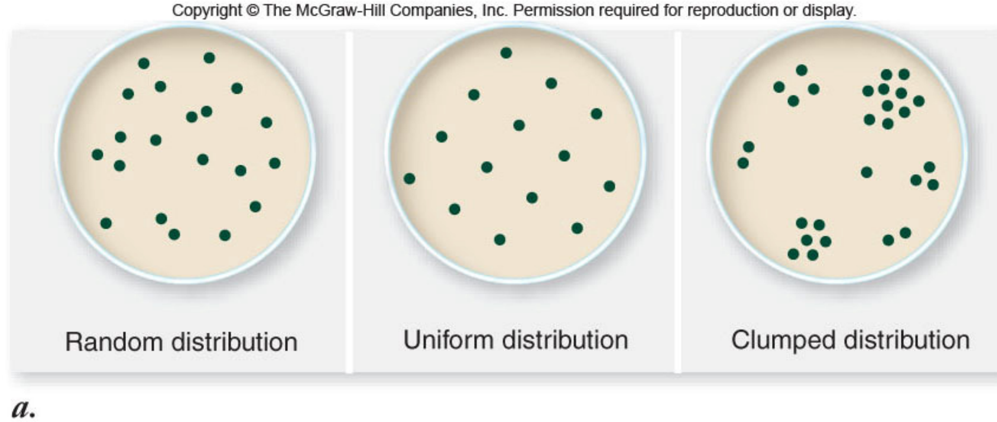
- Dispersal mechanisms
  - Lizards colonized distant islands due to individuals or eggs floating or drifting on vegetation
  - Seeds of plants disperse in many ways



Populations

- Individuals in populations exhibit different spacing patterns
  - **Random spacing:** individuals do not interact strongly with one another; not common in nature
  - **Uniform spacing:** behavioral interactions, resource competition
  - **Clumped spacing:** uneven distribution of resources; common in nature

Populations



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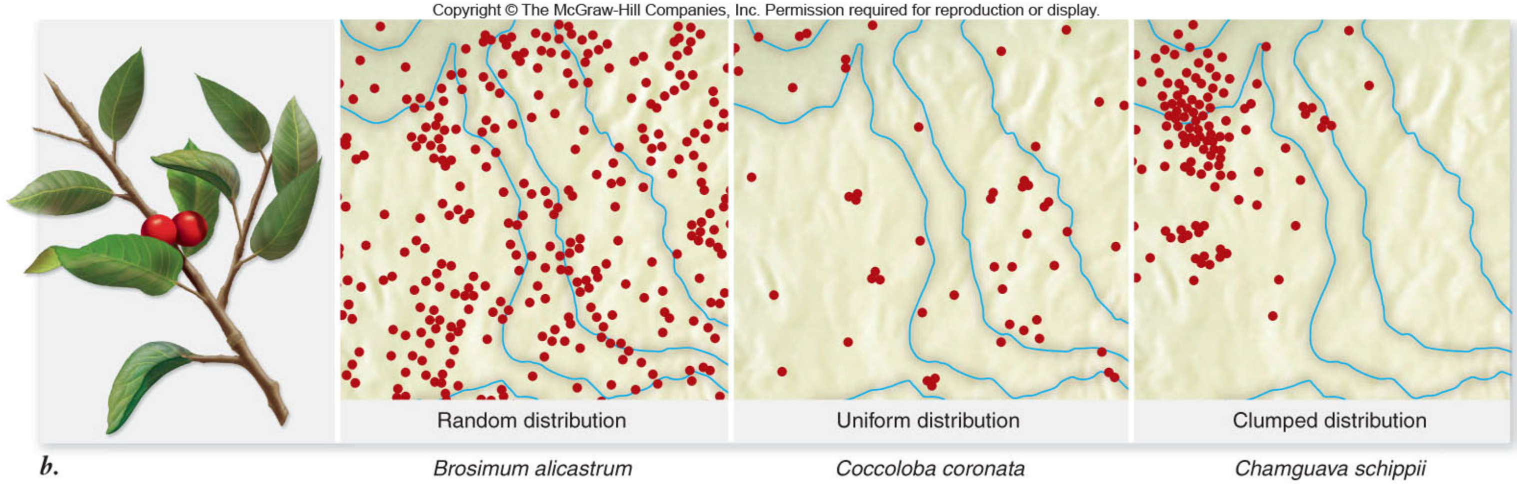
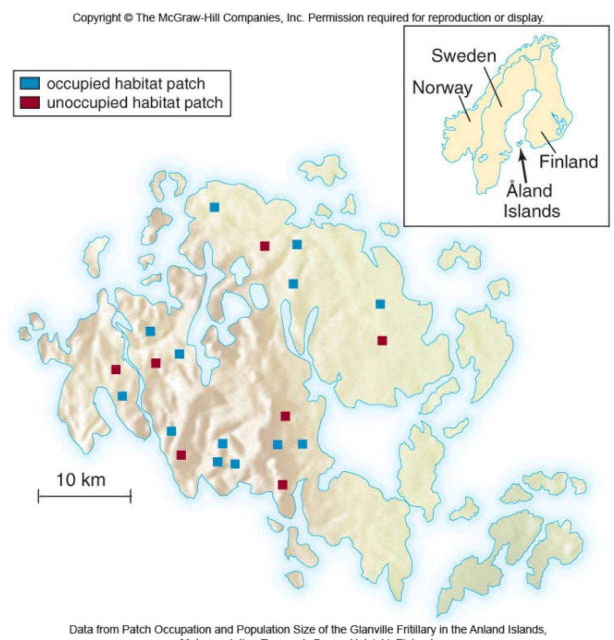


Population dispersion

Populations

- **Metapopulations:** occur in areas in which suitable habitat is patchily distributed and is separated by intervening stretches of unsuitable habitat
- Butterfly metapopulation



Populations

- Dispersal and habitat occupancy
  - Interaction is not symmetrical
  - Populations increase and send out many dispersers
  - Small populations have few dispersers
  - Individual populations may become extinct
  - Population bottlenecks may occur

Populations

- **Source-sink metapopulations:** some areas are suitable for long-term habitat others are not
- Extinctions in some areas due to dry summers
- Metapopulations can have two implications for the range of a species
  - Continuous colonization of empty patches
  - Prevent long-term extinction

