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UNIT 8

Population and Community Dynamics

Teaching Unit 8: Reproduction and Development

(15% percent of the course time; approximately 18-20 hours)

Student Textbook pages 672-747

General Outcomes

- describe a community as a composite of populations in which individuals contribute to a gene pool that can change over time
- explain the interaction of individuals in populations with each other and with members of other populations
- explain, in quantitative terms, the changes in populations over time

Curriculum Fit (See the Curriculum Correlation for Full Listing)

Background: This unit builds on concepts from Science 9, Unit A: Biological Diversity; and *Biology 20*, Unit B: Ecosystems and Population Change.

Contents

- Chapter 19: Genetic Diversity in Populations
- Chapter 20: Population Growth and Interactions

The themes of this unit are Systems, Equilibrium, and Change.

Content Summary

In Unit 8 students explore the interaction of populations within a community, how and why populations change over time, and the impact of population changes on communities. The study of population interaction and change is considered in the context of the concept that "we are all connected" and the importance of preservation of diversity.

In Chapter 19: Genetic Diversity in Populations students look at the impact of changes in gene pools. Section 19.1 introduces and defines the concepts related to genetic diversity: genes, alleles, gene pools, genotype frequency, phenotype frequency, and allele frequency. Once they understand the basic concepts, students can assess the progress of traits from one generation to the next using the principles and two equations developed by Godfrey Hardy and Wilhelm Weinberg (the Hardy-Weinberg principle). The equations are valid if five conditions are met; the implications of not meeting those conditions are explained, including identification of populations that are undergoing microevolution. Practice problems and Investigations 19.A: Applying the Hardy-Weinberg Equation and 19.B: Testing the Hardy-Weinberg Principle give students an opportunity to test their skills with the equations. **BLM 19.1.9: Populations in Hardy-Weinberg Equilibrium** gives students more practice. Students should be able to calculate allele frequencies, genotype frequencies, and numbers of individuals within each genotype in a population.

In Section 19.2, students examine the causes of change in a gene pool—when genetic equilibrium is disturbed—including mutation, gene flow, random mating, genetic drift in small populations, and natural selection. The founder effect and the bottleneck effect also have an impact on genetic diversity. The effect of human impact, as noted in the unit opener, is considered, this time in the context of genetic diversity. The consequences of lack of genetic diversity are revisited—**BLM 19.0.1: Bananas and Biodiversity** could be used here if it was not picked up at the beginning of the chapter. The Connections feature on the use of Biotechnology asks students to consider the possible impact of genetic engineering in terms of conservation, as well as intended and unintended effects.

Chapter 20: Population Growth and Interactions focusses on changes in the size and composition of populations and how those changes affect a community. In order to study population growth, students must first hone their skill in measuring populations. Section 20.1 reviews the basic equation for population density and the most common patterns of distribution: uniform, random, or clumped, and then introduces the factors that affect population distribution. Thought Lab 20.1: Distribution Patterns and Population Size Estimates gives students an opportunity to practice classifying distribution patterns and estimating population size. This information can then be used to assess population growth. Beyond calculating population density, students learn how to determine the growth rate and per capita growth rate of populations. Two growth patterns—exponential (J-curve) and logistic (S-curve)—are linked to biotic and abiotic factors that can limit growth. The concept of carrying capacity leads to a discussion of the range of life strategies—from *r*-selected strategies to *K*-selected strategies—that ensure survival of a species.

In Section 20.2: Interactions in Ecological Communities, students are reintroduced to the interactions that occur within and between populations, including interspecific and intraspecific competition, and producer-consumer interactions (predation and natural defenses, mutualism, commensalism, parasitism). Investigation 20.B: Celebrate the Small Successions and Thought Lab 20.3: Testing the Classical Model of Succession anchor the discussion of succession—the study of communities changing over time.

Section 20.3: Sharing the Biosphere challenges students to assess the significance of population changes and reconsider the concept of sustainability, particularly in connection with the growth of human population and Earth's carrying capacity. The Connections feature continues the topic of human impact with a more in-depth look at the hippo sanctuary introduced in the Unit Opener. By the time students finish this section, they should have an understanding of why Canadian society supports ecological research.

Activities and Related Target Skills

Activity	Target Skills
Chapter 19: Genetic Diversity in Populations	
Launch Lab: Pick Your Plumage, p. 677	■ Identifying variations in physical characteristics ■ Predict three traits that may be considered advantageous
Investigation 19.A: Applying the Hardy-Weinberg Equation, p. 684	■ Asking questions about genotype frequencies based on observable phenotypes, and investigating these frequencies ■ Applying, quantitatively, the Hardy-Weinberg principle to observed data ■ Interpreting data, and communicating results and ideas
Investigation 19.B: Testing the Hardy-Weinberg Principle, p. 686	■ Predicting what will affect allele and genotype frequencies over time in two model populations ■ Performing simulations to demonstrate genetic equilibrium and possible gene pool change ■ Applying, quantitatively, the Hardy-Weinberg principle to observed data ■ Interpreting data, and communicating results and ideas
Thought Lab 19.1: Spirit Bear, p. 692	■ Describing the factors that cause gene pool diversity to change ■ Applying, quantitatively, the Hardy- Weinberg principle to published data, and inferring the significance of the results ■ Assessing the role of the Hardy-Weinberg principle in explaining natural phenomena
Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 696	■ Describing the factors that affect the genetic diversity of an endangered species ■ Assessing the value of captive breeding programs in preserving the genetic diversity of an endangered species
Chapter 20: Population Growth and Interactions	
Launch Lab: Reproductive Strategies and Population Growth, p. 703	■ Graphing two sets of data for population projections ■ Hypothesizing the reason for the shape of each graph
Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 706	■ Analyzing data and applying mathematical models to determine population size ■ Applying conceptual models to describe distribution patterns ■ Asking questions about how distribution patterns influence estimates of population size
Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations?, p. 714	■ Calculating and interpreting population density and changes in population size ■ Evaluating the effects of human activities on grizzly bears ■ Recognizing the intrinsic factors that limit grizzly bear population growth
Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, p. 720	■ Designing and performing experiments to demonstrate intraspecific and interspecific competition ■ Working as a team to communicate ideas and information
Investigation 20.B: Celebrate the Small Successions, p. 727	■ Designing and performing an experiment to demonstrate succession in a microenvironment ■ Designing and performing an experiment to demonstrate the effect of an environmental factor on population growth rates ■ Communicating ideas and results
Thought Lab 20.3: Testing the Classical Model of Succession, p. 729	■ Explaining changes in communities over time, using models of succession

Activities and Related Target Skills

Activity	Target Skills
Thought Lab 20.4: Biological Control or Damage Control?, p. 732	■ Summarizing and evaluating an interspecific relationship ■ Developing, presenting, and defending a position on whether organisms should be deliberately introduced into a new environment
Thought Lab 20.5: Population Growth Rates in Different Countries, p. 734	■ Comparing and assessing the growth rates of human populations in various countries

Conceptual Challenges

Chapter 19

- Evolution is again the subject of discussion, this time in the context of genetic change, and this may remain a sticking point for students of various cultural beliefs. Many students will think evolution requires a great deal of time to occur. Some will have heard that Earth isn't old enough for evolution to have created the diversity of life that exists today. Modern research has shown that evolutionary change can occur in the very short term (geologically speaking, as well as from a human perspective). Once again, the scientific evidence for the theory of evolution may need to be stressed.
- The value of the Hardy-Weinberg equation can sometimes be difficult for students to grasp. To help students understand the importance of the equation, emphasis should be placed on using the equation at least twice for different generations of a population. If allele frequencies are constant, biologists can study factors that keep a population the same, including stabilizing selection. If the frequencies of alleles change, biologists can study other factors, perhaps including directional selection.

Chapter 20

- It should be stressed that *r*-selection and *K*-selection strategies are not a way of classifying living things in the way in which the periodic table classifies the elements. The two life strategies are the examples found at each end of a range of strategies that are used in nature. Therefore, this system of classifying works best in a comparative manner. For example, compared to a grasshopper, a Canada goose is *K*-selected; it is larger, longer-lived, has fewer offspring, and cares for its young. However, compared to an African elephant, Canada geese are *r*-selected; they are smaller, shorter-lived, have more offspring, and care for their offspring less than elephants do.
- Population distribution patterns seen in species are fluid and change over time. Mobile animals will show different distributions during mating season than at other times of the year. The theme of this unit is change, yet concepts used to understand change in populations are often seen as fixed concepts. As animals move, as individuals live and die, patterns of distribution change.
- Students often struggle with the identification and meaning of density-dependent and density-independent factors. Most frequently, density-dependent factors are related to reproduction or survival. Examples include a decrease in the number of seeds, mass of seeds, and number of seed capsules per plant as plant density increases. It is important to note that an increase in a specific factor is not density-dependent unless the rate of increase changes as density increases. In other words, the line of best fit should curve. Hence, predation is only density-dependent if the rate (individuals killed per unit population, for example) increases with density. A change from 10 killed in a population of 100 to 100 killed in a population of 1000 is not density-dependent. (Nor is it a change in rate.)
- Ecologically, distinguishing among predators, primary consumers, and parasites is difficult. If a herbivore consumes an entire plant, it is acting like a predator. If it consumes part of a plant, it is acting like a parasite; often this type of herbivore is called a plant parasite. Parasites of vertebrates do not tend to kill their host directly, although parasites of insects do kill their hosts. Consider presenting this concept in the context of exploitation of a resource so it will be more easily understood.

Using the Unit 8 Opener and Unit 8 Preparation Feature

Student Textbook pages 672-675

The Unit 8 Opener refers to the visit of West African Traditional Leaders to the Calgary Zoo's Conservation Outreach program. The visit was necessary because a community of species along the Black Volta River was under threat, despite a long history of living in the area. After students have read the unit opener, the following points could be used to put the study of population change into context:

- The threats to the Black Volta River community are defined as farming, fishing, and hunting—all human activities. An introductory commentary or class discussion could focus on the idea that conservation programs are usually necessary in order to protect communities of other living species (as well as the abiotic environment) from the incursions and predations of the human species. While the human population is the one taking steps to protect the hippos of the Black Volta River, it is also the human population that is making protection necessary. Students may be able to think of examples closer to home where local species may or may not be protected from the incursions of humans into their habitats.

- The underlying theme that was introduced in Chapter 1 of Biology 20—Considering Connections—could be briefly revisited to set the context for the need to study population interaction and change. The Launch Lab question posed in Chapter 2—Whose planet?—could also be revisited in order to ask students to consider why it is necessary to study the interaction of populations of all species and measure population change.
- The Unit Preparation feature includes a brief review of heredity and evolution, including revising the language of genetics, which was covered in Unit 7 and should be fresh in students' minds. Nevertheless, encourage students to take the Unit Prequiz (found at **www.albertabiology.ca**), Online Learning Centre, Student Edition to gauge their recall, noting that if they are familiar with the background science—particularly the vocabulary used in Unit 7, their experience with this unit will be much easier.

UNIT 8: COURSE MATERIALS

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapters 19, 20	safety goggles	40 pairs	Investigation 20.B
Chapters 19, 20	nonlatex disposable gloves	40 pairs	Investigation 20.B
Chapters 19, 20	aprons	40	Investigation 20.B
Chapter 19 Chapter Opener	paper silhouette of a greater sage grouse paper tail feathers of different lengths paper air sacs of different colours coloured felt pens staplers or clear tape	1 per person 10 per person 2 per person 30, of a variety of colours 5	Launch Lab: Pick Your Plumage, p. 677
Chapter 19, Section 19.1	paper cups (or similar containers) dark-coloured beads light-coloured beads	2 per group for Part 1, 3 per group for Part 2 48 per group 32 per group	Investigation 19.B: Testing the Hardy-Weinberg Principle, pp. 686–687
Chapter 20, Chapter Opener	ruler graph paper	1 per student 2 pieces per student	Launch Lab: Reproductive Strategies and Population Growth, p. 703
Chapter 20, Section 20.1	ruler calculator	1 per student 1 per student	Thought Lab 20.1: Distribution Patterns and Population Size Estimates, pp. 706–707
Chapter 20, Section 20.1	calculator graph paper	1 per student 1–2 pieces per student	Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations?, pp. 714–715
Chapter 20 Section 20. 2	seeds (such as basil, marigold, radish, grass, lettuce, bean, or clover seeds) vermiculite or potting soil flower pots ruler balance scissors other materials as needed for students experimental design	100 2 bags 1 per student 15 5 5 as required	Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, pp. 720–721
Chapter 20 Section 20.2	container of 10% bleach (for used microscope slides, cover slips, and pipettes) paper towels pond water wood shavings or dried grass pH paper microscope slides cover slips long plastic pipettes (NOTE: preferably ones with built-in bulbs, and long enough to reach the jar bottom) mason jars with lids microscope laboratory fridge Protoslo® or methylcellulose (optional)	1 L 5 rolls 4.5 L small bag 45 125 125 1 per group 2 per group 1 per group 1 10 mL	Investigation 20.B: Celebrate with Small Successions, p. 727
Chapter 20, Section 20.3	ruler graph paper	1 per student 2 pieces per student	Thought Lab 20.5: Population Growth Rates in Different Countries, p. 734

CHAPTER 19 GENETIC DIVERSITY IN POPULATIONS

Curriculum Correlation

General Outcome 1: Students will describe a community as a composite of populations in which individuals contribute to a gene pool that can change over time.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–D1.1k describe the Hardy–Weinberg Principle and explain its importance to population gene-pool stability and the significance of non-equilibrium values	Launch Lab: Pick Your Plumage, p. 675 Throughout Section 19.1, p. 676–686	Launch Lab: Analysis, p. 675 Questions for Comprehension: 1, 2, p. 678 Section 19.1 Review: 1, 2, p. 686 Chapter 19 Test
30–D1.2k describe the factors that cause the gene pool diversity to change, i.e., genetic drift, gene flow, non-random mating, bottleneck effect, migration, mutation	Throughout Section 19.2, p. 687–695 Thought Lab 19.1: The Spirit Bear, p. 690 Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 694	Questions for Comprehension: 8, p. 687 9–11, p. 689 12, 13, p. 691 14–17, p. 692 18, 19, p. 693 20, p. 694 Thought Lab 19.1: Analysis, p. 690 Thought Lab 19.2: Analysis, Extensions, p. 694 Section 19.2 Review: 1–8, p. 695 Chapter 19 Review: 1, 7–8, 15–17, 20, p. 698–699 Chapter 19 Test Unit 8 Review: 3, 5–9, p. 742
30–D1.3k apply quantitatively, the Hardy–Weinberg Principle to observed and published data ■ $p + q = 1$ ■ $p^2 + 2pq + q^2 = 1$	Section 19.1: Introducing the Hardy-Weinberg Principle, p. 678 Minding p and q, p. 682 Expanding the Hardy-Weinberg Equation, p. 683 Investigation 19.A: Applying the Hardy-Weinberg Equation, p. 682 Investigation 19.B: Testing the Hardy-Weinberg Principle, p. 684 Thought Lab 19.1: The Spirit Bear, p. 690	Questions for Comprehension: 3–5, p. 680 6, p. 682 7, p. 683 Practice Problems: 1–5, p. 679 Investigation 19.A: Analysis, Conclusions, p. 682 Investigation 19.B: Analysis, Conclusions, p. 684 Thought Lab 19.1: Analysis, p. 690 Section 19.1 Review: 1–7, p. 686 Chapter 19 Review: 1–6, 10–14, p. 698–699 Chapter 19 Test Unit 8 Review: 1–5, 19–25, 31, p. 742–744
30–D1.4k describe the molecular basis of gene-pool change and the significance of these changes over time, i.e., mutations and natural selection, *e.g., drug-resistant bacteria, herbicide resistant plants*	Section 19.1: The Hardy-Weinberg Principle, p, 676 Expanding the Hardy-Weinberg Equation, p. 683 Section 19.2: Mutations, p. 687 Natural Selection, p. 693 Human Activities and Genetic Diversity, p. 693 Connections—Social and Environmental Contexts: Biotechnology and Gene Pools, p. 696	Questions for Comprehension: 7, p. 681 18, p. 691 19, 20, p. 692 Connections—Social and Environmental Contexts, 1–4, p. 696 Chapter 19 Review: 19, 20, p. 699 Chapter 19 Test Unit 8 Review: 8–10, p. 742

	Student Textbook	Assessment Options
Outcomes for Science, Technology, and Society (Emphasis on social and environmental contexts)		
30–D1.1sts explain that science and technology have both intended and unintended consequences for humans and the environment by ■ *discussing the introduction of exotic species into new ecosystems*	Connections—Social and Environmental Contexts: Biotechnology and Gene Pools, p. 696	Connections—Social and Environmental Contexts, p. 696
■ *discussing the development of ecological reserves to preserve gene-pool diversity*	Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 694	Thought Lab 19.2: Analysis, Extensions, p. 694
■ *assessing the bottleneck effect characteristic of small populations and strategies to counteract it, e.g., Whooping crane, Swift fox*	Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 694	Questions for Comprehension: 17, p. 692 Thought Lab 19.2: Analysis, Extensions, p. 694
■ *investigating the role of gene banks in the preservation of endangered species and genotypes, particularly of plants and animals used in agriculture*	Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 694 e.g., Connections—Social and Environmental Contexts: Biotechnology and Gene Pools, p. 696	Thought Lab 19.2: Analysis, Extensions, p. 694 e.g., Connections—Social and Environmental Contexts, p. 696
■ *assessing habitat loss and the responsibility of society to protect the environment for future generations*	Section 19.2: Human Activities and Genetic Diversity, p. 693	Questions for Comprehension: 20, p. 694 Unit 8 Review: 16, 33, 34, p. 743–745
30–D1.2sts explain how concepts, models and theories are often used in interpreting and explaining phenomena by ■ *assessing the role and importance of models in ecology in explaining scientific phenomena, e.g., Hardy–Weinberg Principle.*	Investigation 19.A: Applying the Hardy-Weinberg Equation, p. 682 Investigation 19.B: Testing the Hardy-Weinberg Principle, p. 684 Thought Lab 19.1: The Spirit Bear, p. 690 Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 694	Investigation 19.A: Analysis, Conclusions, p. 682 Investigation 19.B: Analysis, Conclusions, p. 684 Thought Lab 19.1: Analysis, p. 690 Thought Lab 19.2: Analysis, Extensions, p. 694
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
30–D1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ *identifying a question about the resistance of bacteria to specific antibiotics or plants to specific herbicides*	Section 19.2: Mutations, p. 685 e.g., Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 692 e.g., Connections—Social and Environmental Contexts: Biotechnology and Gene Pools, p. 696	e.g., Thought Lab 19.2, p. 692 e.g., Connections—Social and Environmental Contexts, p. 696
Performing and Recording		
30–D1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by ■ *designing and performing an investigation and/or computer simulation to demonstrate population growth and gene-pool change*	Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 694	Thought Lab 19.2: Analysis, Extensions, p. 694
■ researching, integrating and synthesizing information on a related topic, e.g., *–the development and persistence of deleterious genes in gene pools* *–development of bacterial resistance to antibiotics*	e.g., Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane, p. 692 e.g., Connections—Social and Environmental Contexts: Biotechnology and Gene Pools, p. 696	e.g., Thought Lab 19.2, p. 692 e.g., Connections—Social and Environmental Contexts, p. 696

	Student Textbook	Assessment Options
Analyzing and Interpreting		
30–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ *calculating and interpreting problem-solving exercises involving the Hardy–Weinberg Principle*	Investigation 19.A: Applying the Hardy-Weinberg Equation, p. 682 Investigation 19.B: Testing the Hardy-Weinberg Principle, p. 684	Practice Problems: 1–5, p. 681 Section 19.1 Review: 1–7, p. 686 Investigation 19.A: Analysis, Conclusions, p. 682 Investigation 19.B: Analysis, Conclusions, p. 684 Chapter 19 Review: 2–6, 10–14, 18, p. 699 Unit 8 Review: 1, 2, 19–25, 31, p. 742–743
Communication and Teamwork		
30–D1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *using appropriate notation to show gene frequency and changes in gene frequency over time*	Investigation 19.A: Applying the Hardy-Weinberg Equation, p. 682 Investigation 19.B: Testing the Hardy-Weinberg Principle, p. 684	Investigation 19.A: Analysis, Conclusions, p. 682 Investigation 19.B: Analysis, Conclusions, p. 684

Chapter 19

Genetic Diversity in Populations

Student Textbook pages 676–701

Chapter Concepts

19.1 The Hardy-Weinberg Principle

- A gene pool is the sum of all the alleles for all the genes in a population. Population geneticists study gene pools.
- The Hardy-Weinberg principle is a mathematical model that is used to determine allele frequencies and genotype frequencies in a population.
- Sexual reproduction does not, by itself, cause allele frequencies to change from one generation to the next.
- Allele frequencies change over time in populations that are undergoing microevolution. The Hardy-Weinberg equation can be used to detect these changes.

19.2 The Causes of Gene Pool Change

- Genetic mutations, gene flow, nonrandom mating, chance events followed by genetic drift, and natural selection can lead to changes in gene pools.
- The formation of small isolated populations leads to inbreeding and a potential loss of genetic diversity from gene pools.
- Recessive alleles that are harmful in the homozygous state may remain in a gene pool if the heterozygous genotype provides a selective advantage

Common Misconceptions

- Many students will think that individuals can change in response to environmental change. Although some phenotypic change does happen (tanning in response to exposure to UV radiation in humans, for example) these changes are not passed on to offspring and do not constitute evolutionary change. Linking evolutionary change to changes in allele frequency may be difficult for these students to internalize without specific teaching about an example of environmental phenotypic change like tanning. The ability to tan can be inherited; the dark skin of a tanned person cannot.
- Some students link the frequency of an allele to dominance. They think that the most abundant allele must be the dominant one. Use specific examples in human genetics of dominant alleles that are not very abundant to provide clarification. Polydactyly and Huntington's disease are two good examples of dominant alleles that are quite rare. Associating frequency with dominance will make calculating allele frequencies correctly rather difficult because students will start with the wrong phenotype. Starting Hardy-Weinberg calculations with the dominant phenotype leads to incorrect allele frequencies because that phenotype includes heterozygotes and well as homozygotes.
- Some students will link change in allele frequencies directly to microevolutionary change and natural selection. While it can be argued that any change in allele frequency represents microevolution, the other conditions for genetic equilibrium must be tested before a scientist can identify that natural selection is occurring. Once the other conditions have been shown to be reasonably true, an evolutionary biologist can then begin searching for the causes of the selection pressure that is changing the population.
- Many students will hold the simplistic view that any mutation provides matter for selection to work upon. Somatic, or body-based mutations, do not affect the gametes and cannot be passed on. Children do not have the old age spots that their parents or grandparents have. Only mutations that affect the gametes can be inherited and passed to the next generation.

Helpful Resources

Books and Journal Articles

Dobzhanski, T.; Ayala, F.L.; Stebbins, G. L.; and Valentine, J. W. *Evolution*. W. H. Freeman and Co.: San Francisco, CA. 1977.
Futuyma, D. J. *Evolutionary Biology*. Sinauer Associates: Sunderland, MA. 1979.

Web Sites

Web links related to this chapter can be found at **www.albertabiology.ca**. Go to the Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web Links.

List of BLMs

Blackline masters (BLMs) have been prepared to support the material in this chapter. The BLMs are either for assessment (AST); use as overheads (OH); use as handouts (HAND), in particular to support activities; or to supply answers (ANS) for assessment or handouts. The BLMs are in digital form, stored on the CD that accompanies this Teacher's Resource or on the web site at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.

Number (Type)
19.0.1 (HAND) Bananas and Biodiversity
19.0.2 (HAND) Launch Lab: Pick Your Plumage
19.0.2A (ANS) Launch Lab: Pick Your Plumage Answer Key
19.1.1 (OH) Genotype Frequency, Phenotype Frequency, Allele Frequency
19.1.2 (OH) Hardy-Weinberg principle and Hardy-Weinberg equation
19.1.3 (OH) Punnett Squares to Determine Genotype Frequencies
19.1.4 (OH) Sample Problem 1: Albinism in a Snake Population

19.1.5 (OH) Sample Problem 2: Wing Length in Fruit Flies
19.1.6 (HAND) Investigation 19.A: Applying the Hardy-Weinberg Equations
19.1.6A (ANS) Investigation 19.A: Applying the Hardy-Weinberg Equations Answer Key
19.1.7 (OH) Collared Pika: Change in Allele Frequency
19.1.8 (HAND) Investigation 19.B: Testing the Hardy-Weinberg Principle
19.1.8A (ANS) Investigation 19.B: Testing the Hardy-Weinberg Principle Answer Key
19.1.9 (HAND) Populations in Hardy-Weinberg Equilibrium
19.1.9A (ANS) Populations in Hardy-Weinberg Equilibrium Answer Key

19.2.1 (OH) Agents of Evolutionary Change
19.2.2 (HAND) Thought Lab 19.1: Spirit Bear
19.2.2A (ANS) Thought Lab 19.1: Spirit Bear Answer Key
19.2.3 (OH) Genetic Drift in Roses
19.2.4 (HAND) Scientific Interest in Founder Communities
19.2.5 (HAND) Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane
19.2.5A (ANS) Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane Answer Key

19.3.1 (AST) Chapter 19 Test
19.3.1A (ANS) Chapter 19 Test Answer Key

Using the Chapter 19 Opener

Student Textbook pages 676-677

In the chapter opener, students are being asked to consider the importance of biodiversity in order to give the study of population growth and change some context.

Teaching Strategies

- Use **BLM 19.0.1: Bananas and Biodiversity** to highlight the importance of biodiversity and the pitfalls of over-engineering a species. The questions can be used to generate discussion about the importance of biodiversity and the effect of human intervention in nature's processes.
- Use the Launch Lab: Pick Your Plumage, supported by **BLM 19.0.2**, to focus attention on the role of physical traits in the breeding process.

Launch Lab: Pick Your Plumage

Student Textbook page 677

Purpose

Students will work cooperatively with the teacher to determine the effect of sexual selection on the traits of a population of organisms.

