UNIT 7 CHAPTER 37

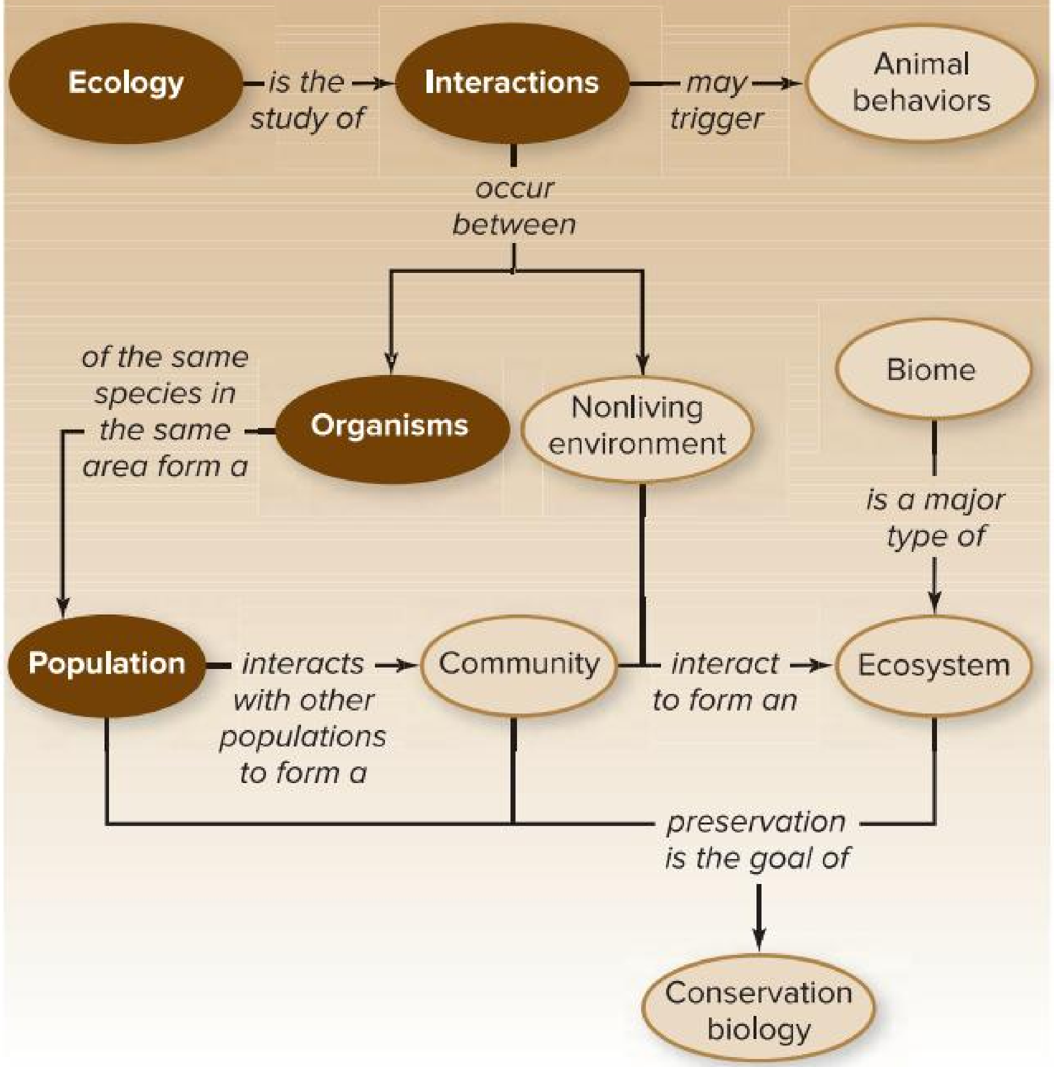
Chapter37 Population

LIU Yang

LEARNING OUTLINE

- 37.1 A Population Consists of Individuals of One Species
- 37.2 Births and Deaths Help Determine Population Size
- 37.3 Population Growth May Be Exponential or Logistic
- 37.4 Natural Selection Influences Life Histories
- 37.5 The Human Population Continues to Grow

SURVEY THE LANDSCAPE
The Ecology of Life



37.1 A Population（种群） Consists of Individuals of One Species

- Ecologists classify these relationships at several levels. The nutria described in the chapter opening essay represent a **population**:a group of interbreeding organisms of one species occupying a location at the same time.
- **A community（群落）** includes all of the populations,representing multiple species,that interact in a given area.
- **An ecosystem（生态系统）** is a community plus its nonliving environment,including air,water,minerals,and fire.
- The study of population ecology is relevant to **disease prediction,land management,the protection of endangered species,and many other fields.**

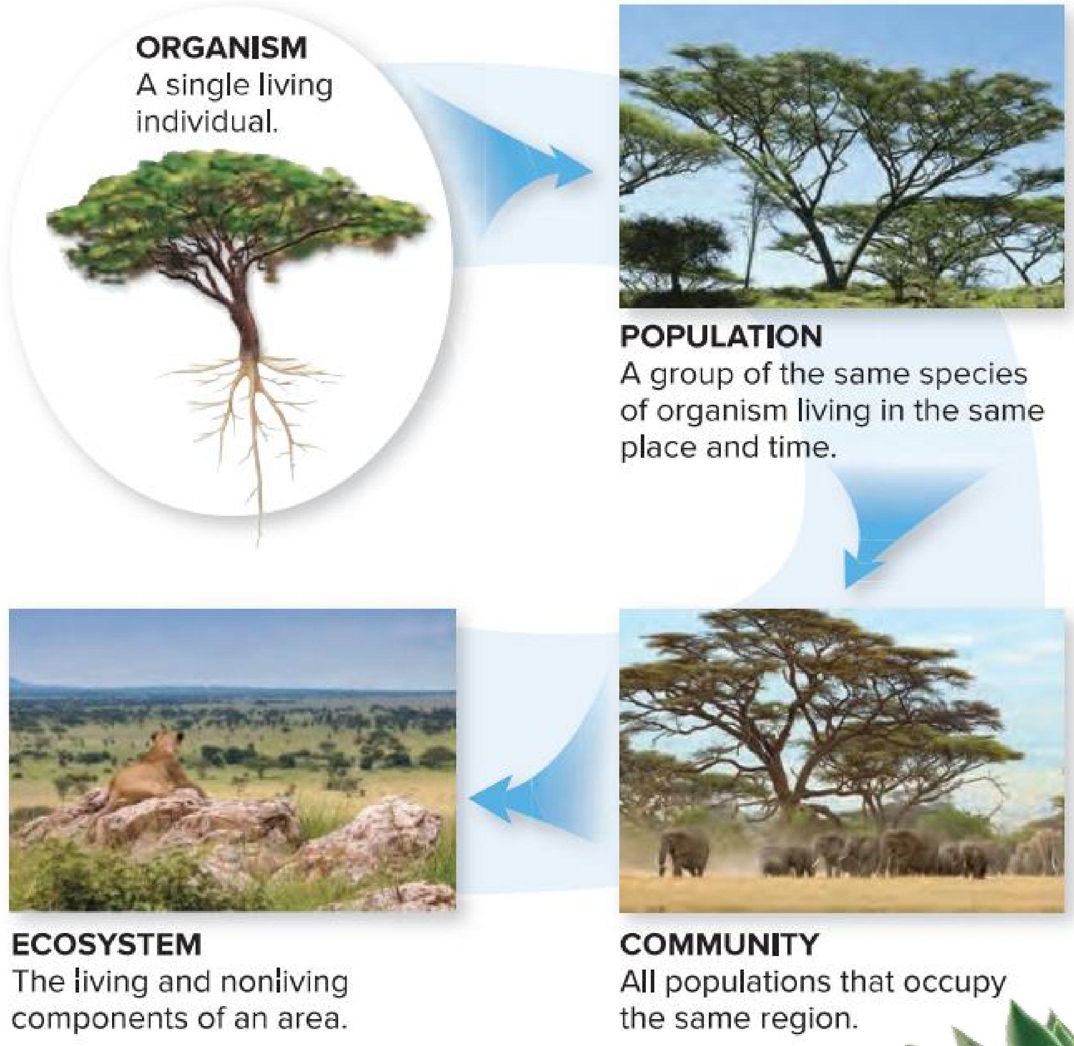


Figure 37.1 From Organism to Ecosystem.

37.1 A Population（种群） Consists of Individuals of One Species

A.Density and Distribution Patterns Are Static Measures of a Population

- The **habitat** (生境) is the physical location where the members of a population normally live.The ocean, desert,and rain forest are typical examples,but an organism's habitat might even be another organism.Your body,for example,is home to billions of microbes.