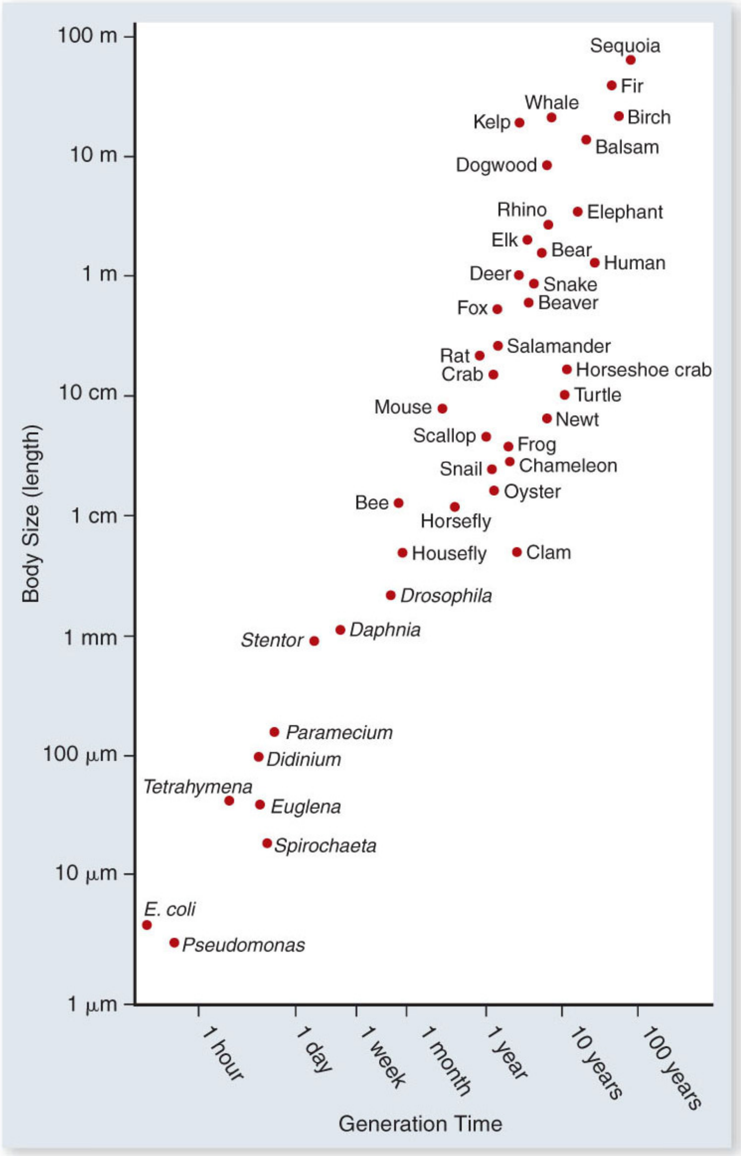
Demography and Dynamics

- **Demography:** the quantitative study of populations
  - How size changes through time
    - Whole population: increasing, decreasing remaining constant
    - Population broken down into parts
      - Study birth and death rates of a specific age

Demography and Dynamics

- Population growth can be influenced by the population’s sex ratio
- Number of births directly related to number of females
- **Generation times:** average interval between birth of an individual and birth of its offspring
- Life span: correlated with generation time. Short generation time equals fast population growth rate, short life span

Demography and Dynamics



Demography and Dynamics

- **Age structure:** determined by the numbers of individuals in a different age group
- **Cohort:** group of individuals of the same age
- **Fecundity:** number of offspring produced in a standard time
- **Mortality:** death rate

Demography and Dynamics

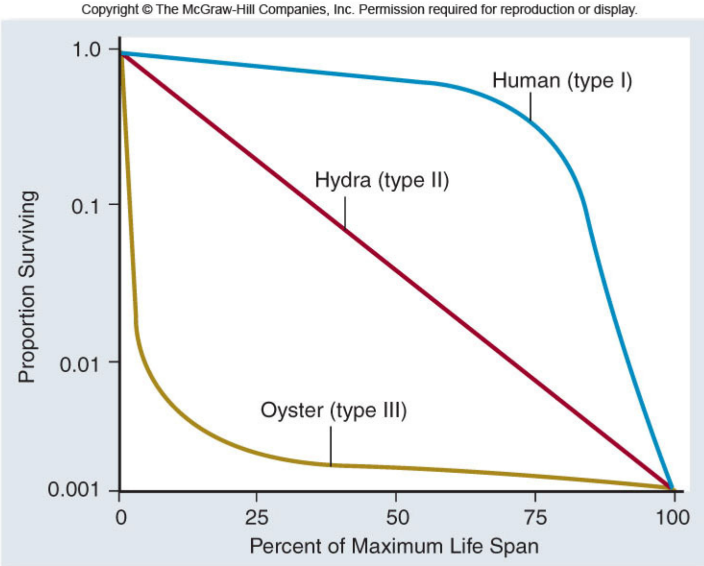
TABLE 55.2 Life Table Cohort of the Grass *Poa annua*, Containing 843 Seedlings

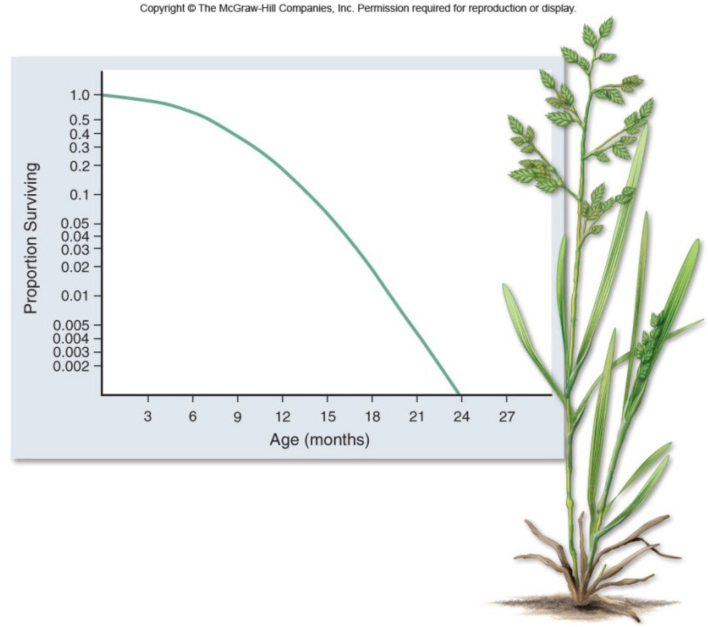
Age (in 3-month intervals)	Number Alive at Beginning of Time Interval	Proportion of Cohort Alive at Beginning of Time Interval (survivorship)	Deaths During Time Interval	Mortality Rate During Time Interval	Seeds Produced During Time Interval	Seeds Produced per Surviving Individual (fecundity)	Seeds Produced per Member of Cohort (fecundity × survivorship)
0	843	1.000	121	0.143	0	0.00	0.00
1	722	0.857	195	0.271	303	0.42	0.36
2	527	0.625	211	0.400	622	1.18	0.74
3	316	0.375	172	0.544	430	1.36	0.51
4	144	0.171	90	0.626	210	1.46	0.25
5	54	0.064	39	0.722	60	1.11	0.07
6	15	0.018	12	0.800	30	2.00	0.04
7	3	0.004	3	1.000	10	3.33	0.01
8	0	0.000	—		Total = 1665		Total = 1.98

Life tables show probability of survival and reproduction through a cohort's life

Demography and Dynamics

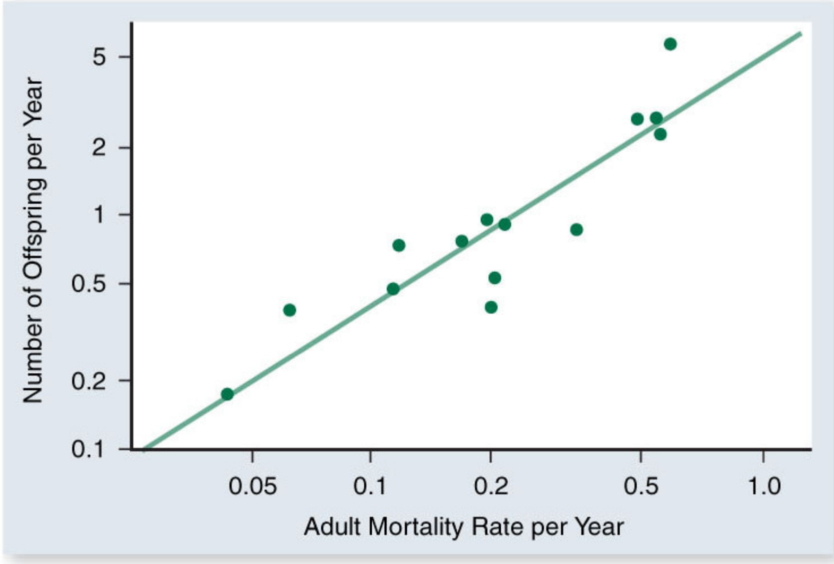
- Survivorship: percent of an original population that survives to a given age
- Survivorship curve: express some aspects of age distribution





Life History

- **Life history:** complete life cycle of an organism
- **Trade-offs**
  - Limited resources: increased reproduction
    - Decrease survival
    - Reduction of future reproduction



Life History

- Individuals that delay reproduction may grow faster and larger, enhancing future reproduction
- Cost of reproduction: add or remove eggs

