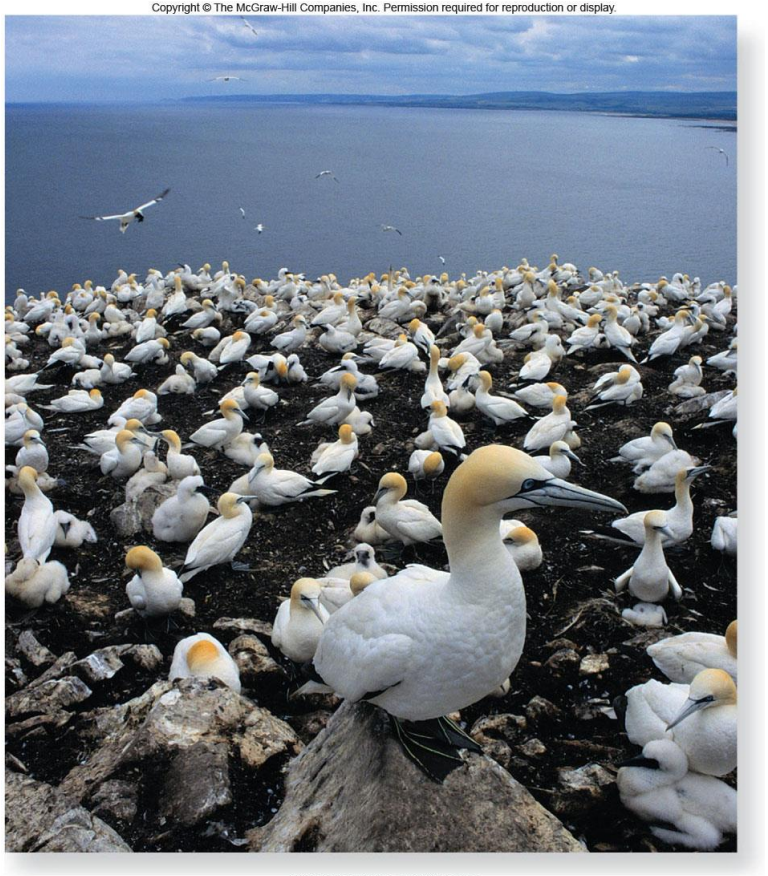
Ecology of Individuals and Populations

Chapter 55



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Environmental Challenge

- Ecology
  - Study of how organisms relate to one another and to their environments
- Key elements of the environment
  - Temperature
  - Water
  - Sunlight
  - Soil

Environmental Challenge

- Homeostasis
  - Individual must maintain a steady-state internal environment regardless of external environment
- Some are "conformers" – adopt temperature, salinity of their surroundings

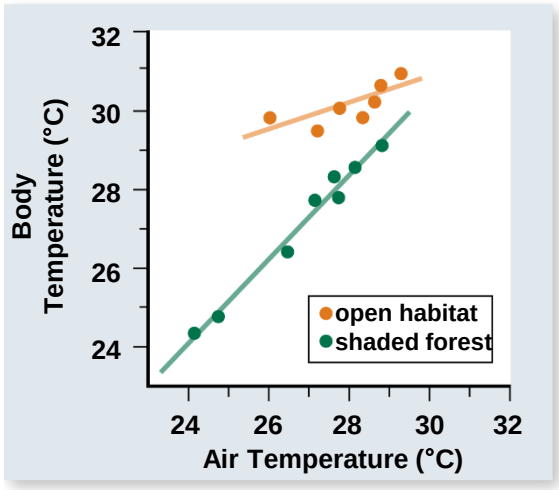
Environmental Challenge

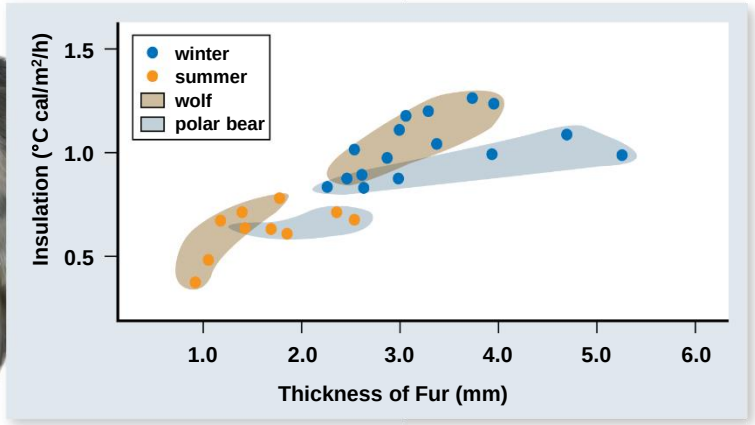
- Reponses can be short or long term
- Short term
  - From a few minutes, to an individual's lifetime
  - Variety of ways to cope
- Long term
  - Natural selection can operate to make a population better adapted to the environment

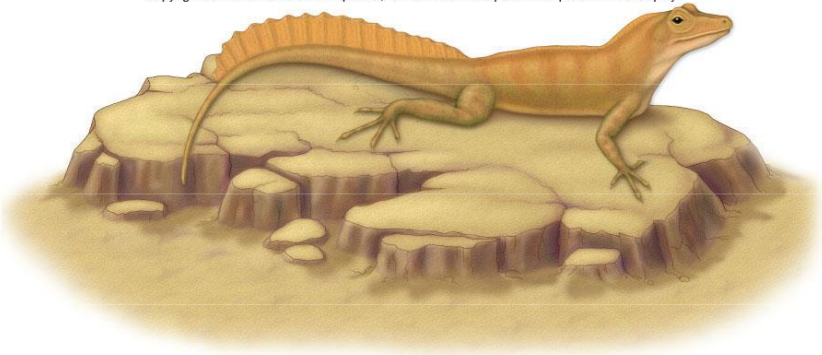
Environmental Challenge

- Coping mechanisms
  - Physiological responses
  - Morphological capabilities
  - Behavioral responses

