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BIOLOGY

CONCEPTS & CONNECTIONS

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CANADIAN EDITION

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10 9 8 7 6 5 4 3 2 1 [CJV]

Library and Archives Canada Cataloguing in Publication

Campbell biology : concepts & connections / Jane B. Reece ... [et al.]. -- Canadian ed.
Includes index.
ISBN 978-0-321-77448-4
1. Biology--Textbooks. I. Reece, Jane B.
QH308.2.C343 2013
570

C2012-908453-0

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About the Authors

Jane B. Reece has worked in biology publishing since 1978, when she joined the editorial staff of Benjamin Cummings. Her education includes an A.B. in biology from Harvard University (where she was initially a philosophy major), an M.S. in microbiology from Rutgers University, and a Ph.D. in bacteriology from the University of California, Berkeley. At UC Berkeley and later as a postdoctoral fellow in genetics at Stanford University, her research focused on genetic recombination in bacteria. Dr. Reece taught biology at Middlesex County College (New Jersey) and Queensborough Community College (New York). During her 12 years as an editor at Benjamin Cummings, she played a major role in a number of successful textbooks. She is lead author of *Campbell Biology*, Ninth Edition, and coauthor of *Campbell Essential Biology*, Fourth Edition, and *Campbell Essential Biology with Physiology*, Third Edition

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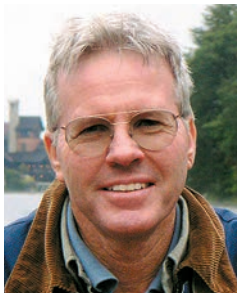

Neil A. Campbell (1946–2004) combined the inquiring nature of a research scientist with the soul of a caring teacher. Over his 30 years of teaching introductory biology to both science majors and nonscience majors, many thousands of students had the opportunity to learn from him and be stimulated by his enthusiasm for the study of life. While he is greatly missed by his many friends in the biology community, his coauthors remain inspired by his visionary dedication to education and are committed to searching for ever better ways to engage students in the wonders of biology.

Kevin G-E. Scott is a senior instructor at the University of Manitoba where he teaches introductory biology for science majors and nonscience majors; ecology for nonbiology majors; and upper-level animal physiology laboratories. In the past, he has also taught courses in immunology, parasitology, human anatomy and physiology, and microbiology. Dr. Scott received a B.Sc. in zoology and a Ph.D. in zoology and cellular, molecular, and microbial biology at the University of Calgary. As an instructor, Dr. Scott has centred his career on teaching and the classroom, where he shares his excitement for biology. This is the first ti Dr. Scott has authored a biology textbook.

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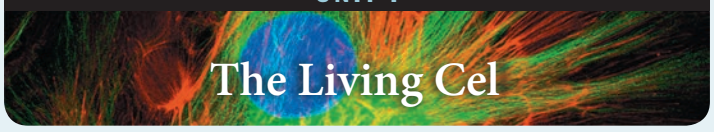

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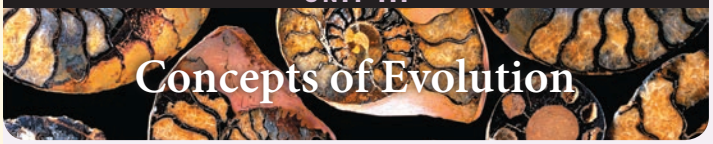

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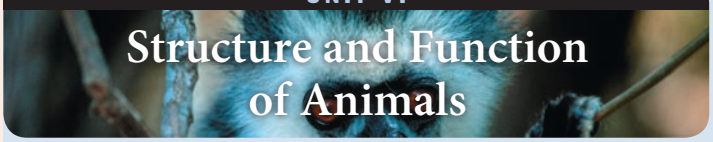

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Preface

Inspired by thousands of students in our own classes over the years and the enthusiastic feedback from many professors who used earlier U.S. Editions, we are delighted to present the Canadian Edition of *Campbell Biology: Concepts and Connections*. We worked hard to reflect the evolving need of today's courses and students, as well as current progress in biology. This book's title continues to honour Neil Campbell' founding role and his many contributions to biology education. The Canadian Edition maintains the dual purposes of prio versions: to engage students from a wide variety of majors in the wonders of the living world and to show them how biology relates to their own existence and the world they inhabit. Most of these students will not become biologists themselves, but their lives will be touched by biology every day. Understanding the concepts of biology and their connections to our lives is more important than ever. Whether we are concerned with our own health or the health of our planet, a familiarity with biology is essential. This basic knowledge plus an appreciatio for how science works are elements of good citizenship in an era when informed evaluations of health issues, environmental problems, and applications of new technology are critical.

