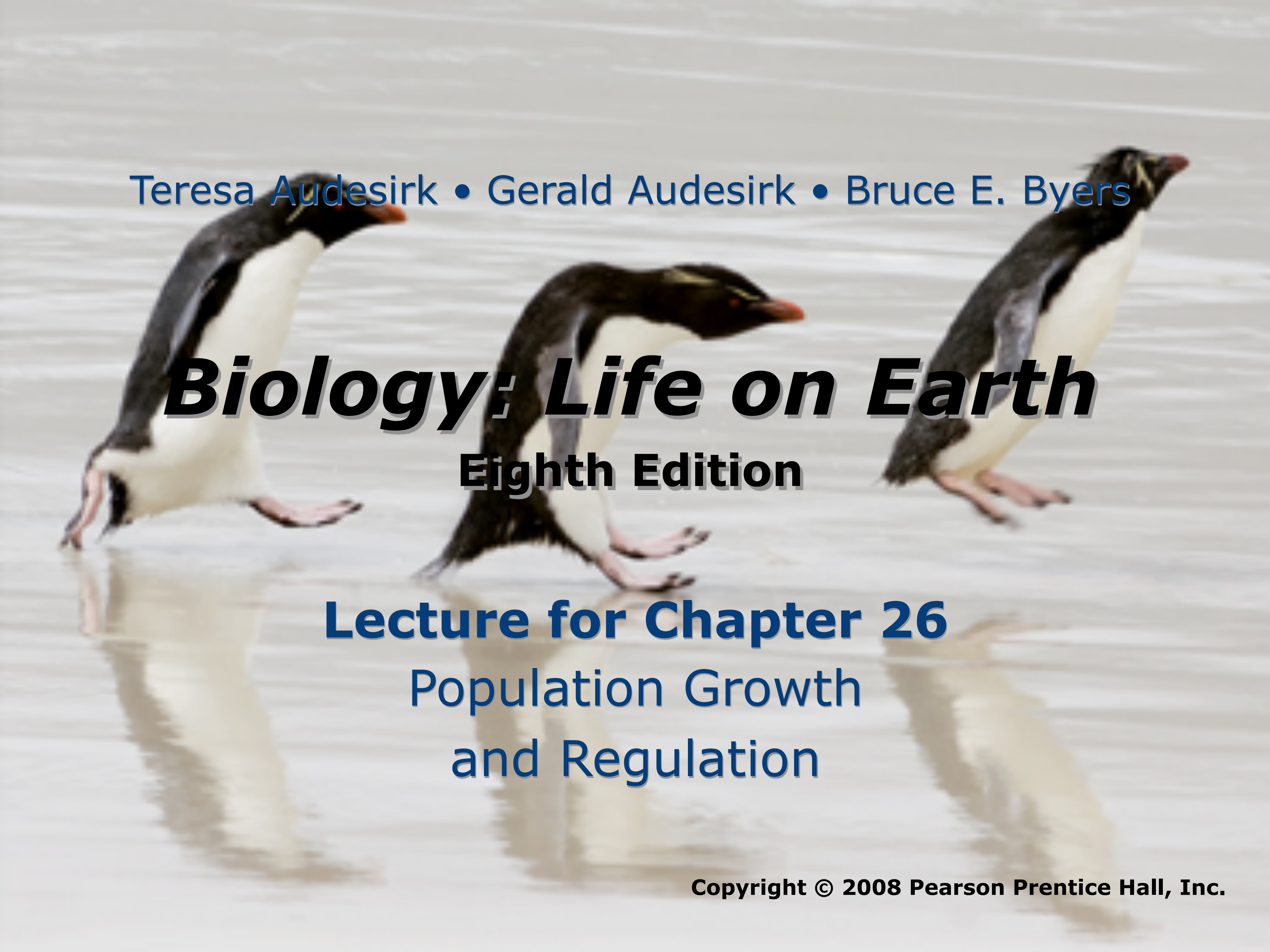


Teresa Audesirk • Gerald Audesirk • Bruce E. Byers

Biology: Life on Earth

Eighth Edition

Lecture for Chapter 26

Population Growth
and Regulation

Chapter 26 Opener Biology: Life on Earth, 8/e

Chapter 26 Outline

Section 26.1 Outline

- **26.1 How Does Population Size Change?**
  - Biotic Potential Can Produce Exponential Growth

The Study of Ecology

- **Ecology**: the study of interrelationships between living things and their nonliving environment

The Study of Ecology

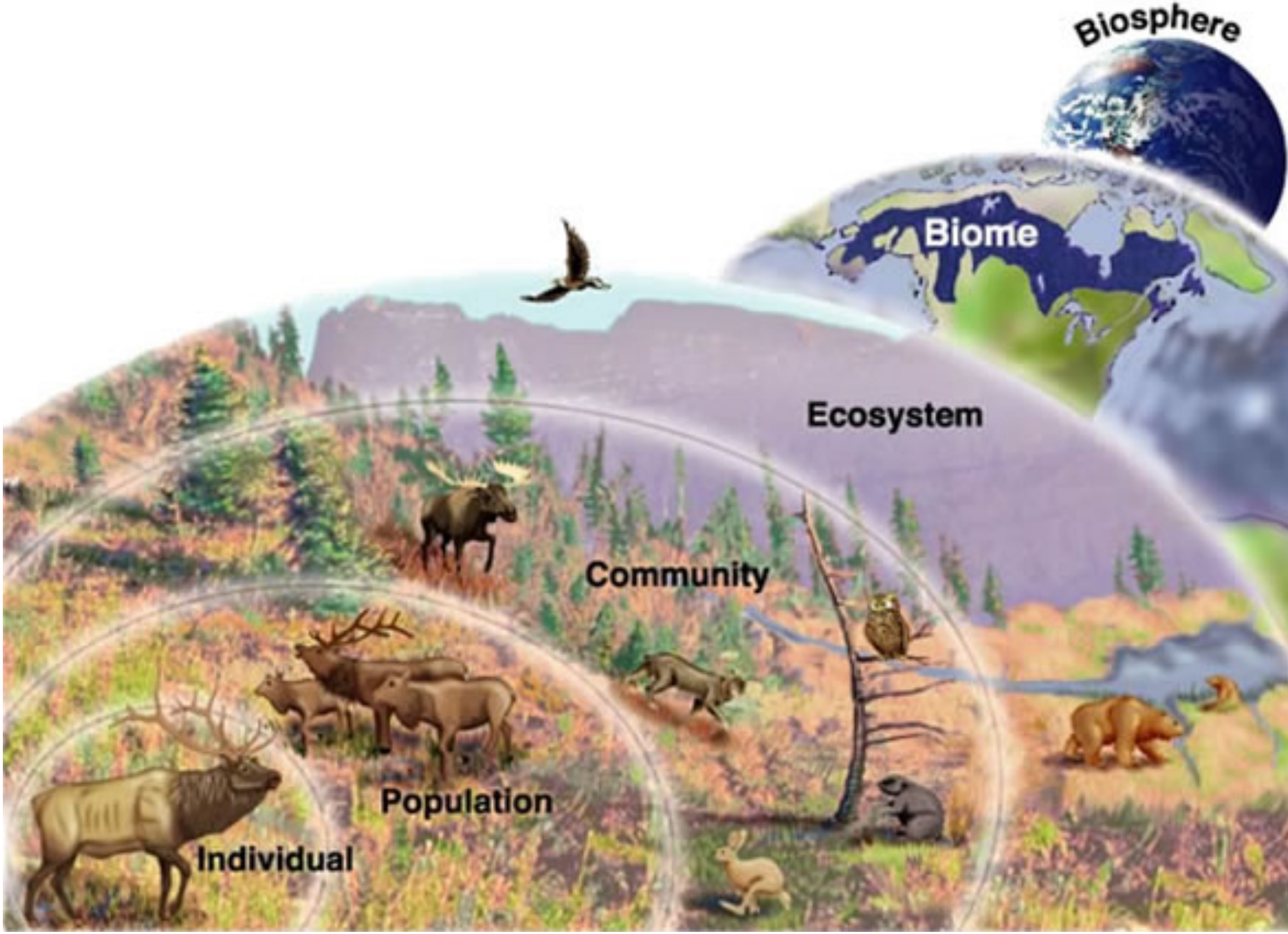
- The environment consists of two components
  - **Abiotic** component: nonliving, such as soil and weather
  - **Biotic** component: all living forms of life

The Study of Ecology

- Ecology can be studied at several organizational levels
  - *Organism*: An individual
  - *Populations*: all members of a single species living in a given time and place and actually or potentially interbreeding
  - *Ecosystem*: all the interacting populations in a given time and place

The Study of Ecology

- Ecology can be studied at several organizational levels
  - *Communities*: all the organisms and their nonliving environment in a defined area
  - *Biosphere*: all life on Earth


Biosphere
Biome
Ecosystem
Community
Population
Individual

How Does Population Size Change?

- Several processes can change the size of populations
  - **Birth** and **immigration** add individuals to a population
  - **Death** and **emigration** remove individuals from the population

How Does Population Size Change?

- **Change in population size**
  = (births – deaths) + (immigrants – emigrants)

How Does Population Size Change?

- Ignoring migration, population size is determined by two opposing forces
  - **Biotic potential**: the maximum rate at which a population could increase when birth rate is maximal and death rate minimal

How Does Population Size Change?

- Ignoring migration, population size is determined by two opposing forces
  - **Environmental resistance**: limits set by the living and nonliving environment that decrease birth rates and/or increase death rates (examples: food, space, and predation)

Population Growth

- The **growth rate** (*r*) of a population is the change in the population size *per individual* over some time interval
- Determined by

  Growth rate (*r*) = birth rate (*b*) – death rate (*d*)

Population Growth

- **Birth rate** (*b*) is the average number of births per individual per unit time
  - Example: if there are 5 births among 10 individuals, $b = 5/10 =$ **0.5**

Population Growth

- **Death rate** (*d*) is the proportion of individuals dying per unit time
  - Example: if 4 of 10 individuals die, $d = 4/10$ $= \mathbf{0.4}$
  - Thus, $\boldsymbol{r = b - d}$

    $= 0.5 - 0.4$

    $= \mathbf{0.1}$

Population Growth

- Population growth per unit of time can be calculated by multiplying growth rate (r) by the original population size (N)

Population growth (G) = rN

- In the previous example, population growth = rN = 0.1(10) = **1**, so the population has grown by one individual

Population Growth

- To determine the size of the population at the end of the time period, add the population growth (*rN*) to the initial population size (*N*)