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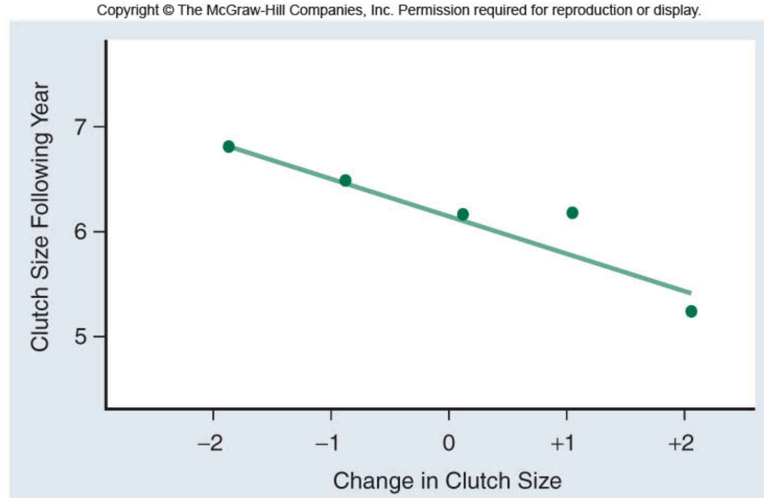
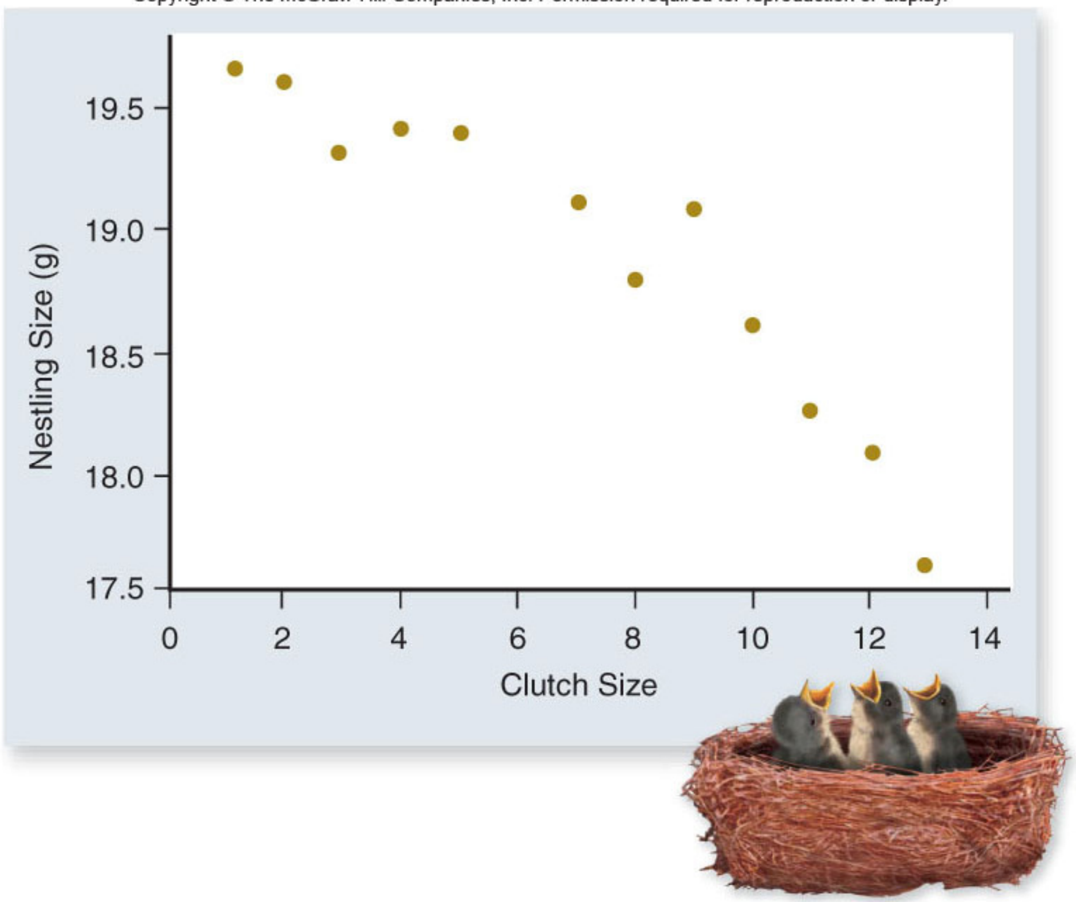


Life History

- Natural selection will favor the life history that maximizes lifetime reproductive success
- Low cost: increased reproduction, low mortality rates
- High cost: decreased reproduction
- Investment may depend on environmental factors that increase or decrease food supply

Life History

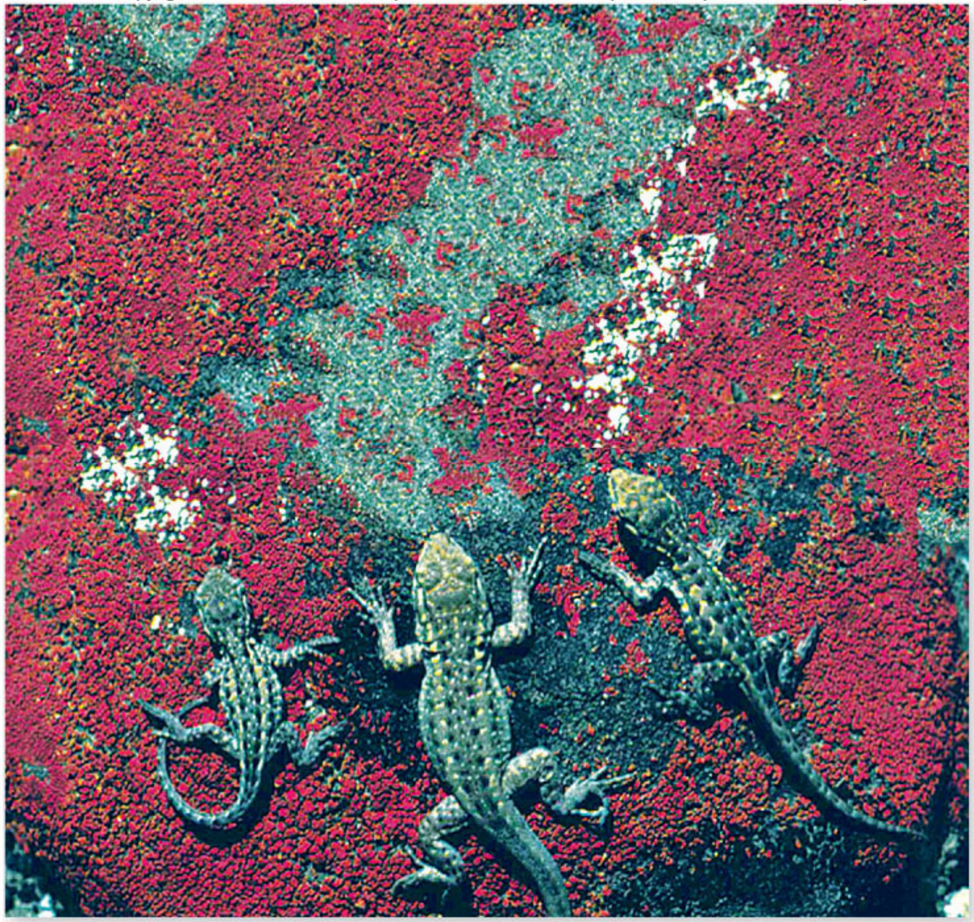


Relationship between clutch size and offspring size

Life History

- Investment per offspring is geared to maximize fitness
- Balance must be reached between the number of offspring produced and size of each offspring
  - Larger offspring have a greater chance of survival
  - Producing many small offspring may result in very low survival rates