The Canadian Edition

In creating a Canadian Edition of *Campbell Biology: Concepts and Connections*, our primary goal is to expose students to biology that they will encounter in Canada. Relating content to local experiences provides a powerful teaching strategy and makes learning more meaningful. The focus on Canadians an Canadian issues, examples, statistics, policies and regulations, flora, fauna, and species allows students to form deeper co - nections with the material. Canadians have made significan contributions to our current understanding of biology, and accordingly this text features their discoveries as well as research conducted in Canada. When students read about a scientist from their own institution, the subject matter comes to life.

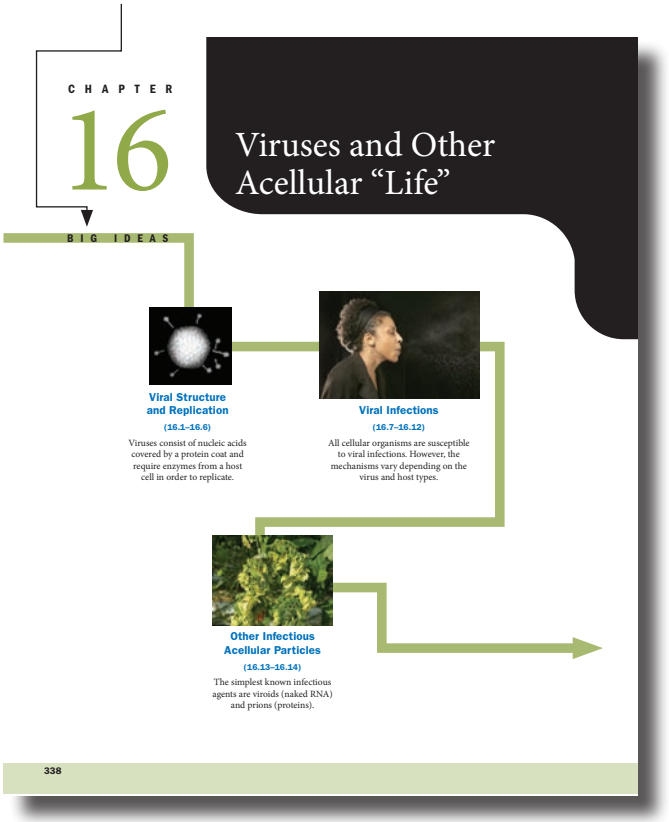
Concepts and Connections

Concepts Biology is a vast subject that gets bigger every year, but an introductory biology course is still only one or two semesters long. This introductory biology textbook i the first to use concept modules to help students recogniz and focus on the main ideas of each chapter. Each module's heading is a carefully crafted statement of a key concept. Fo example, "Two photosystems connected by an electron transport chain generate ATP and NADPH" announces a key concept about the light reactions of photosynthesis (Module 7.8). Such a concept heading serves as a focal point, and the module's text and illustrations converge on that concept with explanation and, often, analogies. The module text walks t student through the illustrations, just as an educator might do in class. And in teaching a sequential process, such as the one diagrammed in Figure 7.8A, we number the steps in the text to correspond to numbered steps in the figure. The synergy between a module's verbal and graphic components transforms the concept heading into an idea with meaning to the student. The checkpoint question at the end of eac module encourages students to test themselves as they proceed through a chapter. Finally, the chapter review lists all the concept statements under the overarching section titles, explicitly reminding students of what they have just studied.

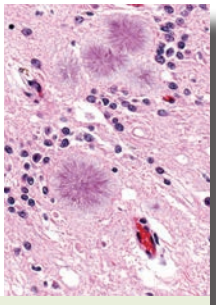
Connections Students are more motivated to study biology when they can connect it to their own lives and interests—for example, to health issues, economic problems, environmental quality, ethical controversies, and social responsibility. In this edition, red tabs labelled *Everyday Biology* indicate the numerous application modules that go beyond core biological concepts. The chapter-opening essays and other sections in th text make connections for readers. Moreover, we connect the content of each chapter to the grand unifying theme of evolution, without which the study of life has no coherence. Thi book remains the only nonmajors biology text to connect every single chapter to evolution, with highlights featured in the green-tabbed *Evolution Connection* modules.