$= N + rN$

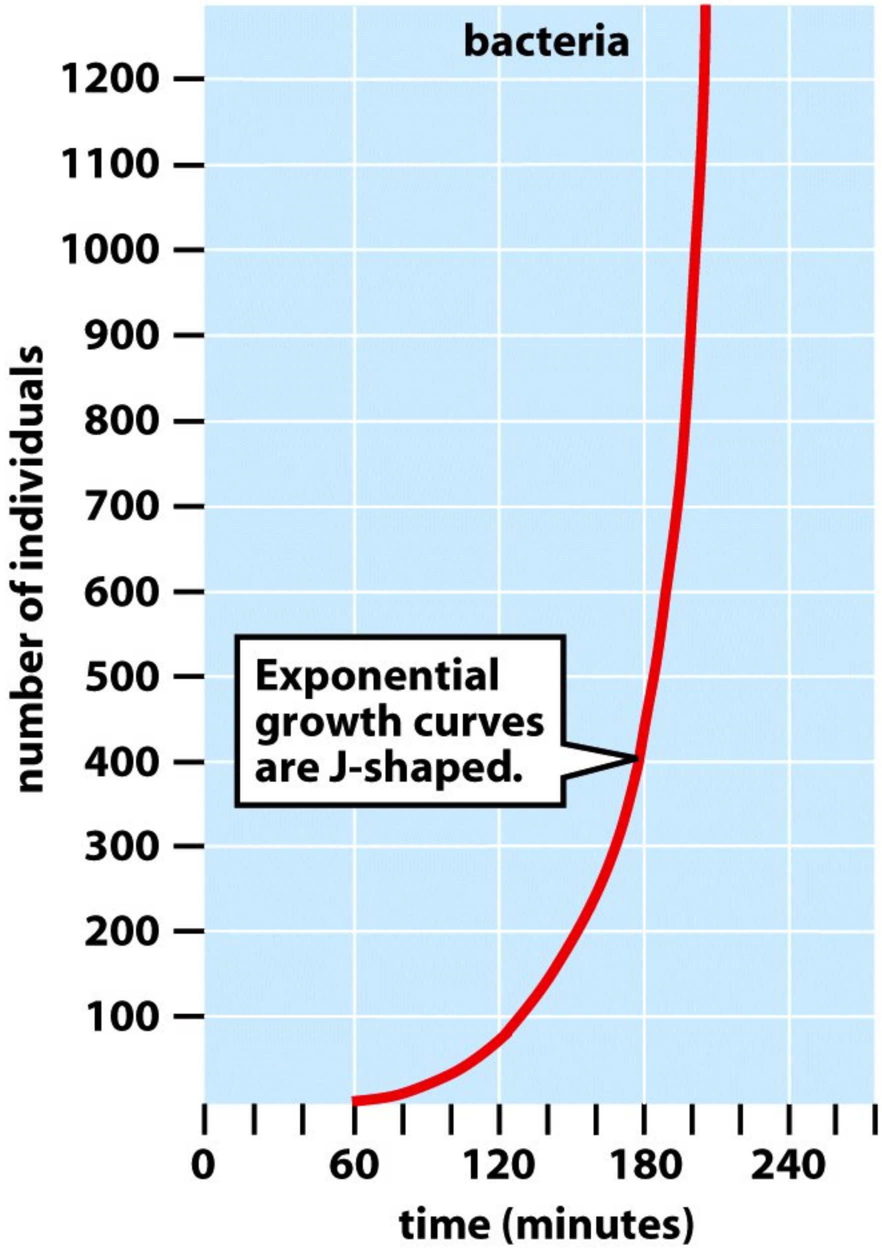
$= 10 + 0.1(10)$

$= 10 + 1$

$= \mathbf{11}$

Exponential Growth

- **Exponential growth** occurs when a population continuously grows at a fixed percentage of its size at the beginning of each time period
  - This results in a **J-shaped growth curve**



time (minutes)	number of bacteria
0	1
20	2
40	4
60	8
80	16
100	32
120	64
140	128
160	256
180	512
200	1024
220	2048

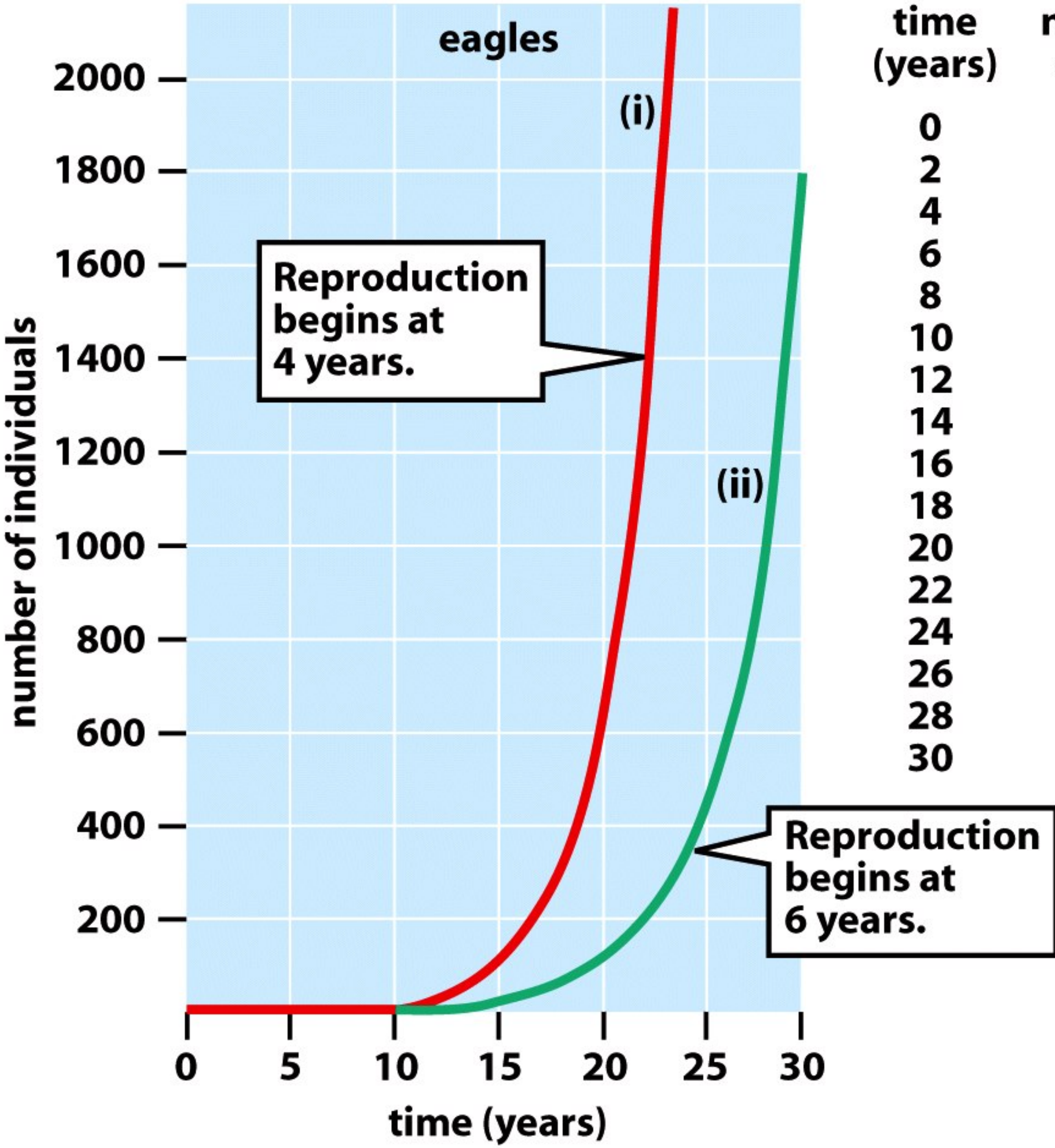
Figure 26-1a part 2 Biology: Life on Earth, 8/e

Biotic Potential

- Biotic potential is influenced by several factors

(1) The age at which the organism first reproduces

- Populations that have their offspring earlier in life tend to grow at a faster rate



time (years)	number of eagles (i)	number of eagles (ii)
0	2	2
2	2	2
4	4	2
6	8	4
8	14	8
10	28	12
12	52	18
14	100	32
16	190	54
18	362	86
20	630	142
22	1314	238
24	2504	392
26	4770	644
28	9088	1066
30	17314	1764

Figure 26-1b part 2 Biology: Life on Earth, 8/e

Biotic Potential

(2) The frequency at which reproduction occurs

(3) The average number of offspring produced each time

(4) The length of the organism's reproductive life span

(5) The death rate of individuals

- Increased death rates can slow the rate of population growth significantly

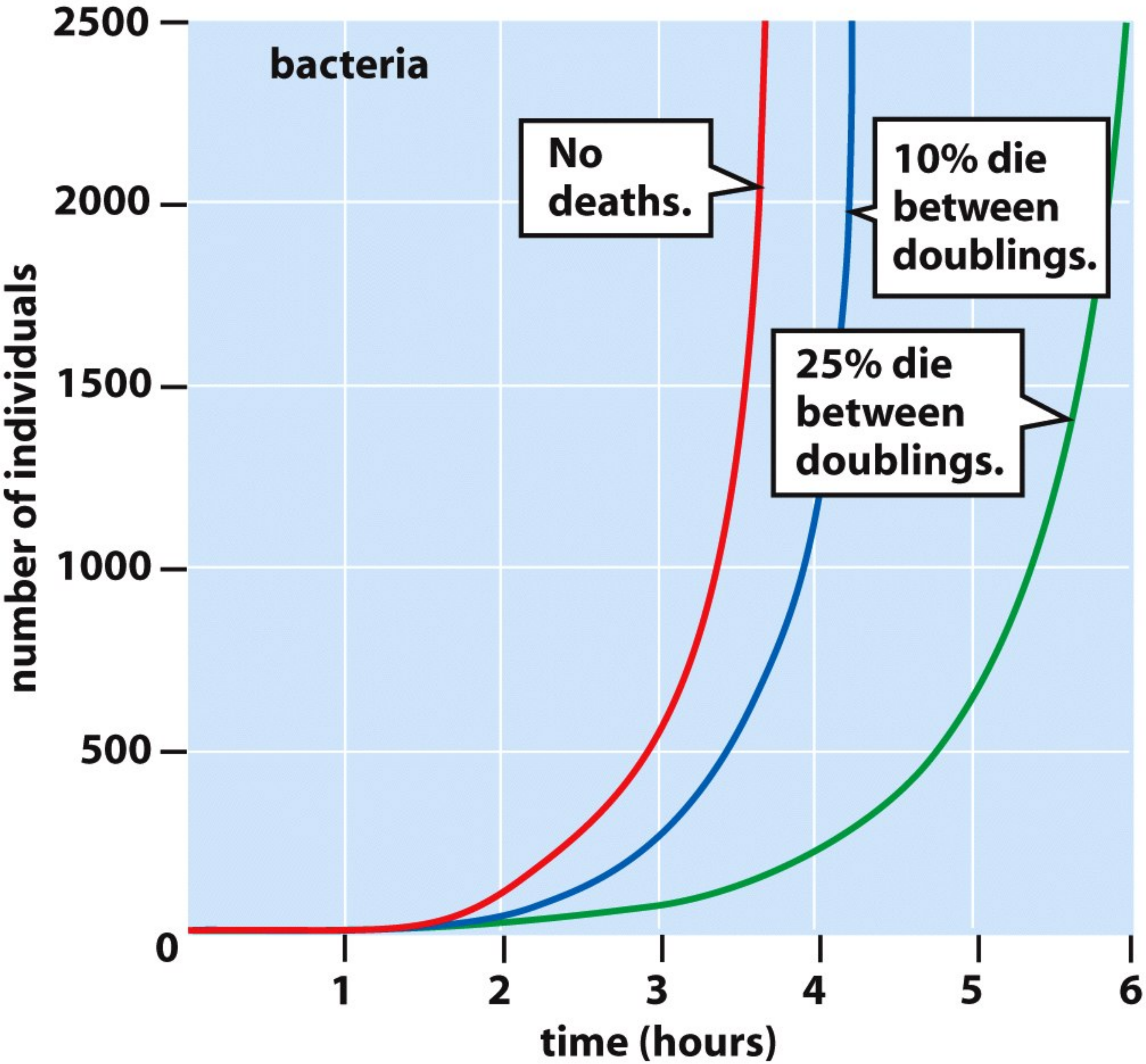


Figure 26-2 Biology: Life on Earth, 8/e

Section 26.2 Outline

- **26.2 How Is Population Growth Regulated?**
  - Exponential Growth Only Occurs Under Special Conditions
  - Environmental Resistance Limits Population Growth

