• For centuries, a high birth rate and high death rate kept the human population small. Better nutrition, sanitation, and health care brought a high birth rate and lower death rate, and the population exploded to its current 6.8 billion. Now we are going through a demographic transition to a low birth rate and low death rate. Developing countries with youthful age structures continue to grow. Developed countries are closer to zero growth, but consume more resources per capita and have bigger ecological footprints.

Review the Concepts

Work through the following exercises to review the concepts of population ecology. For additional review, refer to the activities on the Web at www.masteringbiology.com. The website offers a pre-test that will help you plan your studies.

Exercise 1 (Modules 36.1–36.3)

This exercise will allow you to work with the concepts of population density, dispersion pattern, and sampling. The map on the next page represents a meadow on the edge of the city of Mapleton. It is surrounded by developed and farmed land but has remained relatively undisturbed. Developers plan to build a subdivision that would cover the meadow. The Mapleton Open Space Alliance would like the meadow to remain as public open land. They note that the dwarf hawthorn, an uncommon shrub, is found in the meadow. It is considered a “sensitive species” by the state conservation department. The city council has asked for a construction delay until the status of the shrub is determined. You have been sent to determine the density of the hawthorn population in the meadow, as well as that of a deer mouse that may also be present. Use the map of hawthorn distribution on the next page for your survey, and answer the following questions.

The area of the meadow is 16.8 hectares. (A hectare is a metric unit of area equal to about 2.2 acres, so the meadow totals about 37 acres.) This is too big an area to count every shrub, so you will have to look at sample plots. On the ground, this would be done with GPS and measuring tapes. You can choose random samples by merely dropping a penny on the map, drawing a circle around it, and counting the “shrubs” inside. On the scale of the map, the area covered by a U.S. penny equals 0.2 hectare.

1. Take ten samples. How many hectares does this total? ________
2. What is the total number of shrubs in the ten samples? ________
3. What is the density of hawthorns in shrubs per hectare? ________
4. What is the total number of hawthorns in the meadow? ________
5. How could you make your count more accurate? Why not do this?
6. Look at the map again. What is the pattern of dispersion of the shrubs? What might cause this pattern of dispersion?
7. Why does the mark-recapture method work better for mice than the method used to count the plants?

8. One night, you trap 40 mice, mark them, and let them go. Two nights later, you again trap 40 mice, and 10 of them are marked. What is the total number of mice in the meadow? __________

9. What is the population density of mice in the meadow, in animals per hectare? __________

10. What do you have to assume about the mice and your method for your results to be valid? Could you be wrong? Why or why not?
Exercise 2 (Module 36.3)

Life tables and survivorship curves enable population ecologists to describe and understand life cycles. Check your understanding of life tables and survivorship curves by matching each phrase on the left with a term on the right. Answers may be used more than once.

1. Graph of percent alive at the end of each age interval
2. Tabulation of deaths and chance of surviving
3. Used to set life insurance rates
4. Most die young, but a few live to old age.
5. Characteristic of oysters
6. Death rate constant over life span
7. Characteristic of lizards and squirrels
8. Most offspring live a long life and die of old age.
9. Characteristic of humans and many other large mammals

A. Life table
B. Survivorship curve
C. Type I survivorship
D. Type II survivorship
E. Type III survivorship

Exercise 3 (Module 36.4)

Models devised by ecologists describe two kinds of population growth. Exponential growth is described by this equation: \( G = rN \). \( G \), the number of individuals added to the population per unit of time, depends on \( N \), the size of the population, multiplied by \( r \), the population's per capita rate of increase. Per capita rate of increase, \( r \), is calculated by subtracting the death rate from the birth rate. Exponential growth is unregulated. The bigger the population, the faster it grows. This cannot be sustained for long in real populations, but it is interesting as a theoretical possibility. Populations of fast reproducers such as bacteria and insects can grow at near-exponential rates for short periods.

Let's calculate and graph the exponential growth of a population of aphids for which \( r = 40\% \) (or 0.4) per week. Remember that \( G = rN \). If there are 10 aphids to start with, the number of aphids added by the end of the first week (\( G \)) is equal to \( rN \), or \( 0.4 \times 10 \), which equals 4. So the total population (\( N \)) after one week is 10 + 4 = 14.

