ORGANIC CHEMISTRY

WITH BIOLOGICAL TOPICS

FIFTH EDITION

JANICE GORZYNSKI SMITH
HEIDI R. VOLLMER-SNARR

Mc Graw Hill Education

Periodic Table of the Elements

Atomic number → 67; Symbol → Ho; Name → Holmium; Atomic weight → 164.9303

An element

Group number → 1A; Period number →

Period	1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	8A	Period
1	1 H Hydrogen 1.0079																	2 He Helium 4.0026	1
2	3 Li Lithium 6.941	4 Be Beryllium 9.0122											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984	10 Ne Neon 20.1797	2
3	11 Na Sodium 22.9898	12 Mg Magnesium 24.3050											13 Al Aluminum 26.9815	14 Si Silicon 28.0855	15 P Phosphorus 30.9738	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948	3
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.9559	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.9380	26 Fe Iron 55.845	27 Co Cobalt 58.9332	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.41	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80	4
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.9059	40 Zr Zirconium 91.224	41 Nb Niobium 92.9064	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.82	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.9045	54 Xe Xenon 131.29	5
6	55 Cs Cesium 132.9054	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)	6
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (272)	108 Hs Hassium (270)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 — — (284)	114 Fl Flerovium (289)	115 — — (288)	116 Lv Livermorium (293)	117 — — (294)	118 — — (294)	7

	Period															Period
Lanthanides	6	58 Ce Cerium 140.115	59 Pr Praseodymium 140.9076	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.9253	66 Dy Dysprosium 162.50	67 Ho Holmium 164.9303	68 Er Erbium 167.26	69 Tm Thulium 168.9342	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967	6
Actinides	7	90 Th Thorium 232.0381	91 Pa Protactinium 231.0359	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)	7

Organic Chemistry with Biological Topics

Fifth Edition

Janice Gorzynski Smith
University of Hawaiʻi at Mānoa

Heidi R. Vollmer–Snarr
Stanford University

ORGANIC CHEMISTRY WITH BIOLOGICAL TOPICS, FIFTH EDITION

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 21 20 19 18 17

ISBN 978-1-259-92001-1
MHID 1-259-92001-1

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Cover Image: © *Adam Gault/Getty Images*
Compositor: *Lachina Publishing*
Printer: *LSC Communications*

Library of Congress Cataloging-in-Publication Data

Names: Smith, Janice G. | Vollmer-Snarr, Heidi R. | Smith, Janice G. Organic chemistry.
Title: Organic chemistry with biological topics / Janice Gorzynski Smith, Heidi R. Vollmer-Snarr.
Description: 5e [5th edition, updated]. | New York, NY : McGraw-Hill Education,
2018. | Previous edition: Organic chemistry / Janice Gorzynski Smith
(New York, NY : McGraw-Hill, 2014). | Includes index.
Identifiers: LCCN 2016042232 | ISBN 9781259920011 (hardcover)
Subjects: LCSH: Chemistry, Organic—Textbooks.
Classification: LCC QD253.2 .S6325 2018 | DDC 547—dc23

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About the Authors

Janice Gorzynski Smith was born in Schenectady, New York. She received an A.B. degree *summa cum laude* in chemistry from Cornell University and a Ph.D. in organic chemistry from Harvard University under the direction of Nobel Laureate E. J. Corey. After a postdoctoral fellowship, Jan joined the faculty of Mount Holyoke College, where she was employed for 21 years, teaching organic chemistry and conducting a research program in organic synthesis. After spending two sabbaticals in Hawai'i in the 1990s, Jan and her family moved there permanently in 2000, and she became a faculty member at the University of Hawai'i at Mānoa. She has four children and four grandchildren. When not teaching, writing, or enjoying her family, Jan bikes, hikes, snorkels, and scuba dives, and time permitting, enjoys travel and quilting.

Heidi R. Vollmer–Snarr was born in Pittsburgh, Pennsylvania. She received a B.S. degree in chemistry and a B.A. degree in German from the University of Utah and a Ph.D. in organic chemistry from Oxford University under the direction of Sir Jack Baldwin. As an NIH Postdoctoral Fellow, she worked for Koji Nakanishi at Columbia University and was an Assistant Professor at Brigham Young University, where her research involved the synthesis and photochemistry of ocular retinoid age pigments. Heidi now focuses on curriculum development at Stanford University and serves on the NIH Small Business Sensory Technologies study section and ACS Committee on Chemistry and Public Affairs. She also loves to spend time skiing, biking, and hiking with her husband, Trent, and three children, Zach, Grady, and Elli.