- **Population density**（种群密度） is the number of individuals of a species per unit area or unit volume of habitat. Density varies greatly among species. Because a tiny individual generally requires fewer resources than a large one,it is not surprising that the smallest organisms tend to live at the highest densities.

- **Population distribution patterns**（种群分布模式）describe how individuals are scattered through the habitat space. Organisms may occur in a random pattern if individuals neither strongly attract nor repel one another and the environment is relatively homogeneous（同质的）.More uniform spacing may occur if individuals repel one another,as in the case of strongly territorial animals. Most often, however,a population's distribution is somewhat clumped,with individuals being attracted to one another or to the most favorable patches of habitat.

37.1 A Population（种群） Consists of Individuals of One Species

A.Density and Distribution Patterns Are Static Measures of a Population

- Population density and distribution measurements provide static“snapshots”of a population at one time. By repeatedly using the same method to measure a population's size over multiple generations,ecologists can determine whether the population is growing,shrinking,or stable.

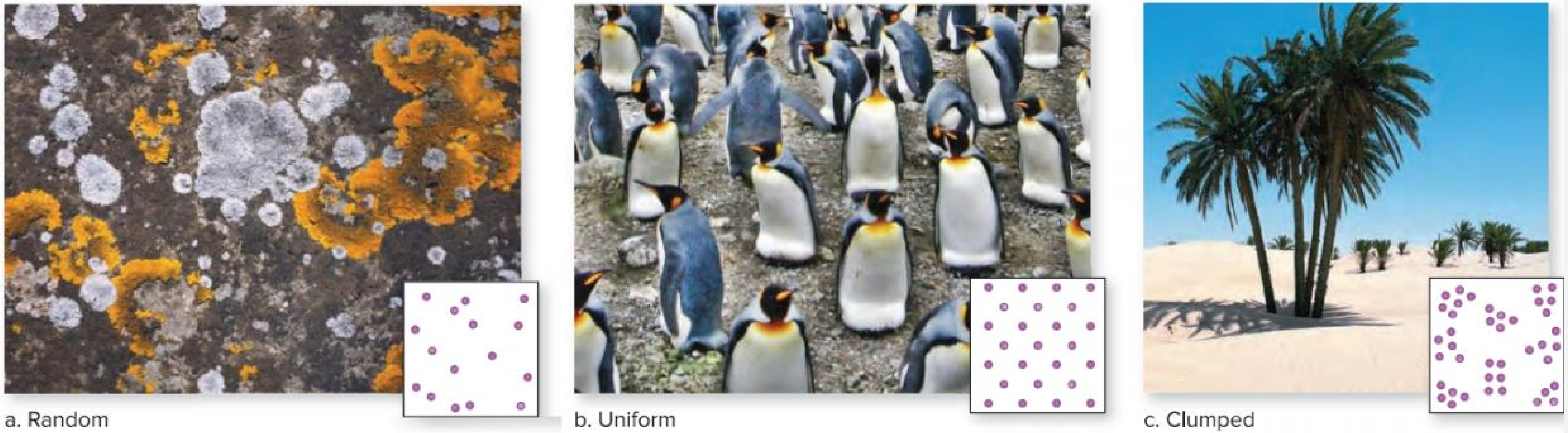


Figure 37.2 **Population Distribution Patterns.** (a) These lichens illustrate random spacing in their rocky habitat. (b) These penguins defend the space around their nests, leading to a uniform distribution. (c) The clumped spacing of these palms reflects unevenly distributed resources—especially water.

37.1 A Population（种群） Consists of Individuals of One Species

B.Isolated Subpopulations（亚种） May Evolve into New Species

- **The overall area occupied by a population is not necessarily fixed. Habitat destruction can eliminate some or all of a population. Conversely,individuals in a population can disperse to new habitats.**But dispersal also occurs as new habitats become available. Plants, animals, and microbes from nearby areas typically colonize the new habitat. **As organisms disperse to new habitats, they may form local subpopulations.**Individuals belonging to a subpopulation are more likely to breed with one another than with members outside the group. But that does not necessarily mean that each subpopulation is isolated from the others.

- Sometimes,however,**a subpopulation becomes physically separated from its parent population, limiting the further exchange of individuals and setting the stage for the evolution of a new species.** How might this occur?The isolated subpopulation often encounters a novel combination of selective forces,such as differences in sunlight,moisture,or nutrient availability.Previously rare variants may therefore have the greatest reproductive success in the new habitat.**Over many generations, natural selection is likely to shape a genetically distinct subpopulation.**If these genetic differences lead to new reproductive barriers,the subpopulation will be unable to interbreed with the parent population.The result:an entirely new species.

37.2 Births and Deaths Help Determine Population Size（种群大小）

- Some populations grow,whereas others remain stable.Still others decline,sometimes to extinction.Population dynamics（种群动力学）is the study of the factors that influence these changes in a population's size.
- **Births and deaths** are the most obvious ways to add to and subtract from a population. If a population adds more individuals than are subtracted,the population grows. If the opposite happens,the population shrinks (and may become extinct).The population size remains unchanged if additions exactly balance subtractions.
- **Regionally,dispersal to new habitats can also increase or decrease a population; immigration** is the movement of individual into a population,and **emigration** occurs when individuals leave. For example,immigration has tremendously increased the human population in the United States over the past 200 or so years.Most Americans are either immigrants or descended from immigrants,and today migration accounts for about half of population growth in this country. Likewise,nonhuman species also disperse to new habitats.

37.2 Births and Deaths Help Determine Population Size（种群大小）

A.Births Add Individuals to a Population

- A population's **birth rate** is the number of new individuals produced per individual in a defined time period.For example,the human birth rate worldwide is about 18.7 births per 1000 people per year.

- The number of offspring an individual produces over its life-time depends on many variables.The number of times it reproduces in its lifetime and the number of offspring per reproductive episode are important, as is **the age at first reproduction**.All other things being equal,the earlier reproduction begins,the faster the population will grow.

Factor	Affected by ...
Additions	
Births	• Number of reproductive episodes per lifetime • Number of offspring per reproductive episode • Age at first reproduction • Population age structure (proportion at reproductive age)
Immigration	• Availability of dispersal mechanism • Availability of suitable habitat
Subtractions	
Deaths	• Availability of nutrients • Predation • Accidents • Genetic/infectious disease
Emigration	• Availability of dispersal mechanism

37.2 Births and Deaths Help Determine Population Size（种群大小）

A.Births Add Individuals to a Population

- **A population's age structure,or distribution of age classes,helps determine its birth rate.** A population with a large fraction of prereproductive individuals will grow. As these individuals enter their reproductive years and produce offspring,the prereproductive age classes swell further,building a foundation that ensures future growth. Conversely, a population that consists mainly of older individuals will be stable or may even decline.This situation can doom a population of endangered plants if,for example,habitat destruction makes it impossible for seedlings to establish themselves. With few young individuals to replace those that die of old age,the population may go extinct.

Factor	Affected by ...
Additions	
Births	• Number of reproductive episodes per lifetime • Number of offspring per reproductive episode • Age at first reproduction • Population age structure (proportion at reproductive age)
Immigration	• Availability of dispersal mechanism • Availability of suitable habitat
Subtractions	
Deaths	• Availability of nutrients • Predation • Accidents • Genetic/infectious disease
Emigration	• Availability of dispersal mechanism

FIGURE IT OUT

1.Population size increases when

a.the sum of birth rate and death rate exceeds the sum of immigration and emigration

b.the sum of birth rate and immigration exceeds the sum of death rate and emigration.

c.the sum of birth rate and emigration exceeds the sum of death rate and immigration.

d.the sum of death rate and immigration exceeds the sum of birthrate and emigration.

2.An age structure for a rat population reveals an equal number of young and old.How will the population size likely change over time?

a.The population size will increase.

b.The population size will decrease

c.The population size will remain approximately the same.

d.The population may go extinct.

37.2 Births and Deaths Help Determine Population Size（种群大小）

B.Survivorship(存活率) Curves Show the Probability of Dying at a Given Age

- **A population's death rate** is the number of deaths per unit time,scaled by the population size.The causes of death may include accidents, disease, predation, and competition for scarce resources. In the human population,for example,the overall death rate is approximately 7.9 per 1000 people per year

- Each individual in a population will eventually die;the only question is when. But species vary tremendously in their **patterns of survivorship**.In species that produce many offspring but invest little energy or care in each one,the probability of dying before reaching reproductive age is very high.In other species, heavy parental investment in a small number of offspring means that most individuals survive long enough to reproduce.