Exponential Growth

- Exponential growth cannot continue indefinitely
- All populations that exhibit exponential growth must eventually stabilize or crash

Exponential Growth

- Exponential growth can be observed in populations that undergo **boom-and-bust cycles**
  - Periods of rapid growth followed by a sudden massive die-off

Exponential Growth

- Example
  - Each year cyanobacteria in a lake may exhibit exponential growth when conditions are ideal, but crash when they have depleted their nutrient supply

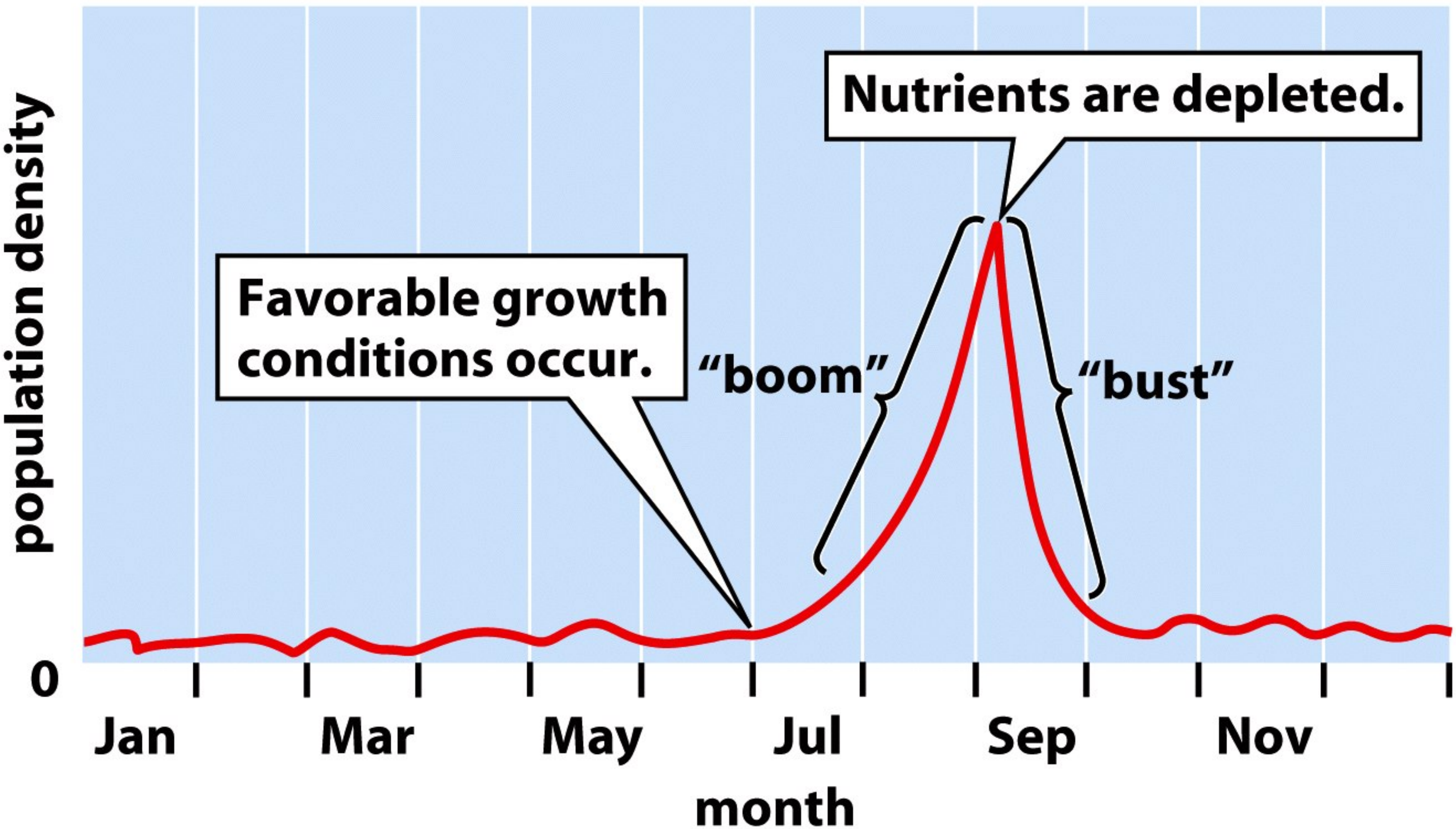


Figure 26-3 Biology: Life on Earth, 8/e

Exponential Growth

- Temporary exponential growth can occur when population-controlling factors are relaxed, such as
  - When food supply is increased
  - When predators are reduced

Exponential Growth

- When **exotic** species are introduced into a new ecosystem, population numbers may explode due to lack of natural predators

Exponential Growth

- When species are protected, e.g. the whooping crane population has grown exponentially since they were protected from hunting and human disturbance in 1940

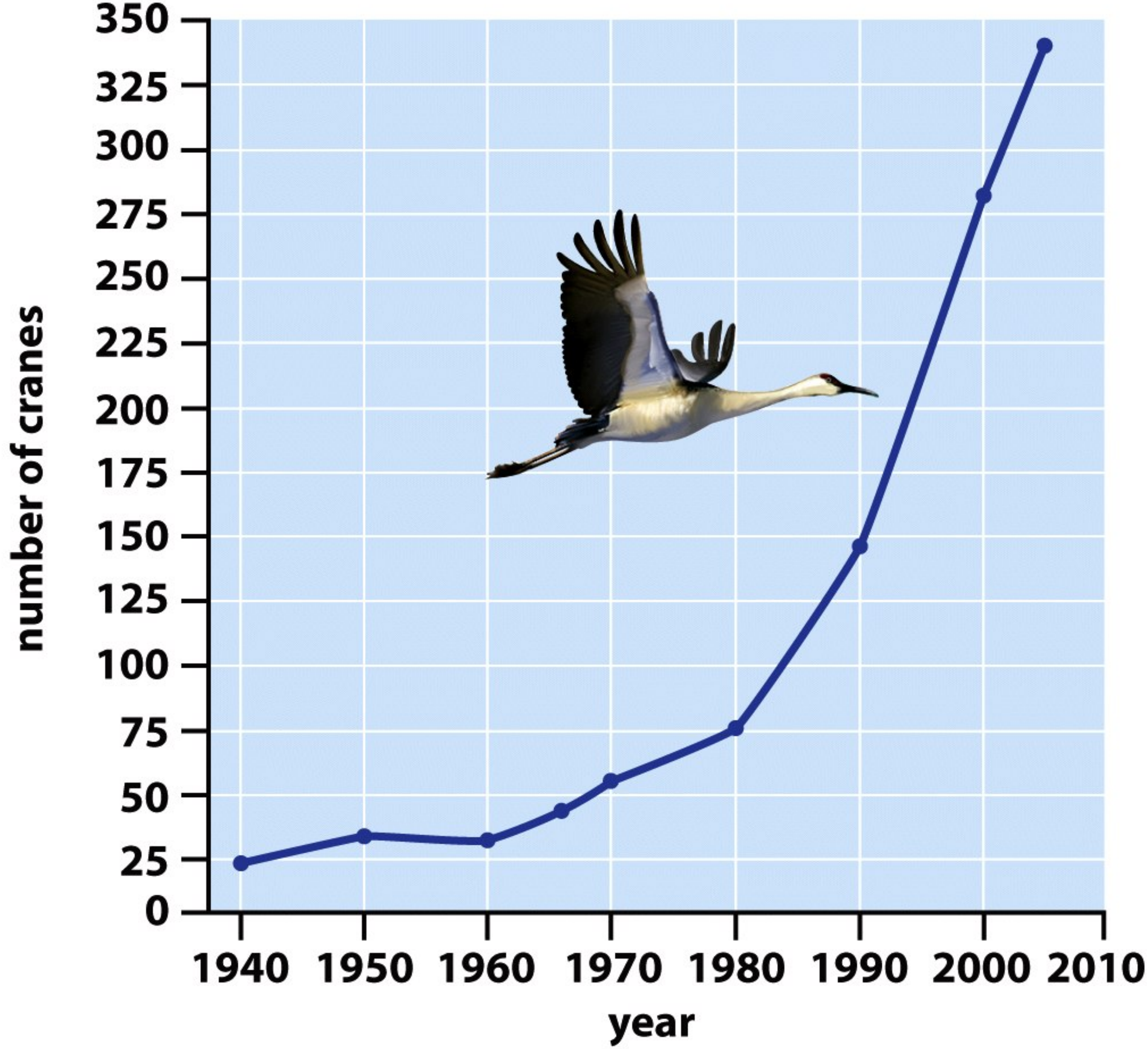


Figure 26-5 Biology: Life on Earth, 8/e

Environmental Resistance

- Many populations that exhibit exponential growth eventually stabilize
- Environmental resistance limits population growth
  - As resources become depleted, reproduction slows

Environmental Resistance

- This growth pattern, where populations increase to the maximum number sustainable by their environment, is called **logistic growth**
- When this growth pattern is plotted, it results in an S-shaped growth curve (or **S-curve**)

A logistic growth curve stabilizes at *K*.

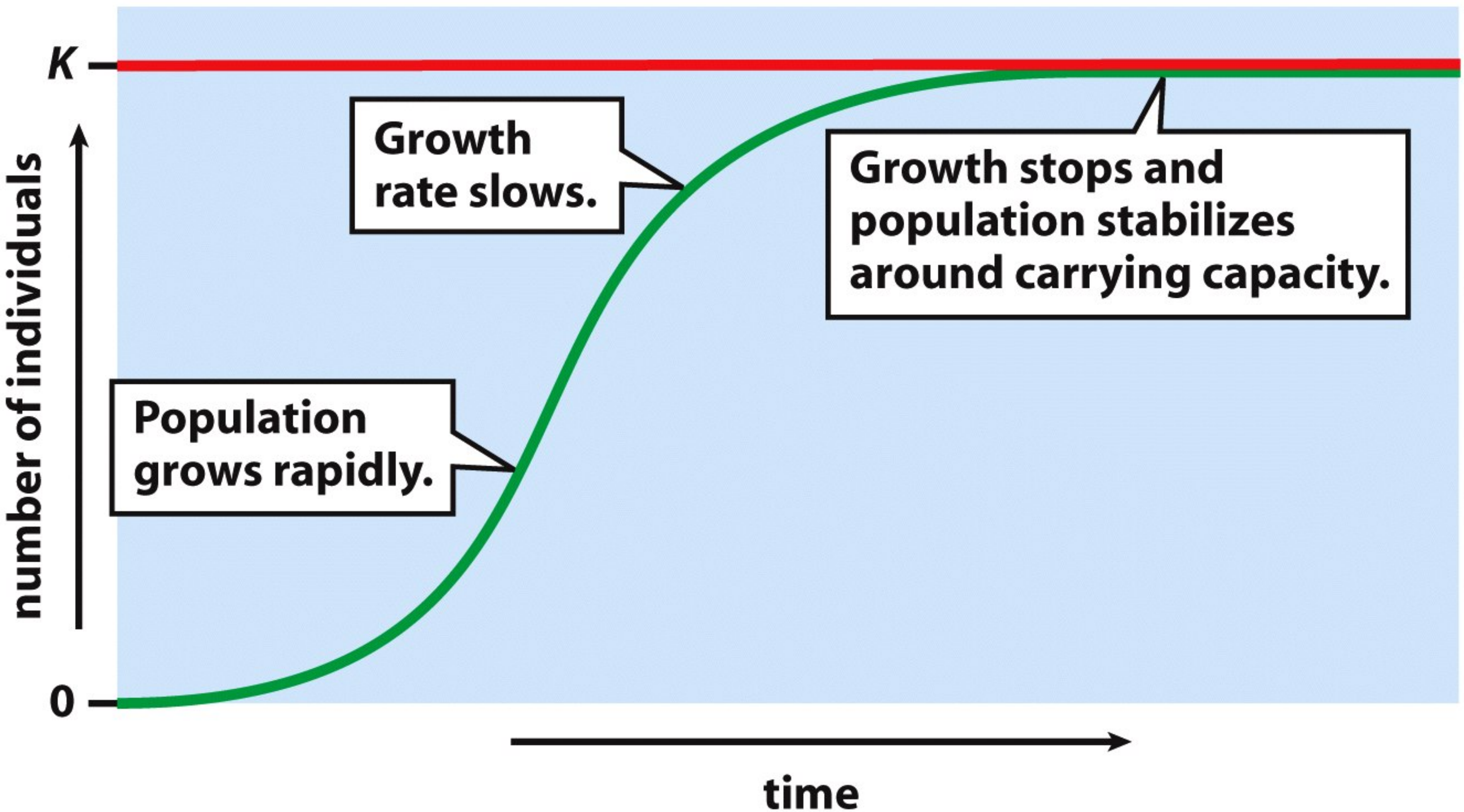


Figure 26-6a Biology: Life on Earth, 8/e

Environmental Resistance

- **Carrying capacity** (**K**) is the maximum population size that can be sustained by an ecosystem for an extended time without damage to the ecosystem