Life History



Courtesy of Barry Sinervo

Variation in baby side-blotched lizards

Life History

- Age at first reproduction correlates with life span
  - Long-lived species delay reproduction
    - Advantage: juveniles gain experience before high cost of reproduction
  - Short-lived species reproduce early
    - Time is important, delay may mean no offspring

Growth and Limits

- Populations often remain the same size regardless of the number of offspring born
- Exponential growth model applies to populations with no growth limits

$$r = (b - d) + (i - e)$$

- *r* = rate of population increase; *b* = birth-rate; *d* = death rate; *i* = immigration; *e* = emigration

Growth and Limits

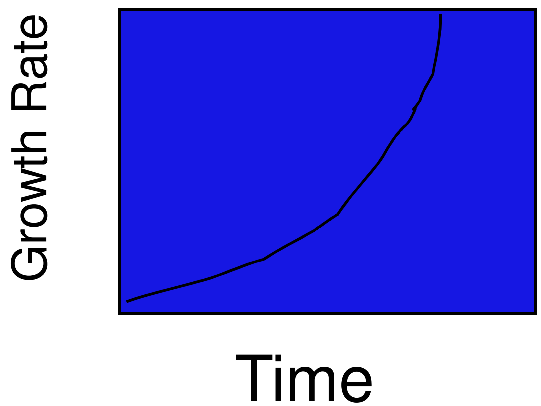
- Biotic potential: *e* = *i* and there are no limits on population growth then:

$$\frac{dN}{dt} = r_i N$$

- N is the number of individuals in the population, *dN/dt* is the rate of change over time; r_i is the intrinsic rate of natural increase for the population = innate capacity for growth

Growth and Limits

- The biotic potential of any population is exponential, even when the rate of increase remains constant
- The actual number of individuals accelerates rapidly



Growth and Limits

- **Carrying capacity:** symbolized by K, is the maximum number of individuals that the environment can support
- Logistic growth model: applies to populations as they reach K

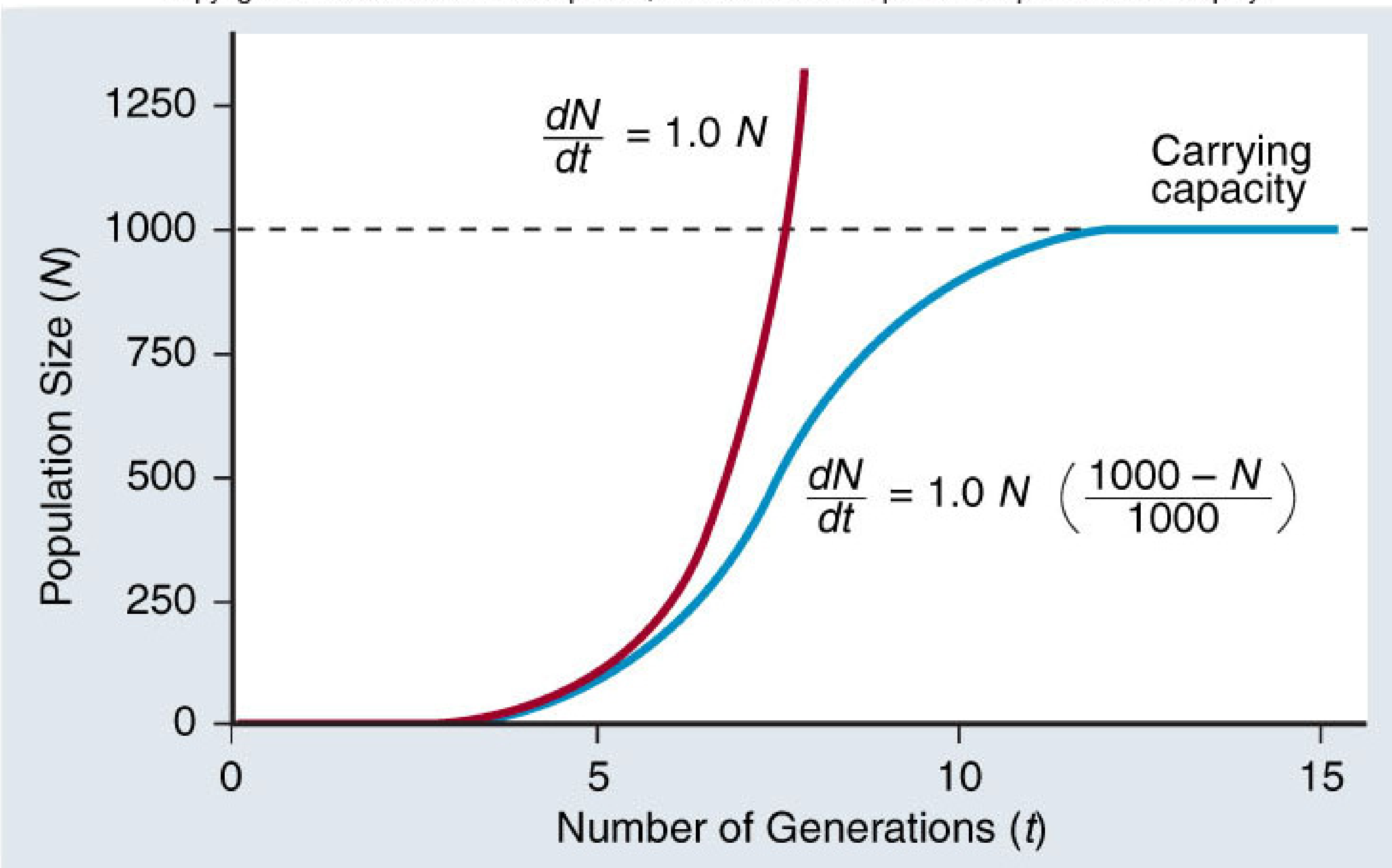
$$dN/dt = rN\,(K-N)/K$$

- *dN/dt* is equal to intrinsic rate of natural increase, adjusted for the amount of available resources