- To help interpret which pattern might apply to a particular species, population biologists developed **the life table**, a chart that shows the probability of surviving to any given age.(Life insurance companies use life tables to compute premiums for clients of different ages.)

37.2 Births and Deaths Help Determine Population Size（种群大小）

B.Survivorship(存活率) Curves Show the Probability of Dying at a Given Age

- **The declining number of survivors in each age class reflects the effects of predation, disease, food scarcity, and all other factors that prevent an individual from reaching its theoretical life span**.The values in a life table are often plotted onto a survivorship curve,a graph of the proportion of surviving individuals at each age. Note that the y axis data are plotted on a logarithmic scale,not a linear one.The log scale makes it easier to see trends along the entire range of values, from 0 to 1000.

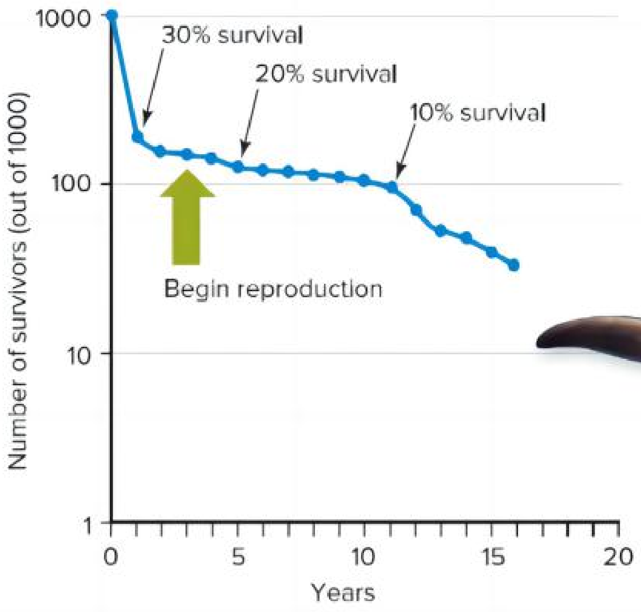
- The survivorship curve reveals important details about the lives of yellow-eyed penguins. For example,only about 32% of the chicks survive their first year,although the death rate slows there after. Moreover,combining life table data with information about fertility at each age can help fill in additional details.For example,reproduction typically begins in year 3 of a yellow-eyed penguin's life.According to the survivorship curve, only about 25% of the penguins that hatch in any given year reach reproductive age. Compare this figure to our own species, in which about 99% of offspring survive long enough to reproduce.

37.2 Births and Deaths Help Determine Population Size（种群大小）

B.Survivorship(存活率) Curves Show the Probability of Dying at a Given Age

Age (years)	Number of Survivors (out of 1000)	
0	1000	
1	324	← 30% survival
2	278	
3	242	← Begin reproduction
4	217	
5	193	← 20% survival
6	172	
7	154	
8	138	
9	122	
10	110	
11	98	← 10% survival
12	87	
13	75	
14	71	
15	63	
16	57	

a. Life table



b. Survivorship curve based on life table

Figure 37.4 Penguin Survivorship. (a) This life table lists the number of survivors remaining each year out of a group of 1000 yellow-eyed penguins that hatch at the same time. (b) A survivorship curve is a graph of the data in a life table. The curve reveals that most penguins die before age 1, after which the death rate levels off.

37.2 Births and Deaths Help Determine Population Size（种群大小）

B.Survivorship(存活率) Curves Show the Probability of Dying at a Given Age

- The survivorship curves of many species follow one of three general patterns . **Type I species**,such as humans and elephants,**invest a great deal of energy and time in each offspring. Most individuals live long enough to reproduce,and the death rate is highest as individuals approach the maximum life span.**
- **Type II species,**including many birds and mammals,**may also provide a great deal of parental care.However,the threats of predation and disease are constant throughout life,and these organisms have an equal probability of dying at any age.**The type II line is therefore straight.
- **Type III species,**such as many fishes and most invertebrates and plants,**may produce many offspring but invest little in each one. Most offspring of type III species therefore die at a very young age.** Of course,these generalized examples do not describe all populations. Many species have survivorship curves that fall between two patterns.The yellow-eyed penguins in figure 37.4,for example,have a survivorship curve that combines features of both type II and type III curves.

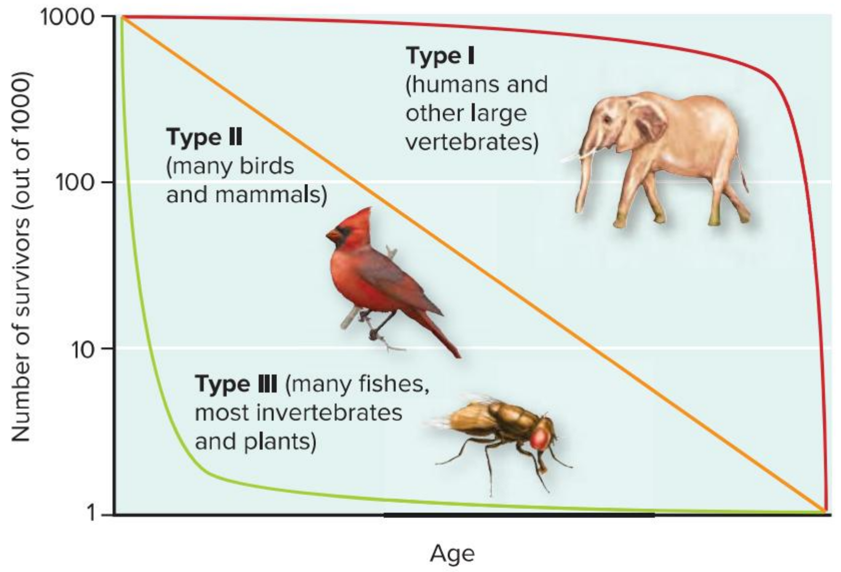


Figure 37.5 **Three Survivorship Curves.** In type I species, most individuals survive to old age, whereas in type III species, most individuals die young. Type II species are in between, with constant survivorship throughout the life span.

FIGURE IT OUT

(T/F)

1. For the survivorship curves, Type I species,such as humans and elephants, invest much more energy and time in each offspring than Type III (carps).

2. For the survivorship curves, Type I species,such as humans and elephants, reproduce much more offspring every single time than Type III (mosquitoes).

37.3 Population Growth May Be Exponential or Logistic（指数型或阻滞型）

- Any population will grow if the number of individuals added exceeds the number removed.**The per capita rate of increase** (人口净增长率),***r***,is the difference between the birth rate and the death rate. (Note that this simplified formula for rignores the effects of immigration and emigration.)For example,a population with 35 births and10 deaths per 1000 individuals per year is growing at a rate(r)of 25 people per 1000 (0.025/yr), or 2.5% per year.Any population with a positive value of r is growing.On the other hand,a negative r means the population is shrinking. If r equals zero, the population is stable.

- But how fast will a population grow,and how large can the population become?Two mathematical models,called **exponential and logistic growth**,illustrate two simple patterns of population growth.

A.Growth Is Exponential When Resources Are Unlimited（J-shaped curve）

- In the simplest model of population growth,exponential growth,the number of new individuals is proportional to the size of the population.In exponential growth,the number of individuals added during any time interval(G)depends only on the per capita rate of increase (r)and the initial size of the population(N),as expressed by this equation:

$$G=rN$$

For example,**suppose that 100 aquatic animals called rotifers are placed in a tank under ideal growth conditions.If r is 0.22 per day,then how many rotifers are added each day?**

37.3 Population Growth May Be Exponential or Logistic（指数型或阻滞型）

- **The answer depends on the size of the population**:The more rotifers in the tank,the larger the capacity to add offspring.A characteristic J-shaped curve emerges when exponential growth is plotted over time. Growth resulting from repeated doubling(1,2,4,8,16,32,...),such as in bacteria,is exponential. Species introduced to an area where they are not native may also proliferate exponentially for a time,since they often have no natural population controls.