Environmental Challenge







Morphological and Behavioral Adaptations

Environmental Challenge

- Natural selection leads to evolutionary adaptation to environmental conditions

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

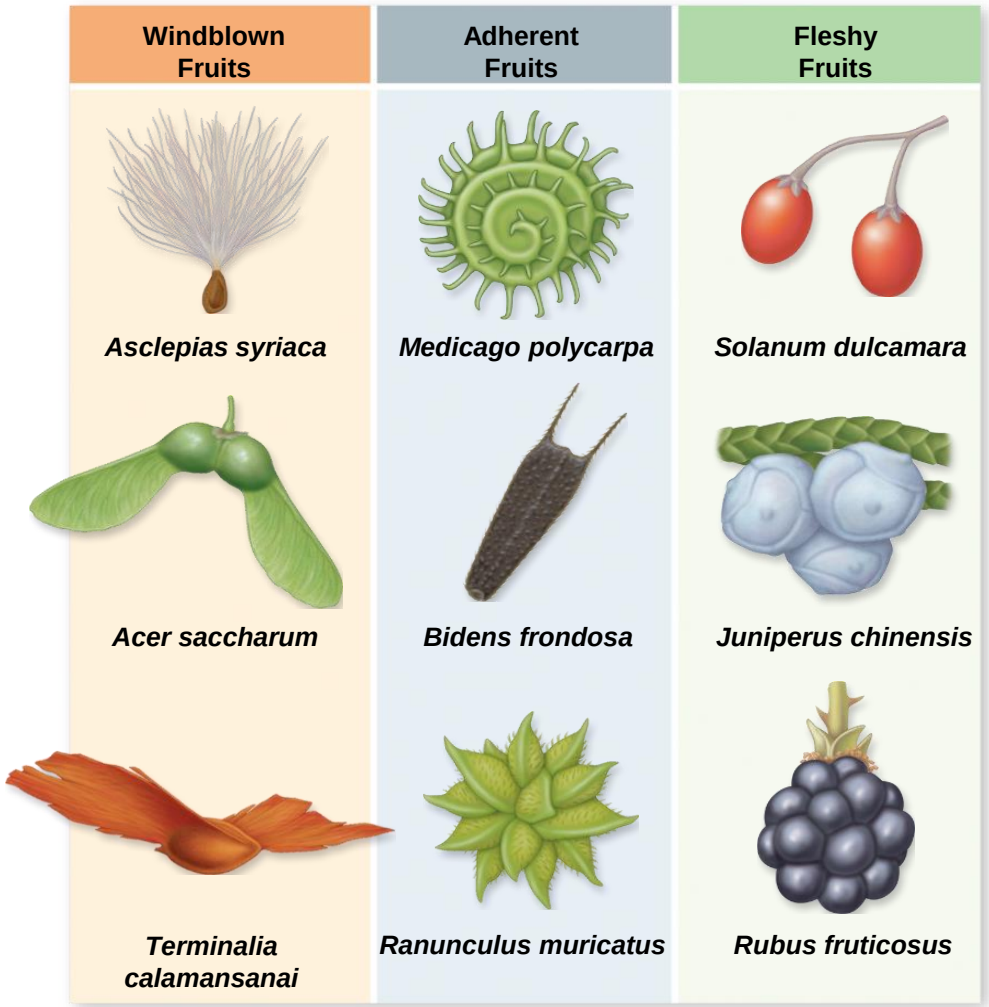
- Range
  - Most species have limited geographic range
    - Devil's hole pupfish lives in a single spring in southern Nevada
  - Polar bears are well adapted for the Arctic but you won't find them in the tropics

Populations

- Ranges change through time
  - Environment changes
  - Circumvent inhospitable habitat to colonize suitable, previously unoccupied areas
  - Humans have expanded ranges of coyotes, introduced starlings

Populations

- Dispersal mechanisms



Populations

- Individuals in populations exhibit different spacing patterns
  - Random spacing
  - Uniform spacing
  - Clumped spacing

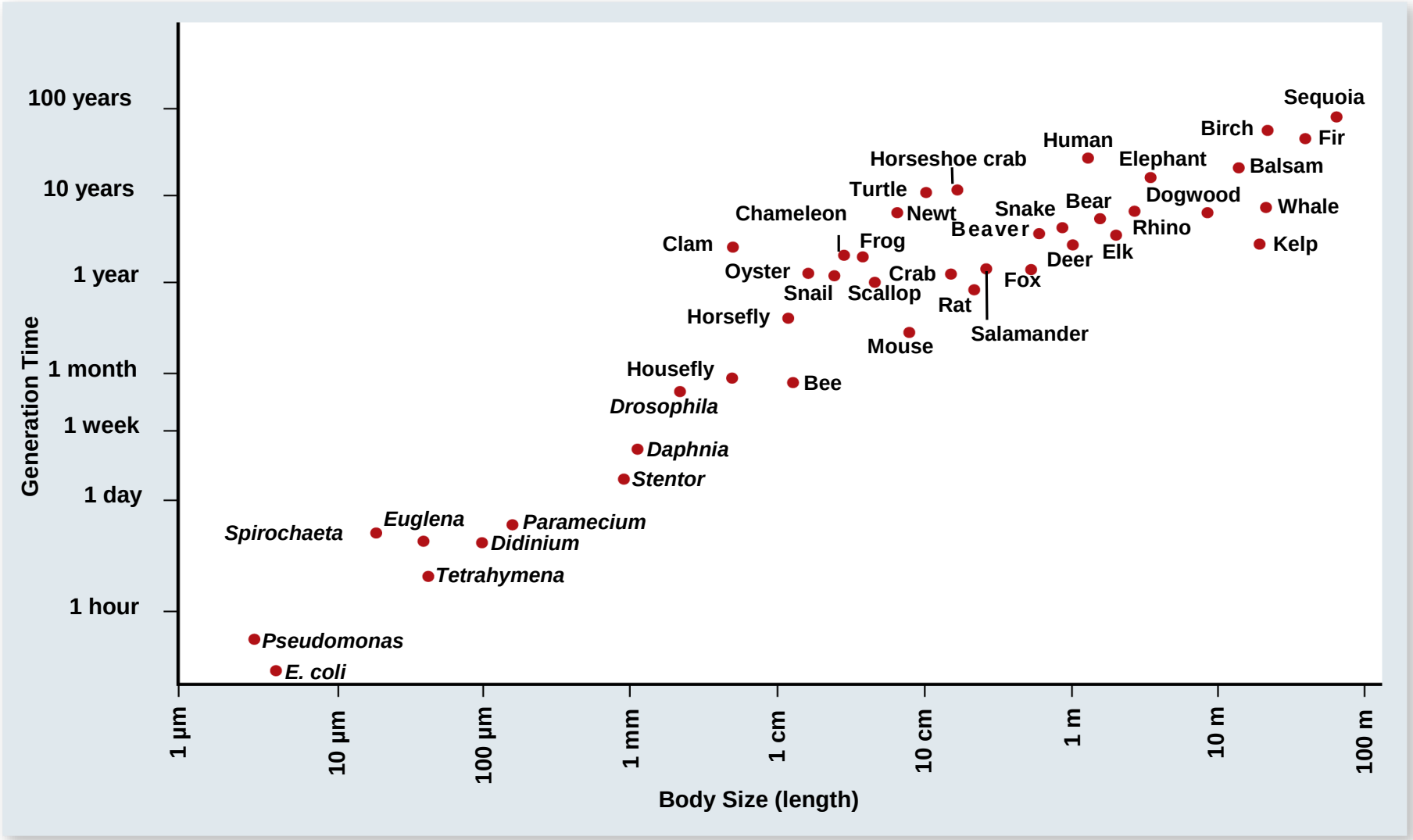
Population Demography

- Demography
  - 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
  - Populations with short generations can increase in size more quickly than populations with long generations

In general, larger organisms have longer generation times.



Population Demography

- 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 in a standard time
- Age structure has a critical influence on a population's growth rate

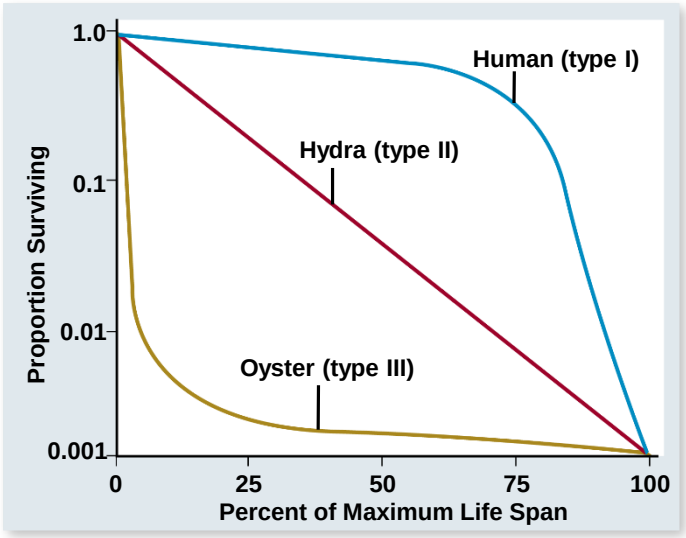
TABLE 55.2 Life Table of the Annual Bluegrass (*Poa annua*) for a Cohort Containing 843 Seedlings