1. Starting with the new total (\( N \)) of 14, how many aphids will be added (\( G \)) in the second week? _____ (Round off fractions.)
2. What will the total population (\( N \)) be at the end of the second week? _____
3. Aphids added in the third week? _____ Total after third week? _____
4. Aphids added in the fourth week? _____ Total? _____
Graph the rate of the aphid population N versus time in weeks. Use the data table below.

Population size was 10 at time = 0. Label the axes of the graph.

7. How would you describe the shape of this graph?

8. Could this kind of growth continue indefinitely? Why or why not?

Real environments will not support exponential growth. Populations are limited by space, food supply, or other factors that slow growth. The population may level off around a density the environment can maintain—carrying capacity. This so-called logistic growth is described by the equation $G = rN(K - N)/K$, where $K$ represents carrying capacity.

The following data chart the growth of a population of deer on a small protected island off the coast of British Columbia, recorded over a 55-year period:

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>92</td>
</tr>
<tr>
<td>1960</td>
<td>99</td>
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<tr>
<td>1965</td>
<td>138</td>
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<td>1995</td>
<td>597</td>
</tr>
<tr>
<td>2000</td>
<td>610</td>
</tr>
<tr>
<td>2005</td>
<td>599</td>
</tr>
<tr>
<td>2010</td>
<td>606</td>
</tr>
</tbody>
</table>
9. Graph the growth of the deer population. Label the axes. How would you describe the overall shape of the graph?

10. What happened to the population around 1990?

11. What may have caused the population density to level off?

12. What is your estimate of the carrying capacity of the island for deer?

13. What is the biological term for this kind of population growth?

14. At what point(s) was population growth slowest? Fastest?
Population growth is limited by both density-dependent (biotic) and density-independent (abiotic) environmental factors. Density-dependent and density-independent factors affect birth rates and death rates in different ways. State whether each of the following words or phrases relates more to density-dependent factors (DD) or to density-independent (DI) factors.

1. Have more effect when the population is larger
2. Have less effect when the population is smaller
3. Effect not dependent upon density of population
4. Competition for food
5. Fire
6. Predation
7. Stress produced by crowding
8. Competition for nest sites
9. Storms
10. Drought
11. Disease
12. Heat and cold
13. Habitat disruption by humans
14. Cause populations to stabilize in size, presumably near carrying capacity
15. Cause rapid population growth followed by unpredictable crashes
16. Seem to cause boom and bust cycles among predators and prey
17. Limit the snowshoe hare population
18. Limit the lynx population
19. Effects of the nonliving environment
20. Effects of organisms
21. Reduce clutch size as song sparrow population grows
22. Responsible for lemming boom and bust population cycles
23. Cause periodic drastic declines in song sparrow population
Population growth rate depends on two factors—per capita rate of increase and population size, symbolized as "r".

Human population could reach 10 billion by the year 2025. 

2 billion by 1970, and grew to 4.5 billion by 1990. Current projections suggest that the population will double to 10 billion by 2050. 

When there were about 2 million people on Earth, after that population grew relatively slowly and steadily until about 1800.

The world's human population now rivals more than 7 billion.

The human population grew relatively slowly and steadily until about 1800.

The world's human population now rivals more than 7 billion.

Exercises (Modules 16-9-36m)

<table>
<thead>
<tr>
<th>1.3</th>
<th>1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>10</td>
</tr>
<tr>
<td>II.</td>
<td>1</td>
</tr>
</tbody>
</table>

Exercises of Organisms

<table>
<thead>
<tr>
<th>Prey of pests</th>
<th>Density-independent factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited mostly by:</td>
<td>No resources abundant</td>
</tr>
<tr>
<td>Population near K</td>
<td>Demographics of</td>
</tr>
<tr>
<td>Age at first reproduction</td>
<td>Of</td>
</tr>
<tr>
<td>Number of offspring per</td>
<td></td>
</tr>
<tr>
<td>Relative body size</td>
<td>Life history emphasizes</td>
</tr>
<tr>
<td>Stability near carrying capacity</td>
<td></td>
</tr>
</tbody>
</table>

Exercises 5 (Modules 16-9-36m)

1. The history emphasizes Which section? Some populations exhibit K-section and others R-section. Compare these contrasting life histories of different species. Under different environmental conditions, Natural selection shapes different life histories.
The Industrial Revolution changed all this. Humans did something that no other species has ever done—they took it into their own hands. Economic development in the United States and \( 9 \) led to improved nutrition, sanitation, and health care. The death rate \( 10 \), while \( 11 \) remained high. Starting in the developed world, the human population began to grow faster and faster. By the mid-1900s, improvements in sanitation and \( 12 \) had spread to the developing world, and there birth rates began to outpace death rates as well.