Special Features

- **See where the chapter takes you: *Big Ideas*** provide a road map to overarching concepts with a visual list at the beginning of each chapter, and subheadings throughout to orient students.



- **Discover and explore:** The **opening essays** of each chapter introduce the topic through stories written to pique interest.



Oh Deer! North America's Prion Disease

"Outbreak of Mad Cow Disease Feared!" is a headline that you have probably seen or heard at least once. The technical name for this disease in cattle is bovine spongiform encephalopathy (BSE) because of the spongy appearance of damaged brain tissue in affected areas. BSE leads to abnormal behaviours and ultimately death in cattle. Of even greater concern is the ability of this disease to also affect humans.

What makes this disease different from other infections is that it is not caused by a living cell (such as a parasite or bacterium) or even a virus, but by a simple infectious protein. Prion proteins have a primary structure (that is, an amino acid sequence) similar to healthy proteins found in the body. However, prion proteins are folded differently. Their different shape lowers their solubility in cytoplasm causing the formation of protein crystals.

What causes an outbreak of BSE? The answer is still being debated. Many believe that it is related to the practice of feeding cattle infected animal by-products, including nervous tissue and bone marrow. Once infected, prions cause normal proteins to refold into the prion shape, making the damaging crystals even larger. Cellular damage in the brain leads to a spongy appearance and neurological symptoms, which progresses to a loss of sensory and motor function, and eventually death.

Prion diseases came into the spotlight in the mid-1990s when several people living in or having visited Great Britain were diagnosed with variant Creutzfeldt-Jakob disease (vCJD), a degenerative neurological condition caused by the same prion as BSE. As of 2012, only two cases of vCJD have been confirmed in Canada. Many of those infected had come into direct contact with the BSE prion. How did this happen? Improper handling of infected animal tissues may have contaminated meat. The subsequent ingestion of contaminated meat by humans probably accounts for the majority of these vCJD cases.

Although cases of BSE have been identified in Canada, there is another lesser-known prion disease in our deer, moose, and elk populations that is of rising concern. Chronic wasting disease (CWD) is a prion disease similar to BSE, characterized by dramatic weight loss. CWD was first identified from an emaciated mule deer in Colorado. Since then, this disease has spread to Southern Alberta, Saskatchewan, and many U.S. states. In endemic areas the incidence of infection in the wild population is 10% to 12% and rising annually. In some captive deer populations the incidence can be as high as 80%. This poses a particular risk to wild deer populations in these regions, and their numbers may drastically decline in the coming decades.

The symptoms of CWD are similar to those of BSE. Initially the animal will exhibit psychological disturbances. At about three to four years after infection, the animal will display unusual behaviours. Physical or motor disturbances follow, including a lack of coordination, excessive urination, weight loss, and finally death.

Unlike the BSE prion, which is transmitted directly by the ingestion of contaminated tissues, the CWD prion can be transmitted indirectly when an animal ingests material contaminated by excretions (such as saliva, feces, and urine). Thus, normal grazing behaviours in endemic areas can place animals at risk for infection. This indirect method of transmission leads to its high incidence and makes it very difficult to contain.

Like other prion diseases, CWD has no treatment. The current method of control is the quarantine of herds and euthanization of infected animals. While these containment methods work well in captive herds, it is difficult to control the disease in the wild populations. The Alberta and Saskatchewan governments, working with the Canadian Food Inspection Agency (CFIA) and the Canadian Cooperative Wildlife Health Centre, have established a surveillance program where local hunters submit heads of

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- **Make connections:** ***Everyday Biology*** modules relate biology to everyday life and interests, making the subject matter relevant and more meaningful.

EVERYDAY BIOLOGY

19.12 Angiosperms sustain us—and add spice to our diets

We depend on the fruits and seeds of angiosperms for much of our food. Corn, rice, wheat, and other grains, the main food sources for most of the world's people and their domesticated animals, are dry fruits. Many food crops are fleshy fruits, including apples, cherries, oranges, tomatoes, squash, and cucumbers. (In scientific terms, a fruit is an angiosperm structure containing seeds, so some of what many people consider vegetables are actually fruits.) While most people can easily recognize grains and fleshy fruits as plant products, fewer realize that spices such as nutmeg, cinnamon, cumin, cloves, ginger, and licorice come from angiosperms. **Figure 19.12** shows the source of a condiment found on most Canadian dinner tables: black pepper. The pepper fruits are harvested before ripening, and then dried and ground into powder or sold whole as "peppercorns." In medieval Europe, peppercorns were so valuable that they were used as currency. Rent and taxes could be paid in peppercorns; as a form of wealth, peppercorns were included in dowries and left in wills. The search for a sea route to obtain pepper and other precious spices from India and Southeast Asia led to the Age of Exploration and had a lasting impact on European history.