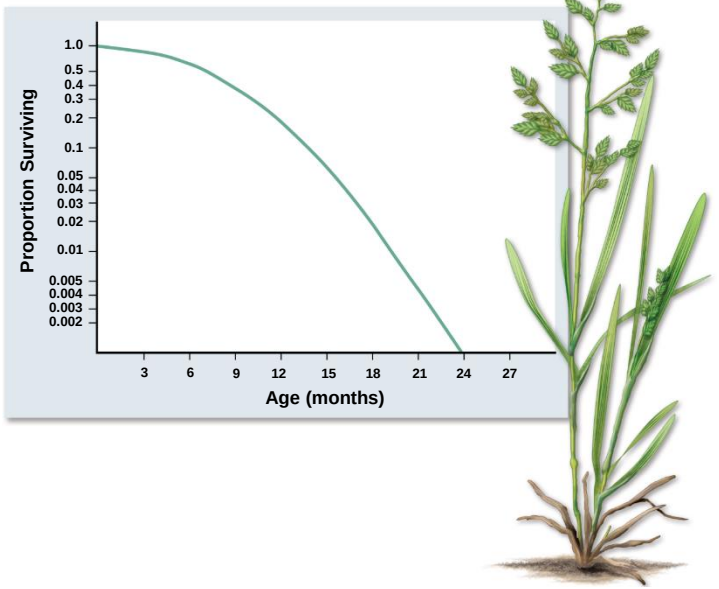
Age (in 3-month intervals)	Number Alive at Beginning of Time Interval	Proportion of Cohort Alive at Beginning of Time Interval (survivorship)	Deaths During Time Interval	Mortality Rate During Time Interval	Seeds Produced During Time Interval	Seeds Produced per Surviving Individual (fecundity)	Seeds Produced per Member of Cohort (fecundity × survivorship)
0	843	1.000	121	0.144	0	0.00	0.00
1	722	0.856	195	0.270	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

Population Demography

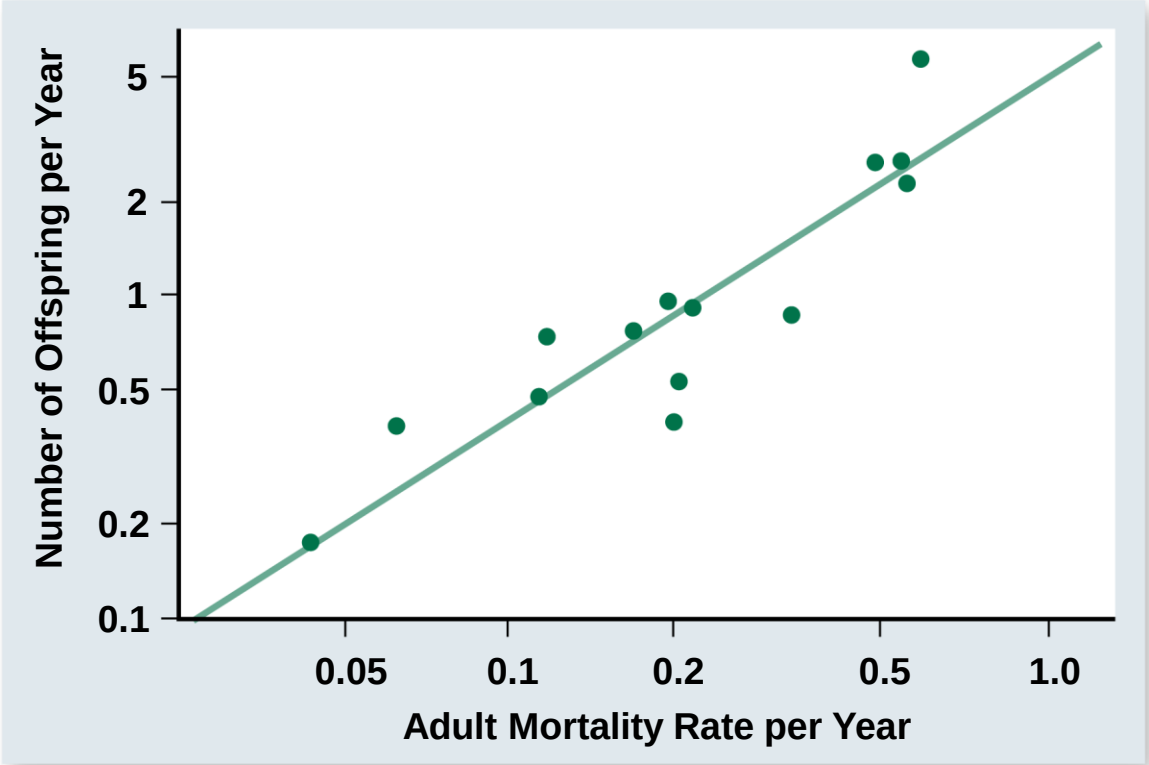
- Survivorship
  - Percent of an original population that survives to a given age
- Survivorship curve
  - Express some aspects of age distribution





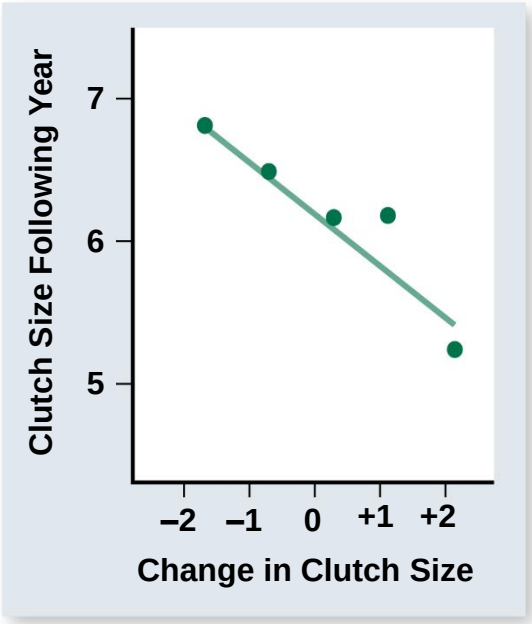
Life History

- Natural selection favors traits that maximize the number of surviving offspring left in the next generation by an individual organism
  - 2 factors affect this quantity
    - How long an individual lives
    - How many young it produces each year



- Life history
  - Complete life cycle of an organism
- Trade-off: limited resources vs increased reproduction

- Collared flycatchers *(Ficedula albicollis)*
  - Experiment demonstrates the trade-off between current reproductive effort and future reproductive success
  - Cost of reproduction