For Megan Sarah Smith and Charles J. Vollmer

Contents in Brief

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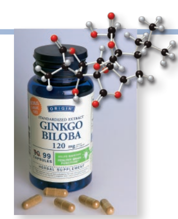
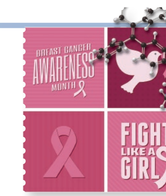
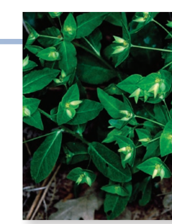
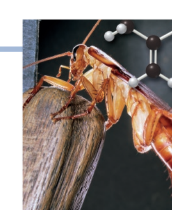





FIRST CHECK
CHOLESTEROL
HOME TEST





Preface

Since the publication of *Organic Chemistry* in 2005, chemistry has witnessed a rapid growth in its understanding of the biological world. The molecular basis of many complex biological processes is now known with certainty, and can be explained by applying the basic principles of organic chemistry. Because of the close relationship between chemistry and many biological phenomena, *Organic Chemistry with Biological Topics* presents an approach to traditional organic chemistry that incorporates the discussion of biological applications that are understood using the fundamentals of organic chemistry.

The Basic Features

Organic Chemistry with Biological Topics continues the successful student-oriented approach used in *Organic Chemistry* by Janice Gorzynski Smith. This text uses less prose and more diagrams and bulleted summaries for today's students, who rely more heavily on visual imagery to learn than ever before. Each topic is broken down into small chunks of information that are more manageable and easily learned. Sample Problems illustrate stepwise problem solving, and relevant examples from everyday life are used to illustrate topics. New concepts are introduced one at a time so that the basic themes are kept in focus.

The organization of *Organic Chemistry with Biological Topics* provides the student with a logical and accessible approach to an intense and fascinating subject. The text begins with a healthy dose of review material in Chapters 1 and 2 to ensure that students have a firm grasp of the fundamentals. Stereochemistry, the three-dimensional structure of molecules, is introduced early (Chapter 5) and reinforced often. Certain reaction types with unique characteristics and terminology are grouped together. These include acid–base reactions (Chapter 2), oxidation and reduction (Chapters 12 and 20), radical reactions (Chapter 15), and reactions of organometallic reagents (Chapter 20). Each chapter ends with Key Concepts, end-of-chapter summaries that succinctly organize the main concepts and reactions.

New to *Organic Chemistry with Biological Topics*

While there is no shortage of biological applications that can be added to an organic chemistry text, we have chosen to concentrate on the following areas.

- **Chapter 3** on functional groups now includes an expanded section on four types of biomolecules—amino acids and proteins, monosaccharides and carbohydrates, nucleotides and nucleic acids, and lipids. This material augments the discussions of vitamins and the cell membrane, topics already part of *Organic Chemistry* in past editions. Phosphorus-containing compounds such as ATP (adenosine triphosphate), the key intermediate used in energy transfer in cells, are also introduced in this chapter.
- **Chapter 6** now uses biological examples to illustrate the basic types of organic reactions, and the energetics of coupled reactions in metabolism is presented. The discussion of enzymes as biological catalysts is expanded, and a specific example of an enzyme's active site is shown.
- **Chapter 17** now applies the discussion of aromatic heterocycles to the bases in DNA, the high molecular weight molecule that holds the encrypted genetic instructions for our development and cellular processes. In addition, new material has been added on the synthesis of female sex hormones with the aromatase enzyme, which has resulted in the development of drugs used to treat estrogen-dependent breast cancers.

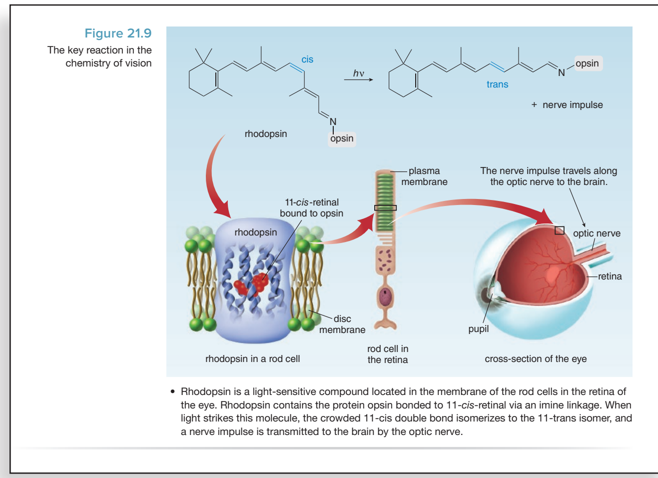
- **Chapter 19** contains a section on the Henderson–Hasselbalch equation, a mathematical expression that allows us to tell whether a compound exists as an uncharged compound or ion at the cellular pH of 7.4. A section on phosphoric acid esters has been added, and the ionization of amino acids is now explained using the Henderson–Hasselbalch equation.
- **Chapter 22** contains additional material on two common carboxylic acid derivatives—acyl phosphates and thioesters. The role of these functional groups in the biosynthesis of amino acids and the metabolism of fatty acids is discussed.
- **Chapter 24** contains a new section on biological carbonyl condensation reactions. Topics include the biological aldol reaction in the citric acid cycle, the retro-aldol reaction in the metabolism of glucose, and the biological Claisen reaction in the biosynthesis of fatty acids.