Time (days)	r	N	$G = rN$	Total Population at End of Day
1	0.22	100	22	122
2	0.22	122	27	149
3	0.22	149	33	182
4	0.22	182	40	222
5	0.22	222	49	271
6	0.22	271	60	331
7	0.22	331	73	404
8	0.22	404	89	493
9	0.22	493	108	601
10	0.22	601	132	733
11	0.22	733	161	894
12	0.22	894	197	1091
13	0.22	1091	240	1331
14	0.22	1331	293	1624
15	0.22	1624	357	1981
16	0.22	1981	436	2417
17	0.22	2417	532	2949
18	0.22	2949	649	3598
19	0.22	3598	792	4390
20	0.22	4390	966	5356

r = Per capita rate of increase
N = Number of individuals at start of time interval
G = Growth rate (number of individuals added per unit time)

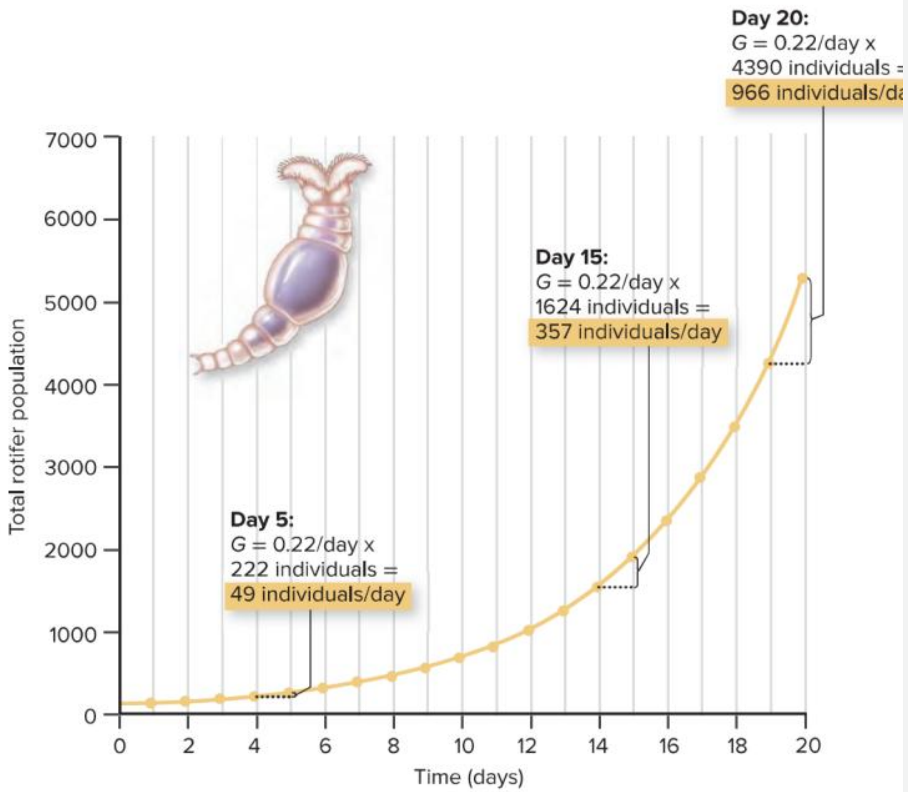


Figure 37.6 Exponential Population Growth. For a population of rotifers with unlimited resources, the number of individuals added each day (G) is the product of the per capita rate of increase (r) and the number of individuals at the beginning of the interval (N). With each generation, G increases, even though r remains constant. Colored bars in the table represent time points that are labeled in the graph.

FIGURE IT OUT

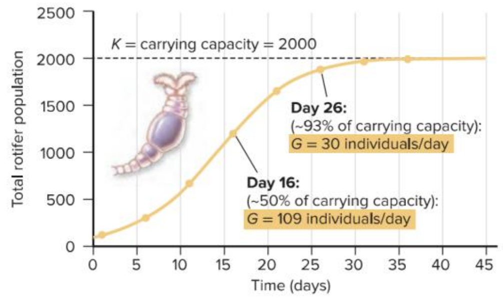
Suppose the grey seals have an r of 0.13 per year.What size population would produce 41,500 pups in 1 year?

37.3 Population Growth May Be Exponential or Logistic（指数型或阻滞型）

B. Population Growth Eventually Slows (S-shaped curve)

- Exponential growth may continue for a short time,but it can not continue indefinitely because some resource is eventually depleted. **Environmental resistance** is the combination of external factors that keep a population from reaching its maximum growth rate. Environmental resistance includes competition, predation,and anything else that reduces birth rates or increases death rates.
- Thanks to environmental resistance,every habitat has a **carrying capacity（承载量）**,which is the maximum number of individuals that the ecosystem can support indefinitely.This carrying capacity imposes an upper limit on a population's size.
- How does this limit affect the population's growth rate?
- According to the logistic growth model,the early growth of a population may be exponential,but growth slows to zero as the population's size approaches the habitat's carrying capacity.The resulting S-shaped curve depicts the leveling off of a population in response to environmental resistance.

Day	r	N	K	$\left(\frac{K-N}{K}\right)$	$G = rN\left(\frac{K-N}{K}\right)$	Total Population at End of Day
1	0.22	100	2000	0.950	21	121
6	0.22	253	2000	0.874	49	301
11	0.22	577	2000	0.711	90	668
16	0.22	1087	2000	0.456	109	1197
21	0.22	1578	2000	0.211	73	1651
26	0.22	1851	2000	0.075	30	1881
31	0.22	1954	2000	0.023	10	1964
36	0.22	1986	2000	0.007	3	1989



r = Per capita rate of increase
N = Number of individuals at start of time interval
K = Carrying capacity
G = Growth rate (number of individuals added per unit time)

Figure 37.8 Logistic Population Growth. When resources become limited, the number of individuals added each day declines. Numbers for N, $(K - N)/K$, and G are shown for selected days only. Colored bars in the table represent time points that are labeled in the graph.

37.3 Population Growth May Be Exponential or Logistic（指数型或阻滞型）

B. Population Growth Eventually Slows (S-shaped curve)

- In logistic growth,the number of new individuals added after each time interval follows this simple equation:

$$G = rN\left(\frac{K-N}{K}\right)$$

- G equals the number of individuals added per unit time;r is the per capita rate of increase; *N* is the number of individuals in the population at a given time;and *K* is the carrying capacity.On the right side of the equation, the term *r*N is the growth rate that would occur if resources were not limiting.The term (*K*-*N*/*K*), however, accounts for the increasing environmental resistance as the population approaches the carrying capacity.When *N* is very small relative to *K*,this expression yields a numerical value near 1, so the population growth rate is high.When *N* is near *K*, the value of the expression drops to near 0,and the growth rate is low.

Day	r	N	K	$\left(\frac{K-N}{K}\right)$	$G = rN\left(\frac{K-N}{K}\right)$	Total Population at End of Day
1	0.22	100	2000	0.950	21	121
6	0.22	253	2000	0.874	49	301
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r = Per capita rate of increase
N = Number of individuals at start of time interval
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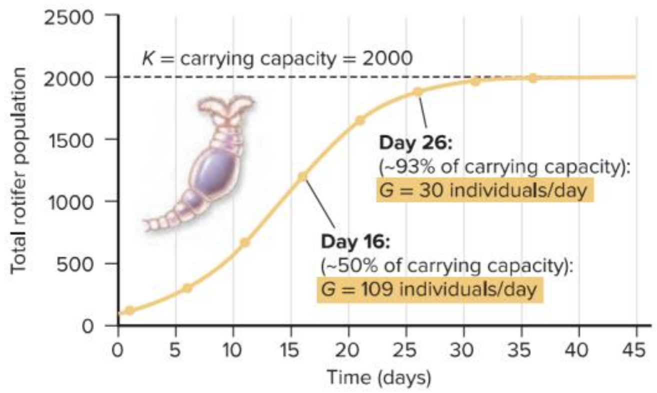


Figure 37.8 Logistic Population Growth. When resources become limited, the number of individuals added each day declines. Numbers for *N*, (*K* – *N*)/*K*, and *G* are shown for selected days only. Colored bars in the table represent time points that are labeled in the graph.

37.3 Population Growth May Be Exponential or Logistic（指数型或阻滞型）

B. Population Growth Eventually Slows (S-shaped curve)

- **Logistic curves often describe populations of disease-causing organisms in confined groups of plants or animals,as in a greenhouse or on a feedlot.**The S-shaped curve simply indicates that the disease cannot continue to spread after all available hosts are infected. In this case,the carrying capacity is determined largely by the number of susceptible hosts.

- **The carrying capacity of an ecosystem,however,typically is not fixed.**A drought that lasts for a decade may be followed by a year of exceptionally heavy rainfall,causing a flush of new plant growth and a sudden increase in food availability.Alternatively,the food on which a species relies may disappear,or a catastrophic flood can drastically reduce the carrying capacity as habitat is destroyed.

- In studying population growth,it is important to understand that some species do not fit neatly into either the exponential or logistic models.In lemmings（旅鼠）,for example,the population fluctuates on a 4-year cycle.The origin of suchboom-and-bust cycles remains mysterious,but predation by stoats(白鼬a type of weasel)appears to be one of the main factors regulating the ups and downs of the lemming population.