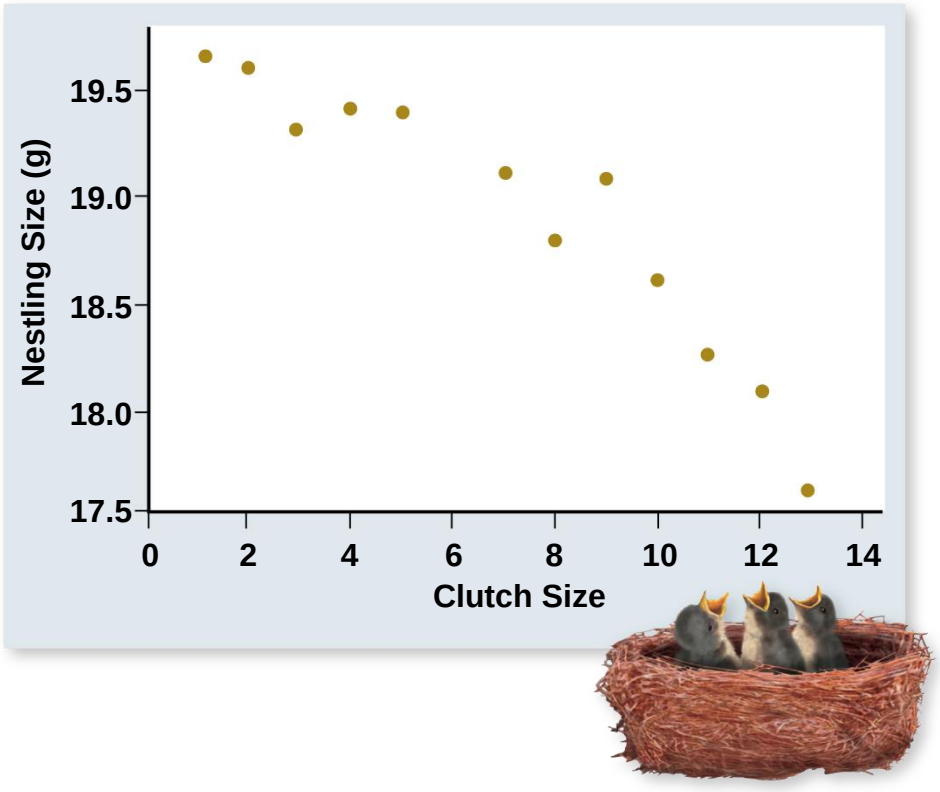


a: © Christian Kerihuel

Life History

- In terms of natural selection, the number of offspring produced is not as important as how many of those offspring themselves survive to reproduce
- Balance between number of offspring and size of offspring
  - Larger offspring have a greater chance of survival
  - Producing many small offspring may result in very low survival rates

Life History



Relationship between clutch size and offspring size

© Barry Sinervo

Variation in size of 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

Environmental Limits to Population Growth

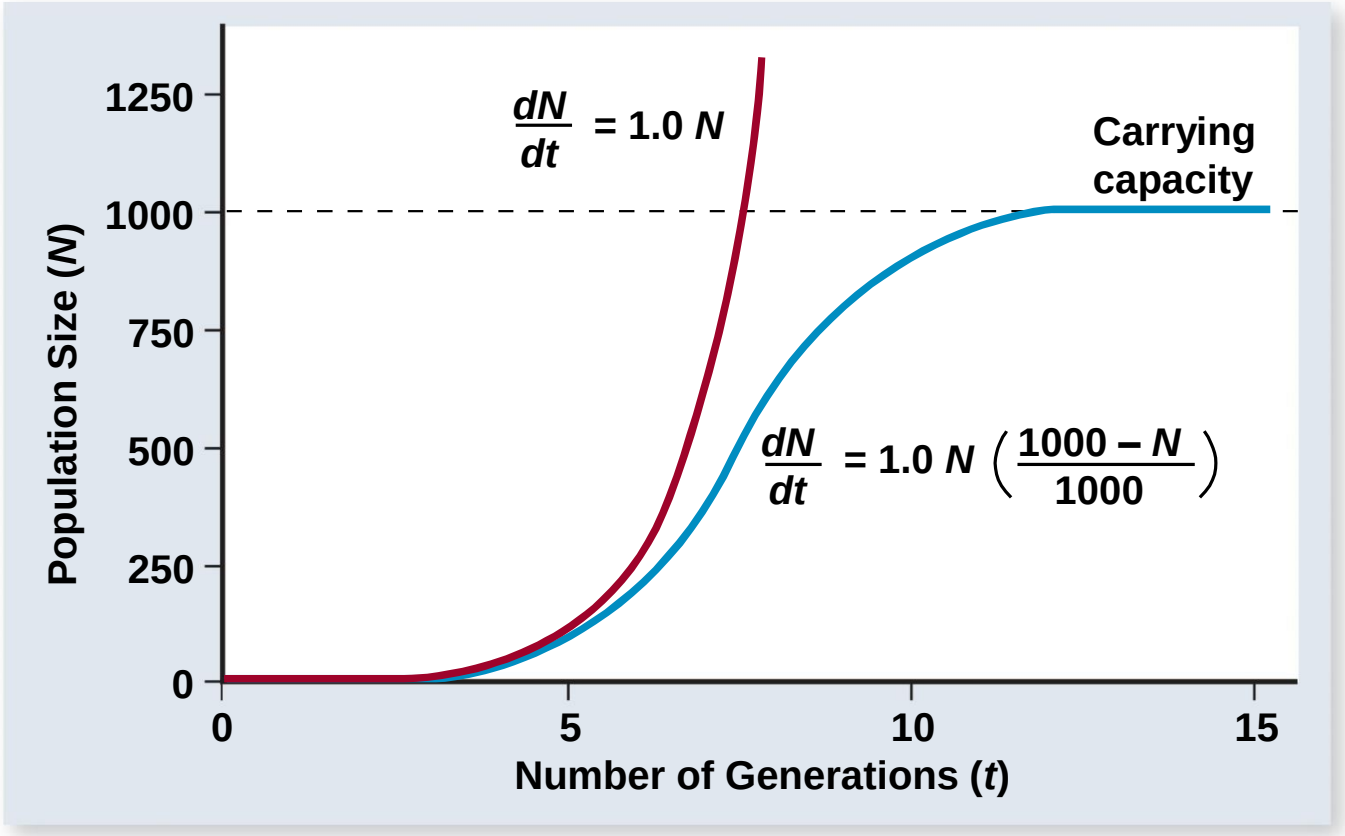
- Populations often remain the same size regardless of the number of offspring born
- Exponential growth model applies to populations with no growth limits
- Biotic potential – ability of a population to grow in ideal conditions

Environmental Limits to Population Growth

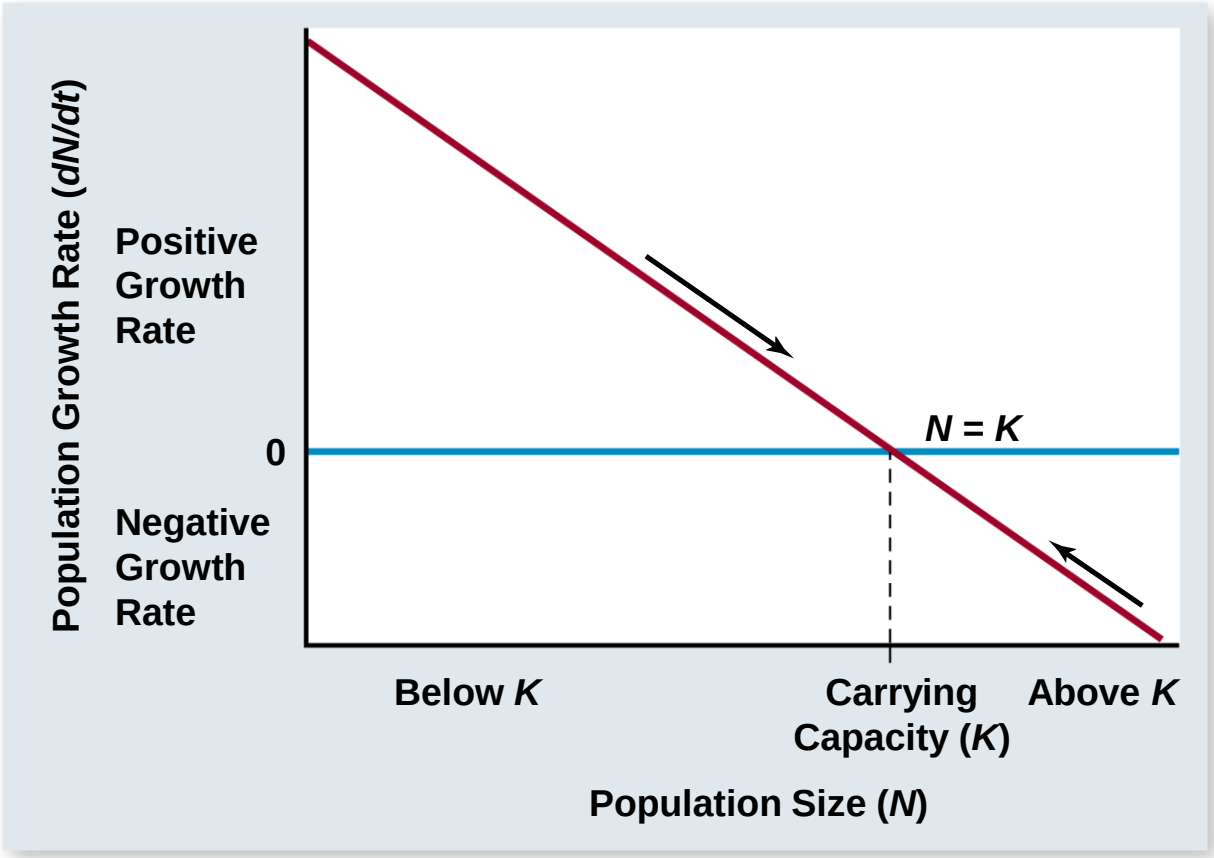
- The biotic potential of any population is exponential, even when the rate of increase remains constant
  - Result of unchecked exponential growth is a population explosion
- All populations eventually reach some limit imposed by a shortage
- Carrying capacity: symbolized by *K*, is the maximum number of individuals that the environment can support