Outcomes

- 30-D1.2k
- 30-D1.sts

Advance Preparation

When to Begin	What to Do
1 or 2 days before	■ Prepare silhouettes of sage grouse, different coloured tail feathers, and different coloured air sacs from paper
1 day before	■ Purchase sufficient coloured felt pens or pencil crayons for your class to provide each student with access to a variety of colours ■ Photocopy **BLM 19.0.2: Launch Lab**

Apparatus	Materials
■ coloured felt pens or pencil crayons	■ sufficient paper to create a sage grouse, 5 to 10 paper tail feathers for each grouse, and an air sac for each grouse

Time Required

- 15 minutes for students to obtain materials and apparatus, and to create their sage grouse
- 30 minutes to conduct the discussion and simulation

Helpful Tips

- Use **BLM 19.0.2: Launch Lab** to support this activity. Modify it as necessry.
- Once the images are complete and have been observed by the class, you may want to either tell the students which characteristics your female sage grouse prefer and let the students identify 4 or 5 males that best meet those criteria, or you can choose 4 or 5 male grouse that meet the criteria, and have students attempt to identify which characteristics have been selected for or selected against. You may want to consider conducting a brief discussion of how this activity is similar to natural selection, and how it is different.
- Artistic students may need cautioning about the time available to create their grouse.
- Since this is not a controlled experiment, it is not intended that students create a formal report of the outcomes.
- There is a strong possibility that some of your students are colour-blind and will not necessarily create colourful grouse. This is not important in the outcome or understanding of this activity. A sensitive teen may consider this trait a defect, but the situation can also be viewed as an opportunity to teach students about variation in humans and diversity in society.

- At step 2 in the procedure, ask students to hold up their grouse. Identify the similarities and differences among the grouse students have produced. Place these similarities and differences in the context of genetic variation among individuals in the population.
- At step 3, identify a combination of two or three characteristics that define low reproductive success in grouse. Students with grouse that have these characteristics are asked to drop their grouse. These grouse do not get to reproduce.

Safety Precautions

Caution students that scissors may be sharp.

SUPPORTING DIVERSE STUDENT NEEDS

Visually impaired students will benefit from a verbal description of the activity set up and the observations. Gifted students may benefit from the opportunity to expand the activity or take it in different directions to explore the concepts of natural selection and evolution.

Answers to Analysis Questions

1. Colour, size, and number are three obvious characteristics that will vary within the population. There will likely be others, depending on the variation in the population.

2. (a) Male birds that reproduced were chosen on the basis of characteristics identified by the teacher. Students should list these characteristics. Females' selection of mates with specific traits, such as bright air sacs and long tail feathers, determined which male bird would reproduce.

(b) The next generation of males will look more like the males that reproduced than the population of males in the previous generation.

3. Traits suggested must all be apparent to the female grouse at the time of mate selection. These may include size, vigour, or type of dancing done by the male grouse—any specific phenotypic characteristic is acceptable.

4. If females choose the healthiest and strongest males as mates, the advantage would be that the males who reproduce are best suited to the environment, as long as the environment does not change. The population thus benefits by having a next generation that is well suited to the environment. The disadvantage is that some genetic diversity may be lost. Non-mating males may have alleles that are advantageous in other situations that are not passed to the next generation.

Assessment Options

- Collect and assess students' answers to Analysis questions.
- Use Assessment Checklist 3 Performance Task Self-Assessment from Appendix A.

19.1 The Hardy-Weinberg Principle

Student Textbook pages 678-688

Section Outcomes

Students will:
- define a gene pool as the sum of all the alleles for all the genes in a population
- describe the gene pool of a population at genetic equilibrium, as well as the molecular basis for gene pool change
- summarize the five conditions upon which the Hardy-Weinberg principle is based
- describe how the Hardy-Weinberg equation is used to determine whether a population is undergoing microevolution
- calculate allele and genotype frequencies in a population, as well as the number of individuals with specific genotypes, and interpret the data
- conduct an investigation to simulate gene pool change and analyze the data

Key Terms

population
genes
allele
gene pool
genotype frequency
phenotype frequency
allele frequency
Hardy-Weinberg principle
Hardy-Weinberg equation
genetic equilibrium
microevolution

Biology Background

- Populations consist of individuals, and individuals carry a variety of genes. Population genetics is the study of all the genetic variation contained in all the individuals of the population. This variation constitutes the gene pool of the population. Gene pools are not static but change from one generation to the next.
- Each gene locus in a population may have two or more forms referred to as alleles. The abundance of these alleles can be determined by using the Hardy-Weinberg principle, which consists of two equations, and a number of conditions that must be met in order for allele frequencies to remain constant over time.
- The first equation, $p + q = 1$, describes the situation where one gene has only two alleles; where p represents the frequency of the dominant allele, and q represents the frequency of the recessive allele. If there are only two forms of the gene, then the sum of the frequency of the dominant allele and the frequency of the recessive allele must be 1, or 100% of all the alleles in the population.

- The second equation represents what happens when all the males in the population (which would be $p + q$ for the males) mate with all the females in the population ($p + q$ for the females). Multiplying either in a Punnett square or as factors of a polynomial, the next generation's allele frequencies will be $p^2 + 2pq + q^2 + 1$. The term p^2 represents the frequency of homozygous dominant individuals; $2pq$ represents the frequency of heterozygous individuals; and q^2 represents the frequency of homozygous recessive individuals. The number of individuals in the population with each genotype can be calculated by multiplying the frequency by the size of the population. Hardy and Weinberg point out that the frequency of dominant alleles and the frequency of recessive alleles will not change, according to the mathematics, unless something external to the population causes them to.
- The conditions required for gene pool stability are: the population is large enough that chance events will not alter allele frequencies, mates are chosen on a random basis, there is no migration, there are no net mutations, and there is no natural selection against any of the phenotypes. When these conditions are met within a population, a state of genetic equilibrium exists.
- If allele frequencies are measured in two different generations of a population and the frequencies are different, one or more of the conditions required for genetic equilibrium are not met. Such populations may be undergoing natural selection. At the very least, their gene pool is changing.

Teaching Strategies

- Use a variety of characteristics, including some rare dominant traits, to establish the habit of looking for the recessive phenotype when initiating analyses with the Hardy-Weinberg equation.
- Have students create imaginary or alien traits that are inherited through simple dominance. Ask students to create practice problems by choosing different allele, genotype, or phenotype frequencies for the traits, and then exchange the problems with their classmates.
- Simplify some human phenotypic characteristics like hair colour into two forms (i.e., black vs. not black) and ask students to survey the frequency of alleles in the grad photos on the walls of your school and observe how these alleles change over time. Epicanthic folds of eyelids may also be fairly visible in grad photos.
- The sample problems on pages 682 and 683 have been converted into overhead masters to assist in teaching the process. See **BLMs 19.1.4** and **19.1.5**.
- In addition to BLMs supporting the activities in this section, a number of overhead masters and reinforcement activities have been prepared for this section. You will find them with the Chapter 19 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.

Number (Type)
19.1.1 (OH) Genotype Frequency, Phenotype Frequency, Allele Frequency
19.1.2 (OH) Hardy-Weinberg principle and Hardy-Weinberg equation
19.1.3 (OH) Punnett Squares to Determine Genotype Frequencies
19.1.4 (OH) Sample Problem 1: Albinism in a Snake Population
19.1.5 (OH) Sample Problem 2: Wing Length in Fruit Flies
19.1.7 (OH) Collared Pika: Change in Allele Frequency
19.1.9 (HAND) Populations in Hardy-Weinberg Equilibrium
19.1.9A (ANS) Populations in Hardy-Weinberg Equilibrium Answer Key

SUPPORTING DIVERSE STUDENT NEEDS

Students requiring extra help may benefit from modelling the movement of chromosomes during fertilization to show visibly how p and q combine to make the three genotypes p^2, $2pq$, and q^2. Because the vocabulary in this section is unfamiliar, contact your resource personnel well ahead of time with a list of terms that may prove problematic so that ESL students can be prepared properly. Alternately, read the text with ESL students, helping them with pronunciation and explaining terms as they come up. Gifted students may benefit from bonus work to increase either the depth or the breadth of their learning. Students may want to do an analysis of allele frequency in their family using characteristics from earlier lab work on human genetic traits.

Biology File: Try This

Student Textbook page 679

The phenotype frequency can be calculated by adding the genotype frequencies for *BB* and *Bb*. Check the calculation by counting all the black mice and dividing this value by the total number of mice.

Answers to Questions for Comprehension

Student Textbook page 680

Q1. A gene pool is made up of all the alleles of all the genes present in a population.

Q2. Genotype frequency is the proportion of a population with a given genotype. Phenotype frequency is the proportion of a population with a given phenotype. Allele frequency is the rate of occurrence of a particular allele in a population, with respect to a particular gene. Therefore, allele frequency contributes to genotype frequency and genotype frequency contributes to phenotype frequency. The three are different levels of scale for examining a population.

Student Textbook page 682

Q3. The five conditions of the Hardy-Weinberg principle are as follows:

1. The population is large enough that chance events will not alter allele frequencies
2. Mates are chosen on a random basis
3. There are no net mutations
4. There is no migration
5. There is no natural selection against any of the phenotypes

Q4. p is the frequency of the dominant allele of a gene locus. p^2 is the frequency of the homozygous dominant genotype in the population.

Q5. The frequency of heterozygotes in a population can be found by multiplying the frequency of the dominant allele by the frequency of the recessive allele and doubling the result ($2pq$).

Solutions to Practice Problems

Student Textbook page 683

1. Problem

Suppose that in a fruit fly population the frequency of the recessive allele that codes for short wings (*l*) is 0.30. What would be the expected genotype frequencies in the next generation?

What Is Required?

You must determine the values for p^2, $2pq$, and q^2, which represent the frequencies of the *LL*, *Ll*, and *ll* genotypes in the next generation, respectively.

What Is Given?

The frequency of the recessive allele (q) that codes for short wings (*l*) is 0.30.

$p + q = 1.00$

Plan Your Strategy

Subtract q from 1.00 to find the value of p.

Find the values of p^2, $2pq$, and q^2.

Act on Your Strategy

Step 1

$p + q = 1.00$

$p = 1.00 - q$

$p = 1.00 - 0.30$

$p = 0.70$

Step 2

$p^2 = (0.70)(0.70) = 0.49$

$2pq = 2(0.70)(0.30) = 0.42$

$q^2 = (0.30)(0.30) = 0.090$

Check Your Solution

$p^2 + 2pq + q^2 = 1.00$

$0.49 + 0.42 + 0.090 = 1.00$

$1.00 = 1.00$

2. Problem

In a pea plant population, the dominant allele for tallness (*T*) has a frequency of 0.64. What percent of the population would be expected to be heterozygous (*Tt*) for the height alleles?

What Is Required?

You must determine the value for $2pq$, which represents the frequency of the heterozygous (*Tt*) genotype in the population, and express this value as a percent.

What Is Given?

The frequency of the dominant allele (*T*) is 0.64.

$p + q = 1.00$

Plan Your Strategy

Subtract p from 1.00 to find the value of q.

Find the value of $2pq$.

Express the value of $2pq$ as a percent.

Act on Your Strategy

Step 1

$p + q = 1.00$

$q = 1.00 - p$

$q = 1.00 - 0.64$

$q = 0.36$

Step 2

$2pq = 2(0.64)(0.36) = 0.46$, or 46%

Check Your Solution

$p^2 + 2pq + q^2 = 1.00$

$(0.64)(0.64) + 0.46 + (0.36)(0.36) = 1.00$

$1.00 = 1.00$

3. Problem

In a randomly mating population of mice, 25.0 out of every 100.0 mice born have white fur, a recessive trait.

(a) Calculate the frequency of each allele in the population.

(b) Calculate the genotype frequencies for the population.

What Is Required?

You must determine the values for p and q, which represent the frequency of each allele in the population.

You must also determine the values for p^2, $2pq$, and q^2, which represent the frequencies of the genotypes in the population.

What Is Given?

The value of $q^2 = \frac{25.0}{100.0}$. This is the frequency of the recessive genotype in the population.

$p + q = 1.00$

Plan Your Strategy

Change the value of q^2 to a decimal.

Take the square root of the value of q^2 to find the value of q.

Subtract q from 1.00 to find the value of p.

Find the values of p^2, $2pq$, and q^2.

Act on Your Strategy

Step 1

$$q^2 = \frac{25.0}{100.0}$$

$$q^2 = 0.250$$

Step 2

$$\sqrt{q^2} = \sqrt{0.250}$$

$$q = 0.500$$

Step 3

$$p + q = 1.00$$

$$p = 1.00 - q$$

$$p = 1.00 - 0.500$$

$$p = 0.50$$

Step 4

$$p^2 = (0.50)(0.50) = 0.25$$

$$2pq = 2(0.50)(0.50) = 0.50$$

$$q^2 = (0.500)(0.500) = 0.250$$

Check Your Solution

$$p^2 + 2pq + q^2 = 1.00$$

$$0.25 + 0.50 + 0.250 = 1.00$$

$$1.00 = 1.00$$

4. Problem

A dominant allele, *T*, codes for the ability to taste the compound phenylthiocarbamide (PTC). People who are homozygous for the recessive allele, *t*, are unable to taste PTC. In a genetics class of 125 students, 88 students can taste PTC and 37 cannot.

(a) Calculate the expected frequencies of the *T* and *t* alleles in the student population.

(b) How many students would you expect to be heterozygous for the tasting gene?

(c) How many students would you expect to be homozygous dominant for the tasting gene?

(d) How could you check your answers for parts (b) and (c)?

What Is Required?

You must determine the values for p and q, which represent the expected frequencies of the *T* and *t* alleles in the student population.

You must also determine the values of $p^2(N)$ and $2pq(N)$, which represent the number of students that you would expect to be homozygous dominant and heterozygous for the tasting gene, respectively.

What Is Given?

The value of $q^2 = \frac{37}{125}$. This represents the proportion of homozygous recessive students (*tt*) in the class.

The total number of students in the class (N):
125 students

$p + q = 1.00$

Plan Your Strategy

Change the value of q^2 to a decimal.

Take the square root of the value of q^2 to find the value of q.

Subtract q from 1.00 to find the value of p.

Find the values of $p^2(N)$ and $2pq(N)$.

Act on Your Strategy

Step 1

$$q^2 = \frac{37}{125}$$

$$q^2 = 0.296$$

Step 2

$$\sqrt{q^2} = \sqrt{0.296}$$

$$q = 0.544$$

Step 3

$$p + q = 1.00$$

$$p = 1.00 - q$$

$$p = 1.00 - 0.544$$

$$p = 0.456$$

Step 4

$$p^2(N) = (0.456)(0.456)(125) = 25.9$$

$$2pq(N) = 2(0.456)(0.544)(125) = 62.0$$

Rounding off to the correct number of significant digits, $p = 0.46$ and $q = 0.54$. The number of students that you would expect to be heterozygous and homozygous dominant for the tasting gene are 62 and 26 students, respectively.

Check Your Solution

37 students + 62 students + 26 students = 125 students

125 students = 125 students

OR

$$p^2 + 2pq + q^2 = 1.00$$

$$(0.456)(0.456) + 2(0.456)(0.544) + 0.296 = 1.00$$

$$1.00 = 1.00$$

5. Problem

In the Caucasian population of North America, one out of every 10 000 babies is born with a recessive condition known as phenylketonuria (PKU). This condition is controlled by a single pair of alleles. People who are homozygous recessive for the PKU gene completely lack the enzyme that is necessary to metabolize the amino acid phenylalanine into harmless by-products. The presence of this amino acid in a baby's diet can slow the development of the baby's brain. What percentage of the Caucasian population of North America would you expect to be heterozygous for the PKU allele?

What Is Required?

You must determine $2pq$ and express it as a percent, which represents the percentage of the Caucasian population of North America expected to be heterozygous for the PKU allele.

What Is Given?

The value of $q^2 = \frac{1}{10\,000}$. This represents the proportion of the Caucasian population of North America born with PKU.

$p + q = 1.00$

Plan Your Strategy

Change the value of q^2 to a decimal.

Take the square root of the value of q^2 to find the value of q.

Subtract q from 1.00 to find the value of p.

Find the value $2pq$.

Express the value $2pq$ as a percent.

Act on Your Strategy

Step 1

$$q^2 = \frac{1}{10\,000}$$

$$q^2 = 0.0001$$

Step 2

$$\sqrt{q^2} = \sqrt{0.0001}$$

$$q = 0.01$$

Step 3

$$p + q = 1.00$$

$$p = 1.00 - q$$

$$p = 1.00 - 0.01$$

$$p = 0.99$$

Step 4

$2pq = 2(0.01)(0.99) = 0.0198$, or 1.98%

Rounding to the correct number of significant digits, 2% of the Caucasian population of North America is expected to be heterozygous for the PKU allele

Check Your Solution

$$p^2 + 2pq + q^2 = 1.00$$

$$(0.99)(0.99) + 2(0.01)(0.99) + 0.0001 = 1.00$$

$$1.00 = 1.00$$

Answer to Question for Comprehension

Student Textbook page 684

Q6. You can tell if a population is at genetic equilibrium if, from one generation to the next, allele frequencies do not change when calculated with the Hardy-Weinberg equation. More than one gene locus should be examined. You can tell if microevolution is occurring if the allele frequencies differ from one generation to the next and the four conditions of the Hardy-Weinberg principle not relating to natural selection have been tested and shown to be true.

Investigation 19.A: Applying the Hardy-Weinberg Equation

Student Textbook page 684

Purpose

Students will learn to apply the Hardy-Weinberg equation to analyze human genetic characteristics.

Outcomes

- 30-D1.3k
- 30-D1.1s
- 30-D1.3s

Advance Preparation

- Photocopy **BLM 19.1.6: Investigation 19.A**

Time Required

- 30 minutes to gather data on class member phenotypes of the traits being investigated
- 40 minutes to conduct the calculations and answer questions

Helpful Tips

- Use **BLM 19.1.6: Investigation 19.A** to support this activity. Modify as necessary.
- Use the list of traits shown on **BLM 19.1.6.** Modify as necessary.
- Caution the students to design a method of data record keeping before they start to collect the data.

SUPPORTING DIVERSE STUDENT NEEDS

Suggest that gifted students determine allele frequencies for a different set of people; parents, uncles and aunts, for example, to see if allele frequencies have changed over time. A helpful resource with information about human genetic traits is http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=OMIM

Answer to Analysis Question

1. Frequencies will vary from class to class. You may want to pick out one dominant allele frequency that is most abundant and one recessive allele frequency that is most abundant to drive home the idea that abundance does not mean a trait is dominant.

Answers to Conclusion Questions

2. The three genotypes will be homozygous dominant, heterozygous, and homozygous recessive. The frequencies of these three genotypes will vary from class to class.
3. This answer will depend on your students' perception of themselves and the North American population. Most likely, they will say their class results will not match those of the rest of North America, probably due to small sample size, or to the ethnic background of their particular class. They may alternately say that the results will match those of North America, in which case they will judge that their class is pretty representative of the rest of the population of North America.

Assessment Options

- Collect and assess students' answers to Analysis and Conclusion questions.

Answer to Question for Comprehension

Student Textbook page 685

Q7. The two equations based on the Hardy-Weinberg principle are used to measure allele frequencies in one generation and then again in another generation. If allele frequencies are different, there has been a change in the gene pool.

Investigation 19.B: Testing the Hardy-Weinberg Principle

Student Textbook pages 686-687

Purpose

Students will determine the effect of random mating on a large population, as well as the effect of a lethal recessive allele on allele frequencies in a large population.

Outcomes

- 30-D1.2k
- 30-D1.3k
- 30-D1.1s
- 30-D1.2s
- 30-D1.3s
- 30-D1.4s

Advance Preparation

When to Begin	What to Do
1 or 2 days before	■ Purchase sufficient dark-coloured beads for your class; 48 per group ■ Purchase sufficient light-coloured beads for your class; 32 per group ■ Purchase sufficient plastic cups (or similar containers) for your class; 2 per group Photocopy **BLM 19.1.8: Investigation 19.B**

Apparatus	Materials
none	■ dark-coloured beads ■ light-coloured beads ■ plastic cups (or similar containers)

Time Required

- 5 minutes to introduce lab objectives and distribute materials
- 40 minutes to complete Part A of the experiment, collect and record data, and clean up
- 20 minutes to pool data for Part A
- 40 minutes to complete Part B of the experiment, collect and record data, and clean up
- 20 minutes to pool data for Part B

Helpful Tips

- Use **BLM 19.1.8: Investigation 19.B** to support this activity. Modify as needed.
- This activity is best conducted on flat horizontal surfaces.

Answers to Analysis Questions

1. (a) The graph should have time interval (generations) on the x axis and genotype frequencies in decimals on the y axis (no units for the y axis). The graph should take up at least 3/4 of the graph paper. There should be a figure number and a caption or title on the graph. Points should be plotted with point protectors, and best fit lines drawn. Different shaped point protectors should distinguish the four different lines, and a key to the shapes should be provided. There should be a statement or two comparing the results as shown by the graph with the predicted results.

(b) The calculation of allele frequencies should be correct for the data obtained by the class. A statement or two making a comparison between the student's prediction and the pooled class allele frequencies should be provided. Ideally, the results should be fairly similar to the predicted outcome.

2. (a) The graph should have time interval (generations) on the x axis and genotype frequencies in decimals on the y axis (no units for the y axis). The graph should take up at least 3/4 of the graph paper. There should be a figure number and a caption or title on the graph. Points should be plotted with point protectors, and best fit lines drawn. Different shaped point protectors should distinguish the four different lines, and a key to the shapes should be provided. This graph should show a decrease in frequency of the recessive allele and an increase in the frequency of the dominant allele. There should be a statement or two comparing the results as shown by the graph with the predicted results.

(b) The calculation of allele frequencies should be correct for the data obtained by the class. There should be a statement or two making a comparison between the student's prediction and the pooled class allele frequencies. Ideally, the results should be fairly similar to the predicted outcome.

(c) The number of alleles will drop as the *LL* genotypes are removed. There will be an increasing effect as the number of alleles in the population continues to drop. This effect results in each individual allele contributing more to each generation than at the start of the experiment.

3. Pooling data from the class increases the size of the data set, and reduces the effects of chance occurrences. Pooling data also reduces the impact of sources of error (variation) on the outcome.

4. Assumptions include: no mortality for dominant phenotypes, no migration, no mutation, all gametes are used to make the next generation, each adult produces only two gametes. Of these, lack of mortality for dominant phenotypes, all gametes being used to make the next generation, and only two gametes formed by each parent are almost certainly false.

Answers to Conclusions Questions

5. Answers will depend on the allele frequencies observed. Changes should be minimal with allele frequencies varying around a constant value for each allele. Conditions of the Hardy-Weinberg principle are met with the exception of the size of the population. Even 80 alleles is a small population in genetics terms.

6. In Part 2, the frequency of the dominant allele should increase, and the frequency of the recessive allele should decrease. This is due to selection (not natural) against the recessive allele. The conditions required for the Hardy-Weinberg principle are not met here; selection is occurring, and the population gets smaller as the activity continues, which increases the effect of chance events and genetic drift.

Assessment Options

- Collect and assess students' answers to Analysis and Conclusion questions.
- Use Assessment Checklist 2 Laboratory Report from Appendix A for Part A.

Section 19.1 Review Answers

Student Textbook page 688

1. No, the frequency of the homozygous dominant genotype will not be the same as the frequency of the homozygous dominant trait. The homozygous dominant trait is the same as the homozygous dominant phenotype, and will include heterozygous individuals if the inheritance pattern is one of simple dominance. If the situation is one of co-dominance or incomplete dominance, then the frequency of homozygous dominant genotype and the frequency of the homozygous dominant phenotype will be the same.

2. This change may be caused when any of the conditions underlying the Hardy-Weinberg principle are not met, but does not indicate that the principle is false.

3. 1/3000 means $q = 0.0183$ and $p = 0.9817$. Thus the frequency of the cystic fibrosis allele in Canada is 0.0183. The frequency of heterozygotes is $2pq$, or 0.0359.

4. (a) $q = 0.20$. $p = 0.80$.

(b) $q = 0.20$ and $p = 0.80$ still.

(c) The frequency of the recessive allele in the second population is 0.435, which is higher than the recessive allele frequency in the first population. While it is possible that this came from the same population as the first sample, it is highly unlikely.

5. We will assume that PKU is a recessive trait. $q = 0.002899$ and $p = 0.9971$. Therefore the frequency of heterozygous individuals is $2pq(100)$ or 0.578 %

6. $q = 0.3873$, and $p = 0.6127$ so the percentage of heterozygous individuals is $2pq(100)$ or 47.5%.

7. (a) The presence of chlorophyll is indicated by a green colour, so having chlorophyll would be the dominant phenotype. Hence $q = 0.250$ and $p = 0.750$. The frequency of homozygous dominant genotype would be p^2 or 0.563.

(b) Carriers would be heterozygotes; frequency is $2pq$. $2pq = 0.375$.

8. (a) Because allele frequencies have changed in the population over time, one or more of the conditions for genetic equilibrium were not being met and evolution occurred. However, because the frequency of the recessive allele has been the same for many successive generations, the population has again achieved genetic equilibrium and is no longer evolving.

(b) The frequency of the recessive allele was stable for the first two generations, then increased dramatically between the second and third generations, then remained stable at this new higher frequency for the next seven generations. Possible hypotheses for this frequency pattern include sudden selection against the dominant allele by a predator, disease, or environmental conditions; and because the population is small, a chance event may have altered the gene pool.