In addition, the later chapters of the text are now reorganized to emphasize the connection of biomolecules to prior sections. The chapter on Amino Acids and Proteins (Chapter 26) now directly follows the chapter on Amines (Chapter 25), followed by the remaining chapters on biomolecules, Carbohydrates (Chapter 27) and Lipids (Chapter 28).

Tools to Make Learning Organic Chemistry Easier

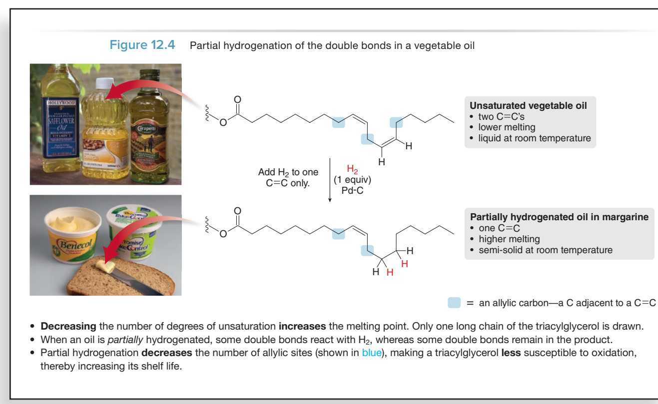
Illustrations

Organic Chemistry with Biological Topics is supported by a well-developed illustration program. Besides traditional skeletal (line) structures and condensed formulas, there are numerous ball-and-stick molecular models and electrostatic potential maps to help students grasp the three-dimensional structure of molecules (including stereochemistry) and to better understand the distribution of electronic charge.



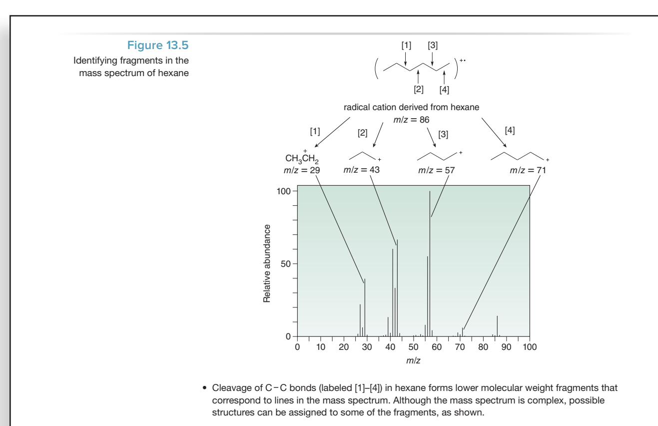
Micro-to-Macro Illustrations

Unique to *Organic Chemistry with Biological Topics* are micro-to-macro illustrations, where line art and photos combine with chemical structures to reveal the underlying molecular structures giving rise to macroscopic properties of common phenomena. Examples include starch and cellulose (Chapter 5), adrenaline (Chapter 7), partial hydrogenation of vegetable oil (Chapter 12), and dopamine (Chapter 25).



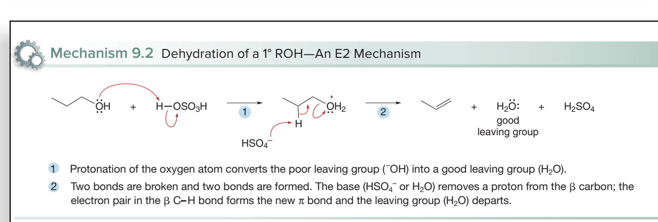
Spectra

Over 100 spectra created specifically for *Organic Chemistry with Biological Topics* are presented throughout the text. The spectra are color-coded by type and generously labeled. Mass spectra are green; infrared spectra are red; and proton and carbon nuclear magnetic resonance spectra are blue.