Environmental Limits to Population Growth

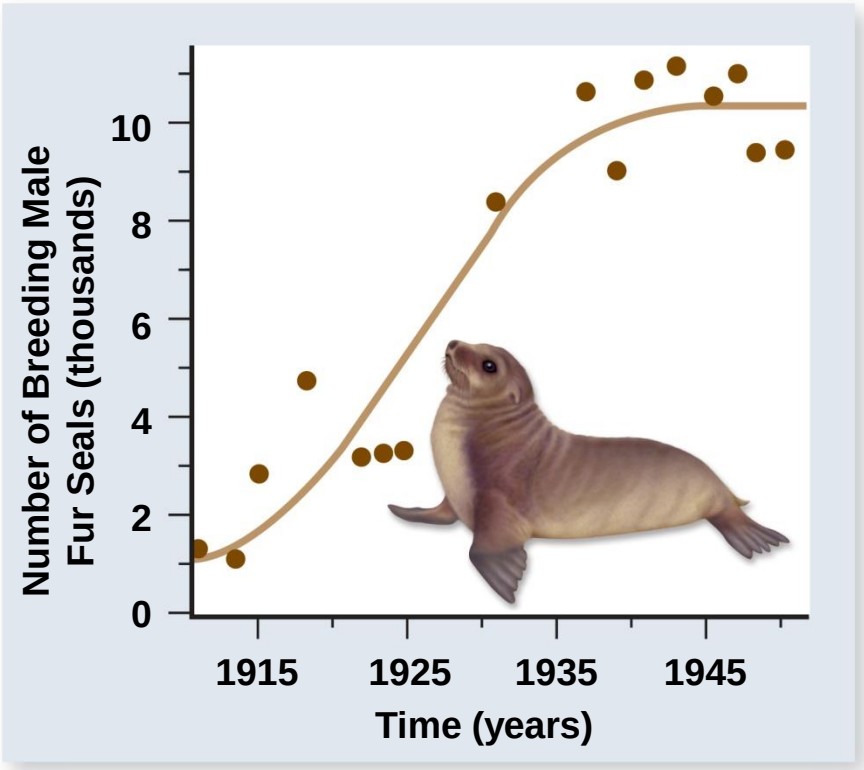
- Logistic growth model: applies to populations as they reach *K*
- If you plot *N* versus *t*, you obtain a sigmoidal growth curve



Red line illustrates the exponential growth model; blue line illustrates the logistic growth model



- 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*



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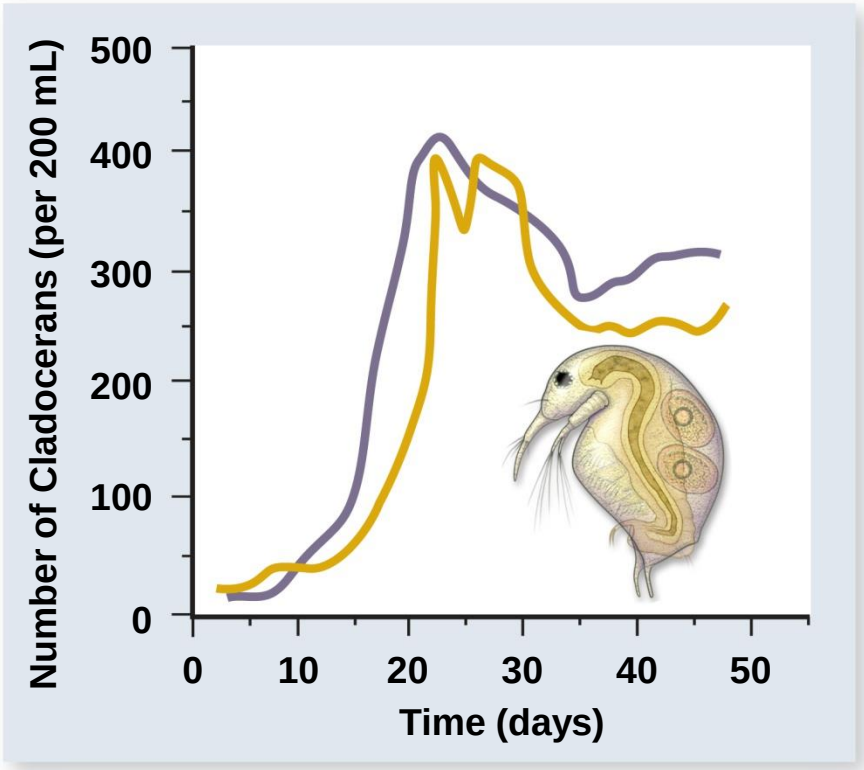


b.

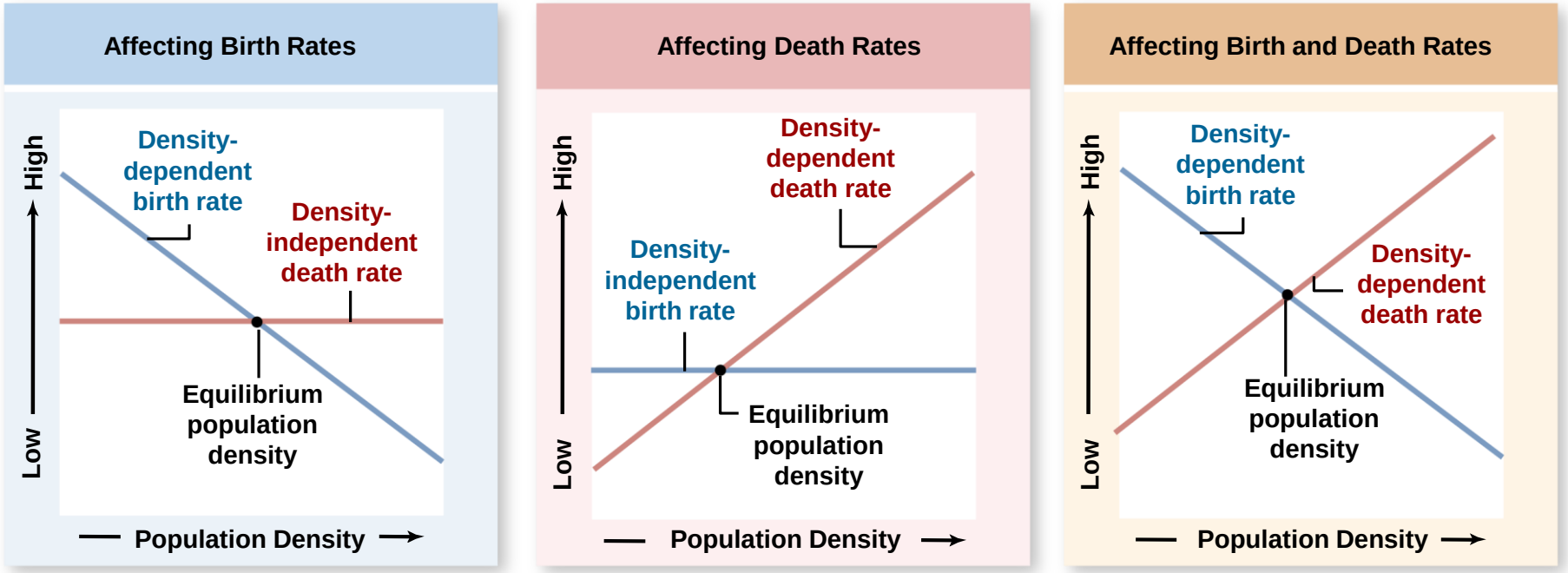
Data from C.E. Goulden, L.L. Henry, and A.J. Tessier, Ecology, 1982.