19.2 The Causes of Gene Pool Change

Student Textbook pages 689-698

Section Outcomes

Students will:

- outline the conditions that are required in order to maintain genetic equilibrium in a population
- identify and compare the effects of mutations, gene flow, non-random mating, and genetic drift on gene pool diversity
- apply, quantitatively, the Hardy-Weinberg principle to published data, and infer the significance of your results
- distinguish between the founder effect and the bottleneck effect on gene pools
- explain how the process of natural selection is related to the microevolution of a population
- explain the cause of heterozygote advantage and how it affects a gene pool
- describe strategies that are used in captive breeding and population management
- explain that genetic engineering may have both intended and unintended effects on gene pools

Key Terms

genetic diversity
mutation
gene flow
non-random mating
genetic drift
founder effect
bottleneck effect
natural selection
heterozygote advantage

Biology Background

- Five causes of evolutionary change are identified: gene flow, non-random mating, genetic drift, mutation, and natural selection.
- Mutations are changes in the DNA base sequence in an individual. Only mutations that occur in gametes are inheritable and can change gene pools. Many mutations are harmful, some are neutral, and a few are beneficial. Any mutation that is retained in the gene pool increases genetic diversity in the population.
- Gene flow describes the net movement of alleles from one population to another. Arrival of new alleles in a population through migration of individuals increases genetic diversity within that population. Genetic diversity in the population losing the allele would decrease only if the individual that left contains the only allele of that type in the population. Genetic diversity between populations decreases with migration.
- Non-random mating occurs in a population when individuals choose their own mates based on certain traits. Individuals with visible favourable traits will have a greater chance of mating than individuals without those traits. The offspring of the next generation will tend to have more of the favourable traits than the previous generation, and some individuals will not have the opportunity to pass on their genes. Mate preference leads to sexual selection and inbreeding or out breeding, depending on the circumstances. Inbreeding leads to increased expression of recessive alleles in the population.
- Genetic drift describes the situation where chance events and encounters determine who mates and who doesn't. Genetic drift has a greater impact on the gene pool of smaller populations than of larger ones. The result of genetic drift is loss of genetic diversity, particularly heterozygosity. Genetic drift is linked with both the founder effect and the bottleneck effect in reducing genetic diversity.
- The founder effect describes the situation where only a few dispersing individuals colonize a new habitat. These individuals initially carry only a small portion of the gene pool of the parent population and may not be typical of the original population. A new population that looks different from the original population results, with a different gene pool.
- The bottleneck effect describes changes in genetic diversity that occur because a large population has undergone a severe drop in population, almost extinction, but then is able to recover to former population levels. The individuals that survive the population crash do not contain all the genetic diversity of the initial larger population. As a result, the new population that develops from the survivors does not have the same genetic diversity of the initial population. Often, the survivors are atypical of the original population, so the population after the bottleneck is quite different from the ancestral population.
- Natural selection results in adaptation to a changing environment. Some individuals are better suited to survival and reproduction than others. They make a larger contribution to the next generation's alleles, and the allele frequencies change. The environment determines the value of mutations. A particular mutation may be unfavourable in some environmental circumstances, but beneficial in others. Sexual selection is a special form of natural

selection where mate preferences drive some of the changes in genotype.

- Human activities affect the genetic diversity of populations. Hunting and habitat destruction reduce genetic diversity, and activities like dam building and industrial development fragment habitat, limiting gene flow between isolated populations. Human transport of individuals from one location to another can increase genetic diversity within populations.

Teaching Strategies

- Use **BLM 19.2.1: Agents of Evolutionary Change** to support your presentation of the topic.
- Once students understand how to use the Hardy-Weinberg equation, take them to a nearby college or university library to find examples of the use of the equation in publications.
- Use the *Red Book of Endangered Species*, or some other source of information about endangered species to assign a species to each student. Have them research the history of the species, and describe how the processes studied in this section apply to their particular species.
- As genetic research has become more sophisticated, scientific interest in founder communities has grown. Use **BLM 19.2.4** to spark a discussion about the ethical considerations involved in exploiting the situation of a founder community.
- In addition to BLMs supporting the activities, two overhead masters and a handout have been prepared for this section. You will find them with the Chapter 19 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.
  Number (Type)
  19.2.1 (OH) Agents of Evolutionary Change
  19.2.3 (OH) Genetic Drift in Roses
  19.2.4 (HAND) Scientific Interest in Founder Communities

SUPPORTING DIVERSE STUDENT NEEDS

- Challenge gifted students to make a difference for an animal or plant that is endangered. This may include letter writing, raising money, or creating works that can be published or displayed, to raise awareness of the plight of the species. Artistically gifted students may enjoy cartooning or writing poetry or songs about one of the processes studied in this section. Students who need extra help may benefit from constructing a self-help booklet with more opportunities to practice each step before adding further steps in the analysis of conditions affecting genetic equilibrium. Pay particular attention to differences in starting points and ending points to help students develop an ability to recognize when Hardy-Weinberg equilibrium conditions are not met.
- Allow ESL students to focus on species they are familiar with from their native lands. Ask students to investigate one of these species in order to reduce the unfamiliarity of the concepts and processes.

Answer to Question for Comprehension

Student Textbook page 689

Q8. The conditions of the Hardy-Weinberg principle describe conditions that must be met for equilibrium to occur. If allele frequencies are seen to change, then the conditions cannot all be met, and the gene pool will change.

Biology File: Web Link

Student Textbook page 690

Regardless of their conclusions, students' responses should likely include reference to:

- the role of the CCR5 gene in the development of HIV (CCR5 is the gene that codes for the chemokine receptor that HIV-1 uses to enter cells)
- the CCR5 $\Delta 32$ HIV-Resistance Allele and its role in the blocking development of HIV
- how the allele could have been /is being selected for in populations that are experiencing high rates of HIV infection (the high number of deaths of those without resistance to HIV, particularly in the age groups most likely to produce offspring, will reduce the number of people who are most susceptible)
- how the CCR5 $\Delta 32$ allele could have been selected for in history and some evidence for its selection (including reference to the bubonic plague (Black Death) and various smallpox outbreaks

Answer to Question for Comprehension

Student Textbook page 691

Q9. A mutation may create an allele that didn't exist in the population before. This new allele, if maintained in the population, increases genetic diversity by adding something that wasn't there before.

Figure 19.10

Student Textbook page 691

With a great deal of movement, gene flow becomes significant. With significant gene flow, population boundaries become blurred. Genetic markers cannot be used to distinguish populations, nor can differences in allele frequencies. Due to the large size of wolf territories, considerable time and resources are required to establish reasonable population boundaries.

Answers to Questions for Comprehension

Student Textbook page 691

Q10. If gene flow brings in alleles that are in different proportion to existing frequencies, the ratio of alleles in the gene pool will change. If gene flow brings alleles into the population that don't already exist there, the diversity of the gene pool will increase.

Q11. The two basic situations that result in gene flow are immigration and emigration; but anything that causes these, like deliberate or accidental human introduction, would also cause changes to the gene pool.

Biology File: Web Link

Student Textbook page 691

The preservation of mountain corridors is key to ensuring that gene flow continues to happen. Young males in particular are able to move freely from one territory to another in search of mates, and this breeding will ensure genetic diversity throughout the populations in the whole Yukon to Yellowstone region.

Students may also note that the alternative—the reduction of territories to small pockets—would reduce the genetic diversity of each isolated population, making each one of them more vulnerable to disease and parasites and increasing the threats to the population's survival. It would have an effect similar to the bottleneck effect, which they will study on page 694.

Thought Lab 19.1: The Spirit Bear

Student Textbook page 692

Purpose

Students will expand their understanding of the Hardy-Weinberg equation and apply that understanding to new situations.

Outcomes

- 30-D1.2k
- 30D-1.3k
- 30-D1.2sts
- 20-C2.1sts

Advance Preparation

- Photocopy **BLM 19.2.2: Thought Lab 19.1**

Time Required

- 30 minutes

Helpful Tips

- Use **BLM 19.2.2 Thought Lab 19.1** to support this activity. Modify as needed.
- This activity could be done as an individual activity to determine students' level of proficiency, or in pairs as a way of solidifying understanding of the Hardy-Weinberg equation.

Answers to Analysis Questions

1. **(a)** The frequency of the recessive allele on Gribbell Island in 0.548 (0.5 to correct significant digits). Students may choose their own notation for the recessive and dominant alleles.

   (b) The frequency of the recessive allele on Princess Royal Island is 0.316 (0.3 to correct significant digits). Students should use the same allele notation as in part (a) because they are dealing with the same allele system for coat colour.
2. **(a)** The heterozygote frequency on Gribbell Island is 0.495 (0.5 to correct significant digits).

   (b) The heterozygote frequency on Princess Royal Island is 0.432 (0.4 to correct significant digits).
3. There are a few correct answers. First, the populations may be small (we have no information otherwise) so genetic drift may be acting in the two populations. Because genetic drift is random, we cannot expect the same allele frequencies in two populations undergoing this process. It is also possible that there are different selection pressures on the two islands, with selection on Gribbell Island tending to favour the white allele more than on Princess Royal Island. Based on the conditions required for genetic equilibrium, students could also say that white bears tend to migrate from Princess Royal Island to Gribbell Island more than the other way around.
4. Inland black bear populations would have lower frequencies of the white coat allele. If these bears migrate into the coastal bears' territory and mate with the coastal bears, the frequency of the recessive white coat allele will decrease as result.
5. If white bears tend to select white bears for mating, the rarity of white bears would reduce the intrinsic rate of growth in bear populations making them more susceptible to genetic changes due to chance events, and to extinction from disease or predators. If black bears tend to select black bears for mating, there is a risk that the white coat allele will disappear from the bear population.

Assessment Options

- Collect and assess students' answers to Analysis questions.
- Use Assessment Checklist 4 Performance Task Group Assessment from Appendix A if the work was done in pairs.

Answers to Questions for Comprehension

Student Textbook page 693

Q12. Non-random mating refers to males or females having choice in accepting a mate. Most animal populations have some form of mate choice so most are mating in a non-random manner.

Q13. Effects may include selection of specific phenotypes, change in allele frequency, elimination of harmful alleles, hybrid vigour, or elimination of harmful alleles.

Biology File: Web Link

Student Textbook page 693

One possible explanation for the loss of genetic diversity was recorded early in the 20th Century:

During two weeks in 1922 one hunting party bagged seven adult lions and badly wounded another three. The last expedition was in 1924, when five more lions were killed. Considering that there are never more than about 30 adult lions in the crater and that most of the wounded animals probably died as well, the breeding population must have been severely reduced.

As well, increased human habitation around Africa's national parks has formed virtually impermeable boundaries, and recently many species have become isolated in small populations, making them even more vulnerable to environmental catastrophe. Add to this the effects of close inbreeding, and many small populations may well be caught in a downward spiral.

Answers to Questions for Comprehension

Student Textbook page 694

Q14. There is an increased likelihood of chance events affecting allele frequencies in small populations.

Q15. The founder effect results when a small population of individuals colonizes a new habitat. They don't carry the entire gene pool of the original population, so some of the alleles are missing. The result can be adoption of a different phenotype, speciation, increased risk of genetically-based health problems, increase in frequency of rare alleles, or a reduction in genetic diversity.

Q16. The founder effect causes increased inbreeding because there are fewer choices of mates in the new habitat since the population is small.

Q17. Situations that result in the bottleneck effect include population decrease due to disease, starvation, human interference including over-hunting, natural disasters, climate change, and dispersal to new habitat. Students can choose any three.

Figure 19.14

Student Textbook page 695

Lack of genetic variation makes the entire population more susceptible to disease, predation, parasitism, and climate change. It will take a long time for genetic diversity to increase to a level similar to what it might have been before the over-hunting.

Answers to Questions for Comprehension

Student Textbook page 695

Q18. Mutations are changes in the DNA base sequence. Natural selection is the process that results in genetic combinations that are most suitable for survival and increased reproduction being retained in a population. Thus mutations provide the variations that the environment can act upon, resulting in natural selection.

Q19. Habitat fragmentation leads to decreased gene flow, and thus reduced genetic diversity within a population. It will also result in increased genetic diversity between or among populations. With fragmented populations, there is an increased impact of random genetic drift.

Student Textbook page 696

Q20. Reduced genetic diversity decreases the species ability to withstand changes in the environment, like global warming. Decreased species diversity results in instability of ecosystems and more difficulty conserving communities.

Thought Lab 19.2: Maintaining Genetic Diversity in the Whooping Crane

Student Textbook page 696

Purpose

Students will describe factors that affect the genetic diversity of a species, and the value of captive breeding programs.

Outcomes

- 30-D1.2k
- 30-D1.1s
- 30-D1.2s
- ICT

Advance Preparation

When to Begin	What to Do
at least 1 day in advance	■ Book time with computer resources in the school ■ Photocopy **BLM 19.2.5: Thought Lab 19.2**

Time Required

- 45 minutes to log on and locate web resources, and to answer questions

Helpful Tips

- Use **BLM 19.2.5: Thought Lab 19.2** to support this activity. Modify as necessary.
- You may wish to provide students with a few web sites that you consider reliable in order to reduce search time.

SUPPORTING DIVERSE STUDENT NEEDS

Among gifted students, you may find one or two who are really interested in wildlife rescue programs. Encourage them to volunteer at a local wildlife rehabilitation centre, or to fundraise for one of the ongoing rescue operations. In many cultures, cranes are highly revered. Students with such cultural backgrounds could be asked to research one of the endangered crane species from other parts of the world and design a rescue program for that species.

Answers to Analysis Questions

1. Genetic diversity would be low compared to the genetic diversity in the crane population in the 1700s or 1800s. The cranes have undergone a bottleneck, probably accompanied by genetic drift, both of which lower genetic diversity.
2. Pair bonding would increase the effort needed to establish a captive breeding program because you could not catch just any two cranes to start the program. You would have to capture both members of a bonded pair, which would be a bit difficult without seeing them at the nest. Likewise, if one member of a pair dies in captivity, the other adult is no longer of use in the program. Effectively, its genetic makeup is removed from the gene pool.
3. Conservationists could not identify which cranes are more likely to be successful unless the environmental tolerances of the genetic information are identified. However, low genetic diversity would lead conservation officers to be concerned about the crane population's ability to survive in the wild should the environment change.
4. Whooping cranes raised as sandhill cranes probably think they are sandhill cranes. They would learn the sandhill crane's mating rituals, for example, but might only be able to respond to the rituals of whooping cranes. Alternatively, they may choose sandhill cranes as prospective mates.
5. Effective techniques include protecting the wild breeding sites, removing predators from the wild breeding sites, banning interference with crane migrations, banning hunting of whooping cranes, and storing eggs and sperm of whooping cranes for future programs. Students should explain their chosen method. The explanation should indicate how the method works and the impact of the action on the population of the cranes.

Answers to Extension Questions

6. A gene bank is a term used to describe the storage of biological tissue for later use in reconstructing a species that is currently on the brink of extinction, or for storage of genetic diversity in agriculturally important species where the farming practices have reduced the varieties currently in production. Gene banks are a last resort for the preservation of a species. For many animals, we lack the technology to use the tissues to create individuals. We store the tissue in the hope that some time in the future we will learn how to successfully use it. For agricultural purposes, gene banks are an important and successful way of retaining genetic diversity that is in the process of being lost by farming and production practices.
7. The question is plural, so students should list at least two methods. Eggs are collected from wild nests. Breeders can take the first and second eggs laid, and the pair will lay a third. Eggs are incubated in separate locations to reduce the impact of disease on the hatchlings. Hatchlings are imprinted with hand puppets so they grow up thinking they are whooping cranes. Technologies should be identified and described.

Assessment Options

- Collect and assess students' answers to Analysis and Extension questions.
- Use Assessment Checklist 2 Laboratory Report from Appendix A to evaluate the experiment.
- Use Assessment Checklist 3 Performance Task Self-Assessment from Appendix A to evaluate the manipulative and interactive skills of the students.

Biology File: Web Link

Student Textbook page 697

Many students may have heard of Canadian Bill Lishman and Operation Migration. Lishman pioneered the use of ultralight aircraft to take part in formation flights of Canada geese in 1988. In the fall of 1992, Lishman and his research were tapped to find out if birds could learn migration routes from airplanes—the scientists' goal was to train a flock of whooping cranes. Early migration experiments were done with non-endangered Canada geese. In 1993 the first migration experiment successfully raised and led 18 Canada geese nearly 650 kilometres from Ontario to Virginia; the birds returned to Ontario on their own in the spring of 1994. Since then numerous migration studies have been done with three species of birds, and over 40 whooping cranes now migrate in eastern North America, thanks to the efforts of Operation Migration and its partners.

Operation Migration uses the "imprinting" technique, ensuring that newly hatched chicks bond with the aircraft as a surrogate parent and learn to fly with the plane.

Section 19.2: Review Answers

Student Textbook page 697

1. The table should have a table number and caption, and should be defined by straight lines. An example is given below.

Conditions	Outcome
population size is large	■ genetic drift ■ reduced genetic diversity
random mating occurs	■ selection ■ changes in allele frequency
no mutations	■ genetic drift ■ changes in allele frequency
no migration	■ increased genetic diversity within population ■ reduced genetic diversity between populations
no natural selection	■ changes in allele frequency ■ microevolution

Sample caption: Table 1. The conditions required for genetic equilibrium to exist, and what happens if these conditions are not met.

2. Mutations lead to increased genetic diversity and may be useful when the environment changes, or when new environments are colonized. Some mutations will result in increased fitness, and some will take predation pressure off other individuals.
3. Decreased genetic diversity in the population they come from, and increased genetic diversity in the population they are going to would result. If the migrants establish a new population, they will contribute all the genetic diversity of the new population.
4. In the founder effect, a small subset of the original population emigrates to a new habitat. The bottleneck effect describes the situation that occurs when a large population crashes, and a small subset of the original population re-establishes the population. The two effects are similar in that they both involve a small population with limited genetic diversity, resulting in a new population that is different from the original population and has a gene pool of low genetic diversity. The two effects differ as follows: the founder effect involves colonizing a new habitat, but the bottleneck effect occurs in the original population; the founder effect retains the original population, resulting in two populations, while the bottleneck effect modifies the original population and only one population results; and the founder effect may lead to the creation of two species, thereby increasing biodiversity, while the bottleneck effect will result in a single new species.
5. Due to a lack of genetic diversity, the population is unable to respond to environmental changes or to withstand disease. Allowing the population size to increase over time by protecting the cheetahs' habitat can increase genetic diversity. This can be done by establishing a wildlife reserve, reducing interspecific competition for prey, decreasing environmental threats such as pollution in their habitat, reducing habitat fragmentation, etc.
6. If the heterozygotes have an advantage (i.e., protection from malaria) over both homozygotes, a lethal recessive allele will remain in the population. This is called heterozygote advantage.
7. Inbreeding leads to a loss of genetic diversity and expression of rare recessive traits in a population. Neither of these leads to new characteristics, and therefore, inbreeding is not likely to lead to evolutionary adaptation.
8. Anti-HIV medications impede microevolution of the virus because, by reducing its rate of reproduction, fewer new mutations are generated per unit of time. As a result, selection pressures have fewer new variants to select for in a changing environment and microevolution is impeded.

Connections (Social and Environmental Contexts) Biotechnology and Gene Pools

Student Textbook page 698

Teaching Strategies

- As students consider the practical implications (e.g., the Cavendish banana) and the ethical implications (e.g., creating sterile seed and forcing farmers to remain as life-long customers) of manipulating nature, remind them that it was this kind of experimentation and manipulation that led to the development of a strain of wheat that could be grown successfully in the Canadian prairies. What do they think of biotechnology in terms of what it can provide for humans? Do they think it should be regulated?

Answers to Connections Questions

1. Transgenic organisms would only be classified as a new species if the transgenic organism could no longer interbreed with the original species to produce viable offspring.
2. If genetic engineers included a gene that either prevented successful reproduction among transgenic organisms, or prevented them from breeding with wild populations, gene flow into wild populations would be substantially reduced. This would not work for microorganisms that reproduce sexually.
3. The release of transgenic organisms into wild populations may alter the gene pool of the wild populations if the organisms interbreed and the genetically engineered genes become incorporated into the wild population's genome.

The genetically engineered genes may affect the wild population by reducing its ability to compete, or by increasing it.

4. Benefits include being able to reproduce large numbers of the endangered species and release them into the wild, to develop a breeding program without needing to capture members of the species, retaining biodiversity and ecosystem stability, and to gain new scientific knowledge about the species. Disadvantages include possible suffering of animals that don't survive to adulthood, loss of focus on wildlife conservation programs, cost, and the possibility that the cloned individuals will not be as fit as their counterparts. Students may also raise the possibility that technology may advance to the stage where cloning may be used for human reproduction. This may be viewed as either a benefit or disadvantage by the students, depending on their reasoning.

Chapter 19: Review Answers

Student Textbook pages 700–701

Answers to Understanding Concepts Questions

1. There are two perspectives possible for answering this question. Students may answer no, stating that microevolution is the gradual change in allele frequencies in a population. As such, a single mutation in one organism does not constitute microevolution. A mutation must be spread through the population to be microevolution. Conversely, students may answer yes, a new mutation alters allele frequencies and would thus be microevolution.

2. $B = 0.70$, $b = 0.30$.

Frequency of heterozygotes $= 2Bb = 0.42$.

3. $q = 0.40$.

$p = 1 - q = 1 - 0.40 = 0.60$

4. Percentage of heterozygotes $= 2pq(100)$.

$q = 0.332$, $p = 1 - q = 0.668$.

$2pq(100) = 44\%$.

Percentage of homozygous dominants = 100% – 44% – 11% = 45%

5. (a) $q = 0.37$ and $p = 0.63$

(b) Predicted number of each genotype: $YY = 176$, $Yy = 152$ and $yy = 72$

6. $q = 0.40$, $p^2 = 0.36$, $q^2 = 0.16$ and $2pq = 0.48$.

7. In small populations, chance events or encounters govern mate choice more frequently than mate preferences. These random encounters drive genetic drift.

8. Genetic drift may allow the expression of rare recessive alleles or traits due to random mating. Gene flow refers to movement of alleles from one population to another due to migration. It is conceivable that gene flow could result in the abundance of a genetic health problem if individuals with the problem migrated to the same place. This is highly unlikely, so the most probable cause would be genetic drift.

9. (a) Population 1: $q = 0.0316$, $p = 0.9684$. $2pq = 0.0612$

Population 2: $q = 0.0548$, $p = 0.9452$. $2pq = 0.104$.

(b) Population 2 is most likely to be from Africa because it has a higher rate of heterozygosity.

(c) Homozygotes for the dominant allele die from malaria. Homozygotes for the recessive allele die from sickle cell anemia. Heterozygotes have some immunity to malaria, and do not get sickle cell anemia, so they have a selective advantage over the homozygotes. Hence, they will be more common. This is called heterozygote advantage.

Answers to Applying Concepts Questions

10. (a) In 1998: 170 allele: 0.800. 172 allele: 0.200.

(b) In 2005: 170 allele: 0.890. 172 allele: 0.110.

(c) The population does not appear to be in genetic equilibrium since the frequencies appear to have changed.

(d) If the 172 allele is recessive, it could remain in the population in heterozygotes, and be hidden. If the heterozygotes are relatively rare, the allele will not be commonly expressed because that would require two heterozygotes to mate, which would rarely happen. If the allele is hidden, it cannot be selected for or against.

(e) Declining populations of the collard pika would result in genetic drift, which may be part of a population bottleneck. Either way, the result would be loss of genetic diversity, and a reduced ability to cope with environmental change.

11. (a) $q = 0.447$, $p = 0.553$.

(b) The percentage of heterozygotes would be $2pq(100) = 49.9\%$.

(c) In the published data, $q = 0.800$, which is much higher.

(d) Some possible answers include increasing the sample size and removing or tagging observed squirrels to prevent counting them twice.

(e) Differences are probably due to a different habitat with different selection pressures. Other possibilities could include genetic drift in one of the populations if it is small, and the founder effect if a population is established by fewer than 100 individuals. Counting errors are another possibility.

12. (a) $M = 0.560$; $N = 0.440$.

(b) $MM = 0.314$; $MN = 0.493$; $NN = 0.194$

(c) In the new colony, as time passes, genetic drift should reduce genetic diversity. Eventually, the population would become all *MM* or all *NN*.

13. (a) $q = 0.0500$ or 5.00%

(b) Carriers are heterozygotes, so students need to find $2pq$.

$p = 1 - 0.0500 = 0.950$.

$2pq = 9.50\%$.

(c) Inbreeding often increases the frequency of heterozygotes mating and so would tend to increase the frequency of recessive alleles.

14. $q = 0.200$ or 20%.

15. Natural selection is a process that results in a change in allele frequencies due to differential reproduction among the members of a population. Genetic drift is a change in allele frequencies due to random chance mating events in a population. Similarities include the following: both occur in populations, both describe changes in allele frequencies, and both result in changes in genotype and phenotype. Differences include the following: natural selection increases adaptiveness, genetic drift doesn't; population size in natural selection is not relevant, but in genetic drift the population must be small; natural selection is not chance driven, but genetic drift is.

16.

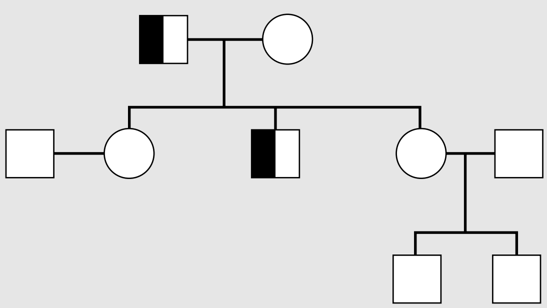


Figure 1

The pedigree must obey the rules of drawing pedigrees. Males are depicted as squares, females as circles. Carriers are vertically half black. Afflicted individuals are all black. Mates are connected with a horizontal line. Offspring of a mating pair are indicated with a short vertical line connected to a horizontal line that connects to all the biological offspring of the mating pair. This pedigree should show heterozygotes in the first generation (generation I) and no heterozygotes in the last generation. See Figure 1 for an example.

Answers to Making Connections Questions

17. Genetic analysis would provide data regarding the bears that were successfully reproducing in specific regions, allowing scientists to identify the best habitat for polar bears. Such habitats could be identified and recolonized with bears bred in captivity. Sperm and eggs from successful bears could be extracted and used to impregnate captive bears, or the successful males could be exposed to more females than normally through transportation programs. The decline in population suggests that the bears might be entering a population bottleneck. Alternatively, they could be undergoing some form of natural selection. Other processes at work might be extinction or extirpation as climate changes. The population is too large for genetic drift to have much effect on the bear population.

18. (a) $q_{ch} = 0.00250$; $q_{tk} = 0.0196$; $q_{j} = 0.00290$.

(b) The toxin producing fungi would be most abundant in Turkey because there would be more advantage for heterozygous individuals. Thus, the frequency of heterozygotes would be highest there, which means the allele frequency would also be the highest.

19. If the afflicted people reproduce, the allele frequency will increase, which would increase the frequency of the affliction.

20. Students should define evolution in a biologically acceptable way. Their evaluation of Tshetverikov's statement should be based on their definition of evolution. One example would be that evolution is any change in allele frequency in a population. A mutation changes allele frequency, so any mutation is evolution. Tshetverikov's statement is incorrect. Another example would be that evolution is the result of survival of the fittest. The mutation would have to be acted on by the environment for evolution to occur, so Tshetverikov's statement is correct. Students' answers should be evaluated based on their reasoning.