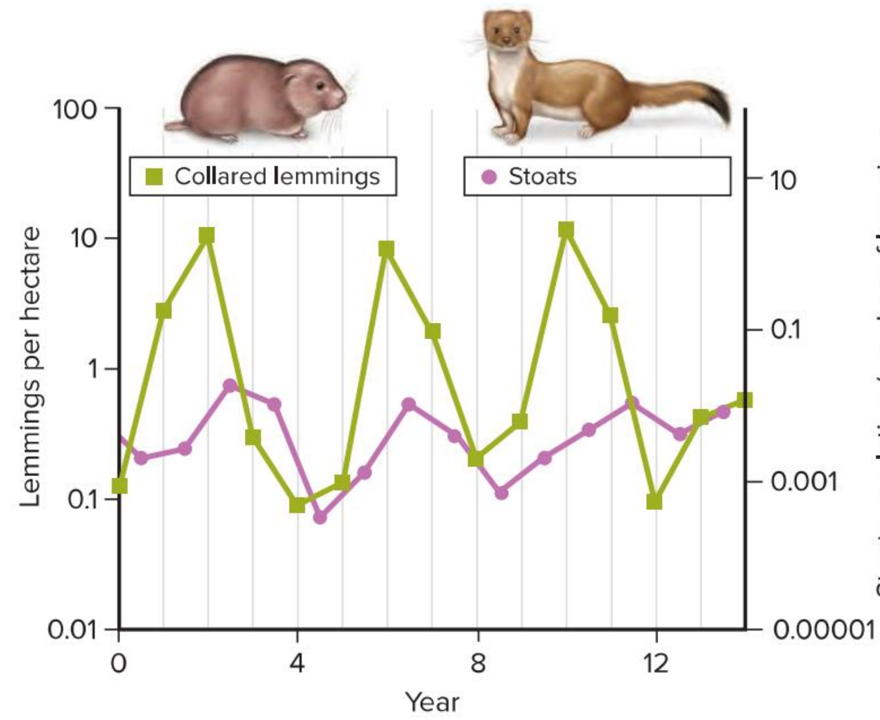


FIGURE IT OUT

1.As a population's size increases toward the ecosystem's carrying capacity

a.environmental resistance increases.

b.the rate of population growth slows

c.the death rate increases.

d.All of the above are correct.

2.Suppose that the carrying capacity for grey seals on Sable Island is 1 million and that r=0.13 per year.Once the population reaches 500,000,how many new pups will be added in the following year?

37.3 Population Growth May Be Exponential or Logistic（指数型或阻滞型）

C.Many Conditions Limit Population Size

- **A combination of factors determines the size of most populations.**The limits on the growth of the population fall into two general categories: **density-dependent and density-independent** .
- **Most density-dependent limits are biotic**,meaning they result from interactions with living organisms. Within a population,competition for space, nutrients, sunlight, food, mates, and breeding sites is density-dependent.When many individuals compete for limited resources,few maybe able to reproduce, and population growth slows or even crashes.
- **Density-independent factors exert effects that are unrelated to population density. Most density-independent limits are abiotic,or nonliving.** Natural disasters such as fires,floods,volcanic eruptions,and severe weather are typical density-independent factors.The high winds of a hurricane,for example,may destroy 50% of the birds' nests in a forest,without regard to the density of the bird population.
- **No matter what combination of factors controls a population's size,it is worth remembering the importance of these limits in natural selection and evolution.**Many individuals do not survive long enough to reproduce.Those that do manage to breed have the adaptations that allow them to escape the biotic and abiotic challenges that claim the lives of many of their counterparts.As these “fittest” individuals pass their genes on,the next generation contains a higher proportion of offspring with those adaptations.

37.4 Natural Selection Influences Life Histories

A.Organisms Balance Reproduction Against Other Requirements

- **A species' life history reflects a series of evolutionary trade-offs**;**after all,supplies of time, energy, and resources are always limited.**Just as an investor allocates money among stocks, bonds, and real estate,a juvenile organism divides its efforts among growth,maintenance,and survival. After reaching maturity,another competing demand—reproduction—joins the list.
- **Reproduction is extremely costly.** Many animals,for example,devote time and energy to attracting mates,building and defending nests,and incubating or gestating offspring. Once the young are hatched or born,the parents may feed and protect them.All of these activities limit a parent's ability to feed itself, defend itself, or reproduce again.In plants,the reproductive investment is also substantial. Flowers, fruits, and defensive chemicals cost energy to produce and take away from a plant's photosynthetic area, reducing the ability to capture sunlight.
- **Besides the total effort allocated to reproduction, the timing is also critical. An organism that delays reproduction for too long may die before producing any offspring at all.On the other hand, reproducing too early diverts energy away from the growth and maintenance that may be crucial to survival.**

37.4 Natural Selection Influences Life Histories

B.Opportunistic and Equilibrium Life Histories Reflect the Trade-Off Between Quantity and Quality

- **Although each species is unique,ecologists have discovered that reproductive strategies fall into patterns shaped by natural selection.**One prominent trade-off is **the balance between offspring quality and quantity.**
- At one extreme are species that have an **opportunistic life history** (also called an ***r***-selected life history), in which individuals tend to be short-lived,reproduce at an early age, and have many offspring that receive little care.The population's growth rate can be very high if conditions are optimal and individuals face little competition for resources;the ***r*** in“***r***-selected”reflects a large per capita rate of increase.In general, however, each offspring has a very low probability of surviving to reproduce; **this pattern is typical of species with type III survivorship curves.**Weeds, insects, and many other invertebrates typically have opportunistic life histories.
- At the other extreme are species with an **equilibrium life history** (also called a ***K***-selected life history), in which individuals tend to be long-lived, to be late-maturing, and to produce a small number of offspring that receive extended parental care .High parental investment in each offspring means that most live long enough to reproduce. The ***K*** in“***K***-selected”stands for the carrying capacity; density-dependent factors such as intense competition for resources keep these populations close to the carrying capacity. Many large mammals **(organisms with survivorship curves that approximate type I) have equilibrium life histories.**

37.4 Natural Selection Influences Life Histories

B.Opportunistic and Equilibrium Life Histories Reflect the Trade-Off Between Quantity and Quality

- **Species vary widely in their life histories;strict adherence to an opportunistic or equilibrium strategy is the exception,not the rule.** For example,some species have intermediate life histories with type II survivorship curves.In addition,even populations of large animals with equilibrium life histories fluctuate greatly in response to changes in their environments.
- **Nevertheless,these two strategies illustrate the important point that natural selection shapes a species' life history characteristics.**These traits therefore reflect the competing demands of reproduction and survival.