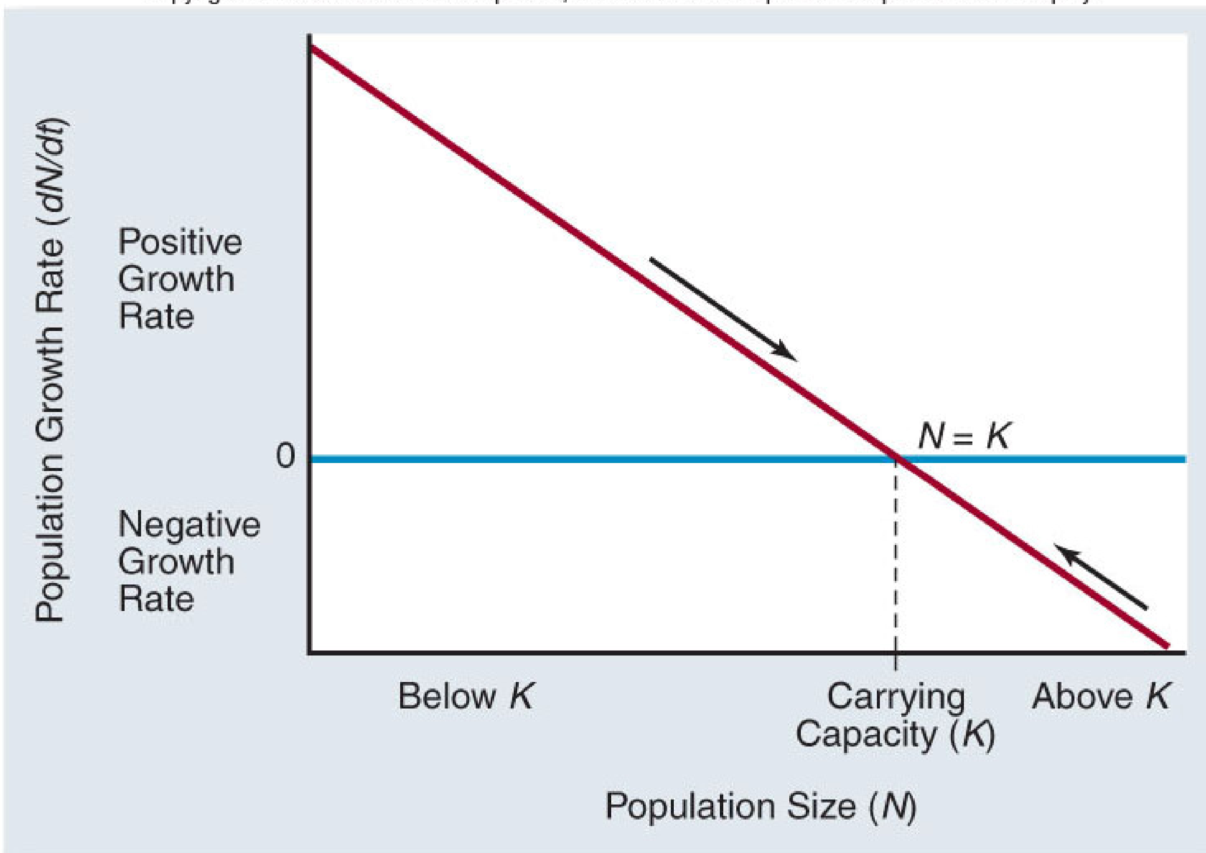
Growth and Limits

- If you plot *N* versus *t*, you obtain a sigmoidal growth curve
- As *N* approaches *K*, the rate of population growth begins to slow
- If $N = K$ the population growth rate is zero
- If the population size exceeds *K* the population size will decline until it reaches *K*

Growth and Limits

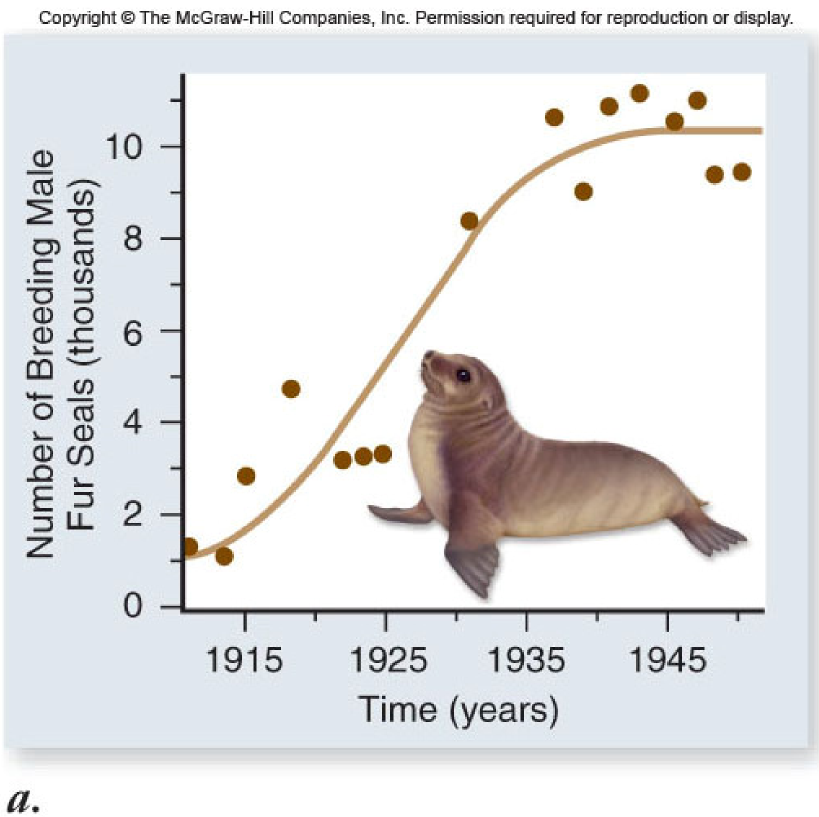


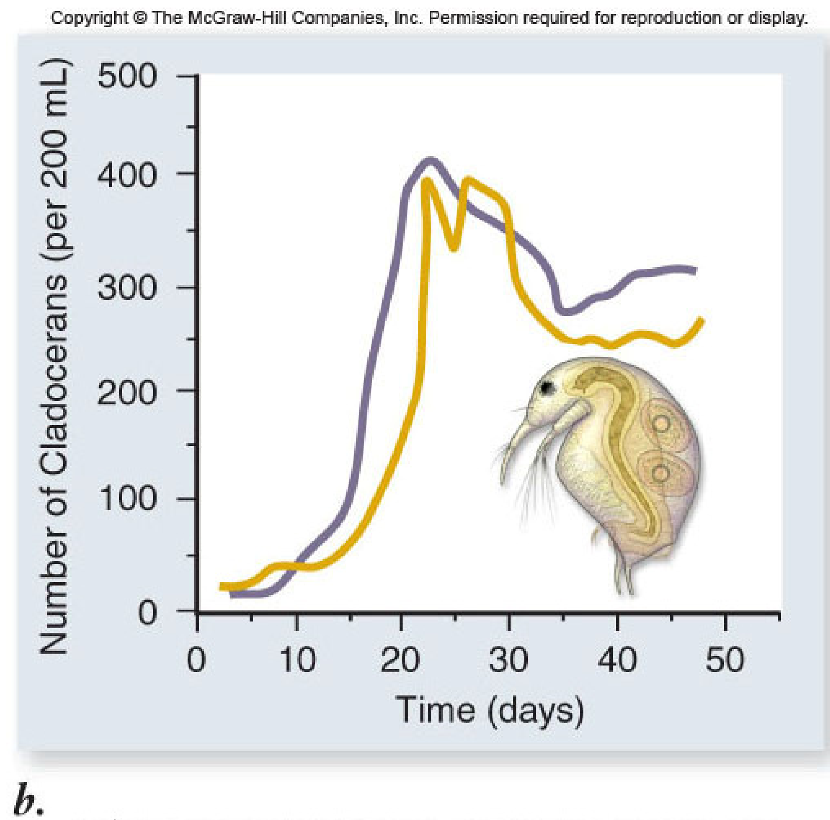
Growth and Limits



Relationship between population growth rate and population size

Growth and Limits





Data from C.E. Goulden, L.L. Henry, and A.J. Tessier, Ecology, 1982.