CHAPTER 20 POPULATION GROWTH AND INTERACTIONS

Curriculum Correlation

General Outcome 2: Students will explain the interaction of individuals in populations with each other and members of other populations.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–D2.1k describe the basis of species interactions and symbiotic relationships and their influences on population changes, i.e., ■ predator-prey and producer-consumer relationships	Section 20.2: Producer-Consumer Interactions, p. 717 Defences Against Consumers, p. 720	Questions for Comprehension: 19, 20, p. 720 21, 22, p. 721 Section 20.2 Review: 2, p. 728 Chapter 20 Review: 11,12, p. 738 Chapter 20 Test
■ symbiotic relationships: commensalism, mutualism and parasitism	Launch Lab: Reproductive Strategies and Population Growth, p. 701 Section 20.2: Symbiotic Relationships, p. 721 Mutualism, p. 721 Commensalism, p.722 Parasitism, p. 722	Launch Lab, p. 701 Questions for Comprehension: 23–26, p. 723 Section 20.2 Review: 4, p. 728 Chapter 20 Review: 6, 18, p. 738 Chapter 20 Test
■ interspecific and intraspecific competition	Section 20.2: Intraspecific Competition, p. 715 Interspecific Competition, p. 716 Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, p. 722 Thought Lab 20.4: Biological Control or Damage Control? p. 722	Questions for Comprehension: 16–18, p. 717 Investigation 20.A: Analysis, Conclusions p. 718–719 Thought Lab 20. 4: Analysis, Extension, p. 730 Section 20.2 Review: 1, 3, p. 728 Chapter 20 Review: 2, 10, p. 738 Chapter 20 Test Unit 8 Review: 4, 15, p. 742–743
30–D2.2k explain the role of defense mechanisms in predation and competition, e.g., *mimicry, protective coloration, toxins, behaviour*	Section 20.2 Defences Against Consumers, p. 720	Questions for Comprehension: 21, 22, p.721 Section 20.2 Review: 2, 3, p. 728 Chapter 20 Test Unit 8 Review: 14, 15, p. 743
30–D2.3k explain how mixtures of populations that define communities may change over time or remain as a climax community, i.e., primary succession, secondary succession.	Section 20.2: Succession: Community Change over Time, p. 723 Disturbing Events, p. 724 Investigation 20.B: Celebrate the Small Successions, p. 725 Thought Lab 20.3: Testing the Classical Model of Succession, p. 727	Questions for Comprehension: 27, 28, p. 726 Investigation 20.B: Analysis, Conclusions, p. 725 Thought Lab 20.3: Analysis, Extension, p. 727 Section 20.2 Review: 5, 6, p. 728 Chapter 20 Review: 20, p. 739 Chapter 20 Test Unit 8 Review: 17, 33, p. 745

	Student Textbook	Assessment Options
Outcomes for Science, Technology, and Society (Emphasis on social and environmental; contexts)		
30–D2.1sts explain why Canadian society supports scientific research and technological development that helps achieve a sustainable society, economy and environment by ■ *discussing public support of scientific work done on predator-prey relationships as part of wildlife management in national and provincial parks, e.g., introduction of wolves*	Thought Lab 20.4: Biological Control or Damage Control? p. 728 Connections—Social and Environmental Contexts: Helping Hippos and Humans, p. 735 Career Focus—Ask a Science Journalist, p. 740	Questions for Comprehension: 29, p. 729 Thought Lab 20. 4: Analysis, Extension, p. 728 Connections—Social and Environmental Contexts, p. 735 Career Focus:1–3, p. 741 Unit 8 Review: e.g., 34, p. 745
■ *assessing the long-term implications of fire control and prevention on population and ecosystem stability, diversity and productivity*	Thought Lab 20.3: Testing the Classical Model of Succession, p. 727 Connections—Social and Environmental Contexts: Helping Hippos and Humans, p. 736	Thought Lab 20.3: Analysis, Extension, p. 727 Connections—Social and Environmental Contexts, 1–4, p. 736 Unit 8 Review: e.g., 34, p. 745
■ *assessing the impact of parasites on humans and how this impact could be reduced*	Thought Lab 20.4: Biological Control or Damage Control? p. 730	Thought Lab 20. 4: Analysis, Extension, p. 730
Skill Outcomes		
Initiating and Planning		
30–D2.1s ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues by ■ *planning an investigation of species interaction in a national park or wilderness area*	Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, p. 718 Thought Lab 20.3: Testing the Classical Model of Succession, p. 727 Thought Lab 20.4: Biological Control or Damage Control? p. 730 e.g. Connections: Social and Environmental Contexts: Helping Hippos and Humans, p. 736 Career Focus: Ask a Science Journalist, p. 740	Investigation 20.A: Analysis, Conclusions p. 718–719 Thought Lab 20.3, p. 727 Thought Lab 20.4, p. 730 e.g. Connections: Social and Environmental Contexts: p. 736 Career Focus:1–3, p. 741 Unit 8 Review: e.g., 34, p. 745
Performing and Recording		
30–D2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by ■ designing and performing an experiment or simulation to demonstrate interspecific and intraspecific competition	Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, p. 718 Investigation 20.B: Celebrate the Small Successions, p. 725 e.g., Thought Lab 20.3: Testing the Classical Model of Succession, p. 727	Investigation 20.A: Analysis, Conclusions p. 718–719 Investigation 20.B: Analysis, Conclusions, p. 725 e.g., Thought Lab 20.3, p. 727
■ designing and performing an experiment to demonstrate succession in a microenvironment and record its pattern of succession over time, e.g., *hay infusion*	Investigation 20.B: Celebrate the Small Successions, p. 725	Investigation 20.B: Analysis, Conclusions, p. 725
■ performing simulations to investigate relationships between predators and their prey, e.g., *computer simulation, role playing*	Section 20.2: Producer-Consumer Interactions, p. 717 Thought Lab 20.4: Biological Control or Damage Control? p. 730	Thought Lab 20.4, p. 730

	Student Textbook	Assessment Options
Analyzing and Interpreting		
30–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ summarizing and evaluating a symbiotic relationship	Launch Lab: Reproductive Strategies and Population Growth, p. 701 Section 20.2: Symbiotic Relationships, p. 719	Launch Lab, p. 701 Questions for Comprehension: 23, p. 721 Section 20.2 Review: 4, p. 728 Chapter 20 Review: 6, 17, p. 738 Unit 8 Review: 13, p. 742
■ *researching and analyzing clear cutting versus selective logging practices*	Section 20.2: Disturbing Events, p. 724 Thought Lab 20.3: Testing the Classical Model of Succession, p. 727	Thought Lab 20.3, p. 727 Unit 8 Review: e.g., 16, 32, p. 743–745
Communication and Teamwork		
30–D2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *researching and presenting practical solutions for reducing the impact of highway fencing on animals in Banff and Jasper National Parks*	Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712	Thought Lab 20.2: Analysis, p. 712–713
■ *developing, presenting and defending a position on whether organisms should be deliberately introduced into new environments*	Thought Lab 20. 4: Biological Control or Damage Control? p. 730	Thought Lab 20. 4: Analysis, Extension, p. 730 Chapter 20 Review: 19, p. 739
■ *researching and presenting characteristics of interrelationships between organisms for analysis by classmates*	Thought Lab 20. 4: Biological Control or Damage Control? p. 730	Thought Lab 20. 4: Analysis, Extension, p. 730

General Outcome 3: Students will explain, in quantitative terms, the change in populations over time.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–D3.1k describe and explain, quantitatively, factors that influence population growth, i.e., ■ mortality, natality, immigration, emigration	Section 20.1: Factors That Affect Distribution Patterns, p. 703 The Rate of Population Growth, p. 706 Section 20.3: Assessing the Significance of Population Change, p. 729 Population Age Structure, p. 731 Earth's Carrying Capacity, p. 734	Questions for Comprehension: 2, 3, p. 705 5–7, p. 707 29, p. 729 30, 31, p. 733 Practice Problems: 1–6, p. 709 Section 20.1 Review: 5, p. 714 Section 20.3 Review: 1, 3, p. 735 Chapter 20 Review: 3, 16, 17, p. 738 Chapter 20 Test
■ change in population size, ΔN = [natality (n) + immigration (i)] – [mortality (m) + emigration (e)]	Section 20.1: Factors That Affect Distribution Patterns, p. 703 The Rate of Population Growth, p. 706 Thought Lab 20.5: Population Growth Rates in Different Countries, p. 732	Practice Problems: 1–6, p. 709 Thought Lab 20.5, p. 732 Section 20.3 Review: 4, p. 735 Chapter 20 Review: 4, 5, 15, p. 738 Chapter 20 Test

	Student Textbook	Assessment Options
30–D3.2k describe the growth of populations in terms of the mathematical relationship among carrying capacity, biotic potential, environmental resistance and the number of individuals in the population, i.e., ■ growth rate, $gr = \frac{\Delta N}{\Delta t}$, where ΔN is change in number and Δt is change in time	Launch Lab: Reproductive Strategies and Population Growth, p. 701 Section 20.1: Population Growth, p. 705 The Rate of Population Growth, p. 706 Factors That Affect Population Growth, p. 707 Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 704	Launch Lab: Analysis, p. 701 Questions for Comprehension: 4, p. 706 5–7, p. 707 8–11, p. 709 12–14, p. 710 Practice Problems: 1–3, p. 709 Thought Lab 20.1: Analysis, Extension, p. 704–705 Section 20.1 Review: 2, 7–9, p. 714 Chapter 20 Review: 5, 14, p. 738 Chapter 20 Test Unit 8 Review: 28, p. 744
■ per capita growth rate, $cgr = \frac{\Delta N}{N}$, where ΔN is the change in number over a specified time period, and N is the original number of individuals	Section 20.1: The Rate of Population Growth, p. 706 Factors That Affect Population Growth, p. 707 Biotic Potential, p. 707 Carrying Capacity, p. 709	Questions for Comprehension: 5–7, p. 707 Practice Problems: 4–6, p. 709 Section 20.3 Review: 2, p. 735 Chapter 20 Test Unit 8 Review: 26, 29, 30, p. 744
■ population density, $\Delta p = \frac{N}{A}$, or $\Delta p = \frac{N}{V}$, where N is number of individuals in a given space; i.e., area (A), or volume (V) occupied by a population	Section 20.1: Density and Distribution of Populations, p. 702 Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 704 Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712	Questions for Comprehension: 1, p. 703 2, 3, p. 705 Thought Lab 20.1: Analysis, Extension, p. 704–705 Thought Lab 20.2: Analysis, p. 712–713 Section 20.1 Review: 1–4, p. 714 Chapter 20 Review: 9, 11, p. 738 22, p. 739 Chapter 20 Test Unit 8 Review: 12, 28–30, p. 743-744
30–D3.3k explain the different population growth patterns, i.e., ■ logistic growth pattern (S-shaped curve) and exponential growth pattern (J-shaped curve)	Launch Lab: Reproductive Strategies and Population Growth, p. 701 Section 20.1: Factors That Affect Population Growth, p. 707 Section 20.3: Population Age Structure, p. 731 Thought Lab 20.5: Population Growth Rates in Different Countries, p. 732	Launch Lab: Analysis, p. 701 Questions for Comprehension: 30, 32, p. 733 Thought Lab 20.5: Analysis, p. 732 Section 20.1 Review: 5, 8 p. 714 Section 20.3 Review: 4, p. 735 Chapter 20 Review: 13, p. 738 Chapter 20 Test Unit 8 Review: 18, 30, 35, p. 743–745
■ open and closed populations	Section 20.1: Carrying Capacity, p. 709 Section 20.3: Earth's Carrying Capacity, p. 732	Questions for Comprehension: 12, p. 710 34, p. 733 Chapter 20 Review: 21, p. 739 Chapter 20 Test Unit 8 Review: 34, p. 745
30–D3.4k describe the characteristics and reproductive strategies of *r*-selected and *K*-selected organisms	Section 20.1: Life Strategies, p. 710	Questions for Comprehension: 15, p. 711 Section 20.1 Review: 9, p. 714 Chapter 20 Review: 8, p. 738 Chapter 20 Test Unit 8 Review: 33, p. 745

	Student Textbook	Assessment Options
Outcomes for Science, Technology, and Society (Emphasis on the nature of science)		
30–D3.1sts explain how concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations by ■ *developing appropriate investigative strategies for analyzing biological issues, e.g., risk/benefit analysis, cost/benefit analysis*	Section 20.3: Assessing the Significance of Population Change, p. 729 Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712 Thought Lab 20.3: Testing the Classical Model of Succession, p. 727	Questions for Comprehension: 29, p. 729 Thought Lab 20.2: Analysis, p. 712–713 Thought Lab 20.3: Analysis, Extension, p. 727 Chapter 20 Review: 19, 21, p. 739
■ *comparing the growth of the human population with that of populations of other species.*	Section 20.3: Growth of the Human Population, p. 731 Population Age Structure, p. 731 Earth's Carrying Capacity, p. 734 Thought Lab 20.5: Population Growth Rates in Different Countries, p. 732 Connections: Social and Environmental Contexts: Helping Hippos and Humans, p. 735	Thought Lab 20.5: Analysis, p. 732 Connections: Social and Environmental Contexts, p. 735 Section 20.3 Review: e.g., 3, p. 735 Unit 8 Review: e.g., 26, 34, p. 744–745
Skill Outcomes		
Initiating and Planning		
30–D3.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ *identifying questions about factors that affect population growth rates*	Launch Lab: Reproductive Strategies and Population Growth, p. 701 Section 20.3: Growth of the Human Population, p. 731 Investigation 20.B: Celebrate the Small Successions, p. 725 Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 704	Launch Lab: Analysis, p. 701 Investigation 20.B: Analysis, Conclusions, p. 725 Thought Lab 20.1: Analysis, Extension, p. 704–705 Section 20.1 Review: 6–8, p. 714 Section 20.3 Review: 1, p. 735 Chapter 20 Review: 21, p. 739 Unit 8 Review: 26, 35, p. 744
Performing and Recording		
30–D3.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by ■ designing and performing an experiment to demonstrate the effect of environmental factors on population growth rate	Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 704 Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712 Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, p. 718 Investigation 20.B: Celebrate the Small Successions, p. 725	Thought Lab 20.1: Analysis, Extension, p. 704–705 Thought Lab 20.2: Analysis, p. 712–713 Investigation 20.A, p. 718 Investigation 20.B: Analysis, Conclusions, p. 725
■ *monitoring a paramecium population over time using a microscope and a grid slide*	Investigation 20.B: Celebrate the Small Successions, p. 725	Investigation 20.B: Analysis, Conclusions, p. 725 Chapter 20 Review: 4, p. 738
■ *researching zebra mussel population growth in the Great Lakes*	Launch Lab: Reproductive Strategies and Population Growth, p. 701 Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712	Launch Lab, p. 701 Thought Lab 20.2, p. 712 Chapter 20 Review: e.g., 22, p. 739
■ *researching the impact of introduced trout species on bull trout* (Salvelinus confluentus) *in Alberta lakes and streams*	Thought Lab 20. 4: Biological Control or Damage Control? p. 730	Thought Lab 20. 4, p. 730 Chapter 20 Review: 19, p. 739

	Student Textbook	Assessment Options
Analyzing and Interpreting		
30–D3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ graphing and interpreting population growth of *r*-selected and *K*-selected organisms	Section 20.1: Life Strategies, p. 710 Thought Lab 20.2 What Limits the Growth of Grizzly Bear Populations? p. 712	Questions for Comprehension: 15, p. 711 Practice Problems: 1–6, p. 709 Thought Lab 20.2: Analysis, p. 712–713 Section 20 Review: 8, 9, p. 714 Chapter 20 Review: 22, p. 739 Unit 8 Review: 30, p. 744
■ *comparing and assessing human population growth rates in various countries*	Section 20.3: Growth of the Human Population, p. 731 Thought Lab 20.5: Population Growth Rates in Different Countries, p. 732	Questions for Comprehension: 30, 31, p. 733 Thought Lab 20.5: Analysis, p. 732 Section 20.3 Review: 2, 4, p. 735 Chapter 20 Review: 21, p. 739 Unit 8 Review: 35, p. 745
■ *demonstrating and assessing the effect of environmental factors on population growth curves*	Section 20.3: Growth of Human Population, p. 731 Population Age Structure, p. 731	Section 20.3 Review: 3, p. 745 Chapter 20 Review: 21, p. 739 Unit 8 Review 32, 35, p. 745
■ *calculating and interpreting density, population change and per capita growth rate*	Section 20.1: Density and Distribution of Populations, p. 702 Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 704 Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712	 Thought Lab 20.1: Analysis, Extension, p. 704–705 Thought Lab 20.2: Analysis, p. 712–713 Chapter 20 Review: 22, p. 739 Unit 8 Review: 26, 28–30, p. 744
■ *calculating population growth rate under ideal conditions given specific parameters*	Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 704 Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712 Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, p. 718 Investigation 20.B: Celebrate the Small Successions, p. 725	Thought Lab 20.1: Analysis, Extension, p. 704–705 Thought Lab 20.2: Analysis, p. 712–713 Investigation 20.A, p. 718 Investigation 20.B: Analysis, Conclusions, p. 725
■ *stating, based on data, a generalization for the growth of a closed population*	Thought Lab 20.1: Distribution Patterns and Population Size Estimates, p. 704 Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? p. 712 Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings, p. 718 Investigation 20.B: Celebrate the Small Successions, p. 725	Thought Lab 20.1: Analysis, Extension, p. 704–705 Thought Lab 20.2: Analysis, p. 712–713 Investigation 20.A, p. 718 Investigation 20.B: Analysis, Conclusions, p. 725
Communication and Teamwork		
30–D3.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *developing, presenting and defending a position on Earth's carrying capacity of* Homo Sapiens	Section 20.1: Carrying Capacity, p. 709 Section 20.3: Earth's Carrying Capacity, p. 732 Connections: Social and Environmental Contexts: Helping Hippos and Humans, p. 735	Questions for Comprehension: 12, p. 710 34, p. 733 Connections: Social and Environmental Contexts, p. 735 Chapter 20 Review: 21, p. 739 Unit 8 Review: 34, p. 745

Chapter 20

Population Growth and Interactions

Student Textbook pages 702–741

Chapter Concepts

20.1 Population Growth

- The density of a population is the average number of individuals in a given area or volume.
- Changes in a population over time can be described quantitatively.
- A J-shaped growth curve is characteristic of a population that is growing at its biotic potential. An S-shaped growth curve is characteristic of a population whose growth is limited by the carrying capacity of its environment.

20.2 Interactions in Ecological Communities

- Intraspecific and interspecific competition may limit the sizes of populations within a community.
- Predator-prey interactions may limit the sizes of producer and consumer populations.
- Mutualism, commensalism, and parasitism are types of symbiosis.
- Succession is a gradual change in community structure over time, due to biotic and abiotic factors.

20.3 Sharing the Biosphere

- Sustainability has social, economic, and environmental dimensions.
- The age structure of a population can be used to predict trends in the growth of the population.
- Earth's carrying capacity for the human population is affected by variables such as trends in birth rates and consumption.

Common Misconceptions

- Biotic potential is different for different individuals in a population, and for different populations in time. There is a tendency among students to think of calculated values as fixed in time and space. It cannot be stressed enough that population parameters are calculated for a population, which is defined, in part, by a fixed or set time. Hence as time changes, so will the population parameters.
- Students may have an animal-based view of the world. Show a student a picture of a moose in a pond surrounded by reeds, bulrushes, shrubs and trees; and students will identify the picture as that of a moose, not as that of bulrushes, even though there are far more plants in the picture. Take care to plan plant examples in your presentations and teaching to remind students that the world does not consist only of animals.
- It is important to realize that the types of population growth curves covered in the curriculum are only two of a wide variety of types of population fluctuations seen in nature and in experimental situations. In fact, most observed populations do not seem to fit either model very well. Other factors affecting the shape of a growth curve include details of life cycles like generation overlap, or time lags in density-dependent factors (the rate of reproduction in the current generation is dependent on some factor relating to density in the previous generation). Difficulties arise because experimental results do not turn out exactly as the models predict but are not so different from models that we must reject the models.
- In high school textbooks, mutualism is any relationship where both individuals benefit from the interaction. There is a tendency in ecological texts to restrict the term to interactions that are obligatory; if the interaction is disrupted, neither species survives. This is an opportunity to point out the changing nature of science.

Helpful Resources

Books and Journal Articles

Begon, M. and Mortimer, M. *Population Ecology.* Blackwell Scientific Publications, Ltd.: California. 1986.

Boutin, S., Krebs, C. J., Boonstra, R., and Sinclair, A. R. E. "Lynx-hare cycles and forest management: lessons from northern Canada." Chapter 14, pp. 487-509 in Zabel, C. J. and Anthony, R. G. eds. *Mammal Community Dynamics: Management and Conservation in the Coniferous Forests of Western North America.* Cambridge University Press: Cambridge. 2003.

Ehrlich, P. R. and Roughgarden, J. *The Science of Ecology.* Macmillan Publishing Co.: NewYork. 1987.

Huffaker, C. B. "Experimental studies on predation: dispersion factors and predator-prey oscillations." *Hilgardia* 27(1958): 343-383.

Keith, L. B. "Role of food in hare population cycles." *Oikos* 40(1983): 385-395.

Strong, D. R. Jr., Simberloff, D., Abele, L.G., and Thistle, A.B. *Ecological Communities: Conceptual Issues and the Evidence.* Princeton University Press: New Jersey. 1984.

Web Sites

Web links related to this chapter can be found at **www.albertabiology.ca**. Online Learning Centre, Instructor Edition, Teacher Web Links.

List of BLMs

Blackline masters (BLMs) have been prepared to support the material in this chapter. The BLMs are either for assessment (AST); use as overheads (OH); use as handouts (HAND), in particular to support activities; or to supply answers (ANS) for assessment or handouts. The BLMs are in digital form, stored on the CD that accompanies this Teacher's Resource or on the web site at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.

Number (Type)
20.0.1 (HAND) Launch Lab: Reproductive Strategies and Population Growth
20.0.1A (ANS) Launch Lab: Reproductive Strategies and Population Growth Answer Key

20.1.1 (HAND) Patterns of Population Distribution
20.1.1A (ANS) Patterns of Population Distribution Answer Key
20.1.2 (HAND) Thought Lab 20.1: Distribution Patterns and Population Size Estimates
20.1.2A (ANS) Thought Lab 20.1: Distribution Patterns and Population Size Estimates Answer Key
20.1.3 (OH) Exponential Growth Pattern
20.1.4 (OH) Sample Problem: Collared Pika
20.1.5 (OH) Logistic Growth Pattern
20.1.6 (OH) Sample Problem: Caribou Transfer
20.1.7 (OH) Life Strategies
20.1.8 (HAND) Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations?
20.1.8A (ANS) Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations? Answer Key

20.2.1 (HAND) Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings
20.2.1A (ANS) Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings Answer Key
20.2.2 (OH) Predator Prey Population Cycles
20.2.3 (HAND) Symbiotic Relationships
20.2.3A (ANS) Symbiotic Relationships Answer Key
20.2.4 (OH) Ecological Succession
20.2.5. (HAND) Investigation 20.B: Celebrate the Small Successions
20.2.5A (ANS) Investigation 20.B: Celebrate the Small Successions Answer Key
20.2.6 (HAND) Thought Lab 20.3: Testing the Classical Model of Succession
20.2.6A (ANS) Thought Lab 20.3: Testing the Classical Model of Succession Answer Key

20.3.1 (HAND) Thought Lab 20.4: Biological Control or Damage Control?
20.3.1A (ANS) Thought Lab 20.4: Biological Control or Damage Control? Answer Key
20.3.2 (HAND) Investigating Human Population Growth
20.3.2A (ANS) Investigating Human Population Growth Answer Key
20.3.3 (HAND) Thought Lab 20.5: Population Growth Rates in Different Countries
20.3.3A (ANS) Thought Lab 20.5: Population Growth Rates in Different Countries Answer Key
20.3.4 (OH) Age Pyramids, 2000: Democratic Republic of Congo, Sweden, Germany
20.3.5 (HAND) Age Structure, 2006: Alberta, Newfoundland and Labrador, Nunavut
20.3.5A (ANS) Age Structure, 2006: Alberta, Newfoundland and Labrador, Nunavut Answer Key

20.4.1 (AST) Chapter 20 Test
20.4.1A (ANS) Chapter 20 Test Answer Key

Using the Chapter 20 Opener

Student Textbook pages 702-703

Teaching Strategies

- As students consider the chapter opening photograph, encourage them to see other populations besides the bison.
- The theme of "we are all connected" could be revisited in terms of the interaction of populations within communities.

Launch Lab: Reproductive Strategies and Population Growth

Student Textbook page 703

Purpose

Students will graph data in order to compare population growth in distinctly different populations. Students will begin thinking about the relationships between a species' reproductive strategies and its patterns of population growth.

Outcomes

- D3.2k
- D3.1s

Advance Preparation

When to Begin	What to Do
1 day before	■ Obtain or photocopy graph paper Photocopy **BLM 20.0.1: Launch Lab**

Apparatus	Materials
■ ruler	■ graph paper

Time Required

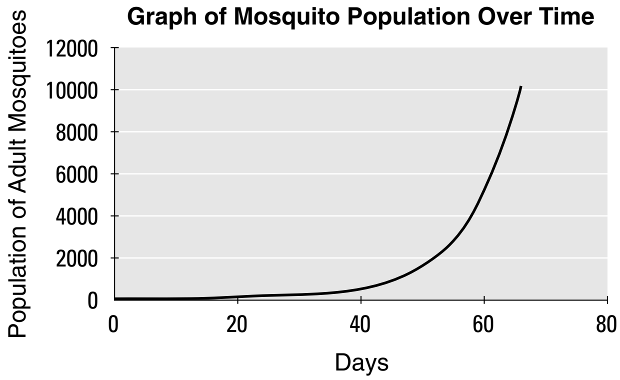
- 30 minutes

Helpful Tips

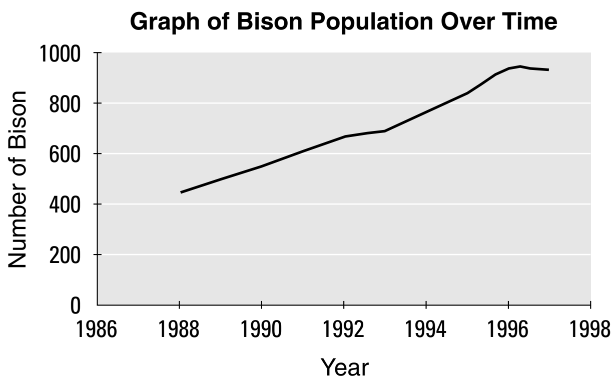
- Use **BLM 20.0.1 Launch Lab** to support this activity. Modify as necessary.
- After students have read the introduction to the chapter and the Launch Lab, have them predict what the graphs of population over time will look like.
- Have students use the top half of a sheet of graph paper to graph the bison population data. They can use the lower half of the same sheet of graph paper to graph the mosquito population data for ready comparison.