Although the world population continues to grow, growth rate peaked in 1962 as health care improved \( 13 \) in the developing countries and widespread use of \( 14 \) started to hold down birth rate. The developing world is catching up, and the world human population finds itself undergoing a demographic \( 15 \), a shift from high birth rates balanced by high death rates to \( 16 \) birth rates balanced by \( 17 \) death rates. Currently, in the developed countries, birth rate and death rate are approximately \( 18 \). In the developing world, the ratio of births to deaths is almost 3:1. Because most people live in the developing countries, this is the biggest factor in world population growth. In fact, out of the more than 74 million people added to the global human population in 2009, more than \( 19 \) million were born in the developing countries!

Reduced \( 20 \) size is the most important change leading to demographic transition. When women’s lives are improved, they \( 21 \) reproduction and have \( 22 \) children. Access to \( 23 \) enables them to practice family planning.

The \( 24 \) structure of a population—the proportion of individuals in different age groups—can help us predict growth trends and social changes. In a \( 25 \) nation such as Mexico, the age structure is a broad-based pyramid, with a large percentage of prereproductive individuals. Couples tend to have large families, and each generation of children outnumber their parents. Even if birth rate is curtailed, such a population will continue to grow for many years because so many young people are coming into their reproductive years. This phenomenon is known as population \( 26 \), and it makes it difficult to put the brakes on population growth. In the developing countries, about \( 27 \) of the population is in this prereproductive group (under the age of 15). In the developed countries, this figure is only \( 28 \) \%.

The age structure of a \( 29 \) nation such as the United States is shaped more like a barrel than a pyramid. Couples average about two children, so the population tends to stabilize. In the U.S., an anomaly is the post-World War II \( 30 \), a population “bulge” that echoes through the years. The boomers swelled school enrollments, competed for jobs, and will soon reach \( 31 \), placing pressure on younger workers and taxpayers as they apply for Medicare and \( 32 \).

The global population is expected to grow to about \( 33 \) billion by the middle of the 21st century. Just to accommodate all the people expected to live on the Earth by 2025, we will have to \( 34 \) food production. But we have already strained the Earth’s resources and severely impacted our environment. Technology allows us to grow more food, but many people are starving and undernourished.
Agricultural lands are depleted. Fresh\textsuperscript{35} for drinking and irrigation is becoming scarce. Overgrazing turns grassland into\textsuperscript{36} As we turn more and more land to our own use, many species face\textsuperscript{37}.

Although populations in the developing world are growing\textsuperscript{38} than those of the developed countries, the per capita environmental impact of developed countries is vastly greater. The\textsuperscript{39}—the amount of land needed to support an individual’s demands on the environment—is one way to measure and compare our ecological impact. An American has an ecological footprint of about 9.4 global hectares, while a resident of India gets by on about 0.8 hectares. If the area of productive land on the Earth is divided by population, we each have a share of about\textsuperscript{40} global hectares. In 2005, the average ecological footprint of the world’s population was 2.7 hectares. This means that our ecological footprint already\textsuperscript{41} available resources.

The problem is not just overpopulation, but overconsumption. The world’s richest countries, which account for only\textsuperscript{42} % of global population, account for 36% of the global footprint. A child born in the United States has an impact on the environment greater than 40 African children.

Will the Earth’s human population eventually reach 9 billion, or even more? Whatever our numbers, there is no question that the overall human birth rate will eventually come into line with the death rate, and globally,\textit{r} will equal 0. But the questions that remain are as follows: Will the balance come about by informed choice, or will it be harshly imposed upon us? Will it occur through a decrease in the\textsuperscript{43} rate or an increase in the\textsuperscript{44} rate? Finally, what kind of life will there be in the future for all the people, and other species, who share an increasingly crowded planet?