? **Suppose you found a cluster of pepper berries like the ones in Figure 19.12. How would you know that they are fruits?**

Each berry has seeds inside it.

▲ **Figure 19.12** Berries (fruits) of *Piper nigrum*

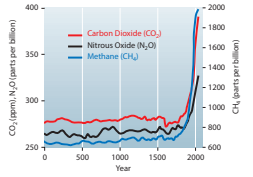
410 UNIT IV The Evolution of Biodiversity

- **Practice good citizenship:** ***Biology and Society*** modules highlight the role of biology in various aspects of society and what students can do to help.

BIOLOGY AND SOCIETY

41.4 Human activities are responsible for rising concentrations of greenhouse gases

Without its blanket of natural greenhouse gases such as CO_2 and water vapour to trap heat, Earth would be too cold to support most life. However, increasing the insulation that the blanket provides is making the planet uncomfortably warm, and that increase is occurring rapidly. For 650 000 years, the atmospheric concentration of CO_2 did not exceed 300 parts per million (ppm); the preindustrial concentration was 280 ppm. Today, atmospheric CO_2 is approximately 385 ppm. The levels of nitrous oxide (N_2O) and methane (CH_4), which also trap heat in the atmosphere, have increased dramatically, too **(Figure 41.4A)**. CO_2 and N_2O are released when fossil fuels—oil, coal, and natural gas—are burned. N_2O is also released when nitrogen fertilizers are used in agriculture. Landfills are a factor responsible for increases of atmospheric CH_4. The consensus of scientists, as reported by the IPCC, is that rising concentrations of greenhouse gases—and thus, climate change—are the result of human activities.



▲ **Figure 41.4A** Atmospheric concentrations of CO_2 and N_2O (y-axis, left), and CH_4 (y-axis, right), as of 2009

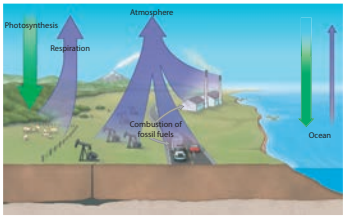
Let's take a closer look at CO_2, the dominant greenhouse gas. Recall from Module 40.7 that atmospheric CO_2 is a major reservoir for carbon. (CH_4 is also part of that reservoir.) CO_2 is removed from the atmosphere by the process of photosynthesis and stored in organic molecules such as carbohydrates **(Figure 41.4B)**. Thus, biomass, the organic molecules in an ecosystem, is a biotic carbon reservoir. The carbon-containing molecules in living organisms may be used in the process of cellular respiration, which releases carbon in the form of CO_2. Nonliving biomass may be decomposed by microorganisms or fungi that also release CO_2. Overall, uptake of CO_2 by photosynthesis roughly equals the release of CO_2 by cellular respiration. CO_2 is also exchanged between the atmosphere and the surface waters of the oceans.

Fossil fuels consist of biomass that was buried under sediments without being completely decomposed (see Module 19.7). The burning of fossil fuels and wood, which is also an organic material, can be thought of as a rapid form of decomposition. While cellular respiration releases energy from organic molecules slowly and harnesses it to make ATP, combustion liberates the energy rapidly as heat and light. In both processes, the carbon atoms that make up the organic fuel are released in CO_2.

The CO_2 flooding into the atmosphere from combustion of fossil fuels may be absorbed by photosynthetic organisms and incorporated into biomass. But deforestation has significantly decreased the number of CO_2 molecules that can be accommodated by this pathway. CO_2 may also be absorbed into the ocean. For decades, the oceans have been absorbing considerably more CO_2 than they have released, and they will continue to do so; but, the excess CO_2 is beginning to affect ocean chemistry. When CO_2 dissolves in water, it becomes carbonic acid. Recently, measurable decreases in ocean pH have raised concern among biologists. Organisms that construct shells or exoskeletons out of calcium carbonate ($CaCO_3$), including corals and many plankton, are most likely to be affected as decreasing pH reduces the concentration of the carbonate ions (see Module 2.16).