Environmental Resistance

- Logistic population growth can occur in nature when a species moves into a new habitat, e.g. barnacles colonizing bare rock along a rocky ocean shoreline
- Initially, new settlers may find ideal conditions that allow their population to grow almost exponentially
- As population density increases, individuals compete for space, energy, and nutrients

Environmental Resistance

- These forms of environmental resistance can reduce the reproductive rate and average life span and increase the death rate of young
- As environmental resistance increases, population growth slows and eventually stops

Environmental Resistance

- If a population far exceeds the carrying capacity, excess demands decimate crucial resources
- This can permanently and severely reduce K, causing the population to decline to a fraction of its former size or disappear entirely

Consequences of exceeding *K*.

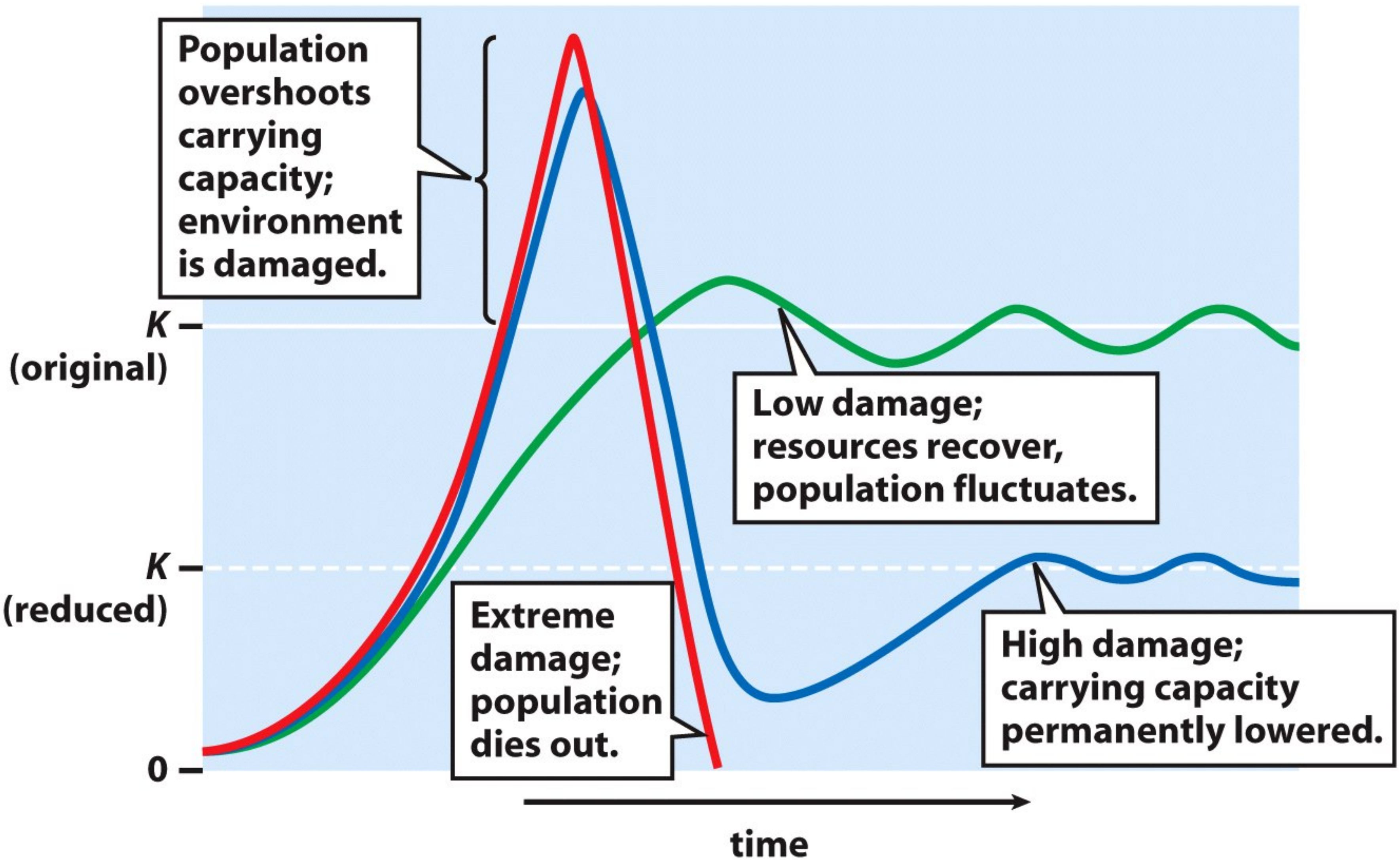


Figure 26-6b Biology: Life on Earth, 8/e

Environmental Resistance

- Example: Pribilof Island reindeer populations

Figure 26-7 part 2 Biology: Life on Earth, 8/e

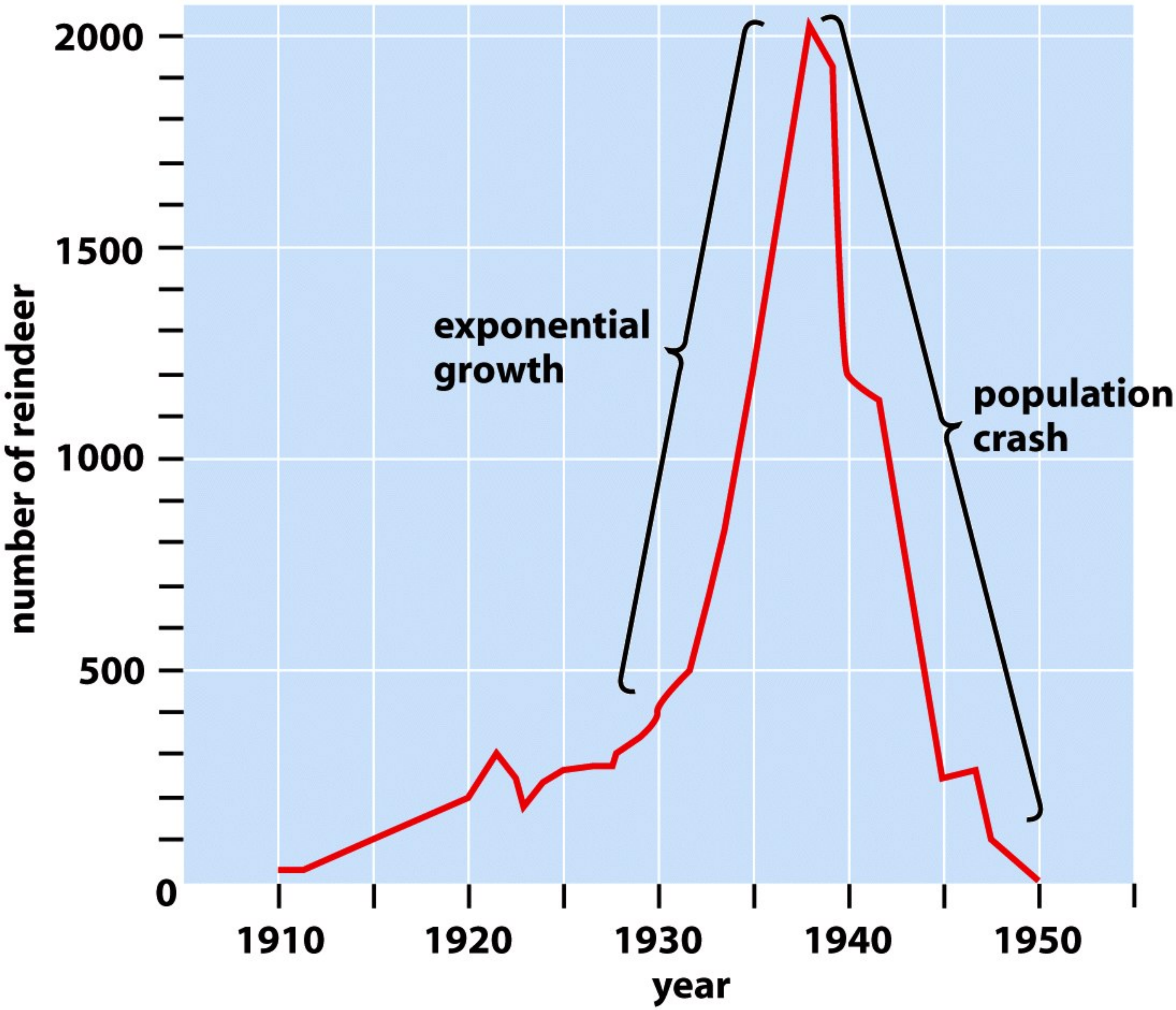


Figure 26-7 part 1 Biology: Life on Earth, 8/e

Environmental Resistance

- In nature, conditions are never completely stable, so both K and the population size will vary somewhat from year to year
- However, environmental resistance ideally maintains populations at or below the carrying capacity of their environment

Environmental Resistance

- Environmental resistance can be classified into two broad categories
  - **Density-independent factors**
  - **Density-dependent factors**

Density-Independent Factors

- **Density-independent factors** limit populations regardless of their density
  - Examples: climate, weather, floods, fires, pesticide use, pollutant release, and overhunting

Density-Independent Factors

- Some species have evolved means of limiting their losses
  - Examples:
  - Migration
  - Dormancy

Density-Dependent Factors

- **Density-dependent factors** become more effective as population density increases
- Exert negative feedback effect on population size