Many populations exhibit logistic growth

Factors that Regulate

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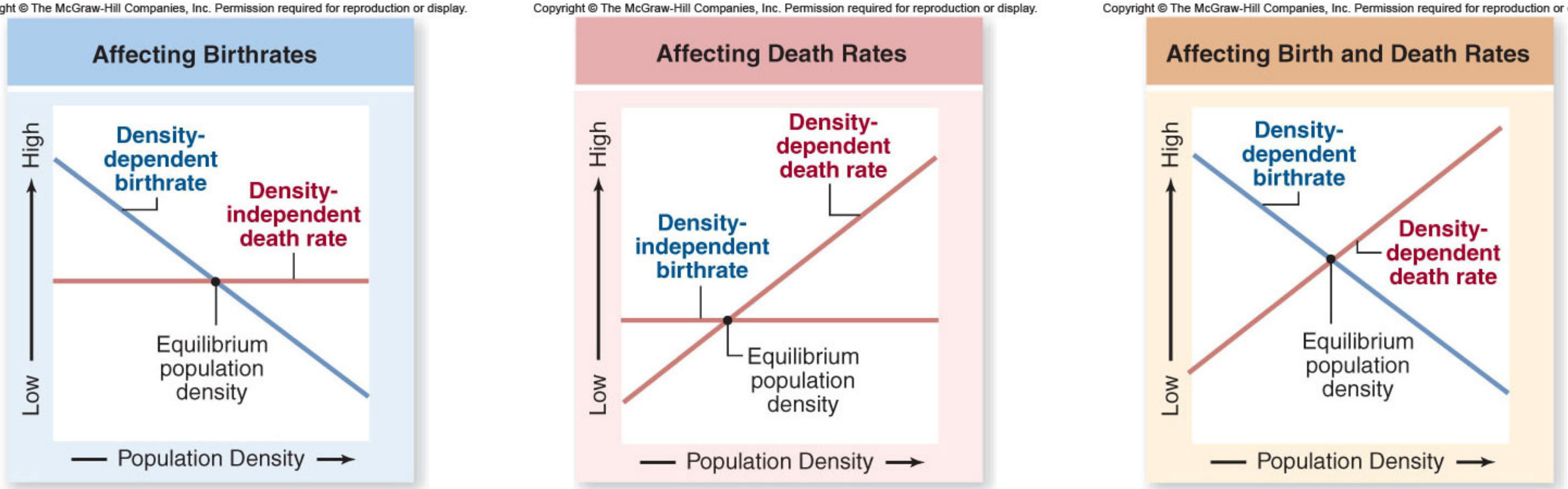
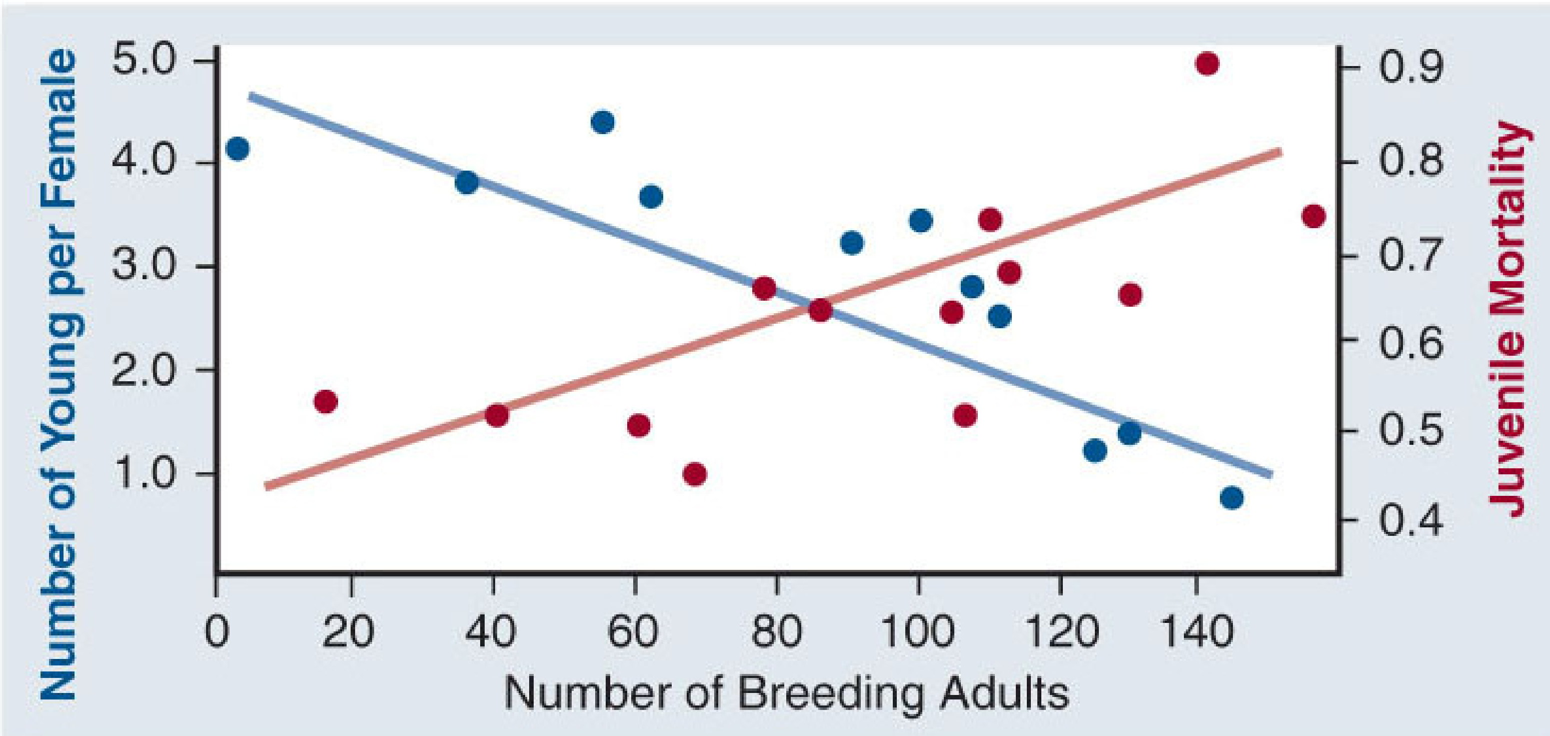


Density-dependent: factors that affect the population and depend on population size

Factors that Regulate

- Negative feedback:
  - population size increases
    - reproductive rates decline
    - mortality rates increase
    - or both

Factors that Regulate



Density dependence in the song sparrow on Mandarte island

Factors that Regulate

At high populations, locusts have different hormonal and physical characteristics and take off as a swarm

(left): © Juan Medina/Reuters/Corbis; (right): © Oxford Scientific/Photolibrary.

Positive feedback: Allee effect (Warder Allee). Growth rates increase with population size

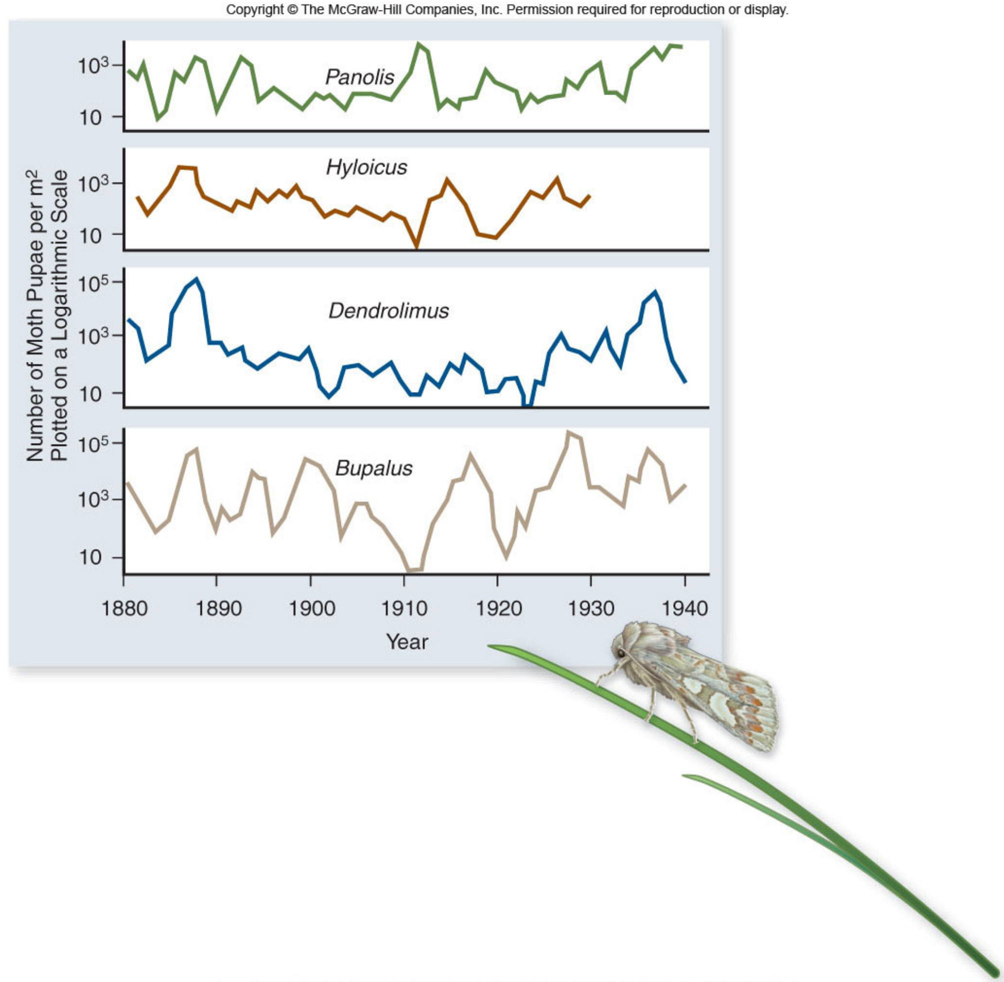
Factors that Regulate

- Density-independent effects: the rate of growth of a population at any instant is limited by something unrelated to the size of the population
- External environment aspects: cold winters, droughts, storms, volcanic eruptions
- Populations display erratic growth patterns because of these events

Population cycles may reflect complex interactions with the environment

Fluctuations in the number of pupae of four moth species in Germany

Which type of factors could be affecting these populations?