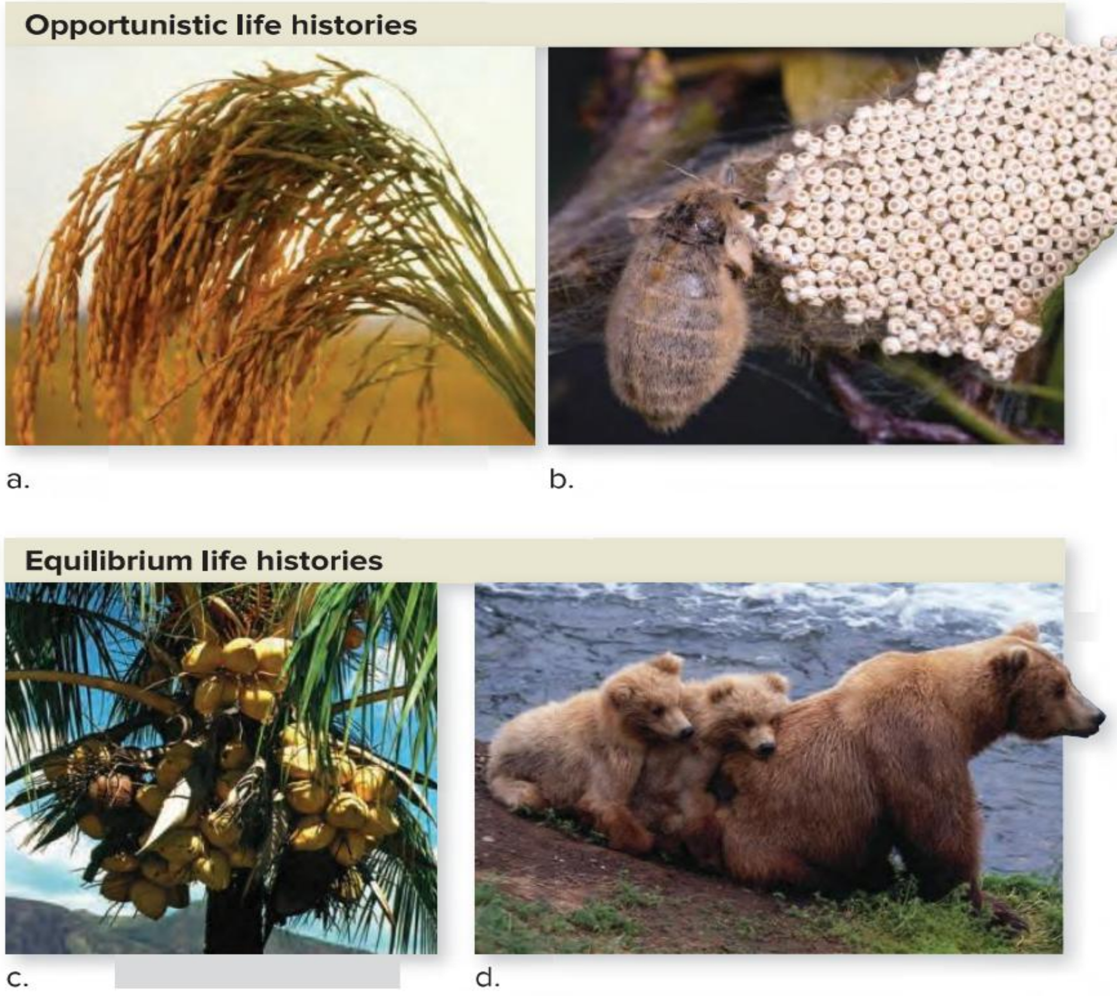


Figure 37.11 **Opportunistic and Equilibrium Life Histories.** (a) Rice plants and (b) tussock moths produce many small offspring and invest little in each one. (c) Each coconut produced by this tree requires a large energy investment. (d) Grizzly bears devote extensive time and resources to rearing a small number of young.

FIGURE IT OUT

1.An opportunistic life history emphasizes ( )

a.large offspring size.

b.high offspring quantity.

c.late reproduction.

d.type I survivorship.

37.5 The Human Population Continues to Grow

The human population has grown exponentially in the last 2000 years.So far,we have found ways to escape many of the forces that limit the growth of other animal populations,such as food availability and disease.Yet exponential growth cannot continue indefinitely.

A.Birth Rates and Death Rates Vary Worldwide

- In early 2017,the world's human population was over 7.4 billion.Since Earth's land area is about 150 million square kilometers, the average population density is about 49 people per square kilometer of land area, but the distribution is far from random. For he most part,the highest population densities worldwide occur along the coastlines and in the valleys of major rivers; very few people live on high mountains, in the middle of the world's major deserts,or on Antarctica.Two countries—China and India—account for one third of all humans.

- Overall, the human population growth rate is about 1% per year and declining. Demographers project that zero population growth may happen during the 22nd century, but no one is certain.Nor do we know how many people will inhabit Earth when that occurs. Clearly, however, less-developed countries are growing at much faster rates than are more-developed countries.

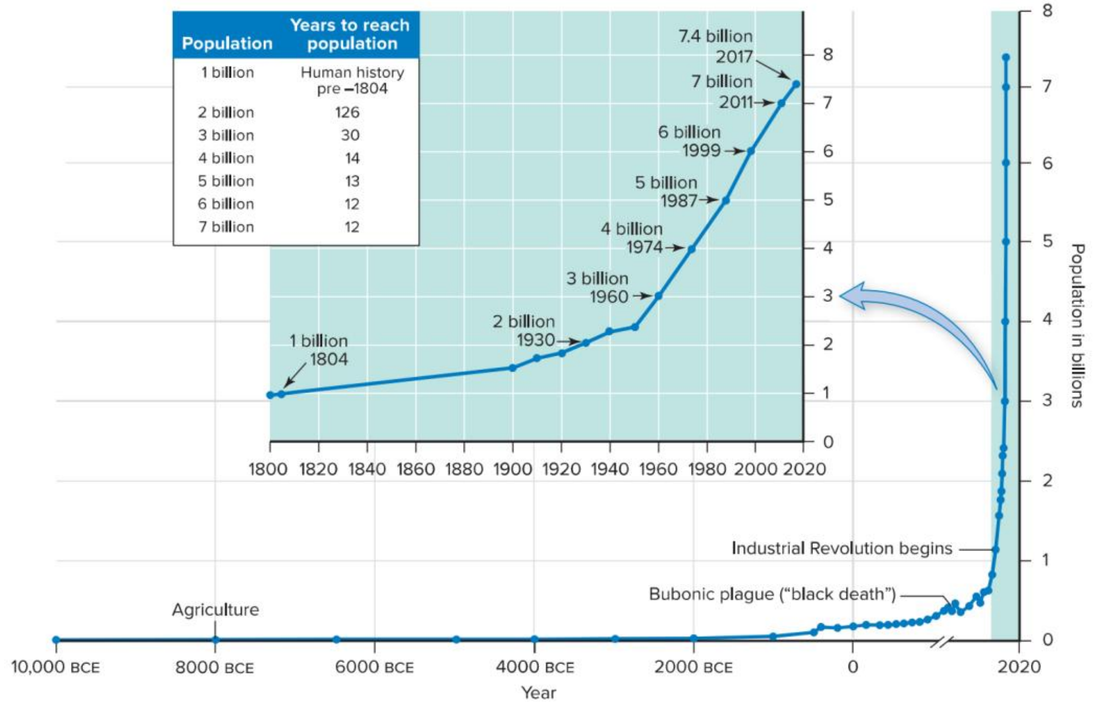


Figure 37.12
Historical Growth of the Human Population. The human population has grown exponentially over the past few thousand years, with the most rapid population growth occurring in the past 200 years (*inset*).
Source: Data from U.S. Census Bureau.

37.5 The Human Population Continues to Grow

- What explains the difference in growth rates?
- **Each country's economic development influences its progress along the demographic transition, during which birth rates and death rates shift from high to low .**In the first stage of the demographic transition, population growth is minimal because both birth rates and death rates are high. Then, during the second stage, improved living conditions and disease control lower the death rate,but birth rates remain high.This transitional period therefore sees the rapid population growth typical of the world's less-developed countries. During the third stage of the demographic transition, birth rates fall; the difference between birth rates and death rates is once again small.The world's more-developed countries have entered this stage,and a few even have declining populations because death rates exceed birth rates.

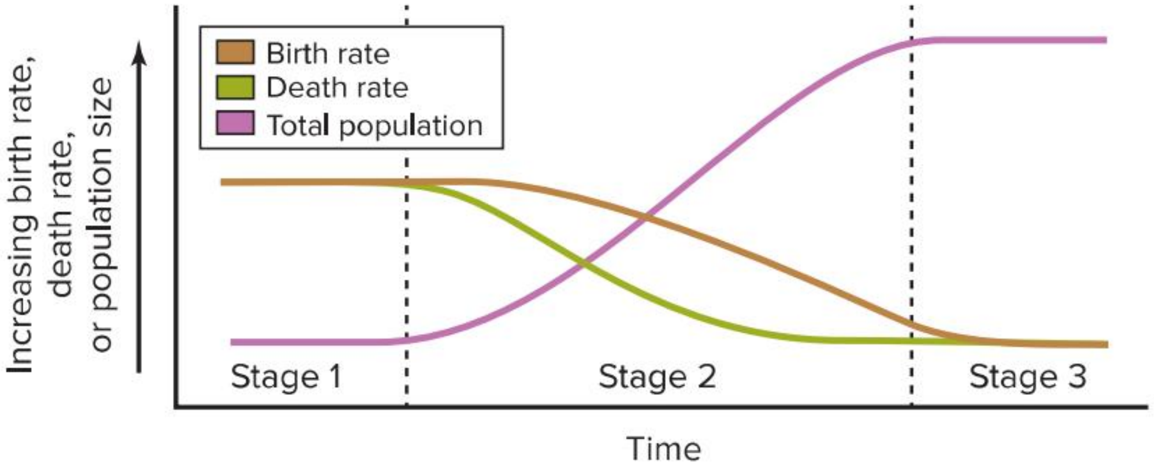


Figure 37.14 The Demographic Transition. During stage 1, birth rates and death rates are high, so the population remains small. Population growth is rapid in stage 2, when death rates fall faster than birth rates. In stage 3, birth rates and death rates are both low, and the population stabilizes.

37.5 The Human Population Continues to Grow

Factors Affecting Birth Rates

- **A population's age structure helps predict its future birth rate.**
- Figure 37.15 shows the age structures for the world's three most populous countries. In India and many other less-developed countries, a large fraction of the population is entering its reproductive years,suggesting a high potential for future growth. In the United States,as in many other developed countries, the population consists mainly of older individuals.Such populations are stable or declining.

