

ESSENTIALS OF

Epidemiology in Public Health

THIRD EDITION



Ann Aschengrau, ScD

Professor, Department of Epidemiology
Boston University School of Public Health
Boston, MA

George R. Seage III, DSc

Professor of Epidemiology
Harvard School of Public Health
Boston, MA



JONES & BARTLETT
LEARNING

World Headquarters
Jones & Bartlett Learning
5 Wall Street
Burlington, MA 01803
978-443-5000
info@jblearning.com
www.jblearning.com

Jones & Bartlett Learning books and products are available through most bookstores and online booksellers. To contact Jones & Bartlett Learning directly, call 800-832-0034, fax 978-443-8000, or visit our website, www.jblearning.com.

Substantial discounts on bulk quantities of Jones & Bartlett Learning publications are available to corporations, professional associations, and other qualified organizations. For details and specific discount information, contact the special sales department at Jones & Bartlett Learning via the above contact information or send an email to specialsales@jblearning.com.

Copyright © 2014 by Jones & Bartlett Learning, LLC, an Ascend Learning Company

All rights reserved. No part of the material protected by this copyright may be reproduced or utilized in any form, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without written permission from the copyright owner.

The content, statements, views, and opinions herein are the sole expression of the respective authors and not that of Jones & Bartlett Learning, LLC. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement or recommendation by Jones & Bartlett Learning, LLC and such reference shall not be used for advertising or product endorsement purposes. All trademarks displayed are the trademarks of the parties noted herein. *Essentials of Epidemiology in Public Health, Third Edition* is an independent publication and has not been authorized, sponsored, or otherwise approved by the owners of the trademarks or service marks referenced in this product.

There may be images in this book that feature models; these models do not necessarily endorse, represent, or participate in the activities represented in the images. Any screenshots in this product are for educational and instructive purposes only. Any individuals and scenarios featured in the case studies throughout this product may be real or fictitious, but are used for instructional purposes only.

This publication is designed to provide accurate and authoritative information in regard to the Subject Matter covered. It is sold with the understanding that the publisher is not engaged in rendering legal, accounting, or other professional service. If legal advice or other expert assistance is required, the service of a competent professional person should be sought.

Production Credits:

Publisher: Michael Brown
Managing Editor: Maro Gartside
Editorial Assistant: Chloe Falivene
Production Assistant: Alyssa Lawrence
Senior Marketing Manager: Sophie Fleck Teague
Manufacturing and Inventory Control Specialist:
Amy Bacus

Composition: diacriTech
Cover Design: Kristin E. Parker
Rights & Photo Research Assistant:
Ashley Dos Santos
Cover Image: © Boguslaw Mazur/Shutterstock, Inc.
Printing and Binding: Edwards Brothers Malloy
Cover Printing: Edwards Brothers Malloy

To order this product, use ISBN: 978-1-284-02891-1

Library of Congress Cataloging-in-Publication Data

Aschengrau, Ann.
Essentials of epidemiology in public health/Ann Aschengrau & George Seage. — 3rd ed.
p. ; cm.
Includes bibliographical references and index.
ISBN-13: 978-1-4496-5733-8 (pbk.)
ISBN-10: 1-4496-5733-8 (pbk.)
I. Seage, George R. II. Title.
[DNLM: 1. Epidemiologic Methods. 2. Epidemiologic Factors. 3. Public Health. WA 950]
RA651
614.4—dc23

2013003160

6048
Printed in the United States of America
17 16 15 14 13 10 9 8 7 6 5 4 3 2 1

*We dedicate this book to our parents,
Carol and Mendel Aschengrau, and Lorraine Seage,
in memoriam, and George R. Seage Jr.*



Contents

<i>New To This Edition</i>	<i>xiii</i>	
<i>Preface</i>	<i>xv</i>	
<i>Acknowledgments</i>	<i>xix</i>	
Chapter 1	The Approach and Evolution of Epidemiology	1
	Introduction	1
	Definition and Goals of Public Health	2
	Sources of Scientific Knowledge in Public Health	3
	Definition and Objectives of Epidemiology	6
	Historical Development of Epidemiology	8
	Modern Epidemiology	27
	Summary	29
	References	29
	Chapter Questions	32
Chapter 2	Measures of Disease Frequency	33
	Introduction	33
	Definition of a Population	34
	Definitions of Health and Disease	37
	Changes in Disease Definitions	37
	Measuring Disease Occurrence	39
	Types of Calculations: Ratios, Proportions, and Rates	41
	Measures of Disease Frequency	42
	Commonly Used Measures of Disease Frequency in Public Health	51
	Summary	53
	References	54
	Chapter Questions	55
Chapter 3	Comparing Disease Frequencies	59
	Introduction	59
	Data Organization	60