Many populations exhibit logistic growth

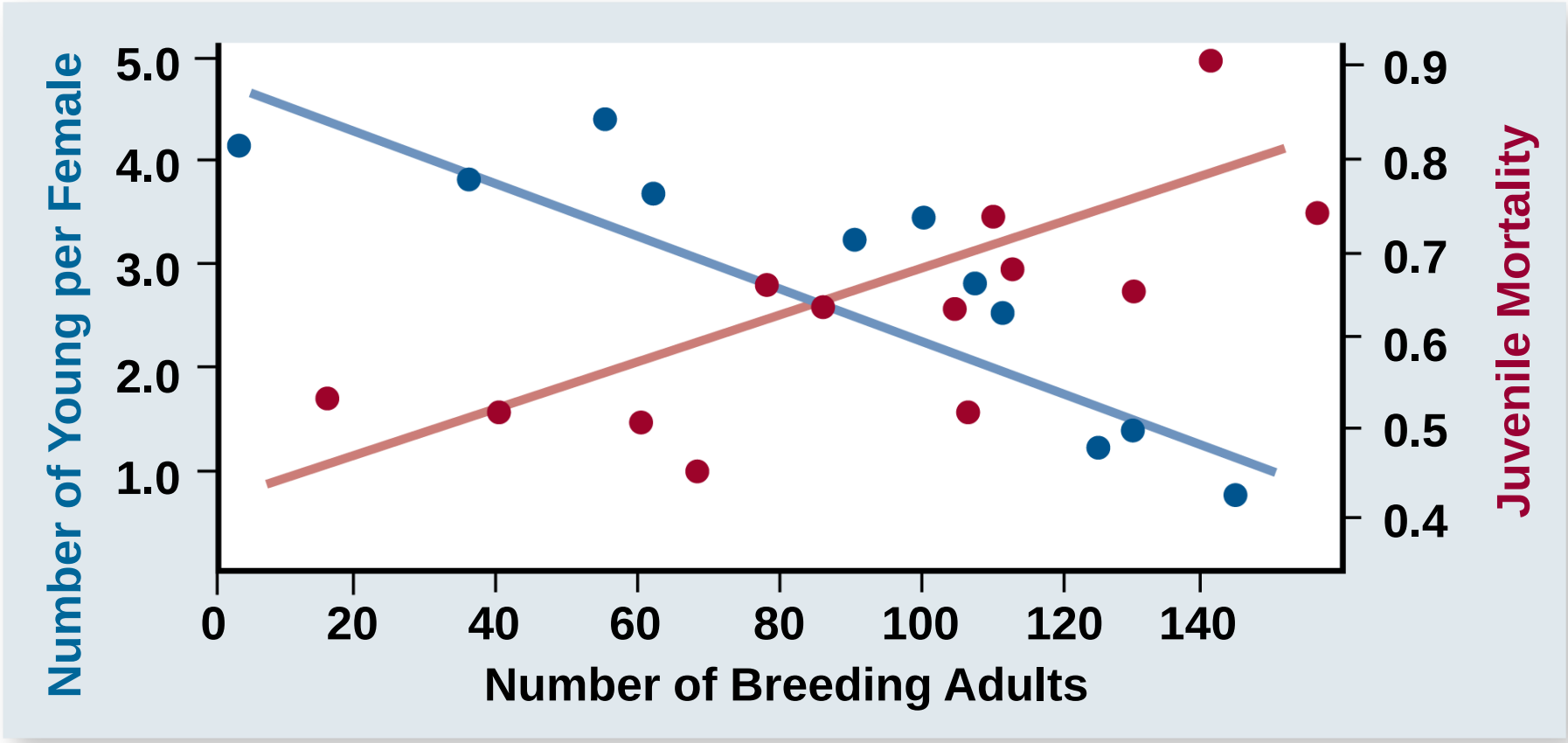
Factors That Regulate Populations

- Density-dependent
  - Factors that affect the population and depend on population size
- Density-independent
  - Other factors, such as natural disasters, affect populations regardless of size

Factors That Regulate Populations



Density-dependent effects result in negative feedback



Density dependence in the song sparrow on Mandarte island

Factors That Regulate Populations

- Density-independent effects
  - 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