Procedure

Student graphs should reflect the following:



Growth of *Aedes* mosquito population over one growing season



Growth of plains bison (*Bison bison*, subspecies *bison*) population of Pink Mountain, British Columbia

Answers to Analysis Questions

1. The graph of the growth of the mosquito population is a steeply rising curve, showing that the population grew quickly over a single growing season. The graph of the plains bison population shows that the population grew slowly but steadily until 1996 and then leveled off.
2. A reasonable hypothesis would be that because of the bison's reproductive strategies (long reproductive cycle and few offspring), its population grew relatively slowly. Perhaps because of limited resources, the bison population reached a maximum of 934 individuals. It would be reasonable to predict that the bison population would remain at about 930 individuals through to 2007 (a horizontal line on the graph) because of limited resources or some other environmental factor. A reasonable hypothesis would be that the reproductive strategies of the *Aedes* mosquito (short reproductive cycle and numerous offspring) caused its population to explode when conditions were favourable for growth. It would be reasonable to predict that the number of adult mosquitoes would crash with the onset of fall, since the adults cannot survive in cold weather.

Assessment Options

- Collect and assess students' graphs and answers to Analysis questions to gauge students' comfort in drawing graphs and their understanding of the concepts covered.

20.1 Population Growth

Student Textbook pages 704-716

Section Outcomes

Students will:

- describe and apply models that represent population density and the distribution of individuals within populations
- describe the four main processes that result in changes in population size and explain, quantitatively, how these processes are related
- analyze population data to determine growth rate and per capita growth rate
- describe how a population's biotic potential and the carrying capacity of its habitat determine its pattern of growth
- compare *r*-selected strategies with *K*-selected strategies in terms of the life cycles of organisms and patterns of population growth

Key Terms

population density (D_p)
growth rate (*gr*)
per capita growth rate (*cgr*)
biotic potential (*r*)
exponential growth pattern
logistic growth pattern
carrying capacity (*K*)
density-dependent factors
environmental resistance
density-independent factors
r-selected strategies
K-selected strategies

Biology Background

- There are a number of ways in which populations can be measured. One is population density, the number of individuals of a species in a volume or area at a specified time. Area is used most frequently to determine the density of terrestrial organisms, and volume is used to determine the density of aquatic organisms, particularly plankton or fish.
- Individuals in a population are found scattered throughout their habitat. The distribution of individuals within a population can be described in three theoretical ways: random, clumped, and uniform.
  - Random distribution follows no discernable pattern. The location of individuals cannot be predicted within the population. This pattern occurs in species that do not

group together for survival or mating, and in habitats where competition between individuals is insignificant. The pattern is very uncommon in nature.

  - Clumped distributions occur when individuals in a population are found in groups, often in the vicinity of food resources, shelter, or mates. Clumped distributions are common in nature, and human settlement in particular follows this pattern.
  - Uniform distributions are highly regular, and individuals are evenly spaced throughout their habitat. Species that are territorial, such as birds of prey, often have uniform distributions, as do cultivated areas like orchards, grain fields, and tree farms.
- The number of individuals in a population changes from year to year. The general factors that affect the growth rate of a population are the number of births and deaths within the population, and immigration to and emigration from the population. Populations grow when births and immigration exceed deaths and emigration.
- The rate of population change, or growth rate, describes the change in the size of the population over time. Growth rates can be positive, which means the population is growing in size, or negative, which means the population is decreasing in size. Population growth rates are independent of the initial population size.
- Change in population size can also be described by relating the growth of the population to the initial population size. This allows scientists to compare how populations are changing based on their reproductive success. This per capita growth rate relates the population growth rate to the initial population size.
- The characteristics of a population or species that determine how often reproduction can occur, and how many offspring are produced are measured together as its biotic potential (*r*). These factors include how often individuals reproduce, how many offspring are produced with each reproductive event, the number of offspring that survive to reproduce, the number of reproductive events that occur in a life span, the age of reproductive maturity, and the life span of individuals in the population.
- Populations growing at their biotic potential exhibit a J-shaped growth curve. This type of population growth is referred to as exponential growth, and cannot continue indefinitely. Exponential growth eventually results in exhaustion of food resources and increased mortality, which causes the population to crash.
- Populations that grow in situations where biotic potential is balanced with mortality eventually reach a point where population size is relatively stable. These growth patterns are called logistic growth patterns and follow an S-shaped curve. The maximum population is referred to as the carrying capacity, and there tends to be no death phase in the population.
- Factors that limit population growth can be classified as density-dependent or density-independent. Density-dependent factors increase or decrease their impact on populations as the population size grows. These factors tend to be biotic in nature, such as parasites and disease. Density-dependent factors tend to set carrying capacity. Density-independent factors have the same effect on a population no matter what the population density. These factors tend to be abiotic in nature.
- Scientists have tried to classify the life history strategies of organisms based on their tendency to grow exponentially or logistically. Species that show high biotic potential are labelled *r*-selected strategists. They tend to be small in size, short-lived, mobile, produce many offspring with each reproductive event, and reproduce often. They do not care for their offspring. Species that show stable populations are called *K*-selected strategists. They tend to be large bodied, live a long time, not be particularly mobile, have few offspring at a time, and reproduce infrequently. They tend to care for their offspring until the offspring can fend for themselves before reproducing again.

Teaching Strategies

- Population growth in Alberta has been the subject of much comment. Ask students for ways to characterize the difference between two populations, contrasting the population of Lethbridge with a smaller or larger centre. Brainstorming should lead to the idea of calculating density, and the formula can then be introduced. It is quite likely that students will have deduced the formula first.
- Similarly, the population change in Lethbridge over the past ten years can be used to introduce the idea that population density can change over time. Students can calculate the change in density for the three populations, but you can also brainstorm or introduce other ways of describing the growth of populations. Here, growth rate and per capita growth rate can be introduced as ways of describing the change in a population. Statistics Canada will be posting the data from the 2006 census throughout 2007. Visit http://www12.statcan.ca/english/census/Index.cfm for the most up-to-date information.
- Use **BLM 20.1.3: Exponential Growth Pattern**. Take advantage of the Launch Lab to introduce logistic and exponential patterns of population growth. Comparison of the two graphs developed from the lab can lead students to identify similarities and differences between the two graphs and between the two species (size, age, reproductive capabilities, care of young). This foreshadows the introduction of *r*-selection and *K*-selection later in this section.
- The classroom can be used as a model population to describe distribution types. You can develop the idea that distribution often changes at different times from the way students are distributed during lectures, labs, or group work.
- Compare distribution of people in older grid-based neighbourhoods with more modern "cul-de-sac" neighbourhoods using city maps.
- Use the students in the class to illustrate factors that change population size. There should be evidence of

immigration and emigration in most biology classes. Most students will have experienced a birth in the family or a death, and the impact of those on the population can be discussed.

- Start each student with a small sample of pond mud and a glass jar early in the course. With measurements taken regularly, they will have data on population sizes of different organisms that can be compared to theoretical population growth curves and distributions.
- In addition to BLMs supporting activities, overhead masters and reinforcement tools have been prepared for this section. You will find them with the Chapter 20 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.

Number (Type)
20.1.1 (HAND) Patterns of Population Distribution
20.1.1A (ANS) Patterns of Population Distribution
20.1.3 (OH) Exponential Growth Pattern
20.1.4 (OH) Sample Problem: Collared Pika
20.1.5 (OH) Logistic Growth Pattern
20.1.6 (OH) Sample Problem: Caribou Transfer
20.1.7 (OH) Life Strategies

SUPPORTING DIVERSE STUDENT NEEDS

- Help ESL students become familiar with the many new terms in this section by using photographs or drawings to illustrate as many terms as possible. Birth and death can be shown using photographs of babies, puppies, kittens, chickens with eggs and chicks, or the like. Any ESL student will be familiar with both immigration and emigration, so try using maps of their native countries and Canada to help drive home the meanings of the words. Have photos of the animals and plants mentioned in this section posted on the wall with their names, and scales to indicate their size so that students not familiar with common Canadian species can become more familiar with them.
- Gifted students may find the concepts in this unit rather simplistic. They may get frustrated with models that don't quite match observations. Mathematically oriented students may benefit from learning how ecologists enhance the equations for population growth so that they more accurately represent what is observed in nature. Identify a few factors that ecologists have considered, and a few other models of dealing with population growth so that these students have somewhere to start, and let them loose to find out more.
- Ask the partners of visually impaired students to describe what they are looking at during work with microscopes. Aural descriptions of sizes, shapes, colours, and motion go a long way to help develop understanding for both the sighted and the visually impaired.

Figure 20.1

Student Textbook page 704

Students likely will suggest that ecological communities are also affected by changes in populations, for example, their growth and decline, variations in their patterns of distribution, and their intraspecific and interspecific interactions (including those involving human populations). Students may also mention changes in abiotic conditions, for example, drought, increased extreme weather, and unusual changes in temperature. The second question is intended to stimulate students' critical and creative thinking and could be used for a brief exchange of ideas in small groups or with the whole class. This chapter is, in effect, an overview of possible answers to this question.

Answers to Questions for Comprehension

Student Textbook page 705

Q1. (a) Population density is defined as the number of individual organisms in a given area or volume.

(b)

$$D_p = \frac{N}{A} \text{ or } D_p = \frac{N}{V}$$

Biology File: Web Link

Student Textbook page 705

Larvaciding is considered to be the most efficient and effective means to control mosquitoes. Larval (immature) mosquitoes are only found in stagnant water, such as that found in roadside ditches and field pools.

The City of Calgary only uses what are termed "biorational" means to control mosquitoes. These products are very specific and have little or no impact on other life forms. The most commonly used product for larvaciding is a naturally occurring soil bacteria, *Bacillus thuringiensis israelensis* or Bti. When the larval mosquitoes eat the Bti, it destroys the stomach, causing the mosquitoes to die before they develop into a biting adult.

Other products used by the city for larvaciding contain Methoprene, which mimics the natural hormones found in larval mosquitoes. Methoprene stops the normal development of larval mosquitoes by not allowing them to mature into biting adults. Both of Bti and Methoprene have a very short residual time in the environment and are rapidly degraded when exposed to ultraviolet light from the sun.

Helicopters are the most efficient means to apply products since they can cover a large area in a short time and mosquito breeding sites are often inaccessible by vehicles. Products are applied in a granular form, which eliminates the possibility of drift exposure.

Thought Lab 20.1: Distribution Patterns and Population Size Estimates

Student Textbook pages 706-707

Purpose

Students will extrapolate the size of a moose population from the density of specific samples to determine the effect of sampling size and population distribution on estimates of population size.

Outcomes

- 30-D3.2k
- 30-D1.1s
- 30-D3.3s
- Scientific Inquiry

Advance Preparation

When to Begin	What to Do
1 day before	■ Photocopy **BLM 20.1.2: Thought Lab 20.1**

Apparatus	Materials
■ calculator ■ ruler	■ **BLM 20.1.2**

Time Required

- 30 minutes

Helpful Tips

- Use **BLM 20.1.2: Thought Lab 20.1** to support this activity. Modify as necessary.

Answers to Procedure Questions

1. Distribution #1 is random, and Distribution # 2 and #3 are clumped.
2. Area per transect is (9.3 km)(0.7 km) = 6.5 km^2.
3. Distribution # 1 has 6, 5, and 3 moose per/transect.
   Distribution # 2 has 9, 5, and 8 moose/transect.
   Distribution # 3 has 9, 20, 5, 14, 8, and 3 moose/transect.
4. Distribution # 1 averages 4.7 moose/transect.
   Distribution # 2 averages 7.3 moose/transect.
   Distribution # 3 averages 9.8 moose/transect.
5. For Distribution #1: density = 4.7 moose/6.5 km^2 = 0.72 moose/km^2
   For Distribution # 2: density = 7.3 moose/6.5 km^2 = 1.1 moose/km^2
   For Distribution # 3: density = 9.8 moose/6.5 km^2 = 1.5 moose/km^2
6. Area of study = (9.3 km)(9.3 km) = 86.5 km^2
   Population size of Distribution #1 = (0.72 moose/km^2)(86.5 m^2) = 62 moose
   Population size of Distribution #2 = (1.1 moose/km^2)(86.5 km^2) = 95 moose
   Population size of Distribution #3 = (1.5 moose/km^2)(86.5 km^2) = 129 moose

Answers to Analysis Questions

1. For Distribution # 1: 62 – 60 = 2
   For Distribution # 2: 95 – 133 = –38
   For Distribution # 3: 129 – 133 = –4
2. For the first population, there was very little difference between the estimate and the size of the actual population.
3. The estimate for the second population is off because the population was clumped and the samples were all taken in the less populated areas. More samples were taken with the third population and the estimate was more accurate as a result. Some of these samples included large numbers that represented the clumped distribution of the population. These samples were not taken in the second population.
4. The sampling technique could involve sampling a moose population in a more limited area, such as a small field or small wooded area, and using random capture, such as quadrant and transect techniques. With small areas, an actual census can be conducted and the results compared to the two estimation techniques to evaluate them.

Answer to Extension Question

5. Scientists could use the density to determine the actual size of a population. If it is too large and there's fear of going above the carrying capacity of the environment, they could inform government sources that grant hunting licenses. More hunting would be permitted to regulate the size of the population. Given the size of this population, you could determine its density by dividing the population size by the area of the range over which this population is found.

Assessment Options

- Discuss the assignment in class or take the activity in for marking.
- Use the activity as a quiz or question on an exam.

Answers to Questions for Comprehension

Student Textbook page 707

Q2 Distribution patterns are influenced by the distribution of resources in a habitat and the interactions among members of a population or members of a community.

Q3 Random distribution in a habitat is characterized by individuals or pairs of organisms distributed throughout a suitable habitat with no identifiable pattern. It occurs when resources are abundant and members of a population do not have to compete with one another or group together for survival. Random distribution in nature is rare. An example is the summer population of individual bull moose and female moose (*Alces alces*) with calves.

In clumped distribution, members of a population are found in groups within their habitat. Most populations exhibit a clumped pattern of distribution, congregating in an area where food, water, or shelter is most abundant. Members of the population are grouped together for survival and share scarce resources. Examples cited in the text are humans, aspens (*Populus tremuloides*), and the snail (*Physella johnsoni*.)

In uniform distribution, members of a species are evenly spaced over a habitat. The members avoid direct competition over resources by dividing up the territory. Examples of this pattern are birds of prey and other organisms that show territoriality to defend their resources and protect their young. The golden eagle (*Aquila chrysaetos*) is a specific example of a species exhibiting uniform distribution.

Student Textbook page 708

Q4 The four processes that affect population size are births (b), immigration (i), deaths (d), and emigration (e).
$\Delta N = (b + i) - (d + e)$

Student Textbook page 709

Q5 Population growth rate (gr) refers to the change in population size (ΔN) over a specific time frame (Δt). The per capita growth rate (cgr) takes into account the initial size of the population and is determined by calculating the change in population size (ΔN) during a given time interval (Δt), and then dividing the change in population size by the original number of individuals in the population (N).

Q6
$$gr = \frac{\Delta N}{\Delta t}$$
$$= \frac{2300 \text{ deer} - 2000 \text{ deer}}{1 \text{ year}}$$
$$= 300 \text{ deer/year}$$

Q7
$$cgr = \frac{\Delta N}{N}$$
$$= \frac{2300 \text{ deer} - 2000 \text{ deer}}{2000 \text{ deer}}$$
$$= 0.15$$

Teaching Strategies for Practice Problems

Student Textbook page 710–711

- The practice problems are straightforward. As an alternative to lecturing, assign students to small groups with one problem each. Groups could be instructed to develop and present a dramatization of the problem and the solution to the class.

Solutions to Practice Problems

Student Textbook Page 711

1. Problem

Suppose that a sample of beef broth initially contains 16 bacterial cells. After 4.0 h, there are 1.6×10^6 bacterial cells in the sample. Assuming that the bacteria reproduce at a constant rate, calculate the growth rate of the bacterial population for the given time interval.

What Is Required?

You must determine the growth rate (gr) of the bacterial population for the given time.

What Is Given?

The values required to calculate the change in population size (ΔN): The original number of bacterial cells was 16.
The final number of bacterial cells is 1.6×10^6.
The change in time (Δt) is given as 4.0 hours.

Plan Your Strategy

Calculate ΔN.

Calculate $gr = \frac{\Delta N}{\Delta t}$.

Act on Your Strategy

Step 1

$\Delta N = (1.6 \times 10^6 \text{ bacteria}) - 16 \text{ bacteria}$
$= 1\ 599\ 984 \text{ bacteria}$

Step 2

$$gr = \frac{\Delta N}{\Delta t}$$
$= 1\ 599\ 984 \text{ bacteria} /4.0 \text{ h}$
$= 399\ 996 \text{ bacteria/h}$
$= 4.0 \times 10^5 \text{ bacteria/h}$

Check Your Solution

$$gr = \frac{\Delta N}{\Delta t}$$

$gr\ (\Delta t) = \Delta N$

(399 996 bacteria/h)(4.0 h) = (1.6 × 106 bacteria) – 16 bacteria

1 599 984 bacteria = 1 599 984 bacteria

2. Problem

The Alberta greater sage grouse population was about 4375 in 1970. By 2002, the population was estimated to be only about 350 birds. Assuming that the population decreased at a constant rate, calculate the growth rate for the population from 1970 to 2002.

What Is Required?

You must determine the growth rate (*gr*) for the Alberta greater sage grouse population from 1970 to 2002.

What Is Given?

The values required to calculate the change in population size (ΔN): The original number of grouse was 4375. The final number of grouse was 350.

The values required to calculate the change in time (Δt): The beginning of the time frame is 1970. The end of the time frame is 2002.

Plan Your Strategy

Calculate ΔN.

Calculate Δt.

Calculate $gr = \frac{\Delta N}{\Delta t}$.

Act on Your Strategy

Step 1

ΔN = 350 grouse – 4375 grouse

= – 4025 grouse

Step 2

Δt = 2002 – 1970

= 32 years

Step 3

$$gr = \frac{\Delta N}{\Delta t}$$

= –4025 grouse/32 years

= –125.78 grouse/year

–125.78 grouse/year ≈ –126 grouse/year

Check Your Solution

$$gr = \frac{\Delta N}{\Delta t}$$

$gr\ (\Delta t) = \Delta N$

(–125.78 grouse/year)(32 years) = – 4025 grouse

– 4025 grouse = – 4025 grouse

3. Problem

Lemna minor, a species of duckweed, can reproduce to form new plants very quickly. Suppose that a small backyard pond contains 25 *L. minor* plants, and the expected growth rate of the population is 1.0×10^2 plants per day. Predict how many *L. minor* plants the pond will contain after 31 days.

What Is Required?

You must determine the size of the *L. minor* population after 31 days.

What Is Given?

The original number (*N*) of *Lemna minor* plants in the pond: 25 plants

The growth rate (*gr*) of the population over 31 days: 1.0×10^2 plants per day

The time frame (Δt): 31 days

Plan Your Strategy

Rearrange the formula for growth rate to solve for ΔN.

Find the value of ΔN.

Add the original number of plants in the population (*N*) to the change in population size (ΔN) to determine the final number of individuals in the population.

Act on Your Strategy

Step 1

$$gr = \frac{\Delta N}{\Delta t}$$

$gr(\Delta t) = \Delta N$

Step 2

(1.0×10^2 plants/day)(31 days) = ΔN

3100 plants = ΔN

Step 3

Final number of individuals in population = $\Delta N + N$ = 3100 + 25 = 3125 plants

Check Your Solution

$$gr = \frac{\Delta N}{\Delta t}$$

= 3100 plants/31 days

= 1.0×10^2 plants/day

4. Problem

According to population surveys of piping plover (*Charadrius melodus*), there were 34 of these birds on Dowling Lake, Alberta, in 1992. The next year, the population of piping plover on Dowling Lake was 39. Calculate the per capita growth rate for the piping plover population during the entire survey period.

What Is Required?

You must determine the per capita growth rate (*cgr*) for the piping plover population during the survey period.

What Is Given?

The values required to calculate the change in population size (ΔN): The original number of piping plover was 34. The final number of piping plover was 39.

Plan Your Strategy

Find the value of ΔN.

Calculate *cgr*.

Act on Your Strategy

Step 1

ΔN = 39 plover – 34 plover

= 5 plover

Step 2

$$cgr = \frac{\Delta N}{N}$$

= 5 plover/34 plover

= 0.147

Rounding to the correct significant digit, the per capita growth rate is 0.15.

Check Your Solution

$cgr(N) = \Delta N$

(0.147)(34) = 5

5 = 5

5. **Problem**

Between 1996 and 2001, Cochrane, Alberta, was the fastest growing municipality in Canada, with a per capita growth rate of 0.589. There were about 7424 people living in Cochrane in 1996. How many people lived there in 2001?

What Is Required?

You must determine the population of Cochrane, Alberta in 2001.

What Is Given?

The value of the per capita growth rate (*cgr*): 0.589

The number of people living in Cochrane, Alberta in 1996 (N): 7424

Plan Your Strategy

Rearrange the formula for per capita growth rate to solve for ΔN.

Find the value of ΔN.

Add the original number of people in the population (N) to the change in population size (ΔN) to determine the final number of individuals in the population.

Act on Your Strategy

Step 1

$$cgr = \frac{\Delta N}{N}$$

$\Delta N = (cgr)(N)$

Step 2

ΔN = (0.589)(7424 people)

= 4372.7 people

4372.7 people ≈ 4373 people

Step 3

Final number of individuals in the population = $\Delta N + N$

= 4373 people + 7424 people = 11 797 people

Check Your Solution

$$cgr = \frac{\Delta N}{N}$$

0.589 = 4372.7 people/7424 people

0.589 = 0.589

6. **Problem**

The experimentally re-introduced grey wolf population of Idaho was 310 at the beginning of 2004. Over the year, 112 pups were born and 49 individuals died or were removed from the study area. Calculate the per capita growth rate of this grey wolf population during the study period.

What Is Required?

You must determine the per capita growth rate of the grey wolf population during the study period.

What Is Given?

The values required to calculate the change in population size (ΔN): The number of pups born (b) was 112. The number of individuals that died or were removed from the study area ($d + e$) was 49.

The original number (N) of wolves in the population: 310 wolves

Plan Your Strategy

Calculate ΔN.

Calculate *cgr*.

Act on Your Strategy

Step 1

$\Delta N = [b + i] - [d + e]$

= [112 wolves] – [49 wolves]

= 63 wolves

Step 2

$$cgr = \frac{\Delta N}{N}$$

= 63 wolves/310 wolves

= 0.203

Rounding to the correct number of significant digits, the *cgr* is 0.20.

Check Your Solution

$cgr(N) = \Delta N$

0.203(310) = 63

63 = 63

Answers to Questions for Comprehension

Student Textbook page 711

Q8. The biotic potential (*r*) of a population is its highest possible per capita growth rate.

Q9. Four factors that determine the biotic potential of a species are

(1) the number of offspring per reproductive cycle;
(2) the number of offspring that survive long enough to reproduce;
(3) the age of reproductive maturity and the number of times that the individuals reproduce in a life span; and
(4) the life span of the individuals.

Q10. An exponential growth pattern is a growth pattern that begins with a brief lag phase (slower growth), followed by much more rapid growth as the number of individuals capable of reproducing continues to increase. This type of growth pattern has a J-shaped curve on a line graph.

Q11. A population growing at its biotic potential would be expected to follow an exponential growth pattern. In the beginning, the growth of a small population is slow since only a few individuals reproduce. The small initial population constitutes the "lag phase," shown by a gentle slope in the curve. As more organisms reproduce, the population will grow in greater and greater quantities, exhibited by a steep increase in the growth curve. Because the birth rate during this phase of exponential growth is much greater than the death rate, the population size increases rapidly.

Student Textbook page 712

Q12. Carrying capacity (*K*) is the theoretical maximum population size that an environment can sustain over an extended period of time. It represents the number of individuals in a population that can live in a given environment without depleting the resources they need or harming their habitat or themselves.

Q13. Density-dependent factors are biotic; that is, they are directly related to living organisms. These factors have a greater impact when population density is high. Examples of density-dependent factors include disease and parasites (which spread more rapidly in a dense population), scarcity of resources due to intense competition, and increased predation, since a dense population means there is an abundance of prey for predators. This differs from density-independent factors, which are abiotic and limit the growth of a population, regardless of its size or density. They include extreme temperatures, drought, floods, forest fires, and destruction of habitat through human intervention.

Q14. Environmental resistance to population growth refers to the combined effects of interacting limiting factors. Environmental resistance prevents a population from growing to its biotic potential and determines the carrying capacity of the habitat.

Student Textbook page 713

Q15.

r-selected life strategies	*K*-selected life strategies
live close to their biotic potential	live close to the carrying capacity of their environment
many offspring per reproductive cycle	few offspring per reproductive cycle
offspring receive little or no parental care	one or both parents care for their young.
short life span	long life span
early reproductive age	later reproductive age
dependent on favourable environmental conditions	not dependent on favourable environmental conditions

Thought Lab 20.2: What Limits the Growth of Grizzly Bear Populations?