As recently as 1990,China's age structure resembled that of present-day India. But China's population now shows a decline in the youngest age classes, so its future growth rate should decline. Between 1980 and 2016, the Chinese government controlled run-away population growth with drastic measures,limiting families to one child.(Couples are now allowed three children.) Although China remains the world's most populous nation,biologists expect India to take the lead by 2025.

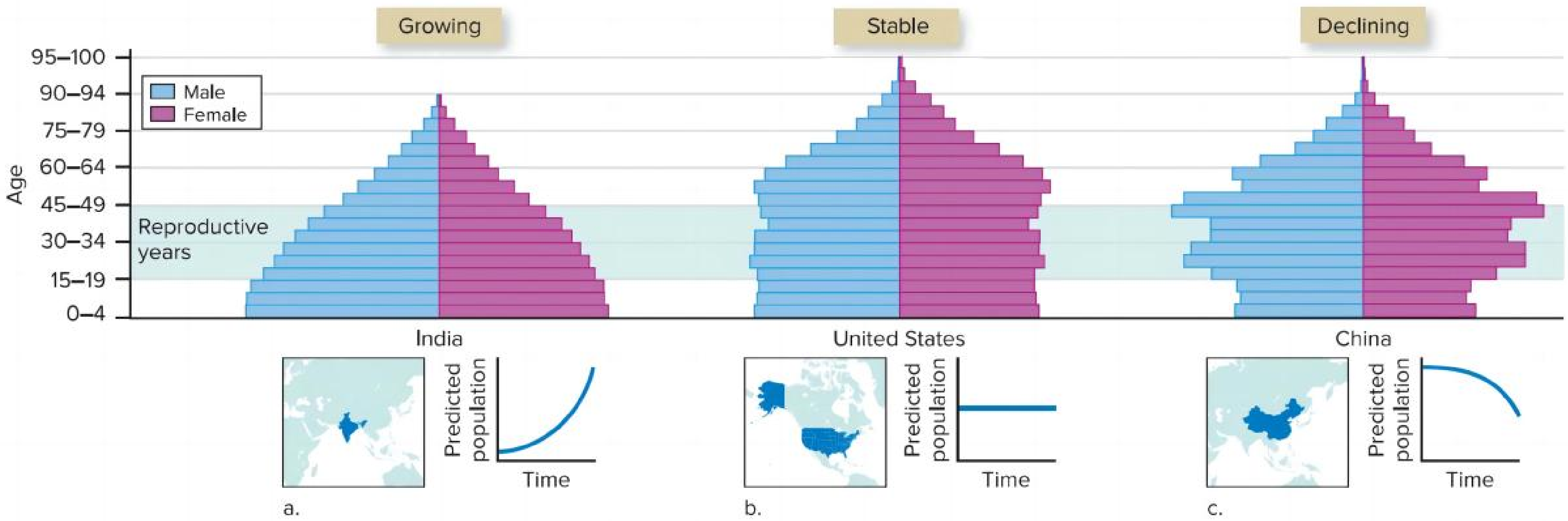


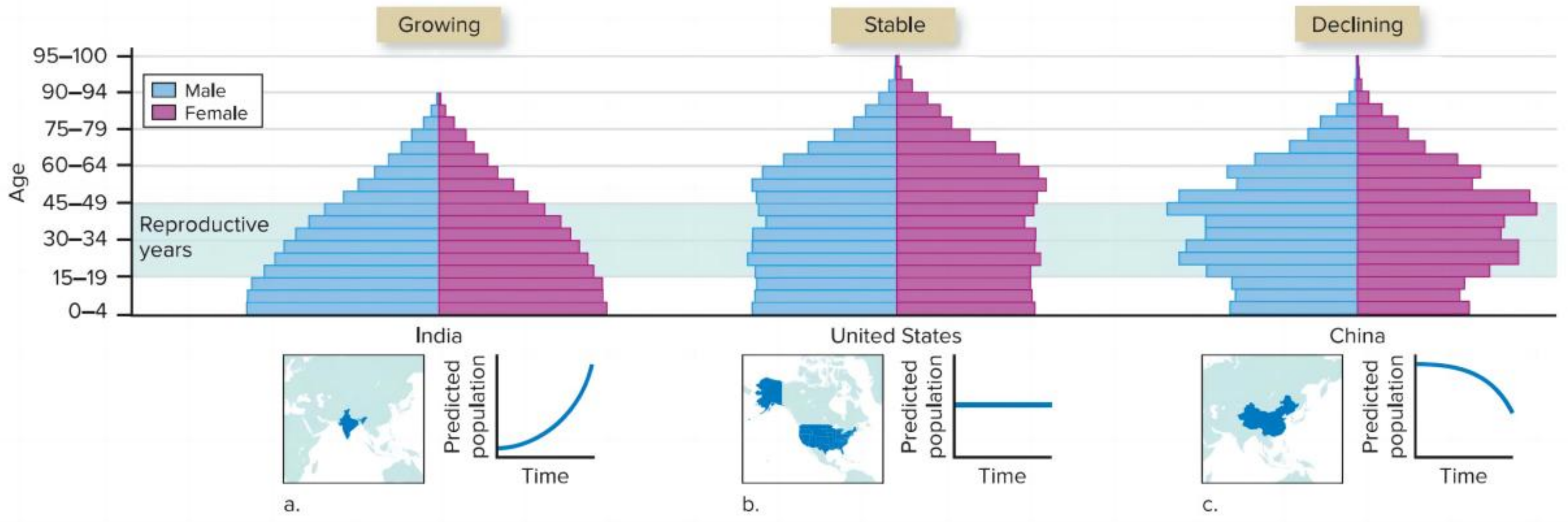
Figure 37.15 Age Structures for Three Human Populations. In age structure diagrams, the width of each bar is proportional to the percent of individuals in that age class. (a) India's population is likely to continue to grow because a high proportion of individuals are in prereproductive age classes. (b) The population of the United States is stable, with roughly equal numbers of people of each age group. (c) China's future growth rate should decline because most of its members are in reproductive or postreproductive age classes.

Source: Data from U.S. Census Bureau, International Data Base.

37.5 The Human Population Continues to Grow

Factors Affecting Birth Rates

- **Overall, why do birth rates tend to decline as the demographic transition progresses?**
- One explanation for this trend is the availability of family planning programs,which are relatively inexpensive and have immediate results.Social and economic factors play an important role as well. Educated women are most likely to learn about and use family planning services,have more opportunities outside the home,and may delay marriage and childbearing until after they enter the workforce.Delayed childbearing often means fewer children and therefore slows population growth.



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Source: Data from U.S. Census Bureau, International Data Base.

37.5 The Human Population Continues to Grow

Factors Affecting Death Rates

- Besides the birth rate, the death rate is the other major factor influencing a population's growth rate. Overall,average life expectancy has increased steadily throughout history—for example, from 22 during the Roman Empire to 33 in the Middle Ages.Today,life expectancy averages around 68 worldwide;it exceeds 80 in a few of the most-developed countries.This dramatic increase reflects centuries of scientific advances in agriculture,medicine,and public health.

Table 37.2 shows the top five causes of death in developed and developing countries.Heart disease,stroke(中风),lung cancer,and dementia（痴呆） top the list in the developed world. Infectious diseases rank relatively low,thanks in large part to sanitation（卫生）, antibiotics（抗生素）, and vaccines （疫苗）.

In contrast,deadly diseases such as respiratory infections（呼吸系统感染）, diarrhea （腹泻）,and HIV/AIDS are more prominent in developing countries. Crowded conditions facilitate the spread of cholera（霍乱） and other waterborne diseases,especially in areas with limited access to clean drinking water. AIDS has taken an especially high toll in sub-Saharan Africa,where about 4.7% of adults are HIV-positive.