Greenhouse gas emissions are accelerating. From 2000 to 2005, global CO_2 emissions increased four times faster than in the preceding 10-year span. At this rate, further climate change is inevitable.

In the next module, we will take a closer look at the rumour about the impact bovine flatulence has on the climate.



▲ **Figure 41.4B** Carbon cycling

? **The amount of CO_2 you are responsible for releasing every year is called your *carbon footprint*. Search for an online calculator that estimates your carbon footprint. What are the primary sources of the CO_2 you generate?**

Transportation and home energy use are the two major categories contributing to carbon footprint.

CHAPTER 41 Conservation and Sustainability 865

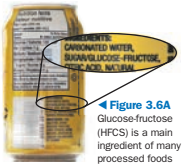
- **Integrate text and visuals:** The **figure** illustrate important concepts in the text while the **surrounding text** explains the figures, which helps students access information easil while promoting a deeper understanding of the subject matter.
- **Test yourself:** Get immediate feedback with a **checkpoint question** at the end of each module.
- **Question what you hear and read:** ***Rumour Has It*** modules within each chapter challenge common misconceptions about biology, thereby encouraging critical thinking.

RUMOUR HAS IT

3.6 Is high-fructose corn syrup to blame for obesity?

If you want to sweeten your coffee or tea, you probably reach for sugar—the disaccharide sucrose. If you drink soft drinks or fruit cocktails, you're probably consuming the monosaccharides of sucrose in the form of high-fructose corn syrup (HFCS; also called glucose-fructose on some Canadian food labels). In fact, if you look at the label of almost any processed food, you will see HFCS on the list of ingredients **(Figure 3.6A)**. You have probably heard rumours linking HFCS to the "obesity epidemic."

What is glucose-fructose? Industrial processing breaks down cornstarch into monomers of glucose, producing what is called corn syrup. Glucose, however, does not taste as sweet to us as sucrose. Fructose, on the other hand, tastes much sweeter than both



◀ **Figure 3.6A** Glucose-fructose (HFCS) is a main ingredient of many processed foods

44 UNIT I The Living Cell

- **Learn about the mechanisms underlying evolution:** ***Evolution Connection*** modules in every chapter relate evolution to a wide spectrum of biology topics and help to explain the mechanisms underlying evolution and the evidence for it.
- **Review the main points:** The ***Reviewing the Concepts*** section provides a helpful summary of the chapter along with key diagrams.
- **Link the chapter's key concepts:** ***Connecting the Concepts*** activities test students' ability to relate topics from the different modules and include concept mapping, labelling, and categorizing exercises.
- **Prepare for assessment:** Questions in the ***Testing Your Knowledge*** section help students to prepare for upcoming tests.
- **Learn the Language of Biology: Appendix D** presents an etymology of biological terminology. Breaking down words into their prefixes, roots, and suffixes assists with learni new terms.

This Book's Flexibility

Though a biology textbook's table of contents must be linear biology itself is more like a web of related concepts without a single starting point or prescribed path. Courses can navigate this network starting with molecules, with ecology, or somewhere in between. The Canadian Edition of *Campbell Biology: Concepts and Connections* provides flexibility as the seven units of the boo are largely self-contained, and in a number of the units, chapters can be assigned in a different order without much loss of cohe - ence. The numbered modules make it easy to omit modules or t relocate modules within a syllabus.

Organizational and Content Highlights of the Canadian Edition

Chapter 1 Designed to engage Canadian students' interest in the discipline from the start, the chapter-opening essay features our cover subject, the Kermode bear. This topic is revisite throughout the chapter and elsewhere in the book. Chapter 1 sets the stage for what is to come by introducing several themes central to the field. Evolution is presented as the unifying concept tha explains the unity and diversity of life on Earth. This introductor chapter introduces the scientific method as a means to understan the world around us, with a focus on observations and hypotheses. The chapter ends with an examination of connections betwee biology, technology, and society, which shows how biology can be linked to our everyday lives.

Unit I – The Living Cell The first unit delves into the lives of l - ing cells.

Chapter 2 begins with an examination of the basic chemistry necessary to understanding biology, such as atoms and compounds, chemical bonding, and the properties of water. This chapter incorporates an engaging discussion about acid precipitation in Eastern Canada.