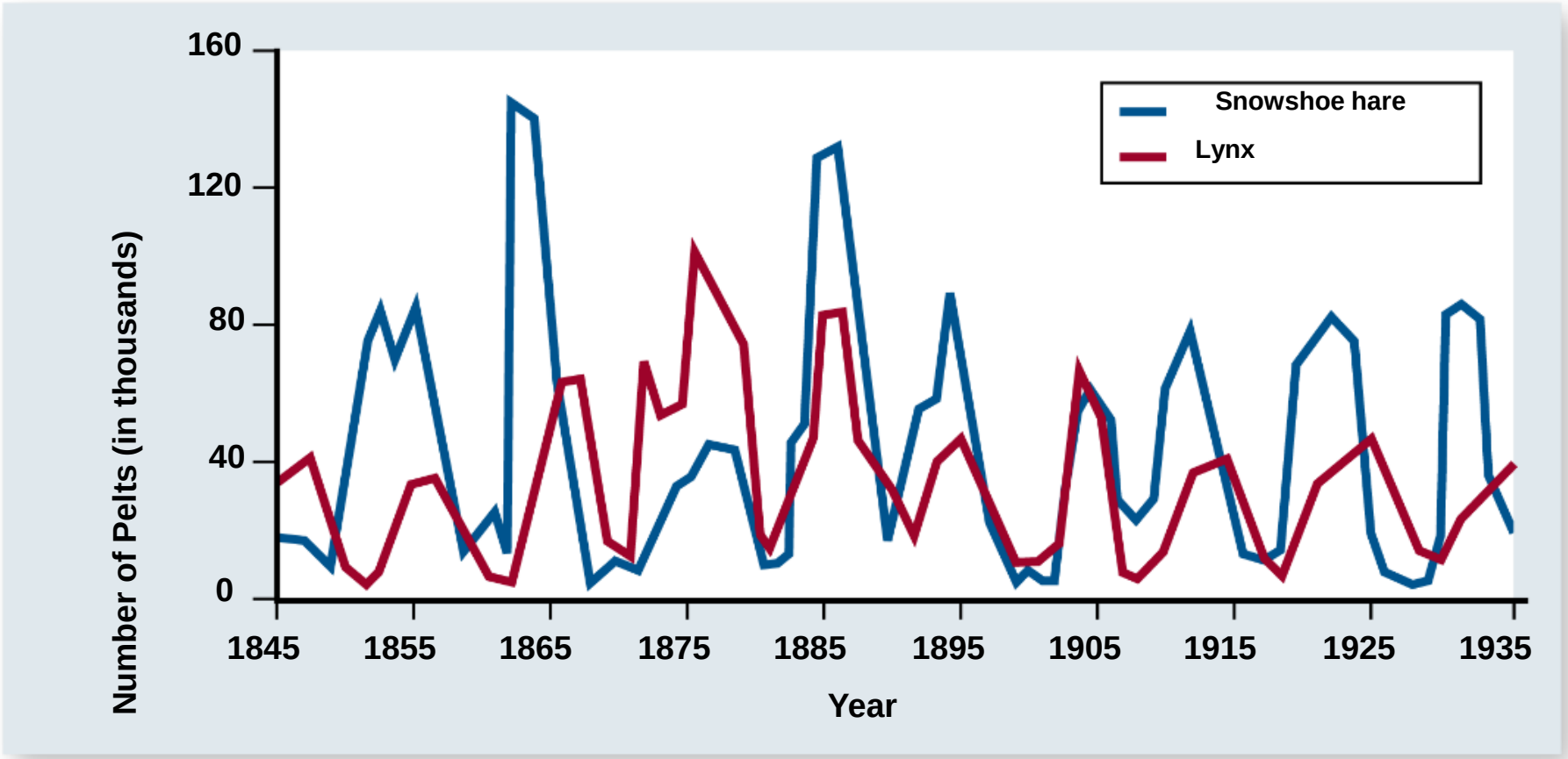
Factors That Regulate Populations

- 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 Populations

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 Populations

- 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

- 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

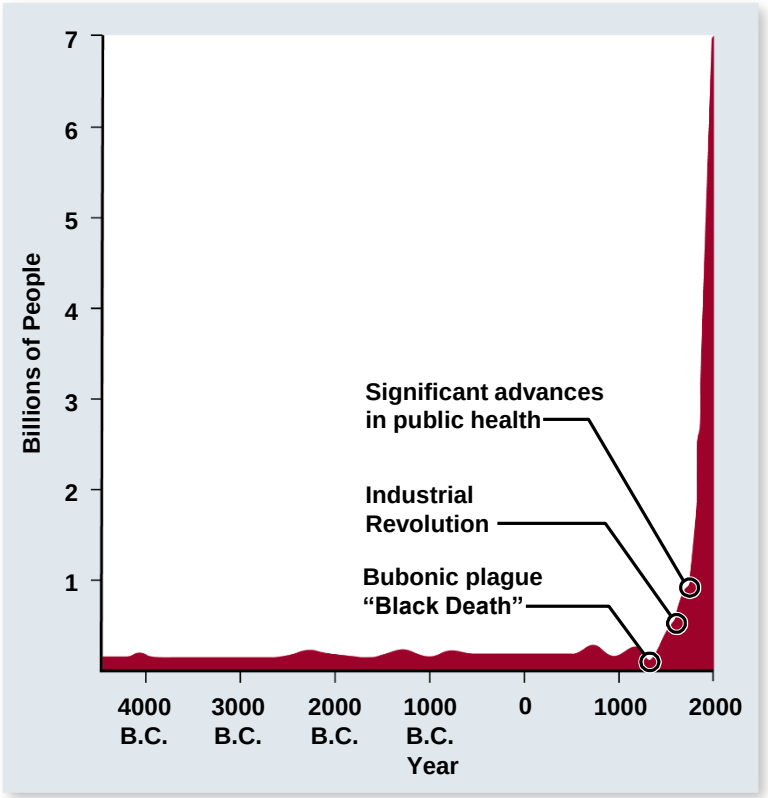
TABLE 55.3 *r*-Selected and *K*-Selected Life History Adaptations

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

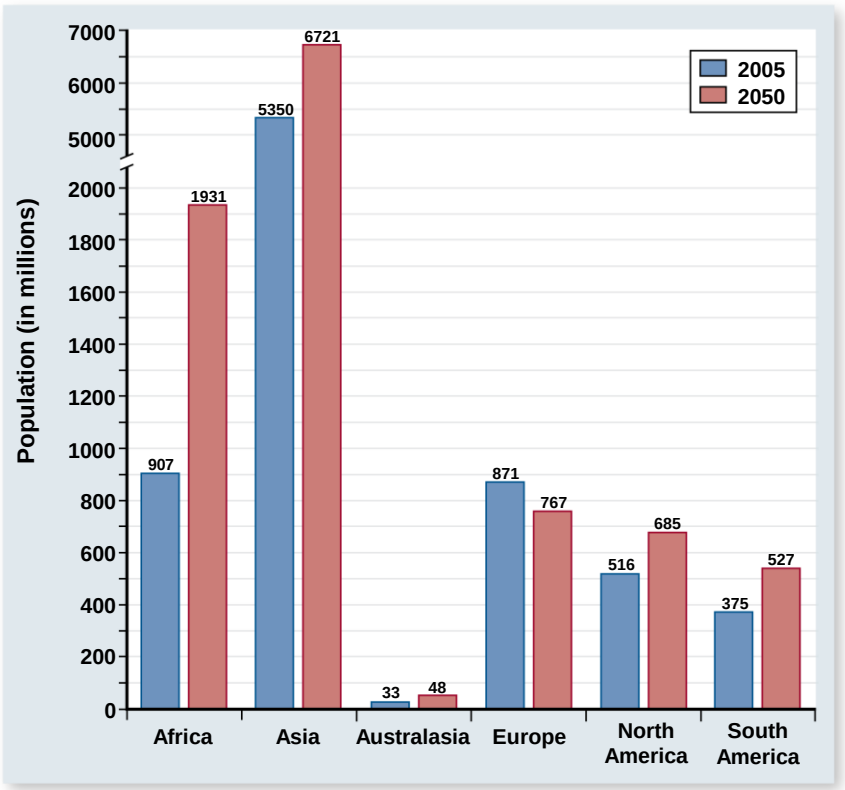
Human Population Growth

- *K*-selected life history traits
  - Small brood size
  - Late reproduction
  - High degree of parental care
- Changes since the 1700s allowed humans to escape logistic growth
- Human populations have grown exponentially
  - Birth rate has remained unchanged
  - Death rate has fallen dramatically