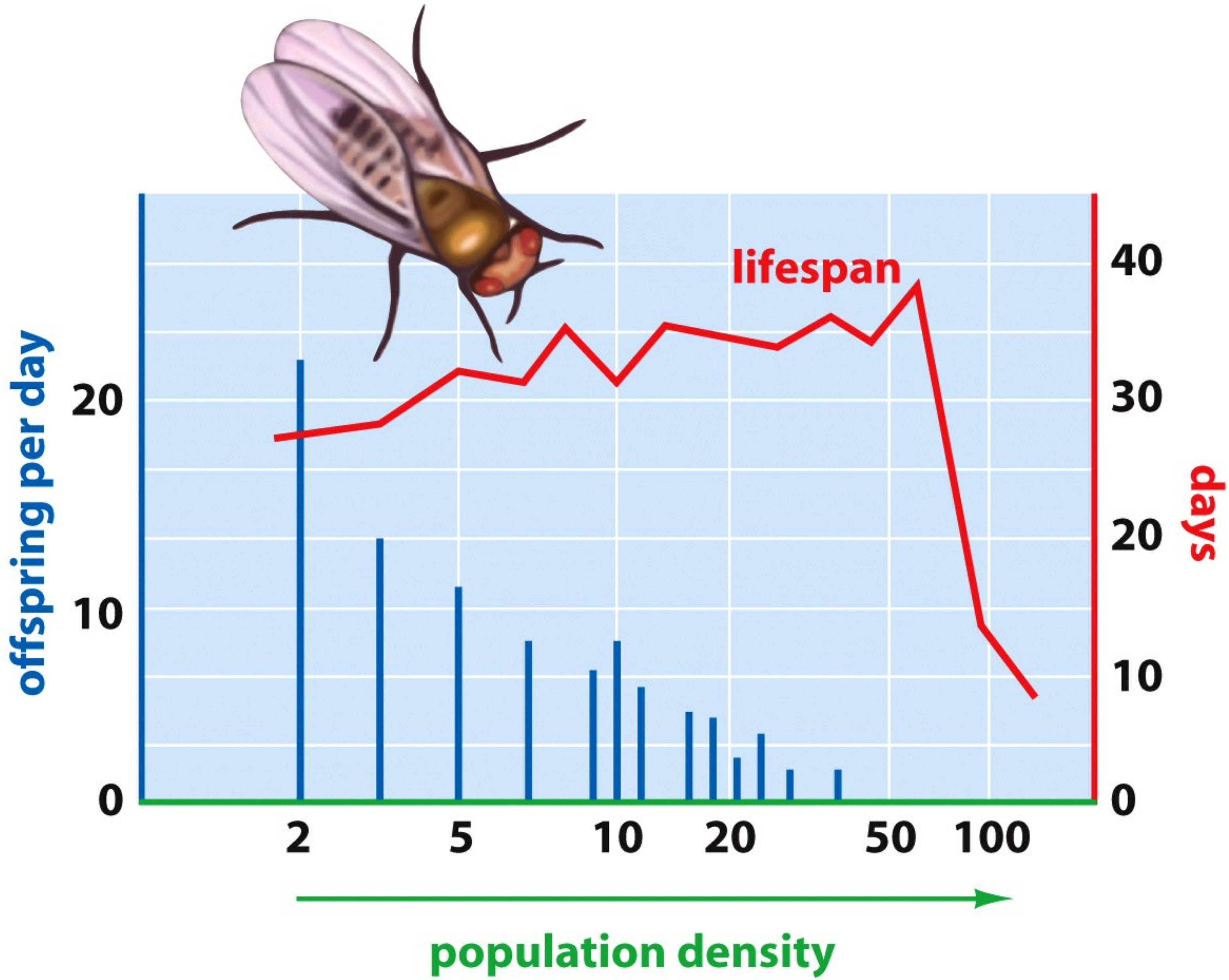


Figure 26-9 Biology: Life on Earth, 8/e

Density-Dependent Factors

- **Density-dependent factors** can cause birth rates to drop and/or death rates to increase
  - Population growth slows resulting in an S-shaped growth curve (or **S-curve**)

A logistic growth curve stabilizes at *K*.

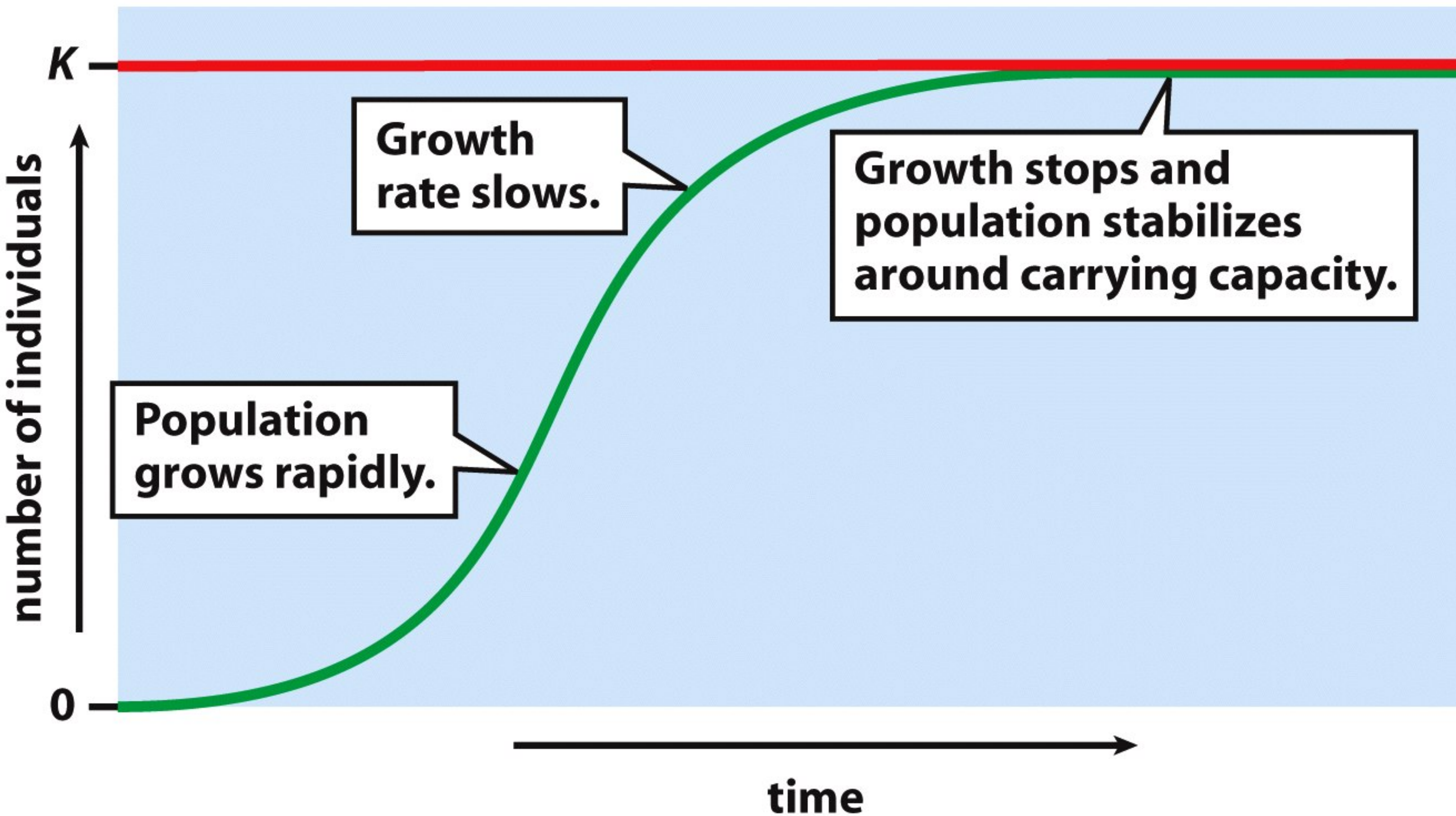


Figure 26-6a Biology: Life on Earth, 8/e

Density-Dependent Factors

- At carrying capacity, each individual's share of resources is just enough to allow it to replace itself in the next generation
- At carrying capacity birth rate (b) = death rate (d)

Density-Dependent Factors

- Carrying capacity is determined by the continuous availability of resources

Density-Dependent Factors

- Include community interactions
  - Predation
  - Parasitism
  - Competition
  - Mutualism
  - Commensalism
  - Herbivory/Carnivory

Predation

- **Predation** involves a **predator** killing a **prey** organism in order to eat it
  - Example: a pack of grey wolves hunting an elk

Figure 26-10 Biology: Life on Earth, 8/e

Predation

- Predators exert density-dependent controls on a population
  - Increased prey availability can increase birth rates and/or decrease death rates of predators
    - Prey population losses will increase

Parasitism

- **Parasitism** involves a **parasite** living on or in a **host** organism, feeding on it but not generally killing it
  - Examples: bacterium causing Lyme disease, some fungi, intestinal worms, ticks, and some protists

Parasitism

- While parasites seldom directly kill their hosts, they may weaken them enough that death due to other causes is more likely
- Parasites spread more readily in large populations

Competition for Resources

- **Competition**
  - Describes the interaction among individuals who attempt to utilize a resource that is limited relative to the demand for it

Competition for Resources

- Competition intensifies as populations grow and near carrying capacity
- For two organisms to compete, they must share the same resource(s)

Competition for Resources

- Competition may be divided into two groups based on the species identity of the competitors
  - **Interspecific competition** is between individuals of different species
  - **Intraspecific competition** is between individuals of the same species

Competition for Resources

- Intense local competition may drive organisms to **emigrate**, though mortality may be intense
  - Example: swarming in locusts

Figure 26-12 Biology: Life on Earth, 8/e

Section 26.3 Outline

- **26.3 How Are Populations Distributed in Space and Time?**
  - Populations Exhibit Different Spatial Distributions
  - Survivorship in Populations Follows Three Basic Patterns

Spatial Distributions

- The spatial pattern in which individuals are dispersed within a given area is that population's *distribution,* which may vary with time

Spatial Distributions

- There are three major types of spatial distributions
  - **Clumped**
  - **Uniform**
  - **Random**