VI CONTENTS

Measures of Comparison	63
Direct Standardization	71
Summary	74
References	74
Chapter Questions	75
Chapter 4 Sources of Public Health Data	79
Introduction	79
Census of U.S. Population	80
Vital Statistics	81
National Survey of Family Growth	86
National Health Interview Survey	87
National Health and Nutrition Examination Survey	88
Behavioral Risk Factor Surveillance System	88
National Healthcare Surveys	88
National Notifiable Diseases Surveillance System	90
Surveillance of HIV Infection	90
Induced Abortion Statistics	91
National Immunization Survey	91
Survey of Occupational Injuries and Illnesses	92
National Survey on Drug Use and Health	92
Aerometric Information Retrieval System	93
Surveillance, Epidemiology, and End Results Program	93
Birth Defects Surveillance and Research Programs	94
<i>Health, United States</i>	94
<i>Demographic Yearbook</i>	94
<i>World Health Statistics</i>	95
Cancer Incidence on Five Continents	95
Other Resources	95
Summary	96
References	98
Chapter Questions	100
Chapter 5 Descriptive Epidemiology	101
Introduction	101
Person	102
Place	104

Time	107
Disease Clusters and Epidemics	108
Main Uses of Descriptive Epidemiology	110
Generation Hypotheses about	
Causal Relationships	110
Public Health Planning and Evaluation	111
Example: Patterns of Mortality in the	
United States According to Age	112
Examples: Three Important Causes of	
Morbidity in the United States	121
Summary	136
References	136
Chapter Questions	140
Chapter 6	Overview of Epidemiologic Study Designs 143
Introduction	143
Overview of Experimental Studies	146
Overview of Cohort Studies	149
Overview of Case-Control Studies	153
When is it Desirable to Use a Particular	
Study Design?	158
Other Types of Studies	160
Summary	167
References	168
Chapter Questions	169
Chapter 7	Experimental Studies 173
Introduction	173
Overview of Experimental Studies	175
Types of Experimental Studies	177
Study Population	183
Sample Size	184
Consent Process	185
Treatment Assignment	185
Use of the Placebo and Masking	188
Maintenance and Assessment of Compliance	189
Ascertaining the Outcomes	193
Data Analysis	195
Generalizability	197
Special Issues in Experimental Studies	198
Summary	199

VIII CONTENTS

References	199
Chapter Questions	202
Chapter 8 Cohort Studies	205
Introduction	205
Cohort Study Definitions and Overview	206
Types of Population Studied	207
Characterization of Exposure	208
Follow-Up and Outcome Assessment	209
Timing of Cohort Studies	210
Issues in the Selection of Cohort Study	
Populations	212
Sources of Information	219
Analysis of Cohort Studies	224
Special Types of Cohort Studies	226
Strengths and Limitations of Cohort Studies	227
Summary	228
References	229
Chapter Questions	231
Chapter 9 Case–Control Studies	233
Introduction	233
The Changing View of Case–Control Studies	234
When is it Desirable to Use the	
Case–Control Method?	238
Selection of Cases	239
Selection of Controls	243
Analysis of Case–Control Studies	251
Applications of Case–Control Studies	255
Strengths and Limitations of	
Case–Control Studies	257
Summary	258
References	259
Chapter Questions	262
Chapter 10 Bias	265
Introduction	265
Overview of Bias	267
Selection Bias	269
Information Bias	276
Summary	288

	References	289
	Chapter Questions	290
Chapter 11	Confounding	293
	Introduction	293
	Definition and Examples of Confounding	294
	Confounding by Indication and Severity	298
	Controlling for Confounding: General Considerations	299
	Controlling for Confounding in the Design	300
	Controlling for Confounding in the Analysis	303
	Residual Confounding	306
	Summary	307
	References	309
	Chapter Questions	310
Chapter 12	Random Error	313
	Introduction	313
	History of Biostatistics in Public Health	314
	Precision	315
	Sampling	316
	Hypothesis Testing and P Values	318
	Confidence Interval Estimation	323
	P-Value Function	327
	Probability Distributions	328
	Hypothesis-Testing Statistics	334
	Confidence Intervals for Measures of Disease Frequency and Association	336
	Sample Size and Power Calculations	341
	Summary	343
	References	345
	Chapter Questions	346
Chapter 13	Effect Measure Modification	349
	Introduction	349
	Definitions and Terms for Effect Measure Modification	350
	Effect Measure Modification Versus Confounding	351
	Evaluation of Effect Measure Modification	352