Mechanisms

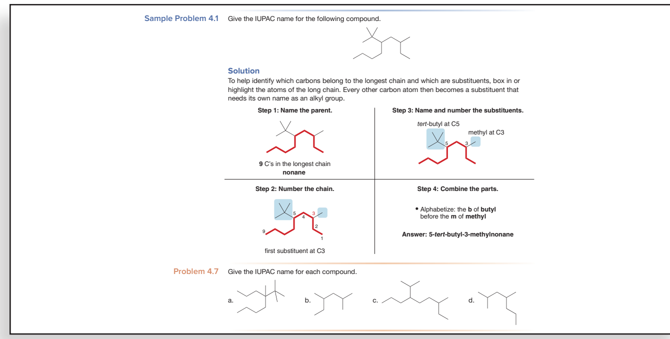
Curved arrow notation is used extensively to help students follow the movement of electrons in reactions.



Problem Solving

Sample Problems

Sample Problems show students how to solve organic chemistry problems in a logical, stepwise manner. More than 800 follow-up problems are located throughout the chapters to test whether students understand concepts covered in the Sample Problems.



Sample Problem 4.1 Give the IUPAC name for the following compound.

Solution

To help identify which carbons belong to the longest chain and which are substituents, box in or highlight the atoms of the long chain. Every other carbon atom then becomes a substituent that needs its own name as an alkyl group.

Step 1: Name the parent.

9 C's in the longest chain
nonane

Step 2: Number the chain.

first substituent at C3

Step 3: Name and number the substituents.

tert-butyl at C5
methyl at C3

Step 4: Combine the parts.

- Alphabetize: the **b** of **butyl** before the **m** of **methyl**

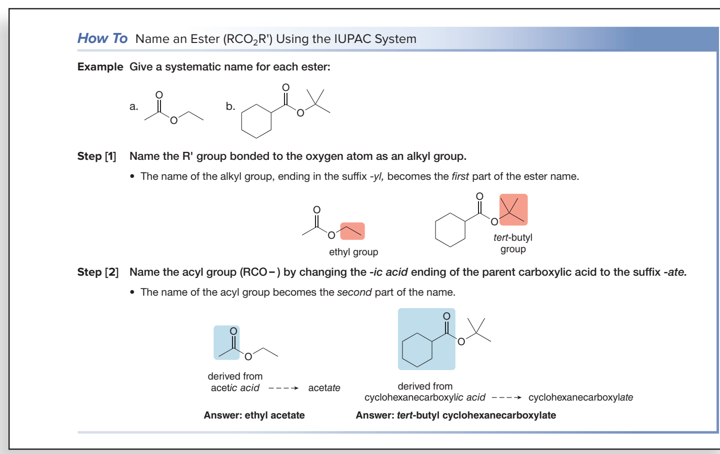
Answer: 5-*tert*-butyl-3-methylnonane

Problem 4.7 Give the IUPAC name for each compound.

a. b. c. d.

How To's

How To's provide students with detailed instructions on how to work through key processes.



How To Name an Ester (RCO_2R') Using the IUPAC System

Example Give a systematic name for each ester:

a. b.

Step [1] **Name the R' group bonded to the oxygen atom as an alkyl group.**

- The name of the alkyl group, ending in the suffix *-yl*, becomes the *first* part of the ester name.

ethyl group
tert-butyl group

Step [2] **Name the acyl group (RCO–) by changing the *-ic acid* ending of the parent carboxylic acid to the suffix *-ate*.**

- The name of the acyl group becomes the *second* part of the name.

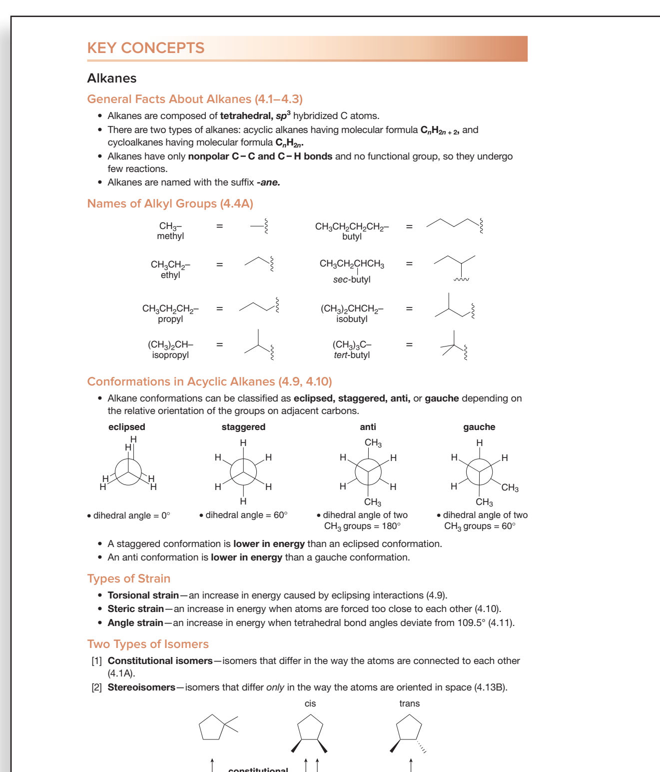
derived from acetic *acid* ---→ acet*ate*
derived from cyclohexanecarboxylic *acid* ---→ cyclohexanecarboxyl*ate*

Answer: ethyl acetate
Answer: *tert*-butyl cyclohexanecarboxylate

Applications and Summaries

Key Concept Summaries

Succinct summary tables reinforcing important principles and concepts are provided at the end of each chapter.