Chapter 3 moves into the chemistry of the major biological molecules, including carbohydrates, proteins, nucleic acids, and lipids. Students will learn about the membrane composition of an Arctic animal of interest.

Chapter 4 tackles cellular structure—that is, cell and cellular components including the nucleus, endomembrane system, mitochondria and chloroplasts, and the cytoskeleton. This chapter features the production of silk proteins by Montreal-based Nexia Biotechnologies.

Opening with an essay on bioluminescence, Chapter 5 examines cellular components with a focus on the structure and function of cell membranes. The exploration of cell function progresses into biochemical reactions, including the flow of energy and how enzymes function. This chapter showcases the research of Dr. Berghuis at McGill University on enzyme inhibitors.

The last two chapters of this unit explain how cells obtain energy to perform work. Chapter 6 begins with an overview of cellular respiration, followed by a more detailed explanation of each of the major steps. An alternative metabolic pathway, fermentation, is introduced, and highlights research on fermentation during beer production by Dr. Speers at Dalhousie University. The chapter concludes with a discussion connecting the major metabolic pathways.

Photosynthesis is the topic of Chapter 7. Following an overview of the entire pathway, this chapter presents a detailed explanation of the light-dependent reactions and light-independent reactions. Chapter 7 showcases Canadian biomass energy plantations growing switchgrass, a C_4 plant.

Unit II – Cellular Reproduction and Genetics Unit II explains the relationship between DNA, chromosomes, and organisms. Students learn that genetics is not purely hypothetical, but connects in many important and interesting ways to their lives, human society, and other life on Earth. This edition provides a basic understanding of genetics t some of the latest discoveries in epigenetics.

Chapter 8 talks about the two major mechanisms of cell division in the eukaryotes, mitosis and meiosis. After explaining the various roles of mitosis, a detailed discussion on the eukaryotic cell cycle follows. Inheritance and genetic recombination are introduced as we look at meiosis and crossing over. A module in this chapter explores the research of University of Calgary's Dr. Buret on the benefits of epidermal growth factor.

Launching with a chapter-opening essay on the phylogeny of show dogs, the discussion of inheritance continues in Chapter 9 with an examination of the patterns of inheritance, including Mendel's laws and their variations. After an interesting discussion on genetic screening as well as the incidence of cystic fibrosis in the small, isolated population of Saguenay–Lac-Saint-Jean, Quebec, this chapter concludes by developing the link between meiosis, Mendelian inheritance, and chromosomal behaviour in an exploration of the chromosomal basis of inheritance.

Fans of the TV series *Breaking Bad* will find Chapter 10's opening essay on the effects of ricin, a toxin, interesting. The flow of information from gene to protein is the topic of this chapter. This discussion includes examinations of DNA structure, DNA replication, transcription, and translation.

Chapter 11 explains how gene expression is controlled. We end this chapter with discussions on two practical examples of controlling gene expression: cloning and cancer.

The final chapter of this unit, Chapter 12, identifies DNA technologies such as gene cloning, genetically modified

organisms, DNA profiling, and the study of whole genomes in the field of genomics. Module 12.8 features the environmentally transgenic "Enviropig" developed at the University of Guelph.

Unit III – Concepts of Evolution A main goal of this book is to present the basic principles of evolution and natural selection, the evidence that support these theories, as well as their relevance to all of biology and to the lives of students.

Chapter 13 explains theories regarding the origins of life on Earth and major evolutionary events. Students will learn more about the Burgess Shale, one of the world's most celebrated fossil fields found in the Rocky Mountains of British Columbia.

Chapter 14 covers the mechanisms of evolution. This chapter begins by explaining that populations are the unit of evolution and goes on to describe both microevolution and macroevolution.

Chapter 15 concludes the evolution unit with an examination of speciation and phylogeny. We introduce students first to different concepts of what a species is and then to how new species can form after barriers to reproduction are established. Module 15.2 explores the hybridization of grizzly and polar bears in the Canadian Arctic. A discussion of phylogeny and the tree of life provides an excellent link between evolution and the next unit on the diversity of life.

Unit IV – The Evolution of Biodiversity The diversity uni surveys all life on Earth in less than 125 pages! Descriptions and illustrations of the unifying characteristics of each major group of organisms, along with a small sample of its diversity, make up much of the content. Two recurring elements are interwoven with these descriptions: evolutionary history and examples of relevance to our everyday lives and society at large.