Student Textbook pages 714-715

Purpose

The status of the grizzly bear in Alberta is listed as *May be at Risk*. While numbers have been increasing, they have not reached the population goal of 1000 bears. This activity reinforces the concepts learned in Section 20.1 and is used to make students aware of how human activities affect the grizzly bear population

Outcomes

- 30-D3.2s
- 30-D3.3s
- 30-D3.4s
- 30-D3.1sts
- Scientific Inquiry
- Stewardship

Advance Preparation

When to Begin	What to Do
2 days before	■ arrange access to school computers if using these facilities Photocopy **BLM 20.1.8: Thought Lab 20.2**

Apparatus	Materials
■ calculator	■ sufficient graph paper or access to computers with spreadsheets or graphing software

Time Required

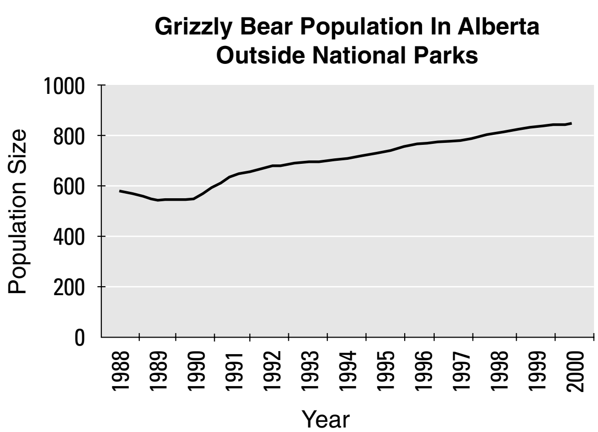
- 45–60 minutes

Helpful Tips

- Use **BLM 20.1.8: Thought Lab 20.2** to support this activity. Modify as necessary.
- The following web site is a good resource for both teachers and students: http://www3.gov.ab.ca/srd/fw/status/reports/pdf/grizzly.pdf
- Arrange time for classroom discussion after the activity. Discussion should centre on the last question—the necessity of humans to act in a responsible manner to co-exist in the same environment with grizzly bears. Attitude is important here. You might ask how the hunters might have felt when the number of hunting licenses was reduced or how travelers feel about decreasing their driving speed on the stretch of highway near Lake Louise. This area is generally ticketed only in the early mornings and evenings when bears are known to be present. Many tickets are written for speeding. Why?
- You might assign some students to do further research in this area and make a presentation to the class.

Procedure

The following graph shows the change in size of the Alberta grizzly bear population outside the National Parks over time.



Answers to Analysis Questions

1. 1990
2. Limiting hunting licenses probably occurred in 1988, but because of their low biotic potential, it took a few years for the bear population to begin to recover.
3. $cgr = \frac{\Delta N}{N}$

   cgr 1991 to 1992: $\frac{669 - 638}{638} = 31/638 = 0.463$ or 4.6%

   cgr 1997 to 1998: $\frac{807 - 776}{776} = 31/776 = 0.399$ or 4.0%

   cgr 1998 to 1999: $\frac{833 - 807}{807} = 26/807 = 0.32$ or 3.2%

   The per capita growth rate is decreasing because the bear population is approaching the carrying capacity of the environment. This may be due to loss of habitat because of human activities like logging or recreational development.
4. **(a)** Region A: $\frac{(31 \text{ bears})(1000)}{14\ 128 \text{ km}^2} = 2.2 \text{ bears}/1000 \text{ km}^2$

   Region B: $\frac{(44 \text{ bears})(1000)}{6089 \text{ km}^2} = 7.2 \text{ bears}/1000 \text{ km}^2$

   Region C: $\frac{(168 \text{ bears})(1000)}{22\ 840 \text{ km}^2} =$

   $7.4 \text{ bears}/1000 \text{ km}^2$

   (b) Students may suggest that because bears require a wide variety of foods, the bear population would be denser in a region where more food is available. Sparsely populated areas could also lack suitable den space to survive the winter. Bears prefer moist temperate mountainous areas as opposed to dry cold mountain regions. Some of the regions might consist mainly of flat plains and have a lower population density as a result. Accept any reasonable answer.
5. Disease and aggression due to intraspecific competition.
6. **(a)** Because females tend to remain in more restricted areas, genetic diversity in the population would decrease.

   (b) If a hesitation to cross barriers exists, this would decrease the chance of mating and could lead to a lower per capita growth rate.
7. **(a)** Grizzly bears have *K*-selected life strategies. They take a relatively long time to become sexually mature, produce few offspring, and care for their young.

   (b) When conditions are ideal, females only average one offspring per year, less when the food supply diminishes. It would take a while for the population to increase.

   (c) Due to the low biotic potential of grizzly bears, conservationists require long term plans to maintain or increase the population size. Every loss of a cub or sexually mature bear from the population requires an increase in the birth rate of the population, something that is difficult to attain when conditions are not ideal.

8. Yes, it is reasonable. The time lost on a trip is negligible. One question that students may want to ask is if there is evidence that bears have been killed in vehicle accidents in this area.
9. Industries competing for grizzly bear habitat include the forestry, oil and gas, utilities, and agricultural industries, along with human recreational activities like hunting. A management board consisting of representatives from these areas, as well as the federal and provincial governments, has been established in Alberta. Some keys to success are to limit the amount of hunting that can be done each year and intensively manage multiple use areas, reduce conflicts between bears and cattle farmers, and decrease human activities in areas of high quality bear habitat.

Assessment Options

- Collect and assess students' answers to Analysis questions.
- Use Assessment Checklist 7 Independent Research Skills from Appendix A, should students do research and make a presentation to the class.

Section 20.1: Review Answers

Student Textbook page 716

1. Scientists often estimate population size, rather than count each member because the habitat of a species may be large or inaccessible, making it too costly, time consuming, or even physically impossible to count each member of a population. Because some species range over a large habitat, it is possible to miss individuals or count them twice, resulting in an inaccurate count when a large area is involved.
2. Population density is defined as the number of individual organisms (*N*) in a given area (*A*) or volume (*V*).
3. Population density is not always a reliable tool for estimating population size because organisms are rarely evenly distributed throughout their habitat. Most often, organisms are clumped in areas where resources are readily available and less prevalent in areas where they are not. Thus, estimating population size based on density without knowing the distribution pattern of a population may result in an overestimation or underestimation of a population.
4. Sufficient appropriate food is a determinant of survival for any species population and its abundance and distribution will always affect the distribution of a population. Specifically, species populations will clump around adequate sources of food.
5.

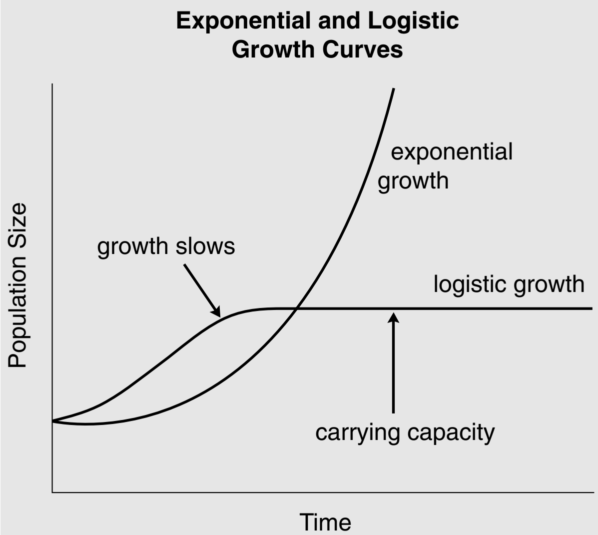
Phase	Comparison of birth and death rates
lag	birth rate greater than death rate
exponential	birth rate much greater than death rate
stationary	birth rate equal to death rate

6. Factors may include three of the following:
   - *Parasites and disease:* increased mortality; if individuals die before their reproductive age or if disease causes sterility, fewer offspring will be produced, again limiting growth; disease may also limit the growth of a population indirectly by reducing the population of another species relied upon as a food source.
   - *Predation:* dense populations attract a larger number of predators and are more likely to suffer losses, often of younger, weaker members who will not reproduce.
   - *Scarcity of resources:* less food and water and fewer safe nesting areas, as well as fewer potential mates leads to higher mortality and lower reproductive rates.
   - *Abiotic factors such as harsh weather (e.g., extreme temperatures, severe storms), drought, floods, and forest fires:* limit population growth by reducing the number of offspring being born or compromising their chances of survival, increasing overall mortality, or destroying habitat, nesting sites, and food sources.
   - *Human activity, such as hunting or harvesting and creation of hazards (i.e. highways):* limits population growth through destruction or fragmentation of habitat, resulting in loss of nesting or breeding sites and food resources; introduces toxins into the forest environment that can poison water sources, contaminate food, and reduce the number of viable offspring surviving to a reproductive age, or cause sterility.
7. Factors may include three of the following:
   - *The number of offspring per reproductive cycle:* The biotic potential is the highest possible per capita growth rate for a population. A high number of offspring per reproductive cycle will, therefore, increase the biotic potential of a population.
   - *The number of offspring that survive long enough to reproduce:* If a high number of offspring survive long enough to reproduce, the population will grow faster than if only a few offspring survive, thus increasing the biotic potential of a population.
   - *The age of reproductive maturity and the number of times individuals reproduce in a lifespan:* If organisms reproduce at a younger age, the population will grow

faster than if sexual maturity is reached later. Similarly, if individuals reproduce more frequently during their lifespan, the population will also grow faster. Both result in an increased biotic potential.

- *Lifespan of individuals:* If individuals live longer, they have more reproductive cycles per lifespan and thus more offspring.

8.



On the logistic growth curve, add an arrow/label pointing to the top curved portion of the S-shape to show the point at which the growth has begun to slow down, and another arrow/label pointing to the flat portion of the S-shaped curve at the top to indicate the point at which the carrying capacity has been reached.

9. Organisms in *r*-selected populations expend energy in order to reproduce rapidly while conditions are favourable, and are hence labelled as opportunistic populations. For instance, the growth rate of infectious bacteria increases rapidly once they enter the body. The bacteria, and other organisms that reproduce close to their biotic potential, employ various life strategies that enable them to take advantage of this window of opportunity, e.g., having an early reproductive age and producing large numbers of offspring. The offspring receive little or no parental care; instead all energy goes into reproduction to create more offspring while favourable environmental conditions such as the availability of food, sunlight, or warm summer temperatures exist.

Populations with *K*-selected life strategies are often referred to as equilibrium populations. This term was likely arrived at because, in contrast to the "boom or bust" lifestyle of *r*-selected populations, a population with *K*-selected life strategies exists close to the carrying capacity of its environment over a long period of time without crashing as a result of depleting its resources, or harming its habitat or itself. Thus, the population is in a stable, or equilibrium, state.

20.2 Interactions in Ecological Communities

Student Textbook pages 717-730

Section Outcomes

Students will:

- describe the interactions among population members and among members of the different populations within a community
- design investigations to measure the effects of intraspecific and interspecific competition on the growth of plants
- explain how producer-consumer Interactions affect population growth
- describe defense mechanisms, such as protective coloration, that have evolved within populations
- understand that symbiosis includes mutual, commensal, and parasitic relationships
- distinguish between primary and secondary succession

Key Terms

intraspecific competition
interspecific competition
predators
prey
protective coloration
symbiosis
mutualism
commensalism
parasitism
succession
primary succession
pioneer community
climax community
ecological disturbance
secondary succession

Biology Background

- Species in an ecological community exist in relationships called interactions. Many different types of interactions are recognized. Almost all interactions impact one or both of the species involved in some way, with some individuals benefiting, and some individuals suffering due to the particular interaction.
- When individuals of the same species struggle with each other for any resource that is in limited supply, both individuals suffer during the competition. This is called intraspecific competition. Individuals with an ability that provides a competitive advantage over other individuals tend to survive periods of intense competition and leave more offspring for the next generation. The trait that provided them with this advantage tends to be passed on to their offspring. Intraspecific competition is density-dependent and tends to result in *K*-selected species populations that function at their carrying capacity. Many

species of animals and plants have developed methods of reducing intraspecific competition between parents and their offspring.

- When individuals of different species compete for the same resource that is in short supply, both individuals suffer during the competition. This is called interspecific competition and is also density-dependent. Two species that require exactly the same resources cannot coexist. One will out-compete the other, and one will become extinct: this is Gause's principle. Consequently, species with similar niches tend to diverge when they come into contact with each other. Introduction of exotic species often leads to competition with native species.
- Producer-consumer interactions are interspecific interactions where one individual eats another. Predators, for example, kill and eat their prey. Predation tends to be density-dependent, with one individual losing (the prey) and one individual gaining (the predator). Producers and consumers affect each other in ways that influence their evolution, and are said to co-evolve. The results of co-evolution include cryptic coloration, defensive chemicals, and physical protective mechanisms such as thorns.
- Co-evolution also leads to types of mimicry. Batesian mimicry describes situations where a harmless species looks and acts like a harmful species. Müllerian mimicry describes the situation where dangerous species look alike, presumably to make it easier for predators to remember what not to eat.
- Symbiosis describes interactions where individuals of different species exist in relationships that are directly dependent.
- Mutualism describes an interaction where individuals of both species involved benefit from the interaction. Typically, the relationship is obligatory and the species won't survive without each other.
- Commensalism describes a relationship where individuals of one species benefit, and the individuals of the other species are unaffected. Commensal relationships often exhibit characteristics of mutualism.
- Parasitism describes the interaction where individuals of one species take nourishment from another, usually without killing the host. Disease organisms are parasites, so parasitism has a huge economic and social impact on humans. Parasites can weaken hosts, leading to other diseases and death.
- Sequential change of species in a habitat over time is called succession. When bare, previously uninhabited ground is colonized, ecologists use the term primary succession to describe these changes. When some disturbance kills or removes individuals from a habitat but evidence of life still remains, ecologists describe the subsequent changes as secondary succession. Both types of succession start with pioneer species forming a pioneer community, and end with a climax community that is self-sustaining. Climax communities are theoretical constructs, and rarely occur in nature. Instead, disturbance, something that destroys all or part of a community, seems to play a major role in stimulating change in community structure.

Teaching Strategies

- Use students' behaviour to model different types of interactions between individuals and relate that behaviour to ecological interactions. For example, two students studying together is a situation where both benefit from the interaction. This mimics mutualism. You can lead into the meaning of the ecological interaction, and ask students to identify the problem of using two students studying as an example of mutualism (i.e., only one species is involved) as well as get them to think of a better analogy (i.e., a human and a dog living together).
- Use Investigation 20.A: Interspecific and Intraspecific Competition and **BLM 20.2.3: Symbiotic Relationships** to highlight the types of interactions that happen among species. Provide an example of an unidentified interaction and ask students to identify the interaction based on which species benefits, is harmed, or is unaffected.
- Use **BLM 20.2.2: Predator-Prey Population Cycles** to get students thinking about patterns and trends in the lynx and snowshoe hare population. Discuss problems that reduce the accuracy in which the data depicts the number of predators and prey (i.e., price of fur, demand for fur, reduction of number of trappers, presence of other prey and predator species). Lastly, summarize modern research that reflects on the accuracy of the model (see Helpful Resources). Draw attention to the fact that this interplay of model and investigation is exactly what science is supposed to be all about.
- Show the movie *Never Cry Wolf* to introduce the idea that predators may actually benefit prey, as well as to review how predators are often stereotyped by society.
- In August and September of 2003, B.C.'s Lake Okanagan Mountain Park was devastated by fire. Wildlife tour operators (adventureokanagan.com) are now offering "safaris" through the area to show visitors how succession works. Students with experience in the area may be able to introduce concepts discussed in Succession: Community Changes over Time (pages 725-728). **BLM 20.2.4** features ecological succession, as does Investigation 20.B: Celebrate the Small Successions.
- The overhead masters and reinforcement tools have been prepared for this section in addition to BLMs to support activities are listed below. You will find them with the Chapter 20 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.

Number (Type)
20.2.2 (OH) Predator-Prey Population Cycles
20.2.3 (HAND) Symbiotic Relationships
20.2.3A (ANS) Symbiotic Relationships Answer Key
20.2.4 (OH) Ecological Succession

SUPPORTING DIVERSE STUDENT NEEDS

- Some gifted students may have difficulties with the grey areas and indistinct boundaries surrounding some of the concepts in this unit. These students may benefit from an exploration of the more rigorous treatment such concepts receive in books on ecology. Have a few introductory university ecology texts around for these students to explore. Artistic students may appreciate the opportunity to illustrate some of the interactions in graphic art form, or to analyze their favourite graphic art (comic) book for interactions.
- The heavy terminology used in this section will be a bit daunting for ESL students. To check for understanding, ask them to give an illustration of each interaction involving species from their native country. Provide your resource teacher or ESL teacher with a list of terms well ahead of time so students can become familiar with them before starting this section. Visually impaired students may benefit from gently touching plants being grown in the experiment on competition, or claws and teeth of predators. Students in wheelchairs may require a lower than normal lab area so they can reach materials and assist in conducting the investigation.

Answers to Questions for Comprehension

Student Textbook page 719

Q16. Intraspecific competition is the competition for resources among members of the *same* species in a community. Interspecific competition is the competition for resources between two or more *different* species in the same community.

Q17. When there is competition for limited resources (e.g., water, light, nutrients, nesting locations, mates), usually the best-adapted individuals get the most access to the resources and survive to reproduce. When the resources are abundant, almost all individuals will get what they need to survive and reproduce. When the carrying capacity of a habitat is reached, the less well-adapted or less healthy individuals will fail to thrive and are unlikely to reproduce, cutting the growth rate of the population.

Q18. When a non-native species competes with a native species, either the native species can out-compete the non-native species and the latter will die out, or the non-native species can out-compete the native species, which will die out.

Biology File: Web Link

Student Textbook page 719

Gause's findings confirm that no two species can successfully occupy the same niche. One species will always have an advantage that enables it to out-compete the other for the necessary resources (light, nutrients, water, space) and effectively shut out or exclude the losing species from the habitat.

Investigation 20.A: Interspecific and Intraspecific Competition Among Seedlings

Student Textbook pages 720–721

Purpose

Students will design and perform investigations to test the effects of intraspecific and interspecific competition on the growth of seedlings.

Outcomes

- D2.1s
- D2.2s
- D2.4s

Advance Preparation

When to Begin	What to Do
1 week before	■ Buy fresh seeds and collect other materials ■ Photocopy **BLM 20.2.1: Investigation 20.A**

Apparatus	Materials
■ ruler ■ scissors ■ balance	■ seeds (such as basil, marigold, radish, grass, lettuce, bean, or clover seeds) ■ vermiculite or potting soil ■ flower pots

Time Required

- 90 minutes over two weeks (30 minutes to design both experiments, 20 minutes to set up both experiments, two or more 10 minute sessions to record observations and clean up, and 20 minutes to complete Conclusions questions)

Helpful Tips

- Use **BLM 20.2.1: Investigation 20.A** to support this activity. Modify as necessary.
- A week before the investigation, check the viability of some of the seeds by placing a few of them in a damp, folded paper towel. Check the seeds over the next day or two to see if they have germinated.
- Before students plan their investigations, remind them that the prefix, *inter*, means "among" or "between," and the prefix, *intra*, means "within."
- Students should count the number of seedlings of each type in every pot. One method of measuring seedling growth is to cut the seedlings off where they come out of the soil, and then measure their total "wet" biomass. Another method is

to measure the height of a number of individual seedlings, and calculate their average (mean) height.

- After the students have designed their experiments, to save time, have each group split the remaining work. Half of the group members can set up the experiment for Part 1, while the other group members set up the experiment for Part 2.
- Students will be able to make line graphs of their results from Part 1 if they test a series of planting densities. Students will be able to make bar graphs of their results from Part 2 if they test a series of different ratios of seed-types per pot.
- *Expected Results:* Both intraspecific and interspecific competition will have an impact on the growth of plants. Competition is a density-dependent limiting factor that limits the growth of a population. A major consequence of *intraspecific* competition is that the survival and/or reproduction of individual organisms normally declines as the density of the population rises. When two or more populations are competing, students might expect to observe as the population density of one species increases, it may limit the density of the competing species as well as its own.

Safety Precautions

The sprouts may become contaminated with mould or bacteria. Remind students that they must not eat anything in the laboratory, including the sprouts.

Answers to Analysis Questions

1. In Part 1, students tested the effect of intraspecific competition on the growth of individual seedlings in a population. The manipulated variable in this experiment was the amount of intraspecific competition, which students could have altered by planting seeds close together in one pot and progressively farther apart in additional pots. Alternatively, students could have planted a specific number of seeds in a series of pots (e.g., 2 seeds in the first pot, 4 in the second, 6 in the third, and so on).

2. In general, students should find that measuring the "wet" biomass of the seedlings or the height of individual seedlings is effective.

3. **(a)** Students' answers will depend on the overall number of seeds they planted, how closely they planted the seeds in one pot compared to another, and the number of pots of seedlings they used. In general, the more trials that they run, the more useful their results will be.

(b) To demonstrate interspecific competition, students may find that some combinations of seedlings work better than others. Probably students will find that the radish, lettuce, grass, clover, and bean seedlings grow faster than the basil or marigold seedlings. A combination of fast-growing seedlings and slow-growing seedlings can be used to demonstrate the ability of one population to out-compete another population. Seedlings that grow at the same rate can be used to demonstrate the inhibition of growth of members of both competing populations. A series of pots can be used to test the effect of growing different ratios of two seed-types together. The results should be compared to the growth of seedlings that were grown with only one type of seed per pot (control trial).

4. Students should mention incorrect assumptions or poorly controlled variables. For example, if students measured the "wet" biomass of the seedlings, they may state that it would be more correct to measure the seedlings' dry biomass. Also, variables that could give one type of seedling an advantage over another type of seedling should be properly controlled, or even tested, in future experiments. Different plant species have different growth requirements, such as an optimal growth temperature, optimal amount of light for seed germination, and optimal amount of available water.

Answers to Conclusion Questions

5. Students should have found that beyond a certain planting density, increasing the degree of intraspecific competition among seedlings resulted in fewer surviving seedlings, smaller seedlings (as measured by total or average biomass, or average height), or both fewer and smaller seedlings.

6. Students will have been able to detect the effect of intraspecific competition on the entire seedling population if they measured the total biomass of the seedlings. Overall, the more intense the intraspecific competition, the more it reduces the overall growth (in biomass) of a seedling population.

7. As a result of interspecific competition for soil nutrients, water, and perhaps light, when two types of seedlings were grown together, members of one or both of the populations did not grow as well as they would have if grown alone.

8. Fast-germinating, fast-growing seedlings were able to out-compete the slower-growing seedlings, which did not grow as well as they would have if grown alone.

9. In testing intraspecific competition in seedlings, the greater the death rate during germination, the fewer seedlings there would be to compete with one another later on. Students might hypothesize that plants with low germination rates (high death rates during germination) will produce healthier populations when planted close together, compared to plants with higher germination rates. They could test this hypothesis by comparing densely planted seedlings of plants with different germination rates.

Since the death rate of plants is highest during germination, in Part 2, those plants with a higher germination rate would have had a competitive advantage over other plants with lower germination rates. Adult plants would not have this competitive advantage, and interspecific competition between adult plants would be due to their relative ability to obtain soil nutrients, water, light, and room to grow. Planting different ratios of adult plants in a garden plot and measuring the amount or rate of growth of individual plants, or the biomass of each population could test this hypothesis.

Assessment Options

- Collect and assess students' data tables, graphs, and answers to Analysis and Conclusion questions.
- Use Assessment Checklist 1 Designing an Experiment and/or have students complete Assessment Checklist 4 Performance Task Group Assessment, from Appendix A.

Biology File: Try This

Student Textbook page 722

The aim of this exercise is to help students understand that scientific terminology can sometimes hinder communication as much as help it. In these situations, for instance, the classification of the "winning" animals is very much a matter of perspective. In fact, some ecologists find terms such as predator and prey to be unnecessarily limiting and prefer, instead, to describe "predator-prey" relationships in terms of exploitation. If students' responses to this exercise are to be assessed, either formally or informally, all reasonable and well-reasoned answers should be accepted.

Answers to Questions for Comprehension

Student Textbook page 722

Q19. In producer-consumer relationships, consumers drive the natural selection of the producers in that those producers able to avoid being chosen by consumers for eating are more likely to survive and reproduce. Likewise, the scarcity or protective adaptations of producers limit the population of consumers that depend on them.

Q20. One hypothesis to explain hare-lynx population cycles is that predator-prey interactions cause the cycles. According to this hypothesis, increasing numbers of the prey population will cause an increase in the number of the predator population (due to greater food supply), which will eventually lead to a decrease in the number of prey, followed by a corresponding reduction in the predator population. Another hypothesis is that greater numbers of hares deplete their food supply, leading to lower quantity and quality of available food, which leads eventually to a population crash.

Student Textbook page 723

Q21. protective coloration

Q22. An organism displaying Batesian mimicry deters predators by looking like another species that is well-defended. The species it is mimicking may be unpalatable, harmful, or poisonous, but the mimic is not. Instead, it relies upon its similarity to the other species to deter predators. Müllerian mimicry is a co-evolved defense mechanism where two or more species that are poisonous, harmful, or unpalatable benefit by mimicking each other.

Biology File: Web Link

Student Textbook page 723

Scientists John Rendler from James Cook University in Australia and David Reznick from the University of California at Santa Barbara have conducted long term studies of guppy populations in streams. Their results provide evidence for the evolution of guppy populations in response to predation pressures. For example, guppies in habitats where there are fewer total predators tend to have fewer, but larger, offspring compared to guppies in habitats with intense predation. In habitats where predation is intense, guppies tend to have colours that camouflage them. Where predators are fewer, male guppies tend to be brightly coloured. Have students predict how variables such as the density of predators in a habitat will affect a guppy population over time. Students can test their predictions using a simulation such as that at http://www.pbs.org/wgbh/evolution/sex/guppy/

Figure 20.17

Student Textbook page 724

As the text notes, there are few examples of true commensalism. As the bison and cattle both benefit when the cowbirds eat insects that are living on the bison's fur and skin, the relationship is actually one of mutualism.

Answers to Questions for Comprehension

Student Textbook page 725

Q23. Symbiosis is the direct or close relationship between individuals of different species that live together. The relationship can be mutual, parasitic, or commensal.

Q24. Students will most likely choose either lichen or *Acacia* trees/ants. In lichen, the algal partner photosynthesizes, providing food for itself and the other partner, a fungus. The fungus provides protection from the elements for the alga. In *Acacia* trees, the leaves produce food (protein and sugar) that stinging ants consume, and thorns provide a living space for the ants. The ants attack other herbivores that would feed on the tree and remove branches of other plants that would compete with the *Acacia* for light.

Q25. Commensalism is a symbiotic relationship in which one partner benefits and the other neither benefits nor is it harmed.

Q26. In a parasitic relationship, one partner benefits at the expense of the other. This is the only symbiotic relationship that results in harm to one of the partners.

Biology File: Web Link

Student Textbook page 725

Students' answers should include the name of the parasitoid being used as a biological control and that of the species of insect it is controlling, as well as how the insect acts as a pest in Alberta. Answers may also include locations where the parasitoid is being used in Alberta, the success of the parasitoid in controlling the pest population, and risks vs. benefits of using biological control. Accept any well-researched answer.