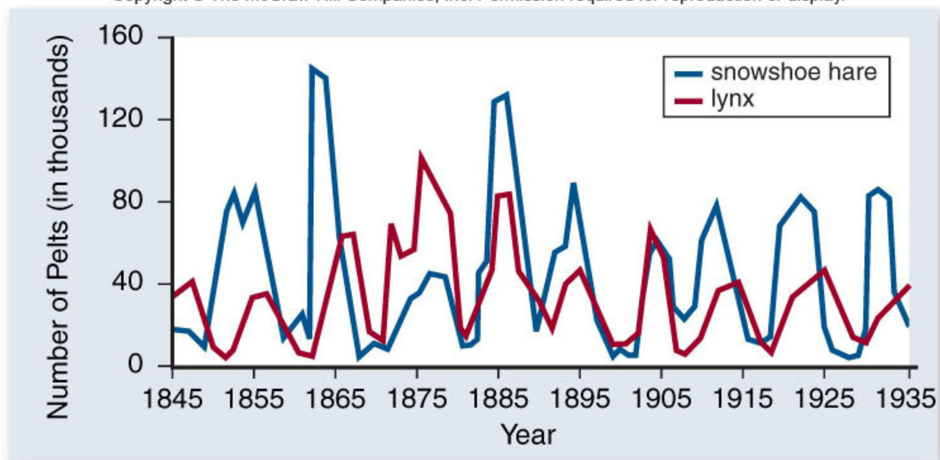
From "Population Changes in German Forest Pests," by G.C. Varley in Journal of Animal Ecology, 18. Copyright © 1949 British Ecology Society. Reprinted by permission.

Factors that Regulate

- North American snowshoe hare has a 10 year cycle
- Population numbers fall 10-fold to 30-fold in a cycle and 100-fold changes can occur
- Two factors generate this cycle:
  - Food plants
  - Predators

Factors that Regulate

C. Krebs 1992: set up experimental plots to determine if overharvesting of plants by hares or increase lynx population cause oscillations in populations



Linked population cycles of the snowshoe hare and the Canada lynx

Factors that Regulate

- Resource availability affects life history adaptations
- When resources are limited, the cost of reproduction is high
- Selection will favor individuals that can compete and utilize resources efficiently
- Can lower reproductive rates
- **K-selected populations:** adapted to thrive when population is near its carrying capacity

Factors that Regulate

- Populations far below carrying capacity, resources abundant
- Costs of reproduction are low
- *r* - selected populations: selection favors individuals with the highest reproductive rates
- Most natural populations show life history adaptations that exist along a continuum of *r and K* - selected traits

Factors that Regulate

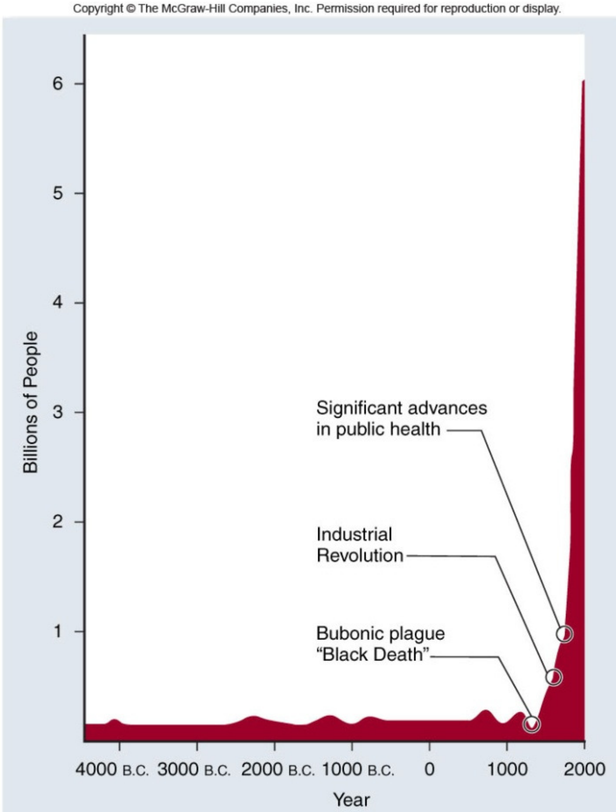
TABLE 55.3 ***r*-Selected and *K*-Selected Life History Adaptations**

Adaptation	*r*-Selected Populations	*K*-Selected Populations
Age at first reproduction	Early	Late
Life span	Short	Long
Maturation time	Short	Long
Mortality rate	Often high	Usually low
Number of offspring produced per reproductive episode	Many	Few
Number of reproductions per lifetime	Few	Many
Parental care	None	Often extensive
Size of offspring or eggs	Small	Large

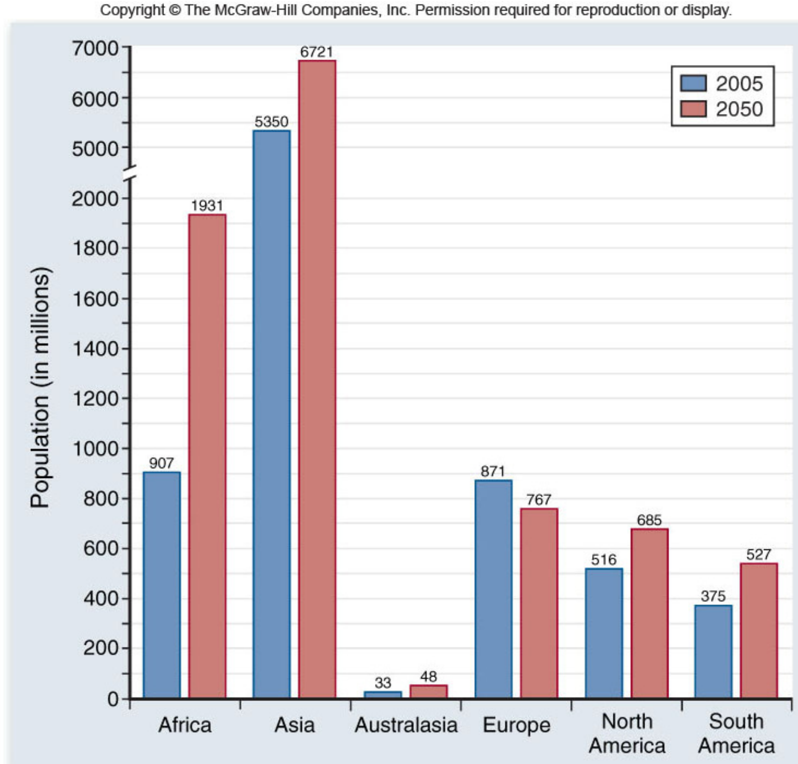
Human Population Growth

- *K*-selected life history traits
  - Small brood size
  - Late reproduction
  - High degree of parental care
- Human populations have grown exponentially
  - Last 300 years birth rate has remained
  - Death rate has fallen dramatically