Opening with an essay on the chronic wasting disease in Alberta deer populations, Chapter 16's discussion of the vast diversity of organisms on the planet starts with organisms that many consider not living: viruses and other acellular, molecular organisms. This chapter compares various viral structures and replicative cycles and several viral infections in bacteria, animals, and plants. The chapter discusses the replicative West Nile virus, a concern of many who live in Canada. Chapter 16 ends with a brief discussion on viroids and prions.

Starting with an essay that details antibiotic resistant bacteria, Chapter 17 explores the diversity and genetics of bacteria. This chapter ends by exposing students to how bacteria can affect their daily lives.

Chapter 18 surveys the diversity of the eukaryotic microorganisms, including the protists and fungi.

Chapter 19 considers the diversity of plants, including a brief exploration of their evolutionary patterns. As the major group of land plants, the final Big Idea focuses on the diversity of the flowering plants.

Invertebrate animal diversity is the topic of Chapter 20. We discuss what an animal is and survey nine of the major animal phyla. This chapter details the impact of invasive earthworms on the soil in Canadian forests. It ends with a brief discussion on the evolution of our understanding of the relationships between the major phyla.

Chapter 21 features vertebrate diversity. In this chapter, we cover the major events in the evolution of the vertebrates, including the evolution of jaws and limbs, and adaptations for life on land. The chapter concludes with a focus on the evolution of primates and humans.

Unit V – Plants: Structure and Function To help students gain an appreciation of the importance of plants, this unit presents the anatomy and physiology of angiosperms with frequent connections to the importance of plants to society.

Focusing on the flowering plants, Chapter 22's opening essay describes Cathedral Grove on Vancouver Island and then the chapter shifts into an overview of plant structure, comparing monocots with eudicots. The chapter next describes three basic organs and three tissue systems of angiosperms as well as primary and secondary growth patterns. A discussion of the mechanisms of plant reproduction and development follows this content. This chapter showcases the work by Dr. Fowler at the University of Saskatchewan on the benefits of planting winter wheat.

The text devotes Chapter 23 to plant nutrition. Covering the uptake of nutrients from the soil and their transport throughout the organism, the chapter highlights common fertilization regimes for Canadian crops.

Chapter 24 discusses how plants can regulate their growth through several plant hormones, and how plants can respond to stimuli such as light and herbivores.

Unit VI – Structure and Function of Animals Unit VI outlines unifying concepts of animal form and function, introducing students to the major organ systems of vertebrates. Most chapters start with an overview of a general problem that animals face followed by a comparison of how different animal address this problem, within an evolutionary context. The earl modules of each chapter discuss the diversity of form and function seen in the animal kingdom. The last part of every chapte devotes a detailed presentation of human body systems, enhanced by an exploration of the health consequences of disorders in those systems.

Chapter 25 starts with an overview of the basic tissue types and organ systems seen among animals. This chapter ends with a discussion on how animals exchange matter and energy with their external environment while they regulate their internal environment.

Chapter 26 addresses animal nutrition, starting with the various ways by which animals acquire their meals. Subsequently, the human digestive system and human nutrition are explored.

The mechanisms of gas exchange seen within the animal kingdom open Chapter 27. Module 27.8 features the fascinating work by Dr. Yauk at Carleton University on the relationship between second-hand smoke and inheritable cancers; consequently, this chapter is very relevant for students. The discussion on the human respiratory system and the transport of oxygen and carbon dioxide within the human body at the end of this chapter links Chapter 27 to the circulatory system covered in Chapter 28.

Chapter 28 covers both the circulatory and urinary systems, which—given their close interactions—creates a natural flow and progression for the coverage of systems. This chapter

offers an overview of animal circulatory systems, including that of the diving sperm whale, and then delves into the human condition.

Chapter 29 focuses on the endocrine system, a third system that relies on circulation. Students can read about the nature of chemical regulation, including how hormones work, and the vertebrate endocrine system, with emphasis on the human animal. An investigation of hormone-based performance enhancing drugs will pique students' interest given the recent media attention of athletes who take those substances to improve results.

Dr. Vance Trudeau's work at the University of Ottawa on the captive breeding of endangered frog species provides an appropriate opening to Chapter 30, which is devoted to animal reproduction and development. Covering the principles of sexual reproduction and embryonic development, the chapter investigates human reproductive systems and the developing human.