KEY CONCEPTS

Alkanes

General Facts About Alkanes (4.1–4.3)

- Alkanes are composed of **tetrahedral, *sp*^{3}** hybridized C atoms.
- There are two types of alkanes: acyclic alkanes having molecular formula $\mathbf{C_nH_{2n+2}}$, and cycloalkanes having molecular formula $\mathbf{C_nH_{2n}}$.
- Alkanes have only **nonpolar C–C and C–H bonds** and no functional group, so they undergo few reactions.
- Alkanes are named with the suffix ***-ane.***

Names of Alkyl Groups (4.4A)

$CH_3–$ methyl	=	$CH_3CH_2CH_2CH_2–$ butyl	=
$CH_3CH_2–$ ethyl	=	$CH_3CH_2CHCH_3$ *sec*-butyl	=
$CH_3CH_2CH_2–$ propyl	=	$(CH_3)_2CHCH_2–$ isobutyl	=
$(CH_3)_2CH–$ isopropyl	=	$(CH_3)_3C–$ *tert*-butyl	=

Conformations in Acyclic Alkanes (4.9, 4.10)

- Alkane conformations can be classified as **eclipsed, staggered, anti,** or **gauche** depending on the relative orientation of the groups on adjacent carbons.

eclipsed — • dihedral angle = 0°
staggered — • dihedral angle = 60°
anti — • dihedral angle of two CH_3 groups = 180°
gauche — • dihedral angle of two CH_3 groups = 60°

- A staggered conformation is **lower in energy** than an eclipsed conformation.
- An anti conformation is **lower in energy** than a gauche conformation.

Types of Strain

- **Torsional strain**—an increase in energy caused by eclipsing interactions (4.9).
- **Steric strain**—an increase in energy when atoms are forced too close to each other (4.10).
- **Angle strain**—an increase in energy when tetrahedral bond angles deviate from 109.5° (4.11).

Two Types of Isomers

[1] **Constitutional isomers**—isomers that differ in the way the atoms are connected to each other (4.1A).
[2] **Stereoisomers**—isomers that differ *only* in the way the atoms are oriented in space (4.13B).

cis trans

constitutional isomers **stereoisomers**

Margin Notes

Margin notes are placed carefully throughout the chapters, providing interesting information relating to topics covered in the text. Some margin notes are illustrated with photos to make the chemistry more relevant.

All soaps are salts of fatty acids. The main difference between soaps is the addition of other ingredients that do not alter their cleaning properties: dyes for color, scents for a pleasing odor, and oils for lubrication. Soaps that float are aerated, so that they are less dense than water.

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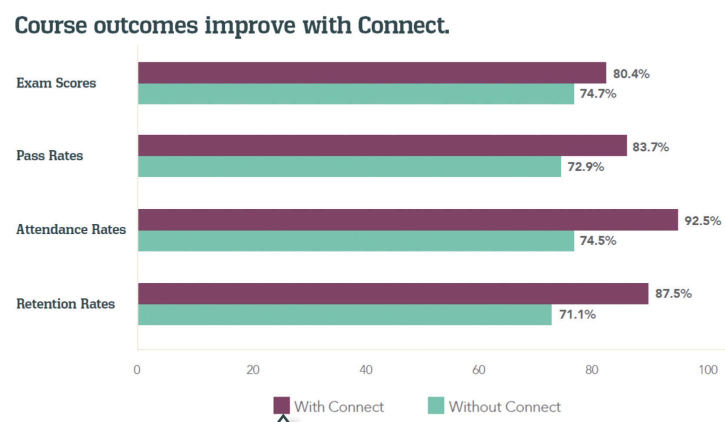

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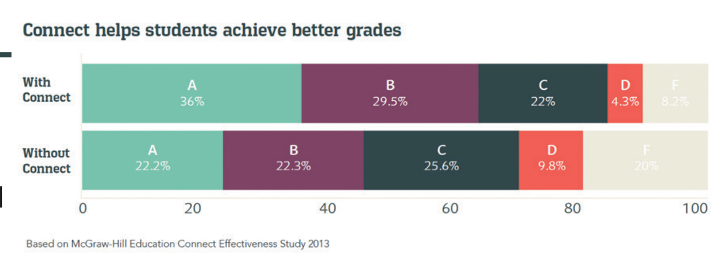