Investigation 20.B: Celebrate the Small Successions

Student Textbook page 727

Purpose

Students will design and perform an experiment to demonstrate succession in a micro-environment. At the same time, students will demonstrate the effect of an environmental factor on the growth rate of populations.

Outcomes

- D2.2s
- D3.2s
- D2.4s

Advance Preparation

When to Begin	What to Do
1 week before	■ Collect pond water
1 day before	■ Collect and prepare materials for investigation ■ Photocopy **BLM 20.2.5: Investigation 20.B**

Apparatus	Materials
■ microscope ■ laboratory fridge	■ container of 10 % bleach (for used microscope slides, cover slips, and pipettes) ■ paper towels ■ pond water ■ wood shavings or dried grass ■ pH paper ■ microscope slides ■ cover slips ■ long plastic pipettes (preferably ones with built-in bulbs; pipettes should be long enough to reach the jar bottom) ■ 2 mason jars with lids

Time Required

- 110-125 minutes (20 minutes for students to complete their experimental plans, 20 minutes for students to set up the micro-environments, three or more 15-minute sessions for collecting data, 15 minutes for Analysis and Conclusions questions)

Helpful Tips

- Use **BLM 20.2.5: Investigation 20.B** to support this activity. Modify as necessary.
- You may wish to have several different ages of pond water ready to ensure there is a sample with plenty of organisms to observe.
- Students will need to add grass or wood shavings to the micro-environments as an initial food source for consumers.
- You may find it helpful to bring in micrographs of unstained pond water micro-organisms, such as diatoms, *Paramecium*, amoebae, cyanobacteria, and purple and green bacteria, for students to observe. A good online source for images is at http://www.microscopy-uk.org.uk/micropolitan/index.html
- Students can aerate the micro-environments by gently shaking the jars twice a day and leaving the lids off or by using fish tank oxygen bubblers.
- Students can test the effect of temperature on succession in the micro-environments by placing one micro-environment in the laboratory fridge and leaving the other at room temperature in the laboratory.
- You may wish to have each group investigate a different environmental factor and then have students share their results.
- A drop of Protoslo® or methylcellulose can be used on the wet mounts in order to slow down protozoans for easier viewing with the microscope.
- *Expected Results:* It is difficult to predict the expected results for this investigation. Results will depend on the organisms in the pond water and the environmental factor that the students select. The goal of this activity is not to arrive at a specific answer but to observe changes in an ecosystem.

Safety Precautions

- To avoid creating completely anaerobic conditions in the jars and to prevent gases, such as hydrogen sulfide, from building up in the jars, leave the lids on the jars loose.
- Do not leave the micro-environments near open flames. Gases that are produced in the micro-environments may ignite.
- Remind students to be careful not to smell the micro-environments or the bleach solution directly. Breathing in either hydrogen sulfide gas or chlorine gas is dangerous.
- Both you and the students should wash your hands after working with the micro-environments.
- Following the completion of the labs, you must ensure that any harmful micro-organisms in the micro-environments

are destroyed. You can accomplish this by soaking the mason jars and their contents in 10 percent bleach for 30 minutes in a fume hood, and then washing the bleach solution down the sink in a fume hood. Alternatively, you could microwave the jars and contents to boiling (at least four minutes). Only use bleach where there is good ventilation, as it gives off chlorine gas under certain conditions.

Answers to Analysis Questions

1. Students might have chosen to test the effect of temperature, aeration, light, or some other factor on the microbial communities.
2. Students may have observed that layers of "scum" developed on the surface of the water over time, that the water became more or less cloudy, or that the layer at the bottom of the jar turned darker. Also, they may have noticed that the micro-environments started to smell different over time. In the oxygen-poor micro-environments, students may have observed gas bubbles floating up from the bottom of the jar due to microbial decomposition of organic matter. By studying samples with the microscope, students probably found that samples of pond water taken at specific depths in the jar contained different types of organisms, and that over time, the relative numbers of each type of organism changed.

Answers to Conclusion Questions

3. Students' answers will depend on the environmental factor that they tested, although in each case, they should have observed changes in the composition of the microbial community over time.
4. Students may speculate that populations of predators (e.g., amoebae) grew in response to an increased density of prey (e.g., bacteria or diatoms). Interspecific competition may have limited the growth of certain populations, allowing other populations to increase in size.
5. Students will have tested different environmental factors, such as the effect of temperature, aeration, light, or some other factor on the microbial communities.

   Answers may refer to changes in density of particular species, the relative numbers of each type of species, and specific depths at which different densities of species were found.
6. Low levels of oxygen would have slowed the growth of oxygen-dependent organisms, such as *Paramecium,* and possibly encouraged the growth of anaerobic bacteria. Similarly, at fridge temperature, the growth of many populations would have been inhibited. Other species, however, would have thrived in cool temperatures. The absence of light would have slowed the growth of photosynthetic organisms such as green algae, diatoms, and cyanobacteria.

Assessment Options

- Collect and assess students' observations (such as scientific drawings) and answers to Analysis and Conclusions questions.
- Use Assessment Checklist 1 Designing an Experiment, from Appendix A, to evaluate the design of the students' experiments.
- Have students complete Assessment Checklist 3 Performance Task Self-Assessment and Assessment Checklist 4 Performance Task Group Assessment from Appendix A.

Biology File: Web Link

Student Textbook page 728

According to the Virtual Museum of Canada (virtualmuseum.ca), First Nations people used fireweed on burns and other skin conditions. They also used it to make a tea that helped soothe gastro-intestinal and bronchial problems. In addition, the firewood shoots were eaten as a vegetable, and young leaves can be added to salads.

Answers to Questions for Comprehension

Student Textbook page 728

Q27. Succession is the sequence of invasion by and replacement of species in an ecosystem over time, as a result of abiotic and biotic factors.

Q28. (a) Primary succession establishes soil in environments in which no life is present, such as bare rocks left behind by a retreating glacier or on a hardened lava bed. Secondary succession refers to the recolonization of an area after an ecological disturbance, such as a forest fire, flood, or agricultural activity. Soil is already present in such cases.

(b) The first species to colonize an area and initiate succession is considered to be the pioneer community. As succession progresses, one species replaces another. The latecomers in the process form a climax community that will remain relatively stable if there are no major environmental changes.

Thought Lab 20.3: Testing the Classical Model of Succession

Student Textbook pages 729

Purpose

Students will analyze data and formulate hypotheses to test the classical chronological model of succession.

Outcomes

- 30-D2.3k
- 30-D2.1sts
- 30-D3.1sts
- Scientific Inquiry

Advance Preparation

- Teach the concepts of primary and secondary succession the day before.
  Photocopy **BLM 20.2.6: Thought Lab 20.3**

Time Required

- 45 -60 minutes

Helpful Tips

- Use **BLM 20.2.6 Thouhgt Lab 20.3** to support this activity. Modify as necessary.
- The data presented in this activity conflicts with that expected from the classical model of succession. Students are asked to formulate a hypothesis and design an activity that would accept or reject their hypothesis.
- A good source of background information for this activity can be found at the University of Calgary Kananaskis Research Centre website: www.kfs.ucalgary.ca/
  Follow the links to Education Programs.

Answers to Analysis Questions

1. This is an example of secondary succession. Secondary succession occurs after a fire or flood when there are plentiful amounts of nutrients available in the environment.

2. The pine trees should be older than the spruce trees.

3. Take a core sample of the trunk close to the roots and count the number of annual rings.

4. The original hypothesis would be incorrect. Both populations started growing at the same time. One is not replacing the other.

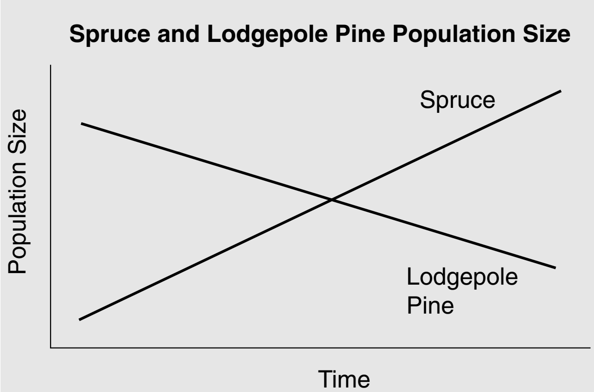
5. Competition for water, space, nutrients in the soil, and predation from animals would all cause seedlings to die.

6. More lodgepole pine seeds successfully germinate than do spruce seeds. (The rate of death is higher for spruce than for pine in section A of the graph.)

7. Because more lodgepole pines seeds have germinated, there is increased competition among the trees for nutrients and light, leading to increased thinning of this species.

8. The shorter trees would die because the taller trees would block the sunlight they require.

9.



Succession in this area is not following a chronological pattern. The species growing together have different growth patterns and are competing with one another for resources.

10. Interspecific competition is more important to the pattern of succession in the study area. All the species growing together in the study area are competing for limited resources. In time, some species will eliminate the others.

Answers to Extension Questions

11. The trees came to grow in the study area because their seeds were previously in the area or were brought to the area by wind or animals.

12. **(a)** A large disturbance like a forest fire would favour those trees that require a lot of light to survive. A small disturbance would favour the shade tolerant trees.

(b) All seeds present in the soil have the potential to germinate.

(c) A lack of moisture would prevent all seeds from germinating, no matter what species are present.

(d) The amount of nutrients in the soil would limit the number of seeds that germinate, no matter what species are present.

The most important factor in determining what species will repopulate an area after an ecological disturbance is "b," the types of seeds in the soil. If the seeds are not there, the plants cannot grow.

Assessment Options

- Collect and assess students' answers to Analysis and Extension questions.

Section 20.2: Review Answers

Student Textbook page 730

1. Interspecific competition is taking place. Reasons for success of the white spruce could include that they have tolerance for a wider variety of soils, are hardier in a greater variety of moisture conditions, and have more consistent reproduction. The lodgepole pine is an early colonizer; its seed cones only open at temperatures associated with forest fires.

2. **(a)** A species often mimics the warning coloration of another species to deter predators. Mimicry is achieved by natural selection, as individuals with such colouring are more likely to survive predation to reproduce.

(b) If the mimic does not mimic the behaviour of its model, predators may realize that the mimic behaves differently and use this difference to distinguish between them.

(c) If the model species were eliminated, predators would eventually realize that the mimic species was not well defended (i.e., not poisonous, unpalatable, or harmful). Predation would increase and the population of the mimic species would decrease.

3. Through natural selection, some individuals in a population have a competitive advantage over other members of their species; for example, some plants are able to grow longer roots to absorb more water. These individuals will be more likely to survive long enough to reproduce and pass on their competitive traits to their offspring. Similarly, members of an animal population may compete with one another for food or shelter. Again, the best-adapted competitors will be more likely to survive and reproduce.

4. **(a)** parasitism

(b) commensalism

(c) mutualism

(d) mutualism

5. Succession is the sequence of invasion and replacement of species in an ecosystem over time. It is driven both by abiotic factors, such as climate, and by biotic factors, such as interspecific competition for changing available resources. Due to interspecific competition and the changing habitat, some populations are better able to survive and will replace those that are not. As the habitat changes, the species of plants and animals change, and community dynamics are in a continual state of flux. Eventually the replacement process ends, and a stable community of varied species develops. This community, known as a climax community, will remain relatively stable if there are no major environmental changes in the future.

6. Student answers should outline a general process of succession. Answers should highlight an initial colonization by annual herbs and grasses, as well as the introduction of various insect, rodent, and bird populations. Predators would soon be attracted to the site, and bushes, shrubs, and trees would become established. Students may mention that over time, shade tolerant species would eventually replace the initial tree population, but this would likely not occur within the time span of ten years. Students may also mention specific species they might see on the site that are local to the area or already present in the neighbourhood. For instance, a student may envision maple trees lining the street and mention this species as a colonizer.

20.3 Sharing the Biosphere

Student Textbook pages 731-738

Section Outcomes

Students will:

- explain why Canadian society supports research and activities to achieve sustainability
- evaluate and summarize the role of an interspecific relationship in the deliberate introduction of a species for biological control, and present a position on the issue
- analyze data on human population growth rates in various countries
- predict Earth's carrying capacity, and justify their position

Key Terms

sustainability
age pyramid

Biology Background

- Human actions change communities. These changes may be rapid and obvious, or slow and difficult to identify. Science can be useful in helping us to understand the changes and their causes.
- Although new species arrive in new habitats naturally, human activity has accelerated the number of species introduced to new habitats, and the rate at which introduction occurs. These introduced species can devastate native species and crops that humans require to survive. Using predators or parasites can control many of these introductions, a procedure called biological control.
- Scientists use principles of population ecology to attempt to understand and predict what human populations will do. Currently, the global human population is in an exponential growth phase, and we cannot tell with certainty what will happen in the future. Some parts of the world support human populations that are stable. Age pyramids can be used to help predict how governments should allocate resources, and what the population will be in the future.
- Amid a great deal of disagreement, estimates of Earth's human carrying capacity suggest values of around 10 billion people. Many factors affect this estimate, however, and it may be impossible at present to predict a carrying capacity with any confidence.

Teaching Strategies

- Use **BLM 20.3.2: Investigating Human Population Growth** to start a discussion with students on the implications of the human growth curve on sustainable development and personal lifestyles. Lead students toward an understanding of how lifestyle has an impact on species today, and on human populations in the future. This is an opportunity to increase awareness and encourage students to make changes in their lifestyles.
- Alberta has a number of deliberately and accidentally introduced species. Assign each student a species that has been introduced into Alberta, and have them design a presentation outlining the impact of the species, the history of its introduction, and steps that are being or could be taken to reduce the impact of the species.
- Use **BLM 20.3.5: Age Structure, 2006: Alberta, Newfoundland and Labrador, Nunavut** to graphically illustrate three populations. Would students class the

populations as rapidly growing population, stable, or in decline?

- The overhead masters and reinforcement tools prepared for this section are listed below. You will find them with the Chapter 20 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.

  Number (Type)
  20.3.2 (HAND) Investigating Human Population Growth
  20.3.2A (ANS) Investigating Human Population Growth Answer Key
  20.3.4 (OH) Age Pyramids, 2000: Democratic Republic of Congo, Sweden, Germany
  20.3.5 (HAND) Age Structure, 2006: Alberta, Newfoundland and Labrador, Nunavut
  20.3.5A (ANS) Age Structure, 2006: Alberta, Newfoundland and Labrador, Nunavut Answer Key

SUPPORTING DIVERSE STUDENT NEEDS

- Gifted students will likely be rather indignant over the impact humans have on the environment and other species. They tend to have a highly developed sense of justice. Give them opportunities to exercise that sense of justice by initiating a new environmentally friendly activity in the school aimed at reducing paper use, electrical use, heating, or waste production. They might like to get involved in supporting an endangered animal or plant species through fund raising or public awareness enhancement. Connect with the Alberta Wilderness Association for information and available programs.
- Asian or African countries can be valuable resources with regards to simpler life styles that have a lesser impact on the environment. Compare how they may have done things in their native country, and how things are done here.

Answer to Question for Comprehension

Student Textbook page 731

Q29 Sustainability refers to the concept of living in a way that meets our needs without compromising the health of future generations or the health of the planet.

Thought Lab 20.4: Biological Control or Damage Control?

Student Textbook pages 732

Purpose

Students will investigate the success of using biological controls to eliminate or control invasive species.

Outcomes

- 30-D2.1sts
- 30-D2.3s
- 30-D3.1sts
- Scientific Inquiry

Advance Preparation

When to Begin	What to Do
3 – 5 days before	■ Arrange access to the library and/or computer resources in the school ■ Prearrange groups and assign a scenario to each group to give students time for research ■ Photocopy **BLM 20.3.1 Thought Lab 20.4**

Time Required

- Allow students 2–3 days to research their topic
- Allow one class for presentations

Helpful Tips

- Use **BLM 20.3.1: Thought Lab 20.4** to support this activity. Modify as necessary.
- Potential helpful web sites include:
  http://www.nps.gov/plants/alien/fact/canu1.htm
  http://www.invadingspecies.com/Programs.cfm?A=Page&PID=24
  http://res2.agr.ca/lethbridge/weedbio/agents/arhicon_e.htm
- A second option is to have students work through the Thought Lab on their own.

Answers to Analysis Questions

1. Students will use the information from the chart to describe their relationship as either predatory or parasitic.
2. It is beneficial when the biological control agent destroys or controls the invasive population. The disadvantage is when the biological control agent also destroys native species.
3. Answers will depend on the interaction given, from very effective (e.g., the cactus moth in Australia) to not useful at all (e.g., the cane toad in Australia).
4. Students may suggest that biological controls that were very specific (the cactus moth for the cactus and the leaf beetle for the purple loosestrife) were successful. The agents that were not specific (like the cane toad for the sugar cane pest and the seed-head weevil for the musk thistle) were not as successful

Assessment Options

- Use Assessment Checklist 4: Performance Task Group Assessment in Appendix A to evaluate the performance of each group.

Thought Lab 20.5: Population Growth Rates in Different Countries

Student Textbook page 734

Purpose

Students will determine the effects of growth rate and initial population size on the shape of population growth curves by examining data from different countries.

Outcomes

- 30-D3.3s

Advance Preparation

When to Begin	What to Do
1-2 days before	■ Check supply of graph paper or book computer lab if students are going to use spreadsheet or graphing software to plot graph ■ Photocopy **BLM 20.3.3 Thought Lab 20.5**

Apparatus	Materials
■ computer, if using ■ ruler, if using graph paper	■ graph paper or access to computer with spreadsheet or graphing software

Time Required

- 30 minutes

Helpful Tips

- Use **BLM 20.3.3: Thought Lab 20.5** to support this activity. Modify as necessary.
- Use this activity as an introduction to your discussion of human population growth and Earth's carrying capacity.

Answers to Analysis Questions

1. Predicted Population Size in Millions from 2001 – 2011 in Selected Countries

Country	cgr %	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Canada	0.3	32.2	32.3	32.4	32.5	32.6	32.7	32.8	32.9	33.0	33.1	33.2
Ethiopia	2.5	77.4	79.3	81.3	83.4	85.4	87.6	89.8	92.0	94.3	96.7	99.1
Finland	0.2	5.2	5.21	5.22	5.23	5.24	5.25	5.26	5.27	5.28	5.29	5.30
Germany	–0.1	82.5	81.7	80.8	80.0	79.2	78.5	77.7	76.9	76.1	75.4	74.6
Greece	–0.1	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.3	10.2	10.1	10.0
India	1.7	1122.4	1141.4	1160.8	1180.6	1200.7	1221.0	1241.8	1262.9	1284.4	1306.2	1328.4
Nigeria	2.4	131.5	134.7	137.9	141.2	144.6	148.1	151.6	155.2	159.0	162.8	166.7

2. Calculation sample:

$$\text{Canada: } cgr = \frac{b}{1000} - \frac{d}{1000} = \frac{10}{1000} - \frac{7}{1000} = 0.003$$

See table in question 1 for all *cgr* values.

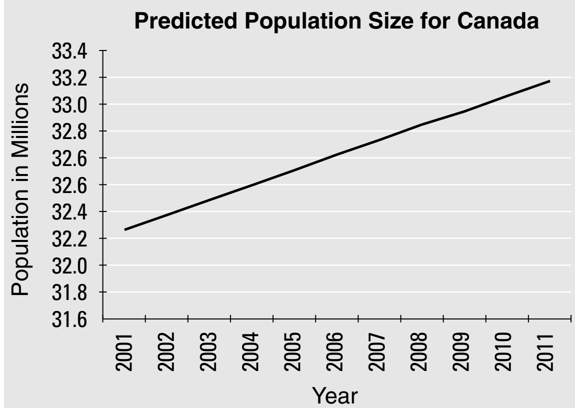
3. Calculation sample:

$$N_{(\text{Canada in 2002})} = N_{(\text{Canada in 2001})} + (cgr)(N_{(\text{Canada in 2001})})$$
$$= (1 + cgr)(N_{(\text{Canada in 2001})})$$
$$= (1 + cgr)(32.2 \times 10^6)$$
$$= (1 + 0.003)(32.2 \times 10^6)$$
$$= 32.3 \times 10^6$$

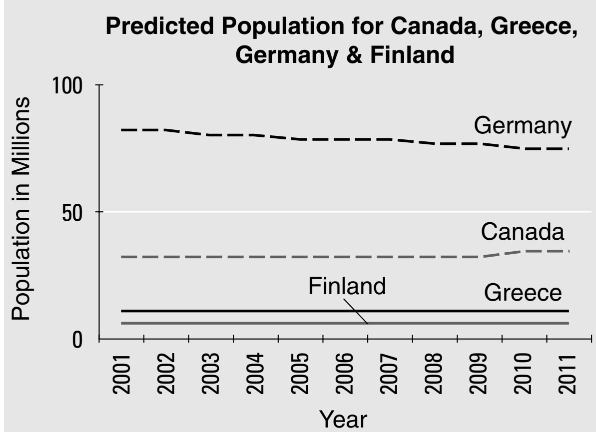
See table in question 1 for all population values.

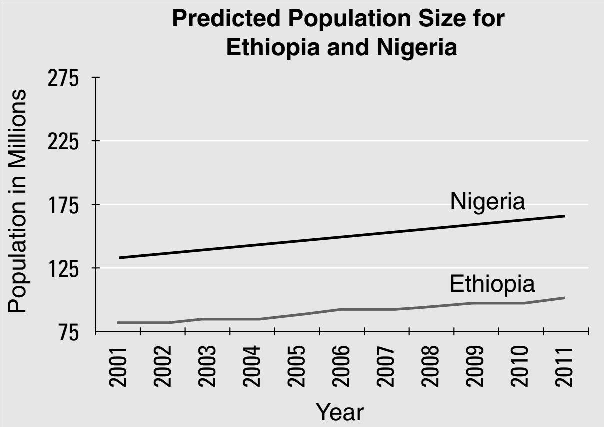
4. See table in question 1 for all population values.

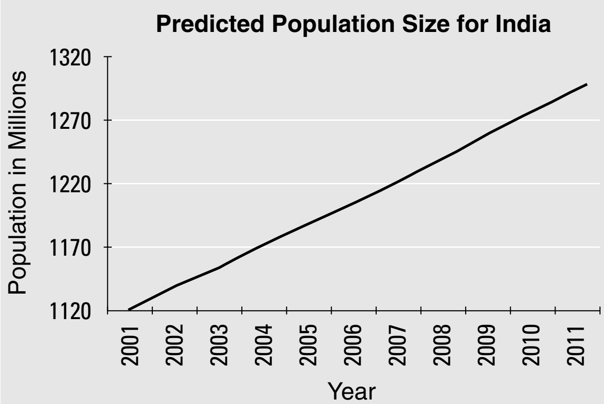
5.



6.







7. The greater the per capita growth rate, the greater the steepness of the curve.
8. The greater the initial size of the population, the greater the steepness of the curve.
9. A negative per capita growth rate indicates that the population is declining. The growth curve would be decreasing instead of increasing.
10. Ethiopia, India, and Nigeria are undergoing exponential growth.
11. The populations of Germany and Greece are decreasing. The population growth of Canada and Finland is slowing down.
12. Canada, Finland, Greece, and Germany would be considered industrialized countries. Population growth in these countries is slowing down or decreasing. Ethiopia, India, and Nigeria would be considered less industrialized countries. Population growth in these countries continues to increase exponentially.

Assessment Options

- Collect and assess students' answers to Analysis questions.

Answers to Questions for Comprehension

Student Textbook page 735

Q30. An age pyramid is a tool that helps demographers assess a population's potential for growth.

Q31. An age pyramid is a stack of layers representing different age categories (usually in five year intervals) showing the percentage of males on the left and percentage of females on the right in each layer. The structure of an age pyramid makes it easy to see the proportion of a population in each of three stages of development, defined as the pre-reproductive stage (0-14 years), reproductive stage (14-44), and post-reproductive stage (45 and older).

Biology File: Web Link

Student Textbook page 736

According to the World Population Clock overseen by the Population Reference Bureau of the United Nations (www.prb.org), each day in 2006 the world population experienced 375,439 births and 154,577 deaths, for a natural increase of 220,862 per day. The natural increase in population for each minute of 2006 was estimated to be 153 people.

Section 20.3: Review Answers

Student Textbook page 737

1. Common answers may include lack of food, clean water, or living space, as well as increased occurrence of disease and violence. Students should be able to justify their choice in terms of global impact of the influence.
2. Because it has the greater population, a reduction in growth would result a larger drop in numbers of births in Brazil than in Turkey. However over time, the impact on Turkey would be greater, because it would experience fewer and fewer births from a shrinking (and already lesser) number of women of reproductive age.
3. As with all other organisms, population density contributes to vulnerability to threats such as disease. The more dense the population, the easier it is to transmit disease among individuals, and it is also likely that resources of all kinds e.g., medicines, healthcare workers, and medical equipment, will be in more demand and supplies may be under pressure.
4. **(a)** The age pyramid for Canada could be described as being rectangular or somewhat like an upside-down triangle. The age pyramids for Ethiopia and India are upright triangle-shaped.

   (b) Based on the age pyramid for 2005, the birth rate in Canada is higher than the death rate, however this situation may reverse as the generation in their middle years ages. Based on the age pyramids for

Ethiopia and India for 2005, these countries' birth rates are much higher than their death rates.

(c) Without increased immigration or an increase in the birth rate in Canada, its population could decline. Otherwise, its population size would remain the same. The large proportion of young people in both Ethiopia and India suggests that their populations will continue to increase substantially in the future. India's population growth may slow sooner than Ethiopia's, since the birth rate in India seems to be stabilizing.

Connections (Social and Environmental Contexts) Helping Hippos and Humans

Student Textbook page 738

Teaching Strategies

- While the sanctuary is designed to protect the hippos and their habitat, it is also designed to bring economic benefit to the local region. Ask students if they feel this is a reasonable trade-off or if the hippo community should be left alone. Some students may wish to investigate the policies designed to protect Canada's national and provincial parks, many of which also combine environmental protection with economic goals, and relate what they find out to the experience at the hippo sanctuary.
- Ask students to consider if the researchers at the Calgary Zoo could benefit from their interaction with the WCHS. If they feel there is no benefit, should the zoo still do these kinds of outreach programs?