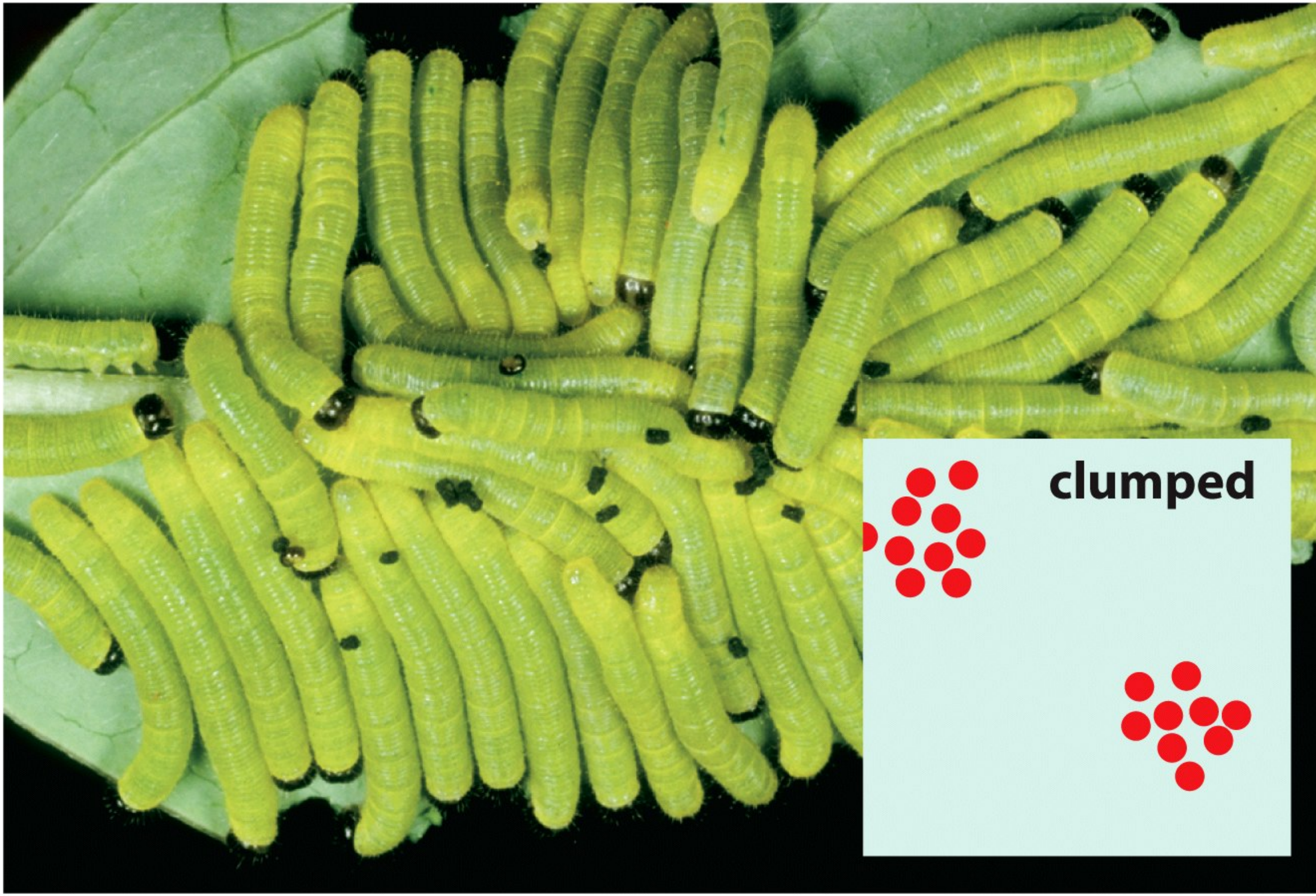


Figure 26-13a Biology: Life on Earth, 8/e

Figure 26-13b Biology: Life on Earth, 8/e

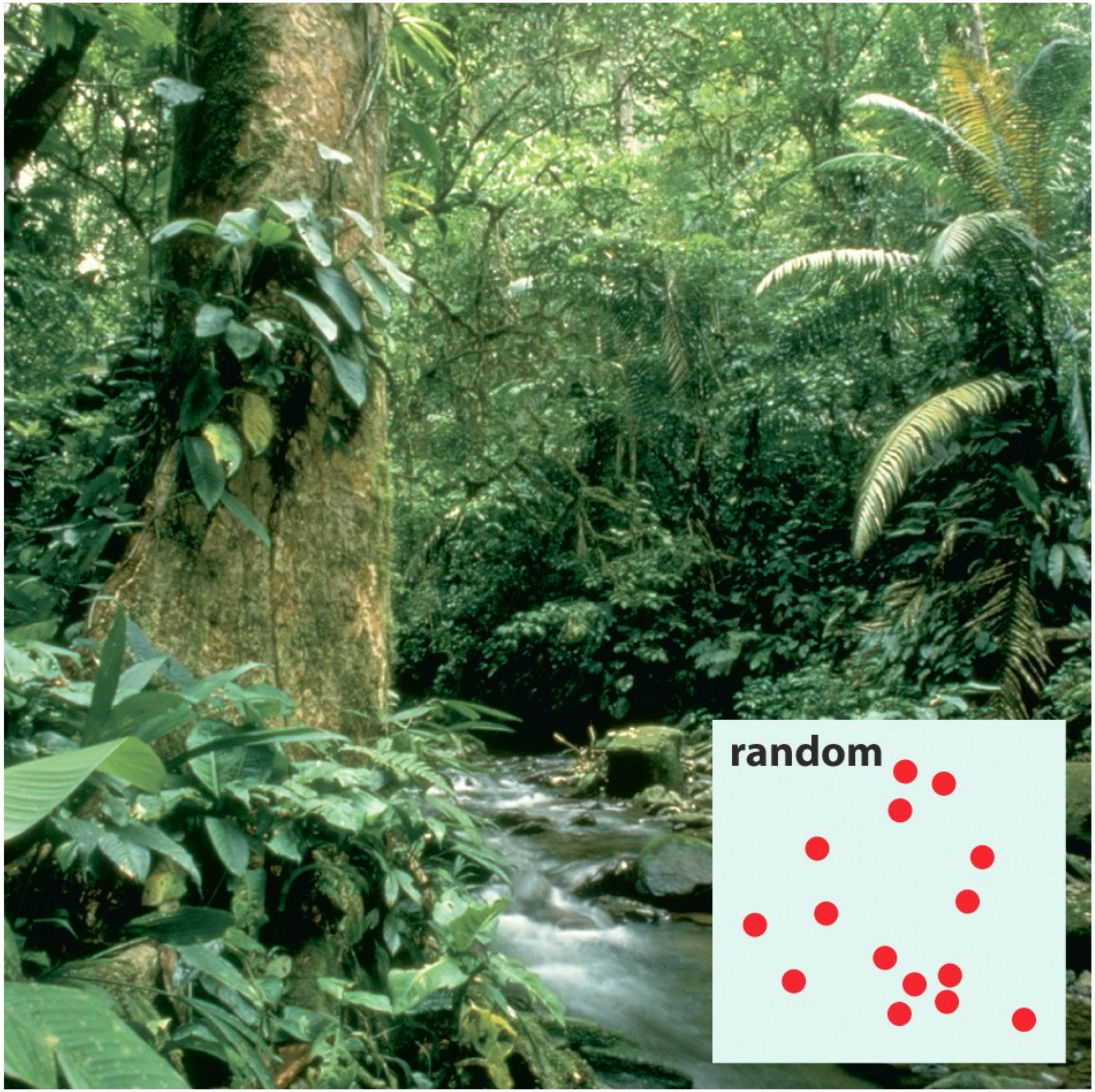
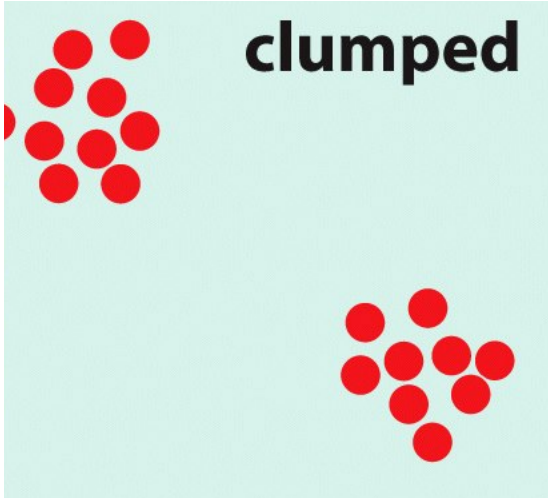


Figure 26-13c Biology: Life on Earth, 8/e

Spatial Distributions

- **Clumped distribution –** includes family and social groups
- Examples: elephant herds, wolf packs, prides of lions, flocks of birds, and schools of fish
- Advantages
  - Provides many eyes that can search for localized food sources
  - Confuses predators with sheer numbers
  - Cooperation for hunting more effectively

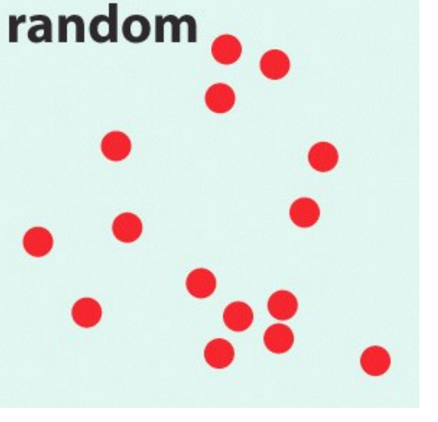


Spatial Distributions

- **Uniform distribution** – constant distance maintained between individuals; common among territorial animals defending scarce resources or defending breeding territories
- Examples: iguanas, shorebirds, tawny owls
- Advantage: a uniform distribution helps ensure adequate resources for each individual

Spacial Distributions

- **Random distribution –** rare, exhibited by individuals that do not form social groups; occurs when resources are not scarce enough to require territorial spacing
- Examples: Trees and other plants in rain forests



Survivorship in Populations

- Survivorship describes the pattern of survival in a population
- **Life tables** track groups of organisms born at the same time throughout their life span, recording how many continue to survive in each succeeding year

Number of survivors by age, out of 100,000 born alive: United States, 2002

Age	Total	Male	Female
0	100,000	100,000	100,000
10	99,105	99,014	99,199
20	98,672	98,436	98,922
30	97,740	97,091	98,424
40	96,419	95,381	97,500
50	93,563	91,809	95,364
60	87,711	84,637	90,826
70	75,335	70,087	80,556
80	52,178	44,370	59,621
90	20,052	13,925	25,411
100	2,095	1,005	2,954

Figure 26-14a Biology: Life on Earth, 8/e

Survivorship in Populations

- A **survivorship curve** for a population can be produced by graphing life table survivorship data
  - Y-axis: the log of the number of individuals surviving to a particular age
  - X-axis: age

Survivorship in Populations

- Three types of survivorship curves can be distinguished
  - **Late loss (Type I)**
  - **Constant loss (Type II)**
  - **Early loss (Type III)**

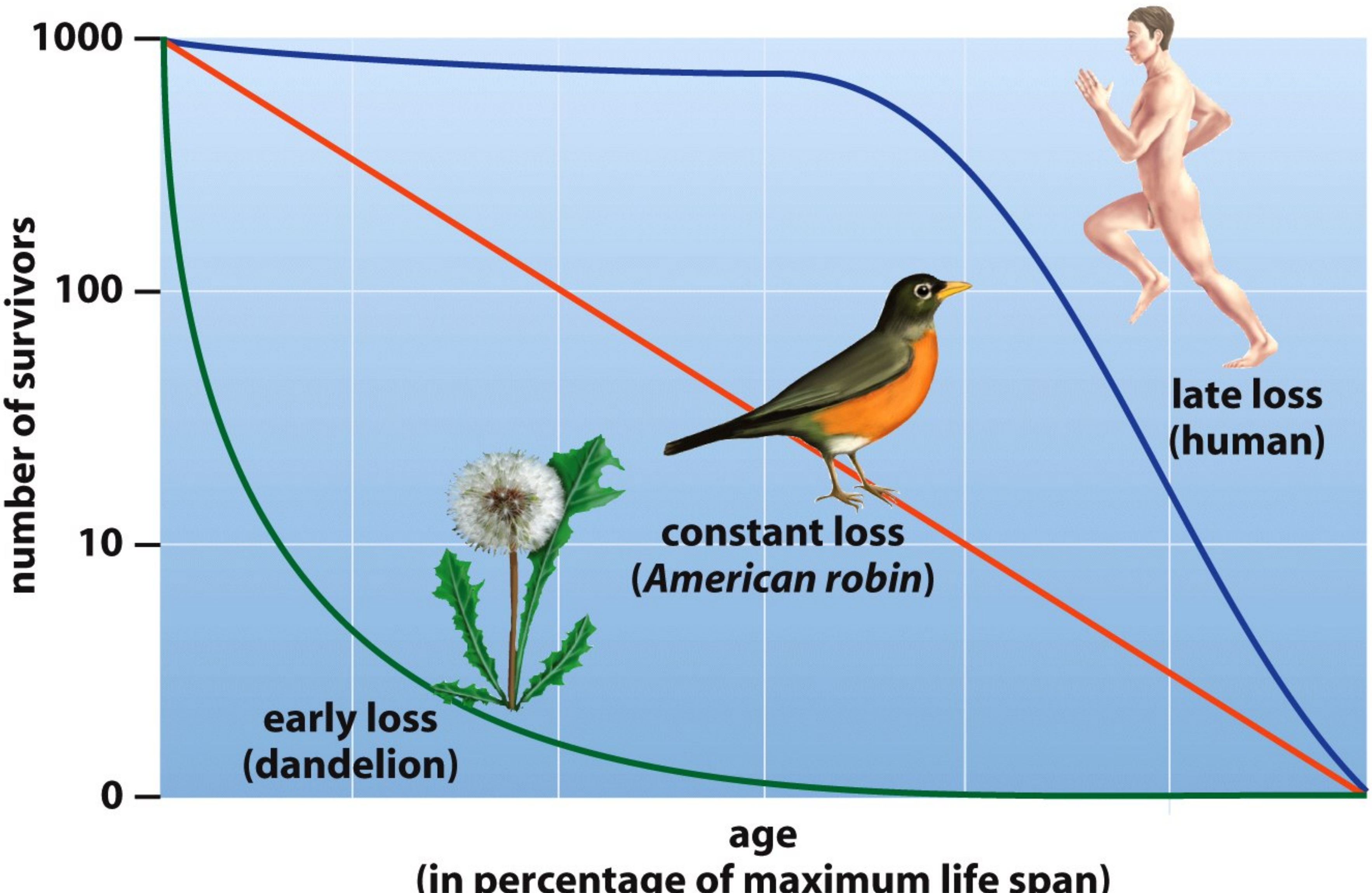


Figure 26-14b Biology: Life on Earth, 8/e

Survivorship in Populations

- *"Late loss" curves*: seen in many animals with few offspring that receive substantial parental care; are convex in shape, with low mortality until individuals reach old age
  - Examples: humans and many large mammals