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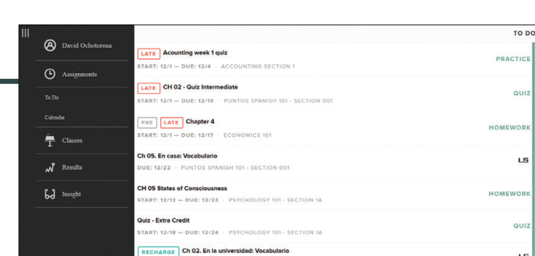

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Presentation Tools

Within the Instructor's Presentation Tools, instructors have access to editable PowerPoint lecture outlines, which appear as ready-made presentations that combine art and lecture notes for each chapter of the text. For instructors who prefer to create their lecture notes from scratch, all illustrations, photos, tables, *How To*'s, and Sample Problems are pre-inserted by chapter into a separate set of PowerPoint slides. They are also available as individual .jpg files.

Photos, artwork, animations, and other media types can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, or attractive printed support materials. All assets are copyrighted by McGraw-Hill Higher Education, but can be used by instructors for classroom purposes. The visual resources in this collection include:

- **Art** Full-color digital files of all illustrations in the book can be readily incorporated into lecture presentations, exams, or custom-made classroom materials.
- **Photos** The photo collection contains digital files of photographs from the text, which can be reproduced for multiple classroom uses.
- **Tables** Every table that appears in the text has been saved in electronic form for use in classroom presentations and/or quizzes.
- **Animations** Full-color animations illustrating important processes are also provided. Harness the visual impact of concepts in motion by importing these files into classroom presentations or online course materials.

Student Study Guide/Solutions Manual

Written by Janice Gorzynski Smith and Erin R. Smith, the Student Study Guide/Solutions Manual provides step-by-step solutions to all in-chapter and end-of-chapter problems. Each chapter begins with an overview of key concepts and includes a short-answer practice test on the fundamental principles and new reactions.

Acknowledgments

Organic Chemistry with Biological Topics is an outgrowth of many fruitful discussions with McGraw-Hill personnel about how best to meld biological applications with basic organic chemistry. Special thanks go to Brand Manager Andrea Pellerito, an organic chemist with extensive teaching experience, who understood the need to maintain the integrity and rigor of organic chemistry in this approach, and devised a method to bring this plan to reality.

Special thanks are also due to Senior Product Developer Mary Hurley, who skillfully navigated the logistics involved with integrating a new project within the framework of an existing text. Much appreciation also goes to Production Manager Sherry Kane, who managed an aggressive but workable production schedule. In truth, this new text is the result of an entire team of publishing professionals, beginning with manuscript preparation and culminating with publication of the completed text that is brought to the chemistry community through the dedicated work of the marketing and sales team. Our sincere appreciation goes out to all of them.

JGS: I especially thank my husband Dan and the other members of my immediate family, who have experienced the day-do-day demands of living with a busy author. The joys and responsibilities of the family have always kept me grounded during the rewarding but sometimes all-consuming process of writing a textbook. This book, like prior editions of *Organic Chemistry*, is dedicated to my wonderful daughter Megan, who passed away after a nine-year battle with cystic fibrosis.

HVS: I am honored to be working with Jan Smith and have already learned so much from her. Thanks to my colleagues Steve Wood, Megan Brennan, Charlie Cox, Jen Schwartz Poehlmann, Chris Chidsey, Dan Stack, and Justin Du Bois for many great conversations about using biological examples to teach the fundamental concepts of organic chemistry. Work on this book would not have been possible without the support of my husband Trent and our three energetic children, Zach, Grady, and Elli. I am also grateful for the encouragement of my mother and brother, Jeanette and Devin Vollmer. This book is dedicated to my father, Chuck Vollmer, who could not have been prouder of my work on this book, but passed away before it was published.

Among the many others that go unnamed but who have profoundly affected this work are the thousands of students we have been lucky to teach over many years. We have learned so much from our daily interactions with them, and we hope that the wider chemistry community can benefit from this experience.

This edition has evolved based on the helpful feedback of many people who reviewed the fourth edition text and digital products, class-tested the book, and attended focus groups or symposiums. These many individuals have collectively provided constructive improvements to the project.

Listed below are the reviewers of the *Organic Chemistry,* fourth edition text:

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Although every effort has been made to make this text and its accompanying Student Study Guide/Solutions Manual as error-free as possible, some errors undoubtedly remain. Please feel free to email one of the authors about any inaccuracies, so that subsequent editions may be further improved.