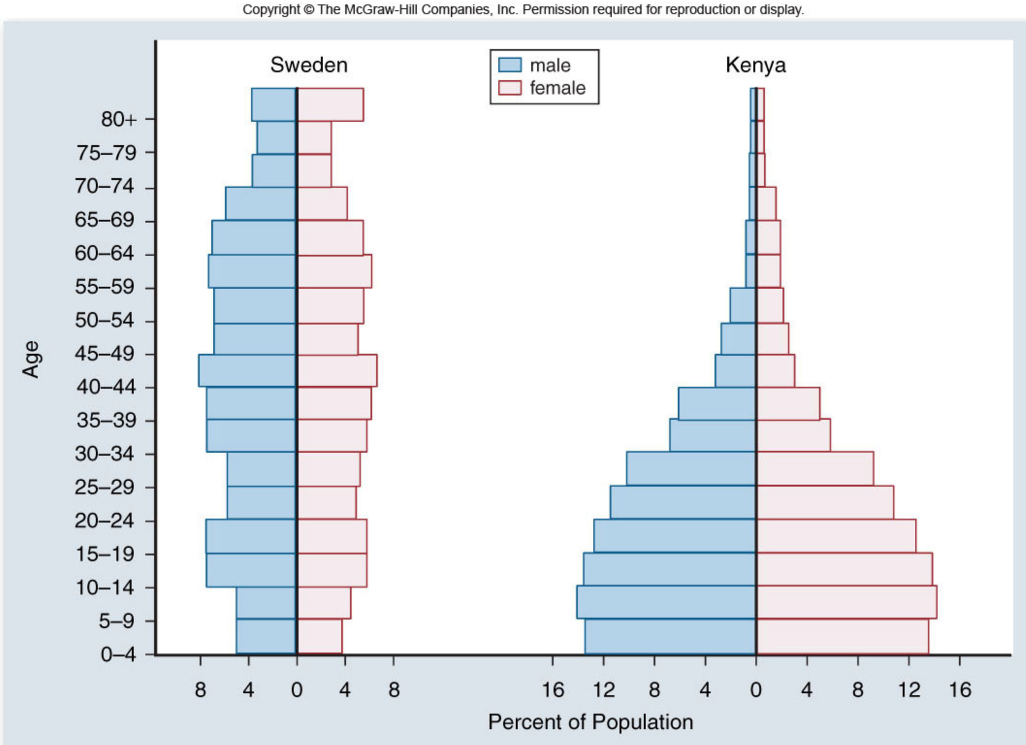
Human Population Growth



History of human population size



Human Population Growth



Population Pyramid: a bar graph displaying the number of people in each age category

TABLE 55.4 A Comparison of 2005 Population Data in Developed and Developing Countries

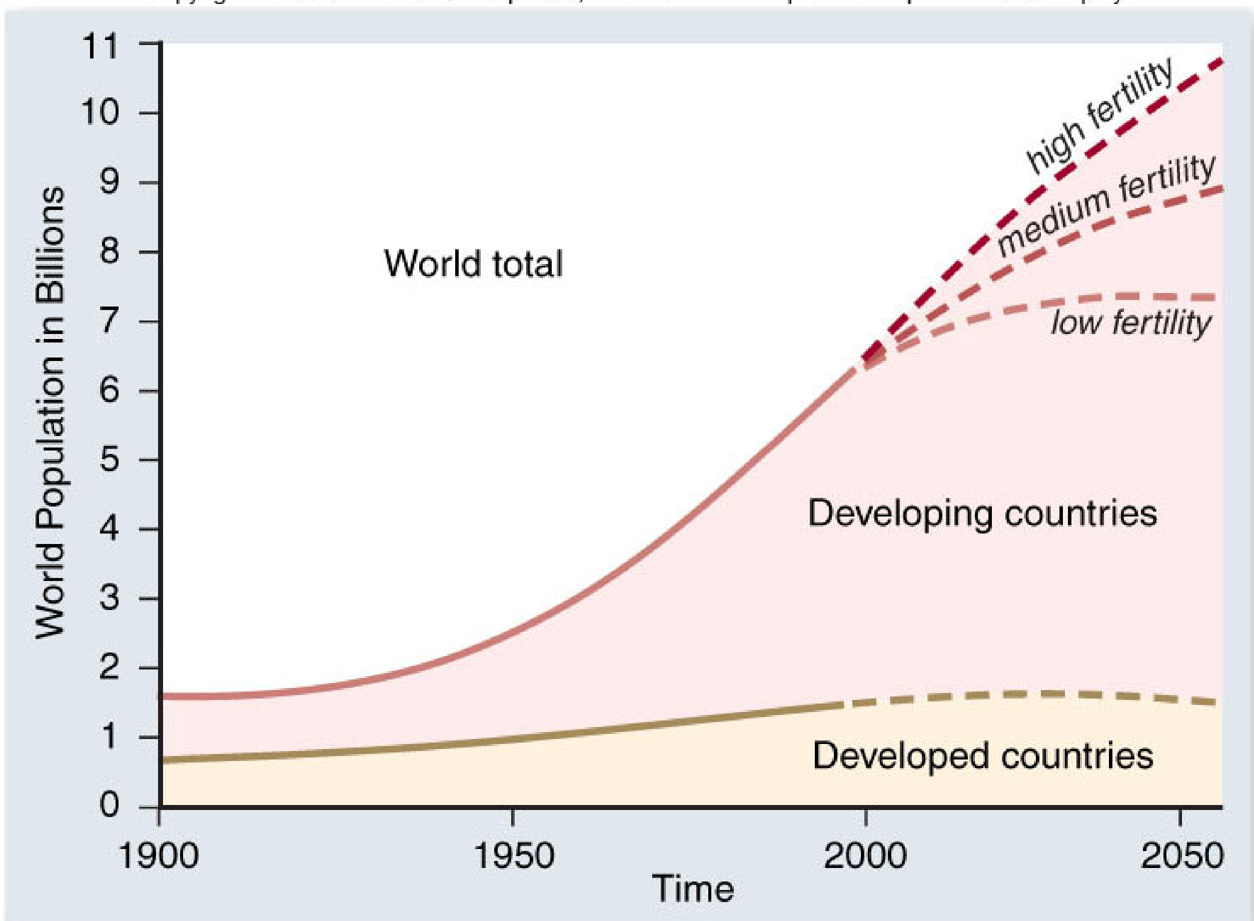
	United States (highly developed)	Brazil (moderately developed)	Ethiopia (poorly developed)
Fertility rate	2.1	1.9	5.3
Doubling time at current rate (years)	75	65	29
Infant mortality rate (per 1000 births)	6.5	30	95
Life expectancy at birth (years)	78	72	49
Per capita GNP (U.S. $)	$40,100	$8100	$800
Population < 15 years old (%)	21	26	44

Earth's rapidly growing human population constitutes, perhaps, the greatest challenge to the future of the biosphere

Human Population Growth

- Uneven distribution among countries
- Increasing gap between rich and poor
- The world ecosystem is already under stress
- What is *K* for the human population?
- Thomas Malthus: Essay on the Principle of Population

Human Population Growth



Distribution of population growth

Human Population Growth

- World population growth rate is declining:
  - High of 2.0% in 1965-1970
  - 2005: 1.2%
  - Still and increase of 78 million people per year

Human Population Growth

- Consumption in the developed world further depletes resources
  - Wealthiest 20% of the world's population accounts for 86% consumption of resources and produces 53% of CO_2 emissions
  - Poorest countries: 20% is responsible for 1.3% consumption and 3% CO_2 emissions

Human Population Growth

Ecological Footprint: amount of productive land required to support an individual at the standard of living of a particular population through the course of his/her life