TABLE 37.2 Top Five Causes of Death in High- and Low-Income Countries

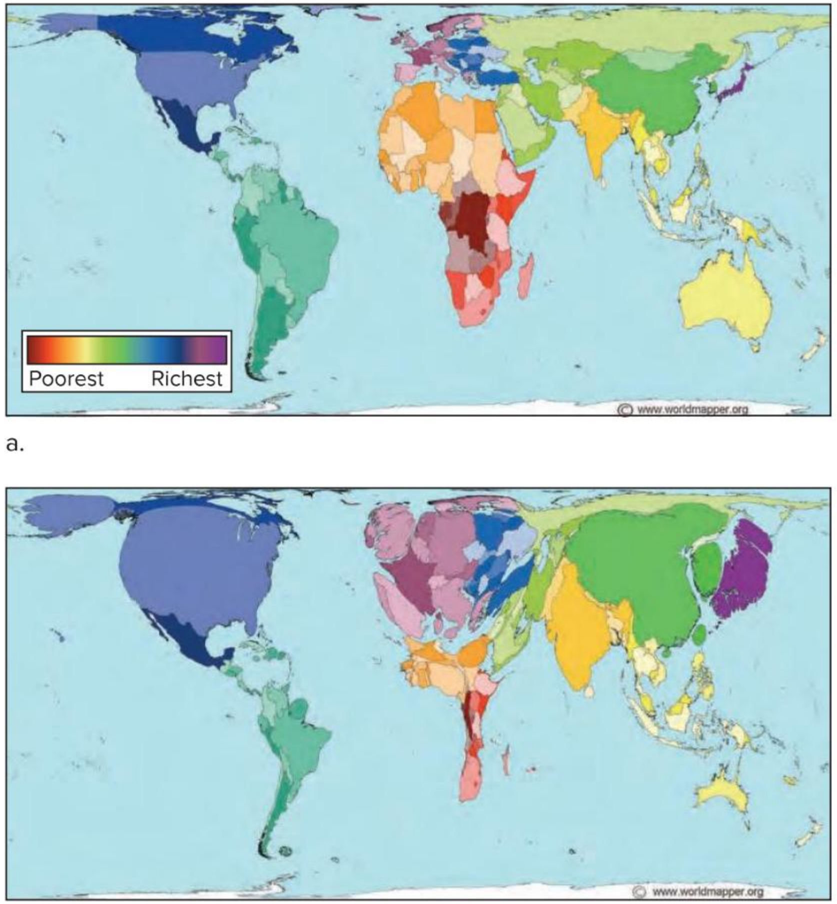
Rank	High-Income Countries	Low-Income Countries
1	Heart disease (coronary artery blockage)	Lower respiratory infection (pneumonia, acute bronchitis)
2	Stroke	HIV/AIDS
3	Lung cancer	Diarrhea (e.g., cholera, rotavirus)
4	Alzheimer disease and other dementias	Stroke
5	Lower respiratory infection (pneumonia, acute bronchitis)	Heart disease (coronary artery blockage)

Source: World Health Organization, "The 10 Leading Causes of Death by Country Income Group."

37.5 The Human Population Continues to Grow

B.The Ecological Footprint Is an Estimate of Resource Use

- **The human population cannot continue to grow exponentially because living space and other resources are finite.**Worldwide, increasing numbers of people will mean greater pressure on land,water,air,and fossil fuels as people demand more resources and generate more waste.
- **Ecologists summarize each country's demands on the planet by calculating an ecological footprint.** Just as an actual footprint shows the area that a shoe occupies with each step, **an ecological footprint measures the amount of land area needed to support a country's overall lifestyle.**The calculation includes, among other measures, **energy consumption** and **the land area used to grow crops** for food and fiber,produce timber,and raise cattle and other animals.**The land areas occupied by streets, buildings, and landfills** are also part of the ecological footprint.Not surprisingly,the world's wealthiest and most populous countries have the largest ecological footprints .



b.

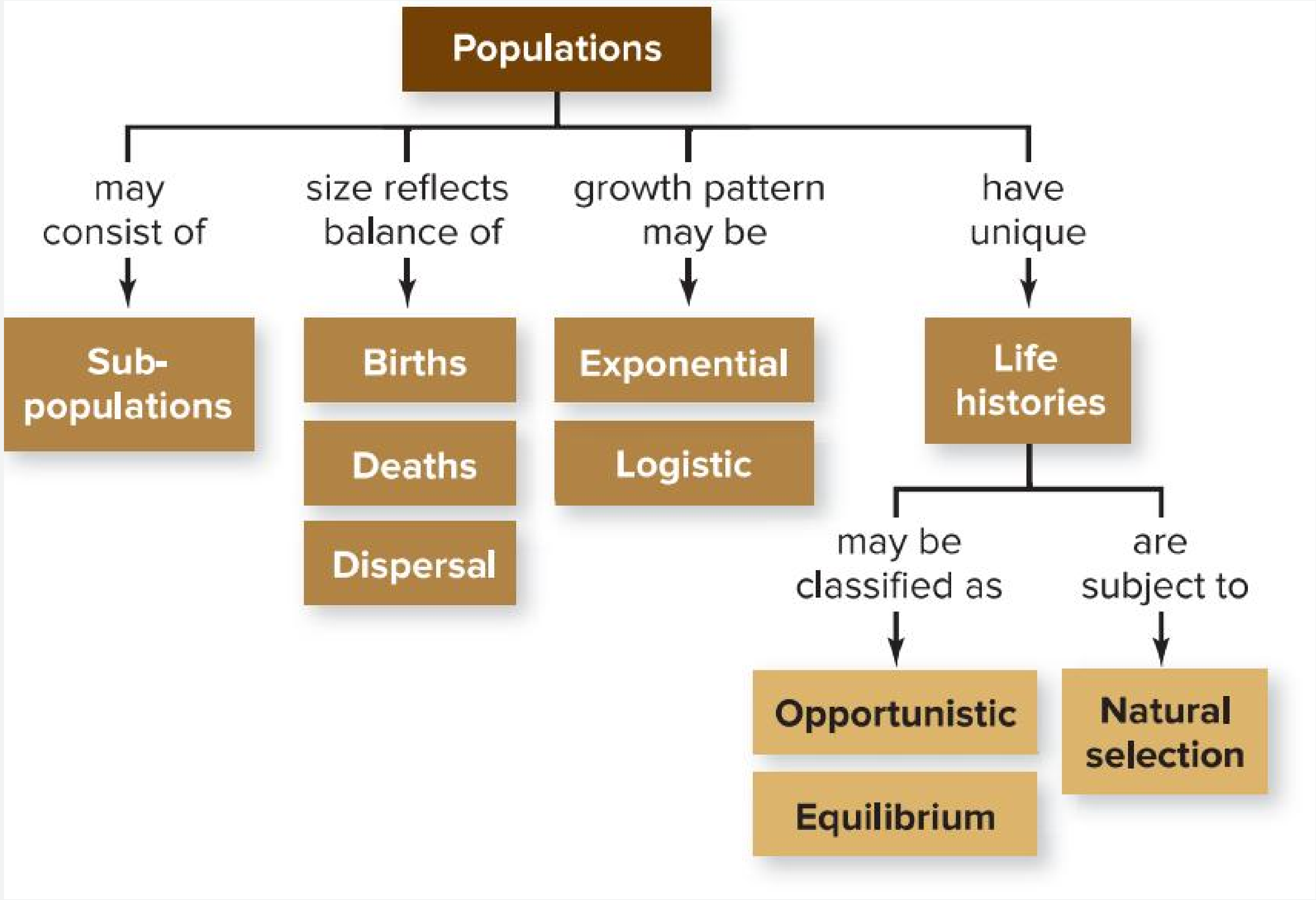
Figure 37.17 **Ecological Footprint.** (a) In a traditional map, each country's size is proportional to its land area. (b) Here, each country's size is proportional to its ecological footprint. Note that the mapmakers grouped countries into 12 regions and assigned each region (not each individual country) a color according to its wealth.

37.5 The Human Population Continues to Grow

B.The Ecological Footprint Is an Estimate of Resource Use

- **Energy consumption accounts for about half of the ecological footprint.The wealthiest countries make up less than 20% of the world's population yet consume more than half of the energy.** Less-developed countries, however, will take a larger share of energy supplies as their populations grow and their economics become more industrialized. Since the vast majority of the energy comes from fossil fuels, the result will be increased air pollution and acid rain. Moreover,the accumulation of CO_2 and other greenhouse gases is implicated in global climate change.
- **Food production is another significant element of the ecological footprint.** Overall, both the demand for food and agricultural productivity rise each year.To boost food production, people often expand their farms into forests,destroying habitat and threatening biodiversity.
- Because the ecological footprint focuses on land area,it does not include water consumption. Nevertheless,the availability of fresh water has declined worldwide as people have demanded more water for agriculture,industry,and household use.In many poor countries,less than half the population has access to safe water for drinking and cooking. As a result,waterborne diseases such as cholera periodically surge through the dense populations of India and many African and South American countries.

- **SUMMARY**


Populations
may consist of
size reflects balance of
growth pattern may be
have unique
Sub-populations
Births
Deaths
Dispersal
Exponential
Logistic
Life histories
may be classified as
are subject to
Opportunistic
Equilibrium
Natural selection