With much aloha,

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List of *How To*'s

How To boxes provide detailed instructions for key procedures that students need to master. Below is a list of each *How To* and where it is presented in the text.

List of Mechanisms

Mechanisms are the key to understanding the reactions of organic chemistry. For this reason, great care has been given to present mechanisms in a detailed, step-by-step fashion. The list below indicates when each mechanism in the text is presented for the first time.

List of Selected Applications

Applications make any subject seem more relevant and interesting—for nonmajors and majors alike. The following is a list of the biological, medicinal, and environmental applications that have been integrated throughout *Organic Chemistry with Biological Topics.* Each chapter opener showcases an interesting and current application relating to the chapter's topic. (Code: G = general; M = medicinal; B = biological; E = environmental)

Prologue

G Methane, the main component of natural gas
G Ethanol, the alcohol in beverages
E Trichlorofluoromethane, a CFC responsible for destroying the stratospheric ozone layer
M Amoxicillin, a widely used antibiotic
M Fluoxetine, the antidepressant Prozac
M AZT, a drug used to treat HIV
M Capsaicin, a compound found in topical pain relief creams
E DDT, a nonspecific pesticide that persists in the environment
M The antimalarial drugs quinine, chloroquine, and artemisinin

Chapter 1 Structure and Bonding

M L-Dopa, a drug used to treat Parkinson's disease (Chapter opener and Section 1.14)
M Alendronic acid (Fosamax), a drug used to prevent osteoporosis (Section 1.5)
B Enanthotoxin, a poisonous compound isolated from hemlock water dropwort (Section 1.7)
G Vanillin, the principal component in the extract of the vanilla bean (Section 1.8B)
M Structures of active ingredients in common sunscreens (Section 1.8B)
G Ethane, a component of natural gas (Section 1.10A)
G Ethylene, a hydrocarbon used to make the plastic polyethylene (Section 1.10B)
G Acetylene, a gas used in welding torches (Section 1.10C)
G Cucumber aldehyde, the compound responsible for the odor of freshly cut cucumbers (Section 1.10C)
M Sinemet, a drug used to treat Parkinson's disease that combines L-dopa and carbidopa (Section 1.14)
B Vitamin B_6 (Section 1.14)

Chapter 2 Acids and Bases

M Aspirin, a common analgesic and antipyretic (Chapter opener and Section 2.7)
M The acid–base chemistry of morphine (Section 2.1)
M The nasal decongestant pseudoephedrine (Section 2.5, Problem 2.17)
M Glycolic acid, an α-hydroxy acid used in skin care products (Section 2.5, Problem 2.20)
E Sulfuric acid, a major contributor to acid rain (Section 2.6)
M Salicin, an analgesic found in willow bark (Section 2.7)

Chapter 3 Introduction to Organic Molecules and Functional Groups

B Vitamin C, a water-soluble vitamin that is important in the formation of collagen (Chapter opener and Section 3.5B)
E Hemibrevetoxin B, a neurotoxin produced by algal blooms ("red tides") (Section 3.2B)
M Diethyl ether, the first common general anesthetic (Section 3.2B)
B Sucrose and the antibiotic amoxicillin (Section 3.2B, Problem 3.3)
M Dexamethasone, a synthetic steroid (Section 3.2B, Problem 3.5)
B Spermine, isolated from semen, and meperidine, the narcotic Demerol (Section 3.2B, Problem 3.6)
M The anticancer agent doxorubicin (Adriamycin) (Section 3.2B, Problem 3.7)
M Thyrotropin-releasing hormone (Section 3.2C, Problem 3.8)
M Tamiflu, an antiviral drug used to treat influenza (Section 3.2C, Problem 3.9)
B Pyruvic acid, lipoic acid, and folic acid as examples of biological molecules with multiple functional groups (Section 3.2C, Problem 3.10)
B Biological phosphorus compounds (Section 3.2D)
G How geckos use van der Waals forces to stick to walls (Section 3.3B)
B Ionic, water-soluble biological compounds: isopentenyl diphosphate and acetylcholine (Section 3.4C)
G MTBE, a high-octane additive in unleaded gasoline, and 4,4'-dichlorobiphenyl, a PCB (Section 3.4C)
B Phenylalanine and 11-*cis*-retinal (Section 3.4C, Sample Problem 3.4)