Survivorship in Populations

- *"Constant loss" curves*: an approximate straight line, indicates an equal chance of dying at any age
  - Example: some bird species

Survivorship in Populations

- *"Early loss" curves*: high early mortality as most offspring fail to become established; are concave in shape
  - Typical of most plants and many animals that do not receive parental care
  - Examples: most invertebrates and fish

Section 26.4 Outline

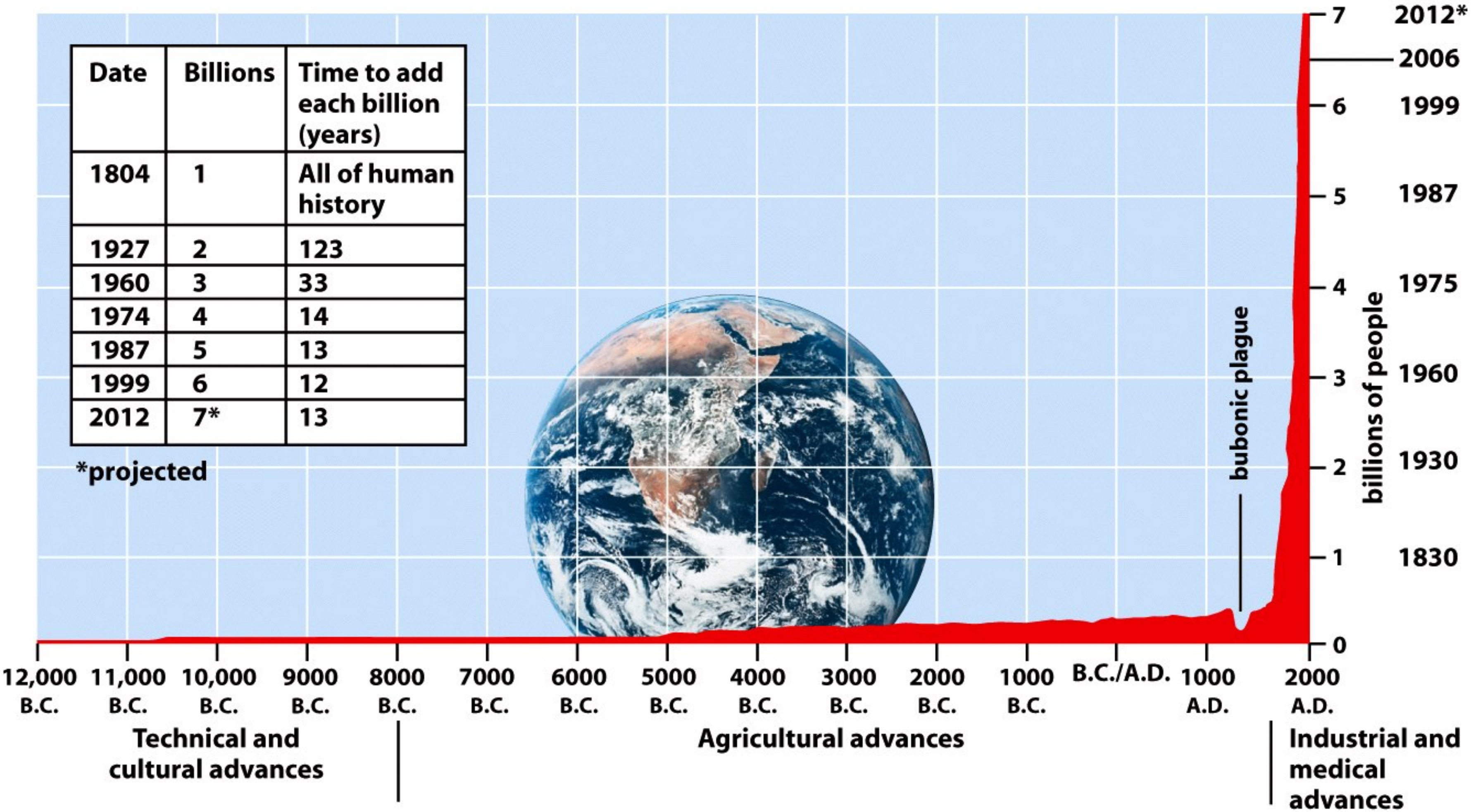
- **26.4 How Is the Human Population Changing?**
  - – Demographers Track Changes in Human Populations
  - – The Human Population Continues to Grow Rapidly
  - – Population Growth Is Unevenly Distributed
  - – The Current Age Structure of a Population Predicts Its Future Growth

Demography

- **Demography** is the branch of science that studies the changing human population
- *Demographers* track population changes in different countries and regions
- Demographic data are used to formulate policies in public health, housing, education, employment, immigration, and environmental protection

Rapid Human Population Growth

- In the last few centuries, the human population has grown at nearly an exponential rate
  - Follows a J-shaped growth curve



Date	Billions	Time to add each billion (years)
1804	1	All of human history
1927	2	123
1960	3	33
1974	4	14
1987	5	13
1999	6	12
2012	7*	13

*projected

Figure 26-15 Biology: Life on Earth, 8/e

Rapid Human Population Growth

- Over the last decade, the rate of human population growth seems to be stabilizing
  - 75-80 million people added per year
- Are we entering the final bend of the S-shaped growth curve?

Technological Advances

- Most species must "make due" with the resources in an area
- Humans have manipulated the environment to increase the Earth's carrying capacity

Population Age Structure

- **Age structure**
  – Refers to the distribution of human populations according to age groups

Population Age Structure

- Age structure can be shown graphically
  - Age is shown on the vertical axis
  - The number of individuals in each age group is shown on the horizontal axis, with males and females placed on opposite sides

Population Age Structure

- All age-structure diagrams peak at the maximum life span, but the shape below the peak reveals if the population is expanding, stable, or shrinking

Population Age Structure

- Population is expanding
  - Reproductive-age adults have more children than they need to replace themselves
  - Pyramid-shaped
  - Example: Mexico

Population pyramids for Mexico

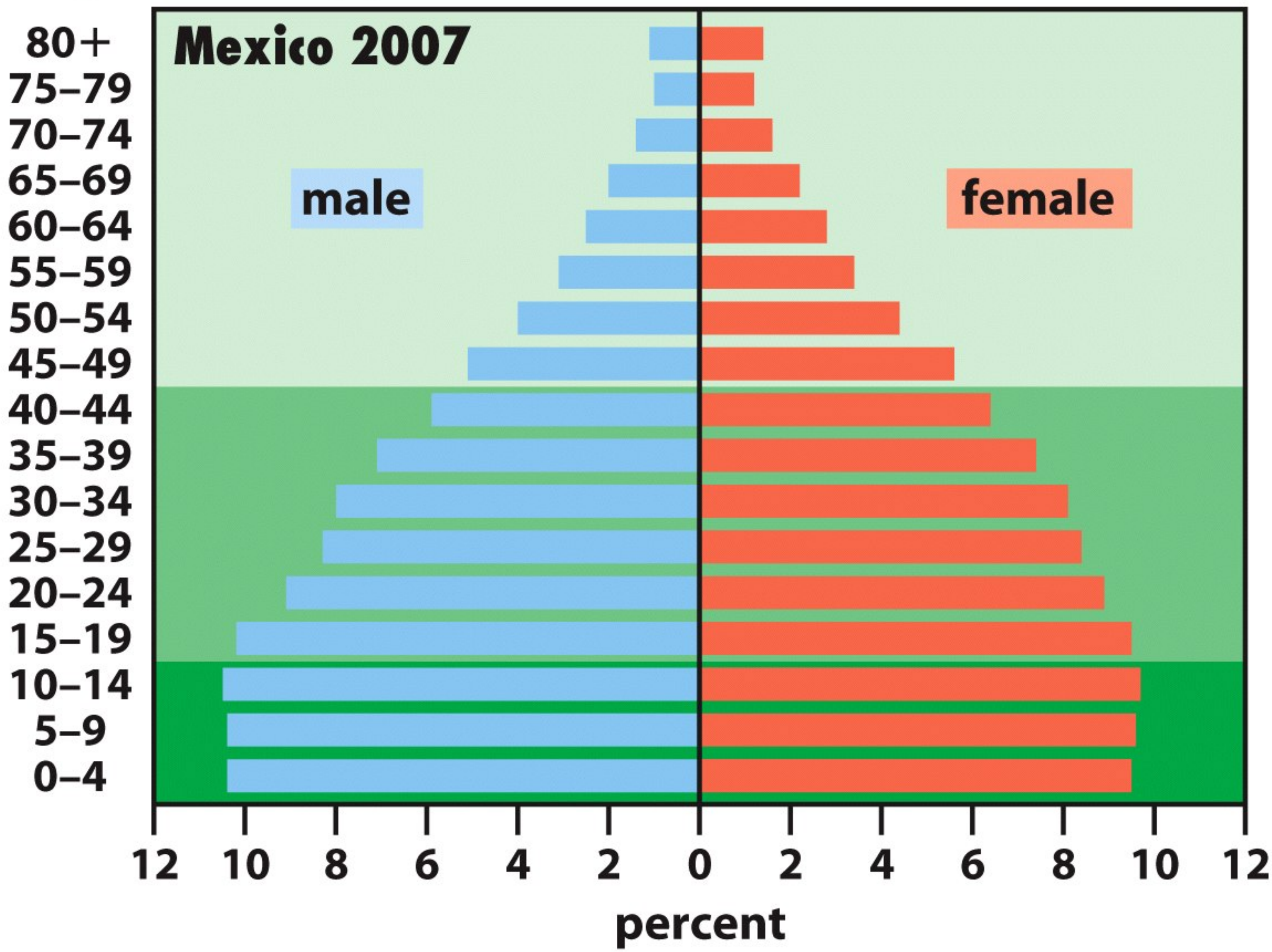


Figure 26-18a Biology: Life on Earth, 8/e

Population Age Structure

- Population is stable
  - Reproductive-age adults have just the children they need to replace themselves
  - Relatively straight sides
  - Example: Sweden