Answers to Connections Questions

1. The WCHS helps the locals meet economic goals through ecotourism and by allowing Wechiau residents to continue to fish in the Black Volta River. The proceeds from ecotourism also help residents meet social goals, such as building new schools and drilling new boreholes for drinking water. In addition, residents have been learning about local biodiversity. At the same time, the WCHS helps protect the hippos as well as numerous other species in the ecological community.
2. Students may suggest that when a community has a sense of ownership in a conservation project, they are more likely to actively and willingly participate. Also, a local community may have special knowledge about a particular habitat or species that could be drawn on to develop a more effective conservation program. Furthermore, the conservation program is more likely to last if the local community can continue to run the program on their own.
3. For more information, students can visit: http://www.calgaryzoo.org/AboutTheZoo/ConservationOutreach/

The Conservation Outreach Department of the Calgary Zoo is actively involved in efforts to protect tree kangaroo species and snow leopards (*Panthera uncia*) in Asia, and grey wolves, grizzly bears, and whooping cranes in North America. The department is also working to protect the endangered African wild dog (*Lycaon pictus*). In addition, the Calgary Zoo is a "sister zoo" of the Guyana Zoo in South America, an area that contains a large portion of all biodiversity on Earth but has very limited economic resources to devote to conservation. Although many of the species Conservation Outreach works to protect lie outside Canada's borders, these species are unique in the world, and so many Canadians support protecting them. As Conservation Outreach continues to help more people around the world learn more about the significance and vulnerability of biodiversity, more species and ecosystems can be protected.

Chapter 20: Review Answers

Student Textbook pages 740–741

Answers to Understanding Concepts Questions

1. Student answers may include the following:
   - Population crash if carrying capacity of the environment is exceeded
   - Intraspecific and interspecific competition for limited resources such as food
   - An increase in parasites or disease
   - Human intervention such as pesticide spraying or addition of toxins to the environment
   - Increased predation
   - Abiotic/density-independent factors such as harsh weather (a particularly cold winter or hot summer), fire, drought, or flood
2. Student responses should include the names of the species, a description of the environment, the nature of the competition (e.g., the factors that were in contention), and evidence of a drop in population size of one species.
3. Births (*b*), immigration (*i*), deaths (*d*), and emigration (*e*)
4. $D_p = \frac{N}{V}$

   $= \frac{(4 + 6 + 5 + 3 + 6 + 6)\ \textit{Paramecia}}{6 \text{ drops}}$

   $= 5\ \textit{Paramecia}/\text{drop}$

   $N_{(40\ mL\ sample)} = (5\ \textit{Paramecia}/\text{drop})(20 \text{ drops/mL})(40 \text{ mL})$
   $= 4000\ \textit{Paramecia}$
5. The birth rate must be greater than the death rate.
6. The two types of symbiotic relationships are parasitism and mutualism. The bacterium is acting as a parasite in the first case (where it produces an ulcer) because the bacterium benefits and the host is harmed. In the second

case, where the presence of the bacterium in the stomach can prevent the development of esophageal cancer and acid reflux in the host, the relationship is one of mutualism, as both bacteria and host benefit.

7. $cgr = \frac{\Delta N}{N}$

$= \frac{[b + i] - [d + e]}{N}$

$= \frac{[106 + 42] - [53 + 15]}{1000}$

$= 0.08$

8. The *r*-selected reproductive strategies that make species ideal for the early successional role include the generation of many offspring per reproductive cycle, ability of offspring to survive with little or no parental care, an early reproductive age, and living close to their biotic potential, all of which ensure a large number of offspring will quickly populate the area. Although it may not be intuitive to students, a short life span also helps ensure the area is populated quickly as it ensures less competition between the parent and its large number of offspring.

9. The three patterns of distribution are random, uniform, and clumped. Patterns of distribution are influenced by the distribution of resources in a habitat and the interactions among community members.

10. It limits the growth of populations.

11. Both predation and parasitism decrease the number of organisms per area or volume, and so the number of organisms of reproductive age and the birth rate will decrease.

12. The plants supply food to the herbivores in the same way that the prey supplies food to the predators. In turn, the population of herbivores limits the population of the plants in the same way that predator populations limit their prey populations. In both cases, if the herbivores or the predators become too numerous for their food source, they could cause a crash in the plant/prey population that will in turn cause a crash in their own population.

Answers to Applying Concepts Questions

13. (a) The age pyramid will be an inverted pyramid.

(b) The population size would decrease over time. The death rate would be greater than the birth rate because there are few youths, indicating a low birth rate, and a large elderly population, indicating a relatively high death rate.

14. Environmental resistance to population growth is the result of the combined effects of various, interacting limiting factors. Environmental resistance prevents a population from growing at its biotic potential and determines the carrying capacity of the habitat.

15. $gr = \frac{\Delta N}{\Delta t}$

$\Delta N = (gr)(\Delta t)$

$\Delta N = (10 \text{ plants/year})(5 \text{ years})$

$\Delta N = 50 \text{ plants}$

final number of individuals in population = $\Delta N + N$ = 50 plants + 100 plants = 150 plants

16. The activity should include a defined space, representation of two or three populations, and representation of a fixed amount of resources. Activities should be evaluated in terms of practicality for classroom demonstration, the level of involvement of the theoretical students, and outcomes that show the effect on population growth without creating mayhem in the classroom.

17.
- *Bacterium:* Biotic or density-dependent growth limiting factors include lack of appropriate nutrients, and intraspecific and interspecific competition. Abiotic or density-independent factors include inhospitable temperature and the presence of growth limiting agents such as antibiotics or toxins.
- *Tree:* Biotic or density-dependent growth limiting factors include lack of appropriate nutrients, lack of light, and intraspecific and interspecific competition. Abiotic factors include drought, inhospitable temperatures, a change to intolerable soil pH, fire or flood, presence of growth limiting agents such as toxins, and soil erosion.
- *Mammal:* Biotic growth limiting factors include lack of food, water, or shelter; lack of suitable nesting sites; predation; and intraspecific and interspecific competition. Abiotic factors include harsh weather conditions and presence of growth limiting agents such as toxins.

18. (a) Mutualism. The ants benefit by receiving the food package and the plant benefits by having its seeds dispersed away from the parent, limiting intraspecific competition as they mature. The plant also benefits because its seeds are protected from fire and seed-eating organisms.

(b)
- Commensalism. The Argentine ant benefits, but the plant does not.
- Interspecific competition
- Differing niches

(c) The small seeds are protected from fire and seed-eating insects, so they are more likely to mature and produce offspring than the large seeds. Due to this natural selection, the allele frequency for the small seeds will increase and the plant will produce more small seeds over time.

19. The main danger in increasing the numbers of mollusks is that the increased population may turn to other food sources once the algae has been reduced and in the process, change the ecosystem of the sea. If it did not adapt to other food sources, the mollusk population itself would crash.

20. Comparison of Early and Late Stages of Succession

Characteristic	Early Succession	Late Succession
amount of available light	high	low
biodiversity	low	high
plant biomass	low	high
interspecific competition	low	high
intraspecific competition	low	high

Answers to Making Connections Questions

21. *Possible Benefits:* Because population growth will slow over time, China's resources will be stretched less thinly and the standard of living will be higher. Spread of disease may be less, as living conditions will improve and allow for better hygiene.

Drawbacks: The policy has resulted in an overabundance of males who will have great difficulty finding a mate, and an even greater number of spoiled only children. The impact of abiotic events such as pandemics or natural disasters will be more severe in a slower growing population. The social structure may not be able to support a one-child policy that leaves one family of any marriage without support.

22. (a) Fragmented Forest:

$$D_p = \frac{N}{A}$$

$$= \left(\frac{5 + 12 + 8 + 4 + 11}{5}\right) \text{caterpillars/leaf}$$

$$= 8 \text{ caterpillars/leaf}$$

Continuous Forest:

$$D_p = \frac{N}{A}$$

$$= \left(\frac{8 + 6 + 10 + 9 + 3}{5}\right) \text{caterpillars/leaf}$$

$$= 7.2 \text{ caterpillars/leaf}$$

(b) Fragmented Forest:

(2000 leaves/tree)(8 caterpillars/leaf) = 16 000 caterpillars/tree

Continuous Forest:

(2000 leaves/tree)(7.2 caterpillars/leaf) = 14 400 caterpillars/tree

(c) The assumption was made that the caterpillars were distributed uniformly on the leaves throughout the tree.

(d) Parasitism

(e) Fragmented Forest:

$$\text{Average infection rate} = \frac{\left(\frac{3}{10} + \frac{2}{12} + \frac{2}{8} + \frac{4}{12}\right)}{4}$$

$= 0.26$

Continuous Forest:

$$\text{Average infection rate} = \frac{\left(\frac{2}{6} + \frac{3}{8} + \frac{4}{8} + \frac{6}{12}\right)}{4}$$

$= 0.43$

(f) Because more caterpillars are infected in the continuous forest sample area, which also has a smaller population of caterpillars, one can reasonably conclude that the flies are killing off some of their hosts.

(g) No, there could be fewer caterpillars in the continuously forested area for many reasons. For instance, a type of bird that preys on the caterpillars may require an unfragmented forested habitat. Thus, there are larger numbers of the predators in the continuous forest and the caterpillar population is smaller as a result. In another scenario, humans may have sprayed pesticide on the continuous forest but not on the fragmented forest, thus reducing the population size in the former. Finally, the caterpillars may prefer the leaves of species of trees found in the fragmented forest only.

(h) Secondary succession

Career Focus: Ask a Science Journalist

Student Textbook pages 742–743

Teaching Strategies

- Survey the class for their sources of science information in the media. Do they know the name of the science reporter for their local newspaper? Do they watch science-related television programs or look for information on the Internet?
- Ask students how they rate (and evaluate) science information they read in the popular media. For example, do they trust celebrities who speak out on environmental or other issues? Why? Or why not?
- Ask the class if they plan to pay attention to media reports about science after high school? Do they think this is something they should be aware of in later life?

Answers to Go Further... Questions

1. Decisions about animal population management are based not only on numbers but also on factors such as whether or not the population is a danger to humans (such as elk in the town site of Banff, Alberta) or a nuisance to humans (such as gophers in golf courses). Also, a large animal population in an inappropriate location may be damaging the habitat, making it unusable for other species.

2. Traditional knowledge of Alberta's forests may help scientists to better understand the long-term population dynamics that occur in forest communities. Students may also suggest that traditional knowledge of interspecific interactions could make it easier to correctly predict how a change in one population could affect another. Accept any other reasonable answer.
3. Specific environmental issues are very complicated and, as in all fields of science, answers to ecological questions are rarely concrete. The general public needs to understand the complex nature of environmental issues; otherwise people become confused and thus unable to use scientific information to make decisions. They may even feel unable to discuss environmental issues. As people become more at ease with the idea that the scientific method will always bring up more questions, they are probably going to trust the scientific method more. Students may also suggest that if people rely on black-or-white answers to complex environmental issues, the answers will probably not be realistic.

Unit 8: Review Answers

Student Textbook pages 744–747

Answers to Understanding Concepts Questions

1. Phenotype frequency = 81% + 18.0 % = 99.0%
2. q^2 = 16.0/100 or 0.160

   $q = 0.400$

   $p + q = 1.00$

   $p = 1.00 - q$

   $p = 1.00 - 0.400$

   $p = 0.600$

   The frequency of the dominant allele is 0.600.
3. No. A population is at genetic equilibrium if there is no change in allele frequencies over time. When a population is evolving, a change in allele frequencies is occurring. Thus, a population at genetic equilibrium is not evolving.
4. Intraspecific competition refers to competition for limited resources among members of the same species. As a result of this competition, often only the best-adapted individuals survive to reproduce, reducing the growth rate. In many species, if offspring do not disperse away from their parent or parents, they will be in competition for limited resources. To avoid such competition, insect larvae often look completely different from adults and undergo a complete metamorphosis during their maturation. For instance, to eliminate competition for food between adult and young, the adult butterfly extracts nectar from flowers while immature caterpillars eat leaves.
5. q represents the frequency of the recessive allele in the population. q^2 represents the frequency of the homozygous recessive genotype in the population.
6. Because their gene pool is smaller, small populations are more likely to lose alleles if a chance event causes a reduction in the size of the population, thereby decreasing their genetic diversity. In general, large populations do not experience genetic drift, because chance events are unlikely to affect overall allele frequencies. For example, in a large population of gophers, predators are unlikely to kill all of the gophers with a particular allele, as they may in a small population.
7. Yes. Microevolution is the gradual change in allele frequencies in a population over time. Students may cite the text example of microevolution, i.e. the development of DDT-resistance in *Anopheles* mosquito populations over time, as a similar example.
8. A mutation is a change that occurs in the DNA of an individual. It is the environment that makes certain mutations relatively beneficial, neutral, or detrimental. Natural selection occurs when a mutation produces a phenotype that gives one individual a survival advantage over another.
9. Sexual selection. The peahen preferentially mates with peacocks that have long tails.
10. **(a)** interspecific competition

    (b) The yield increases when the weed population is controlled because interspecific competition for limited resources is decreased. With fewer weeds present, the crop has less competition for nutrients, water, space, and light.
11. **(a)** $D_p = \dfrac{N}{A}$

    $N = (1 \text{ lizard}/3.8 \text{ km}^2)(29 \text{ km}^2)(47)$

    $N = 359$ lizards

    (b) It was assumed that the distribution of this population was uniform throughout its habitat.
12. **(a)** uniform distribution

    (b) clumped distribution

    (c) uniform distribution

    (d) random distribution

    (e) clumped distribution
13. **(a)** mutualism

    (b) commensalism

    (c) parasitism

    (d) protective coloration

    (e) parasitism

    (f) commensalism with mosquito; parasitism with mammalian host
14. **(a)** Müllerian mimicry

    (b) Batesian mimicry

15. You would expect to find a uniform distribution pattern within a population where this process is occurring. Because the sponges exhibit territorial behaviour, it is likely that they will be evenly distributed based on the range of the inhibitory chemical they secrete.

16. Larger animals require a larger territory per individual to graze or hunt in to support their energy requirements, thus they are more affected by habitat loss.

17. Common examples of succession include organisms repopulating an area after a volcanic eruption or the passage of a glacier (primary succession), and after a forest fire or flood (secondary succession). Biotic factors that change during succession include types of species in the community, degree of biodiversity, and intraspecific and interspecific competition for these resources. Abiotic factors that change during succession include levels of nutrients, organic matter, moisture in the soil, soil pH, physical structure of the soil (in primary succession), and availability of light and living space.

18. The age pyramid would have a rectangular shape.

Answers to Applying Concepts Questions

19. $p = 0.70$

$p + q = 1.00$

$q = 1.00 - p$

$q = 1.00 - 0.70$

$q = 0.30$

$2pq = 2(0.70)(0.30)$

$2pq = 0.42$ or 42 %

The percentage of the next generation expected to be heterozygous for this trait is 42%.

20. (a) $q^2 = 1.00/10\ 000$

$q^2 = 0.000100$

$q = 0.0100$

The frequency of the recessive allele is 0.0100.

(b) $q^2 = 0.000100$

$q = 0.0100$

$p + q = 1.00$

$p = 1.00 - q$

$p = 1.00 - 0.0100$

$p = 0.990$

The frequency of the dominant allele is 0.990.

(c) $2pq = 2(0.990)(0.0100)$

$2pq = 0.0198$

The frequency of heterozygotes in the population is 0.0198.

21. Half of population with recessive allele (f) = 50%

$q^2 = 50.0/100$

$q^2 = 0.500$

$q = 0.707$

$p + q = 1.00$

$p = 1.00 - q$

$p = 1.00 - 0.707$

$p = 0.293$

The frequency of the dominant freckle allele (F) that would lead to these results is 0.293.

22. (a) $q^2 = 16.0/100.00$

$q^2 = 0.160$

$q = 0.400$

$p + q = 1.00$

$p = 1.00 - 0.400$

$p = 0.600$

The frequency of the dominant allele is 0.600. The frequency of the recessive allele is 0.400.

(b) $2pq = 2(0.600)(0.400) = 0.480$

48.0% of the population is expected to be heterozygous for this trait.

23. (a) $q^2 = 1.00/2500.00$

$q^2 = 0.000400$

$q = 0.0200$

The frequency if the recessive allele is 0.0200.

(b) Carriers have a heterozygous genotype.

$p + q = 1.00$

$p = 1.00 - q$

$p = 1.00 - 0.0200$

$p = 0.980$

$2pq = 2(0.980)(0.0200)$

$2pq = 0.0392$

3.92 % of the population are carriers.

24. (a) In a class of 36, 12 were non-rollers and 24 were rollers.

$q^2 = 12.00/36.00$

$q^2 = 0.3333$

$q = 0.5773$

The frequency of the recessive allele is 0.5773.

$p + q = 1.00$

$p = 1.00 - q$

$p = 1.00 - 0.5773$

$p = 0.4227$

The frequency of the dominant allele is 0.4227.

(b) $2pq = 2(0.4227)(0.5773) = 0.4880$, or 48.80 %

$(0.4880)(36) = 17.57$

You would expect 18 of the 24 tongue rollers to be heterozygous.

25. (a) For year 1:

$q = 24.00/176.00$

$q^2 = 0.1364$

$q = 0.3693$

$p + q = 1.00$

$p = 1.00 - q$

$p = 1.00 - 0.3693$

$p = 0.6307$

The frequency of the recessive allele is 0.3693. The frequency of the dominant allele is 0.6307.

$q^2 = 0.1364$

$p^2 = (0.6307)^2$

$p^2 = 0.3978$

$2pq = 2(0.6307)(0.1364) = 0.4658$

The frequency of the homozygous dominant genotype is 0.3978.

The frequency of the heterozygous genotype is 0.4658.

The frequency of the homozygous recessive genotype is 0.1364.

For year 5:

$q = 7.00/56.00$

$q^2 = 0.125$

$q = 0.3536$

$p + q = 1.00$

$p = 1.00 - q$

$p = 1.00 - 0.3536$

$p = 0.6464$

The frequency of the recessive allele is 0.3536. The frequency of the dominant allele is 0.6464.

$q^2 = 0.125$

$p^2 = (0.6464)^2$

$p^2 = 0.4178$

$2pq = 2(0.6464)(0.125) = 0.4571$

The frequency of the homozygous dominant genotype is 0.4178.

The frequency of the heterozygous genotype is 0.4571.

The frequency of the homozygous recessive genotype is 0.125.

(b) In the observed population, more than one of the Hardy-Weinberg conditions is not being met. The population is not large enough to ensure that chance events do not alter allele frequencies, and natural selection is possibly occurring. Therefore, this population is evolving. The frequency of the dominant allele has increased over time, and the frequency of the recessive allele has decreased over time, giving evidence to this.

(c) Students may have included the following conditions: disease or parasites that affect squirrels of a specific coat colour preferentially, increased susceptibility to skin cancer in the light-coloured squirrels, higher visibility of light-coloured squirrels to predators, genetic disease linked to one particular genotype, and female preference for mating with male squirrels of a specific coat colour.

(d) If light-coloured fur were dominant to black, natural selection processes would be selecting against the dominant allele. The frequency of the dominant allele would have decreased and the frequency of the recessive allele would have increased.

26. (a) For 1970—1980:

$$cgr = \frac{\Delta N}{N}$$

$$= \frac{(4440 \times 10^6 \text{ people}) - (3699 \times 10^6 \text{ people})}{(3699 \times 10^6 \text{ people})}$$

$$= 0.200$$

For 1980—1990:

$$cgr = \frac{\Delta N}{N}$$

$$= \frac{(5280 \times 10^6 \text{ people}) - (4440 \times 10^6 \text{ people})}{(4440 \times 10^6 \text{ people})}$$

$$= 0.189$$

For 1990—2000:

$$cgr = \frac{\Delta N}{N}$$

$$= \frac{(6068 \times 10^6 \text{ people}) - (5280 \times 10^6 \text{ people})}{(5280 \times 10^6 \text{ people})}$$

$$= 0.149$$

(b) The *cgr* of the human population was decreasing during this time period.

(c) People may be living longer on average so it may take a while for the decrease in *cgr* to cause a decrease in population. Also, because the human population is so large, the number of children being born is still very high despite the decreasing growth rate. As such, it will take time before population growth slows.

(d) Answers may include any of the following factors: increased mortality due to increased incidence of disease, depleted global resources such as food and water due to overpopulation pressures, war, increased incidence of severe weather due to global warming resulting loss of life and famine, and a cultural trend toward smaller families.

27. (a) $gr = \frac{\Delta N}{\Delta t}$

$gr = \frac{[b + i] - [d + e]}{\Delta t}$

$gr = \frac{52 \text{ shrikes} - 116 \text{ shrikes}}{5 \text{ years}}$

$gr = -12.8$ shrikes/year ≈ -13 shrikes/year

(b) Final number of individuals in population = $\Delta N + N = (52 - 116) + 232 = 168$ shrikes

28. $D_p = \frac{N}{A}$

$N = (9 \text{ plants/m}^2)(100 \text{ m})(100 \text{ m})$

$N = 90\ 000$ plants

Four limiting factors that could cause decreased production in the plants if the density increased are lack of light due to shading by crowded plants, spread of disease or pests in a crowded population, over-competition for resources such as water and minerals, and poor root development due to overcrowding.

30. (a) $cgr = \frac{\Delta N}{N}$

$\Delta N = (0.30)(812 \text{ gophers})$

$\Delta N = 243.6$ gophers ≈ 244 gophers

Final number of individuals in population $= \Delta N + N$

$= 244$ gophers $+ 812$ gophers

$= 1056$ gophers

(b) $cgr = \frac{\Delta N}{N}$

$\Delta N = (0.30)(1056 \text{ gophers})$

$\Delta N = 316.8$ gophers ≈ 317 gophers

Final number of individuals in population $= \Delta N + N$

$= 317$ gophers $+ 1056$ gophers

$= 1373$ gophers

(c) Students may include any of the following factors: a scarcity of resources such as shelter, food and water; increased disease and parasites; increased predation; harsh weather, drought, floods, and forest fire; human activity such as destruction of habitat, introduction of toxins into the environment, and construction of hazards.

(d) Density-dependent factors include a scarcity of resources such as shelter, food, and water; increased disease and parasites; and increased predation. Density-independent factors include harsh weather, drought, floods, and forest fire; human activity such as destruction of habitat; introduction of toxins into the environment; and construction of hazards.

30. (a) Students' graphs will show an increasing trend between years 1 and 6 and then a sudden drop between years 6 and 7.

(b) For year 1:

$D_p = \frac{N}{A}$

$N = (17.5 \text{ snails/m}^2)(5 \text{ m}^2)$

$N = 87.5$ snails

For year 3:

$D_p = \frac{N}{A}$

$N = (108.9 \text{ snails/m}^2)(5 \text{ m}^2)$

$N = 544.5$ snails

For year 1 to year 3:

$cgr = \frac{\Delta N}{N}$

$= \frac{544.5 \text{ snails} - 87.5 \text{ snails}}{87.5 \text{ snails}}$

$= 5.22$

(c) $D_p = \frac{N}{A}$

$N = (143.8 \text{ snails/m}^2)(5 \text{ m}^2)$

$N = 719$ snails

(d) Factors may include any of the following: a particularly harsh winter; scarcity of resources due to over population; decreased population of plants that snails rely upon as food; drought; introduction of a new predator to the area; an outbreak of disease or a parasite infestation; destruction of the snails' habitat to put in a new road; contamination of their environment by a new chemical plant nearby; a forest fire; flooding; and increased competition for resources from another species.

Answers to Making Connections Questions

31. (a) Both alleles begin with an identical frequency of 0.5. Over time, the long wing allele (*L*) approaches (but does not reach) 1.0. The short wing allele (*l*) approaches but does not reach 0.0.

(b) In this experiment, natural selection is working against the short wing phenotypes, as this appears to hinder their ability to mate. As a result, the allele frequencies in the population are changing, with the frequency of the recessive short wing allele (*l*) approaching zero.

(c) Most students will realize that, because the long wing allele is dominant, some long wing flies will be heterozygous. Thus, the short wing allele (*l*) will probably never become zero.

32. (a) As succession moves through its stages from early to late, the following changes are depicted on the graph: Net productivity initially increases quickly and then levels off near the middle of succession, reaching its highest level of net productivity. It remains steady until the late stages of the process. Biomass increases slowly at the beginning and then increases more rapidly toward the middle of succession. It continues to increase steadily until the end of the graph. Biodiversity increases steadily at the beginning of succession, peaks in the middle and then dips near the late stages of succession.

(b) Net productivity increases rapidly as highly productive early colonizers with *r*-selected life strategies increase in great number. As competition increases and resources become more limited, net productivity levels off. Biomass increases slowly in the early stages as grasses, annual herbs, and other early colonizers colonize the site. It increases more rapidly toward the middle of succession, as trees and bushes become established, and continues to increase steadily as the community grows. Biodiversity increases steadily at the beginning of succession and peaks in the middle as the early species now provide habitat, food, and other resources for later species. Finally, it dips during the late stages of succession, as interspecific competition reduces biodiversity slightly.

33. These species do not produce many young and hence cannot replace their population rapidly. Also, they tend to be highly specialized for survival and reproduction in their particular habitats. Therefore, small changes to their habitat may have large impacts on their survival.

34. Students may identify some of the following values of high biodiversity: increased stability and resiliency of ecosystem functioning; aesthetic value; source of new drugs, new foods, and other beneficial products; source of economic income if managed properly (e.g., sale of exotic species or ecotourism). Countries can promote ecotourism, sale of exotic foods, or sale of exotic species for pets (e.g., aquarium fish). However, care should be taken to conduct these activities in an environmentally sustainable way.

35. (a) Nigeria's population will probably grow fastest over time, because most of its population is in or entering their reproductive years. The populations of Finland and Sweden are relatively stable.

(b) A decrease in the birth rate in Finland would probably cause its population to decline slightly over time, but a decrease in the birth rate in Greece would likely have a greater effect, because its population already appears to be in decline. A decrease in the birth rate in Nigeria could have a dramatic effect in slowing the rate of population growth, although the population would continue to grow because of the large number of young people.

(c) Students may suggest that, as the work force of Finland and especially Greece reaches retirement age, there will be not enough younger people to fill their places, which could hurt the economy of both countries. Students may also suggest that in Nigeria, insufficient employment opportunities could result in more widespread poverty. Accept any other reasonable answer.

(d) Students should predict that as more people contract HIV and die of AIDS, the death rate in Nigeria would increase, which would slow the population's growth rate or even put it into decline.