B Adrenaline and estrone (Section 3.4C, Problem 3.17)
B Progesterone and testosterone (Section 3.4C, Sample Problem 3.5)
B Norethindrone, an oral contraceptive, and arachidonic acid, a fatty acid (Section 3.4C, Problem 3.18)
B Vitamin A (retinol), a fat-soluble vitamin found in the vision receptors of the eyes (Section 3.5A)
B β-Carotene, a precursor to vitamin A (Section 3.5A)
B Vitamin B_3 and vitamin K_1 (Section 3.5B, Problem 3.19)
B Avocados as a source of pantothenic acid, vitamin B_5 (Section 3.5B, Problem 3.20)
M Morphine and heroin (Section 3.7A, Problem 3.23)
M The antibiotics nonactin and valinomycin (Section 3.7B)
B The reactive features of isopentenyl diphosphate and pyruvic acid (Section 3.8)
B The nucleophilic thiol of coenzyme A (Section 3.8)
B Methionine, ATP, and *S*-adenosylmethionine (Section 3.8, Problem 3.28)
B Amino acids and proteins (Section 3.9A)
B Monosaccharides and carbohydrates (Section 3.9B)
B Nucleotides and nucleic acids (Section 3.9C)
B Lipids (Section 3.9D)
M, B End-of-chapter problems: 3.33–3.35, 3.37, 3.38, 3.40, 3.48–3.57, 3.60, 3.61, 3.63–3.65, and 3.67

Chapter 4 Alkanes

E Oil slicks that result from crude petroleum being spilled into the ocean from oil tankers or oil wells (Chapter opener)
B The cockroach pheromone undecane (Section 4.1)
B Cyclohexane, one component of mangoes (Section 4.1)
B Allicin, a compound responsible for the odor of garlic (Section 4.3)
M Systematic names, generic names, and trade names in over-the-counter drugs like Motrin (Section 4.3)
G Fossil fuels such as natural gas and petroleum (Section 4.7)
E The combustion of alkanes and how it contributes to climate change (Section 4.14B)
B Lipids such as fat-soluble vitamins, phospholipids, waxes, prostaglandins, and steroids (Section 4.15)
B Pristane, a high molecular weight alkane found in shark liver oil (Section 4.15, Problem 4.33)
B End-of-chapter problems: 4.66 and 4.69

Chapter 5 Stereochemistry

M, B Paclitaxel (Taxol), a drug used to treat ovarian, breast, and other cancers (Chapter opener)
B How differences in the three-dimensional structure of starch and cellulose affect their shape and function (Section 5.1)
M, B Identifying stereogenic centers in Darvon (an analgesic), ephedrine (a decongestant), and fructose (a simple sugar) (Section 5.4A)
M The three-dimensional structure of thalidomide, an anti-nausea drug that caused catastrophic birth defects (Section 5.5)
M, B Identifying stereogenic centers in paclitaxel (anticancer agent) and sucrose (Section 5.5)
M Identifying stereogenic centers in gabapentin (a drug used to treat seizures and chronic pain), gabapentin enacarbil, cholesterol, and Zocor (cholesterol-lowering drug) (Section 5.5, Problems 5.9 and 5.10)
M Assigning *R* and *S* configurations in the drugs Plavix and Zestril (Section 5.6, Problems 5.14 and 5.15)
B The sweetener sorbitol (Section 5.9, Problem 5.24)
B The specific rotation of MSG, a common flavor enhancer (Section 5.12D, Problem 5.32)
M Chiral drugs and how mirror image isomers can have drastically different properties—the analgesic ibuprofen, the antidepressant fluoxetine, and the anti-inflammatory agent naproxen (Section 5.13A)
B The sense of smell and how mirror image isomers (e.g., carvone and celery ketone) can smell different (Section 5.13B and Problem 5.35)
M, B End-of-chapter problems: 5.36, 5.43, 5.49, 5.50, 5.53, 5.55, 5.60, and 5.65–5.71

Chapter 6 Understanding Organic Reactions

B Entropy changes in the metabolism of glucose (Chapter opener and Section 6.4)
B A biological substitution reaction: the hydrolysis of a triacylglycerol to glycerol + fatty acids (Section 6.2A)
B A biological elimination reaction in the citric acid cycle (Section 6.2B)
B A biological addition reaction with a thioester, a key step in fatty acid metabolism (Section 6.2C)
B Four enzyme-catalyzed steps in the citric acid cycle (Section 6.2C, Problem 6.2)
B The air oxidation of vegetable oils (Section 6.3C, Sample Problem 6.1)
B Examples of exothermic reactions: the hydrolysis of ATP and the oxidation of glucose (Section 6.4)
B Coupled reactions in metabolism (Section 6.5C)
G The reaction of gasoline with O_2 (Section 6.9A)
G Refrigeration and spoilage (Section 6.9A)
B Enzymes, biological catalysts (Section 6.11)
B End-of-chapter problems: 6.27, 6.28, 6.32, 6.39, 6.41, 6.52, and 6.56