Population pyramids for Sweden

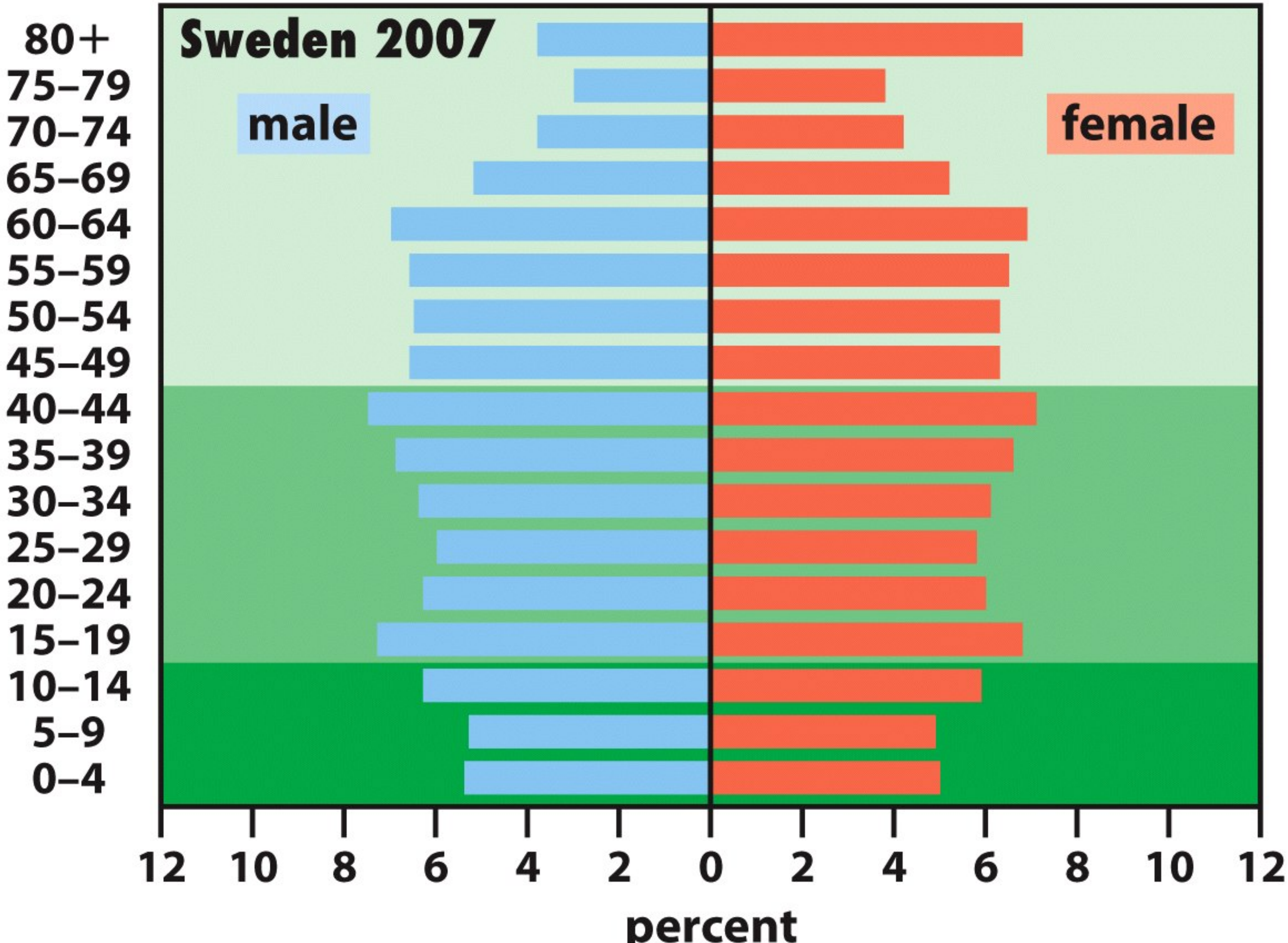


Figure 26-18b Biology: Life on Earth, 8/e

Population Age Structure

- Population is shrinking
  - Reproductive-age adults have fewer children than they need to replace themselves
  - Narrow base
  - Example: Italy

Population pyramids for Italy

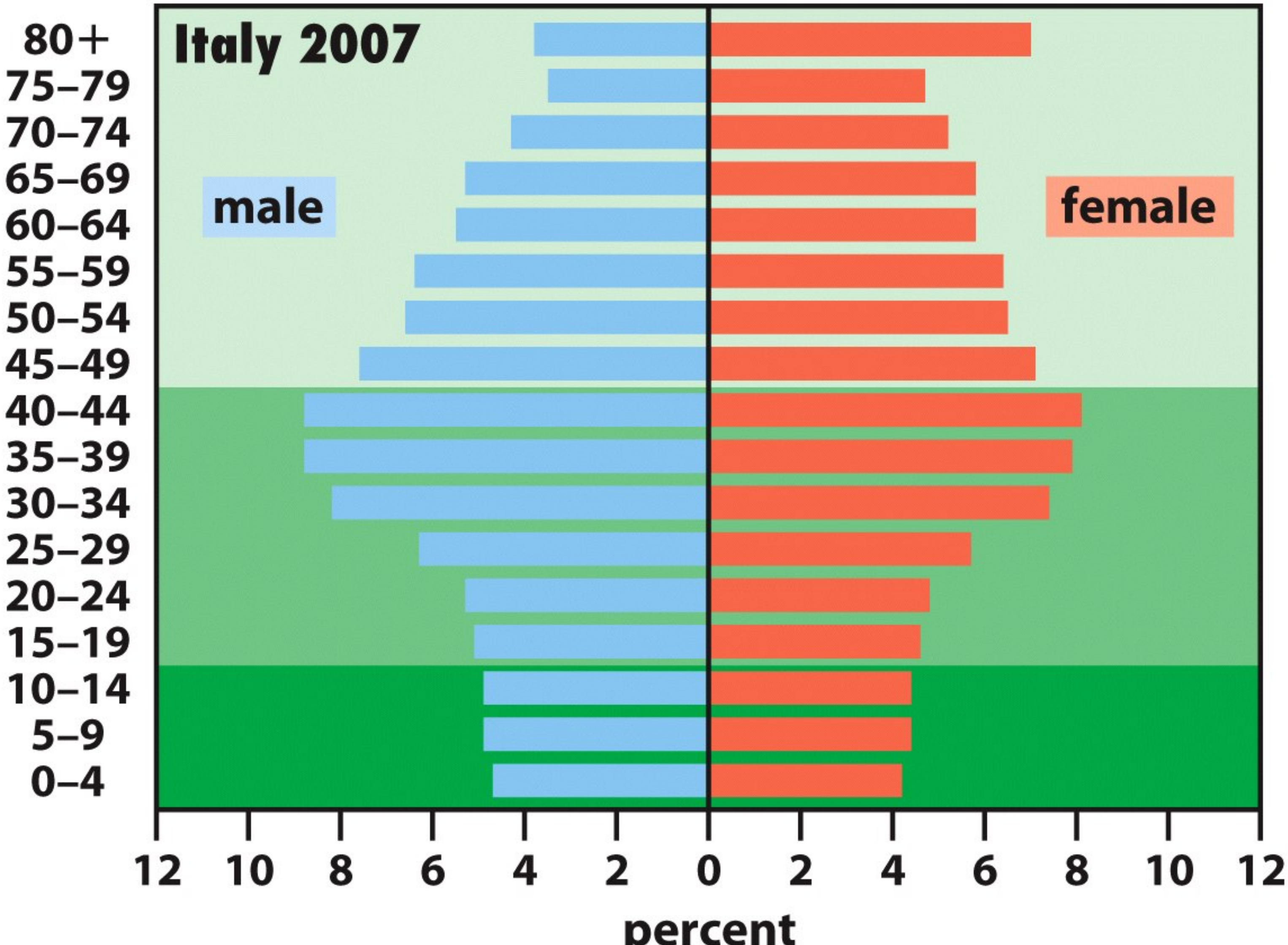


Figure 26-18c Biology: Life on Earth, 8/e

Population Age Structure

- Average-age structure diagrams have been made for developed and developing countries with predictions for 2025 and 2050…

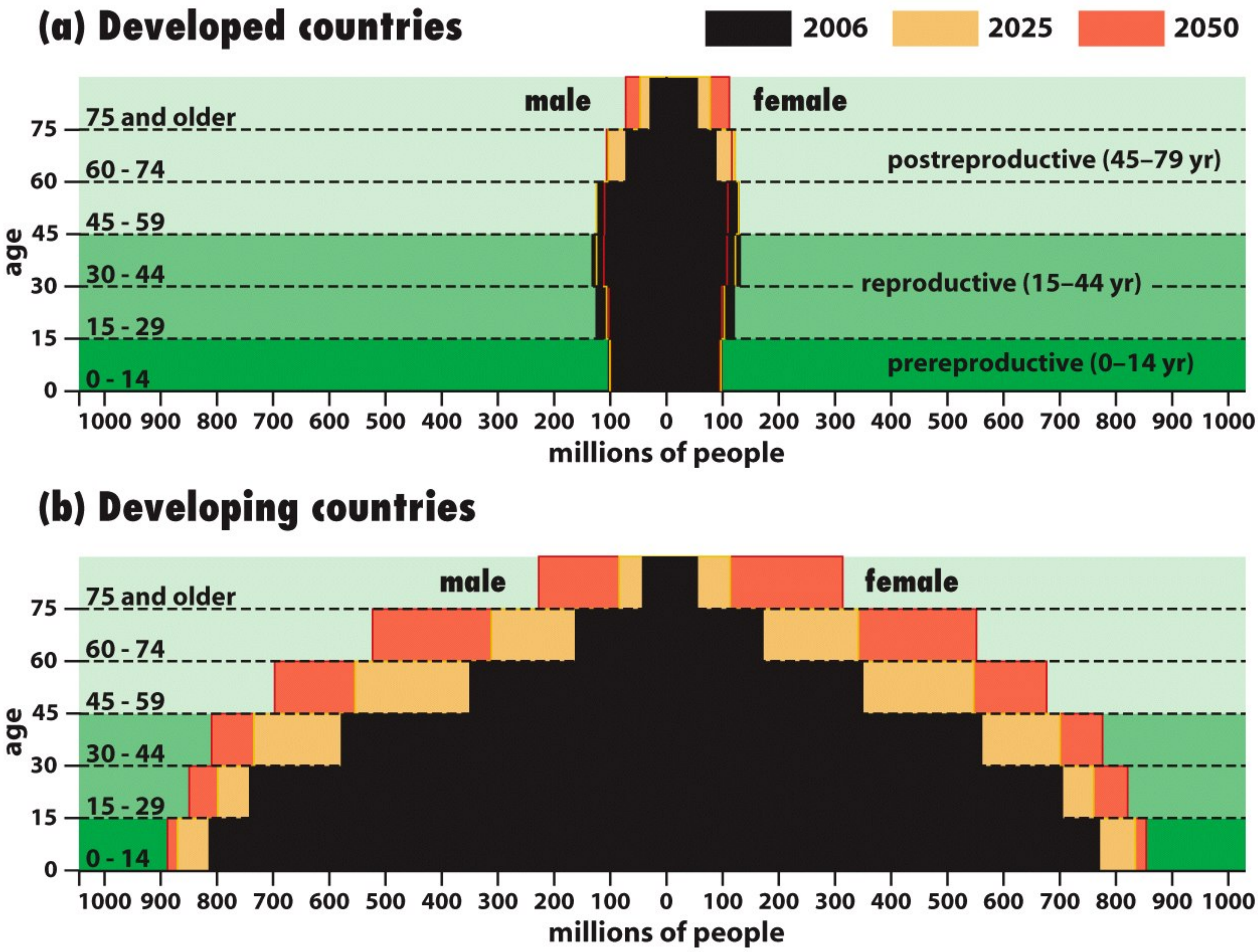


Figure 26-19 Biology: Life on Earth, 8/e