Human Population Growth

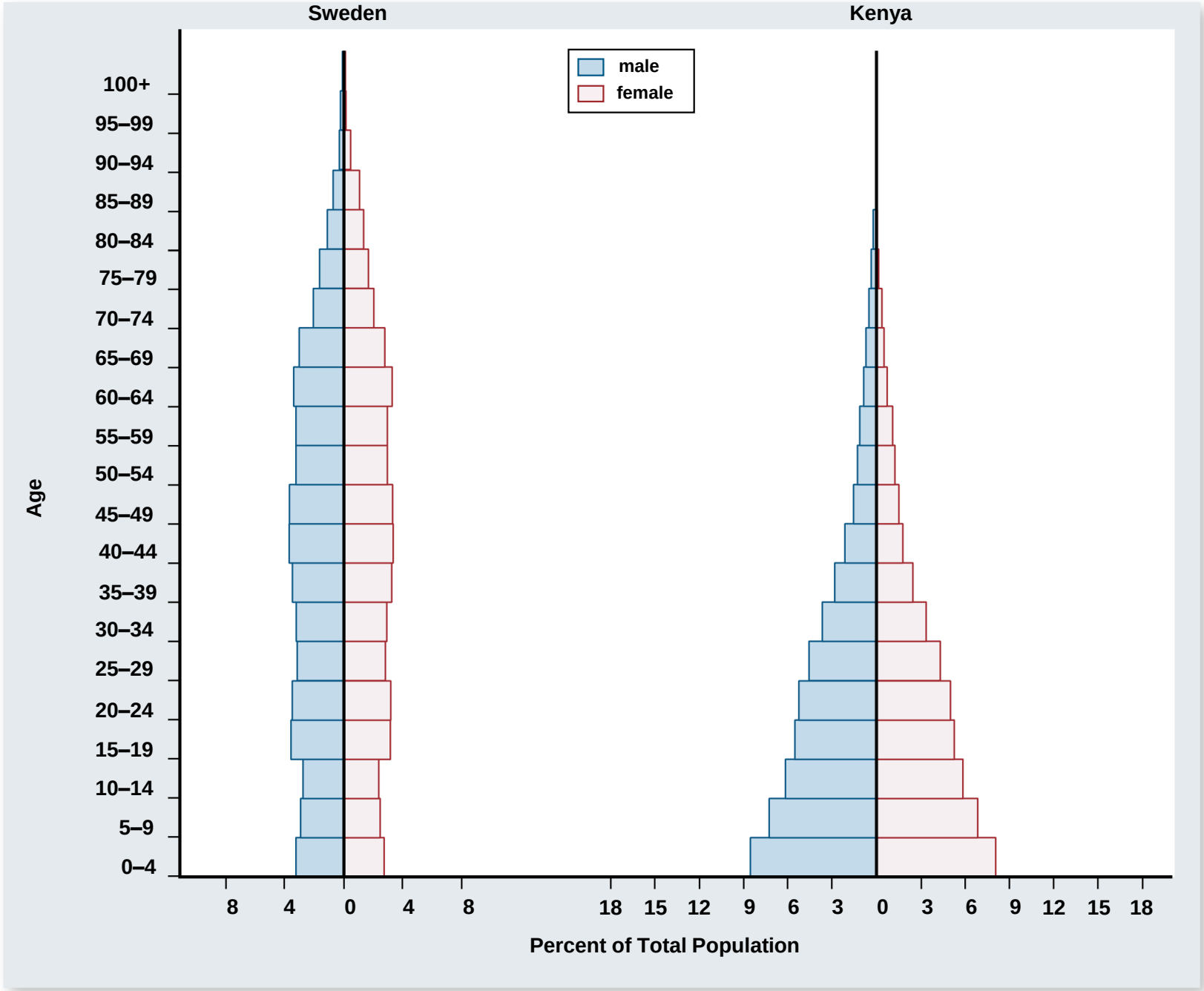


History of human population size



Projected population growth in 2050

- Population Pyramid
  - Bar graph displaying the number of people in each age category
  - Kenya's population could double in less than 35 years, whereas Sweden's will remain stable


Sweden
Kenya
male
female
100+
95–99
90–94
85–89
80–84
75–79
70–74
65–69
60–64
55–59
50–54
45–49
40–44
35–39
30–34
25–29
20–24
15–19
10–14
5–9
0–4
Age
8
4
0
4
8
18
15
12
9
6
3
0
3
6
9
12
15
18
Percent of Total Population

Human Population Growth

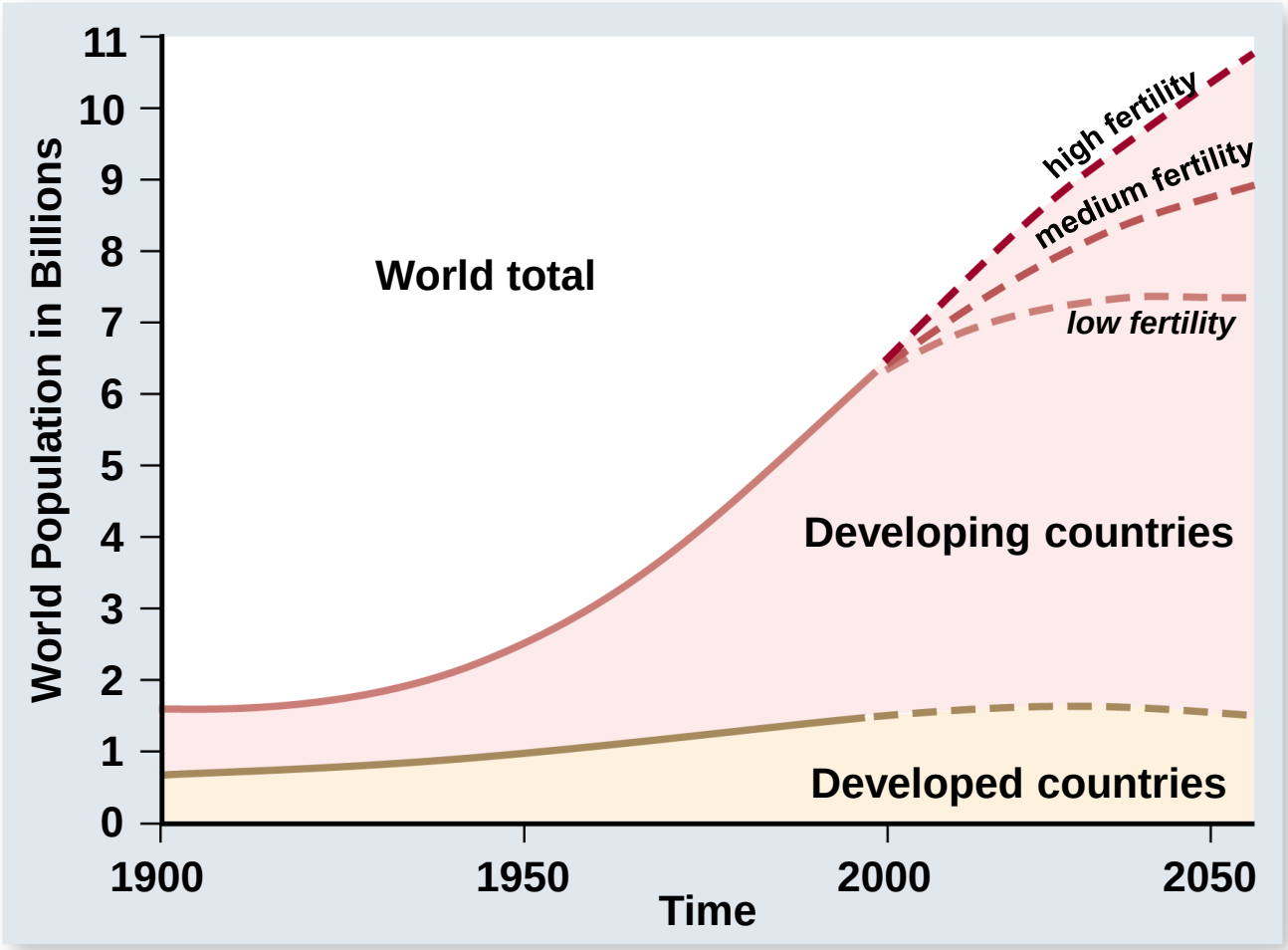
- Earth's rapidly growing human population constitutes perhaps the greatest challenge to the future of the biosphere
- Uneven distribution among countries
- Increasing gap between rich and poor
- The world ecosystem is already under stress
- What is *K* for the human population?

TABLE 55.4 A Comparison of 2010 Population Data in Developed and Developing Countries

	United States (highly developed)	Brazil (moderately developed)	Ethiopia (poorly developed)
Fertility rate	2.1	2.2	6.0
Doubling time at current rate (years)	80	55	28
Infant mortality rate (per 1000 births)	7	28.3	86.9
Life expectancy at birth (years)	78	74	53
Per capita GDP (U.S. $)*	$48,387	$11,769	$1093
Population < 15 years old (%)	13	25	44

*GDP, gross domestic product.

Human Population Growth



Distribution of population growth

Human Population Growth

- World population growth rate is declining
  - High of 2.0% in 1965–1970
  - 1.2% in 2008
  - Still an increase of 78 million people per year
- Attributed to increased family planning efforts and the increased economic power and social status of women

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