Chapter 31 examines the organization and evolution of nervous systems in animals and the function of neurons and the transmission of electrical signals. This chapter highlights the research of Dr. Norman Doidge on retraining the adult brain and the work of the Rick Hansen Foundation on spinal cord injuries. The chapter concludes with an exploration of the human brain.

The examination of the nervous system continues in Chapter 32 by delving into the senses. First covering sensory reception, the chapter then focuses on hearing and balance, vision, taste, and smell.

Highlighting the University of Calgary's Dr. Cy Frank and his knee surgery techniques in the chapter-opening essay sets the tone for Chapter 33's coverage of the skeletal and muscular systems and animal locomotion. First, the chapter introduces the requirements for locomotion. This is followed by a deeper investigation of skeletons and muscle contraction. This chapter includes the research of Drs. Rudnicki (University of Ottawa), Rossi (University of British Columbia), and Tremblay (Université Laval) on satellite cells and muscle repair in Duchenne muscular dystrophy (Module 33.13).

Finally, Chapter 34 explores animal defences and their immune systems. In this chapter, we talk about innate and acquired immunities, and end with the conditions that may result from specific examples of inappropriate immune responses.

Unit VII – Ecology The final unit of this book explores t basic principles of ecology and how these principles apply to environmental challenges.

Chapter 35 explores the physical and chemical factors that influence life on Earth. Opening with an essay on Arctic sea ice, this chapter offers an overview of the major aquatic and terrestrial biomes. The chapter closes with the water cycle, which connects the biomes.

Chapter 36 revisits animals, this time focusing on behavioural ecology and the forms of learning and reproductive and social behaviours. This chapter profiles work by Dr. Wilson at the Bamfield Marine Sciences Centre on Pacific herring communication.

Chapter 37 covers population ecology by exploring population structure and dynamics, and applies these principles to the human population. This chapter includes a discussion of the Atlantic cod moratorium.

Beginning with details of the devastating effects of the mountain pine beetle, Chapter 38 covers concepts of community ecology with an exploration of aspects of community structure (that is, species interactions) as well as community dynamics (that is, disturbances). Landscape ecology, a new topic for this edition, includes a module on structural changes in communities across a landscape and a module on transition zones between adjacent communities.

A new chapter to *Campbell Biology: Concepts and Connections*, Chapter 39 on symbioses explores some of the more intimate interactions between species. It examines symbiotic relationships such as mutualism, parasitism, commensalism, altruism, and mimicry. A discussion of the co-evolution of symbioses ends this new chapter.

Chapter 40's focus is ecosystem ecology. Beginning with an examination of ecosystem structure, the chapter offers a detailed look at ecosystem dynamics, including energy flow and chemical cycling within ecosystems. Module 40.10 offers insight into the eutrophication of Lake Winnipeg.

The final chapter of Unit VII and the book features conservation and sustainability, returning to the importance of good citizenship by examining the impact of human actions. While this chapter reviews human activities that lead to a loss in biodiversity, we convey a message of hope and optimism by showcasing the restoration of aquatic ecosystems in La Mauricie National Park in Quebec and by focusing on how we can contribute to sustainability and conservation.

Appendices The appendices to this book include: the periodic table of the elements, now with electronegativity values (Appendix A); amino acids found in proteins (Appendix B); major organic functional groups and their properties (Appendix C); a new appendix on the etymology of the terminology of biology (Appendix D); and answers to the end-of-chapter review questions (Appendix E).

Instructor Ancillaries

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Acknowledgements

This Canadian Edition of *Campbell Biology: Concepts and Connections* is the result of the combined efforts of man talented and hardworking people. I wish to extend my heartfelt appreciation to all those who contributed, especially the authors of the U.S. Editions. The final version of this book was shap by input from the dedicated reviewers listed in the next column, who have shared their experiences and ideas to improve the book.

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For many students, introductory biology is the only science course that they will take during their college or university years. Long after today's students have forgotten most o the specific content of their biology course, they will b left with general impressions and attitudes about scienc and scientists. We hope that this Canadian Edition of *Campbell Biology: Concepts and Connections* helps to make those impressions positive and supports instructors' goals for sharing the fun of biology. In our continuing efforts t improve the book and its supporting materials, we benefi tremendously from instructor feedback, not only in formal reviews but also via informal communication. Please let us know how we are doing and how we can improve the next edition of the book.

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