X CONTENTS

	Synergy and Antagonism	356
	Choice of Measure	357
	Evaluating Effect Measure Modification and Confounding in Stratified Analyses	358
	Summary	359
	References	360
	Chapter Questions	361
Chapter 14	Critical Review of Epidemiologic Studies	363
	Introduction	363
	Guide to Answering the Critique Questions	366
	Sample Critiques of Epidemiologic Studies	374
	Summary	387
	References	387
Chapter 15	The Epidemiologic Approach to Causation	389
	Introduction	389
	Definitions of a Cause	391
	Characteristics of a Cause	393
	Risk Factors Versus Causes	394
	Historical Development of Disease Causation Theories	395
	Hill's Guidelines for Assessing Causation	398
	Use of Hill's Guidelines by Epidemiologists Today	403
	Sufficient-Component Cause Model	405
	Why Most Scientists Believe that HIV is the Cause of AIDS	407
	Summary	410
	References	411
	Chapter Questions	413
Chapter 16	Screening in Public Health Practice	417
	Introduction	417
	Natural History of Disease	418
	Definition of Primary, Secondary, and Tertiary Prevention	419
	Appropriate Diseases for Screening	421
	Characteristics of a Screening Test	424
	Lead Time	428

Predictive Value: A Measure of Screening	428
Program Feasibility	428
Evaluating a Screening Program	431
Bias	432
Selecting an Outcome	435
Study Designs to Evaluate Screening Programs	436
Examples of the Effect of Screening on	
Public Health	438
Summary	440
References	442
Chapter Questions	444
Chapter 17	
Ethics in Research Involving Human	
Participants	447
<i>(Contributed by Molly Pretorius Holme)</i>	
Introduction	447
Historical Perspective	448
International Ethical and Research	
Practice Guidelines	455
The U.S. Regulatory Framework for	
Human Subjects Research	456
Limitations Posed by Ethical Requirements	458
Contemporary Examples	459
The Informed Consent Process	460
Summary	464
References	464
Chapter Questions	465
Chapter 18	
Answers to Chapter Questions	
(Chapters 1–17)	467
Index	489



New To This Edition

- Completely updated with new examples, the latest references, and public health statistics.
- Nearly 50 new review questions.
- Updated discussion of certain epidemiologic methods.
- New figures depicting epidemiologic concepts.



Preface

What is epidemiology and how does it contribute to the health of our society? Most people don't know the answer to this question. This is somewhat paradoxical because epidemiology, one of the basic sciences of public health, affects nearly everyone. It impacts both the personal decisions we make about our lives and the ways in which governments, public health agencies, and medical organizations make policy decisions that affect how we live.

In recent years, the field of epidemiology has expanded tremendously in size, scope, and influence. The number of epidemiologists has grown rapidly, along with the number of epidemiology training programs in schools of public health and medicine. Many subspecialties have arisen to study public health questions from the molecular to the societal level.

Recent years have also witnessed an important evolution in the theory and methods of epidemiologic research. For example, epidemiologists have considerably changed their views about the appropriate way to conceptualize and design the case-control study. We used to think that the case-control study was a backwards and inferior design, but we now realize that it is a valid and efficient design in many settings. In fact, our current conceptualization of the major epidemiologic study designs reveals many more similarities among them than previously thought.

Epidemiologists' thinking about causality has also changed. Where once we used Sir Austin Bradford Hill's guideposts as an uncompromising checklist for "proving" causation, we now acknowledge that Hill's causal guidelines have many exceptions and uncertainties and causal relationships can never be proven. Epidemiologists have also begun to use some newer conceptual models of causation, such as the counterfactual causal model, as a way to bridge the gap between theories of causation and the practice of epidemiology.

Unfortunately, few of these changes have been taught in introductory epidemiology courses, particularly those for master's-level students. We believe this has occurred mainly because instructors have mistakenly assumed the new concepts were too difficult or arcane for beginning students. As a consequence, many generations of public health students have received a dated education.

Our desire to change this practice was the main impetus for writing this book. For over two decades we have successfully taught both traditional and new concepts to our graduate students at Boston University and Harvard University. Not only have our students successfully mastered the material, but they have also found that the new ideas enhanced their understanding of epidemiology and its application.

In addition to providing an up-to-date education, we have taught our students the necessary skills to become knowledgeable consumers of epidemiologic literature. Gaining competence in the critical evaluation of this literature is particularly important for public health practitioners because they often need to reconcile confusing and contradictory results.

This textbook reflects our educational philosophy of combining theory and practice in our teaching. It is intended for public health students who will be consumers of epidemiologic literature and those who will be practicing epidemiologists. The first five chapters cover basic epidemiologic concepts and data sources. Chapter 1 describes the approach and evolution of epidemiology, including the definition, goals, and historical development of epidemiology and public health. Chapters 2 and 3 describe how epidemiologists measure and compare disease occurrence in populations. Chapter 4 characterizes the major sources of health data on the U.S. population and describes how to interpret these data appropriately. Chapter 5 describes how epidemiologists analyze disease patterns to understand the health status of a population, formulate and test hypotheses of disease causation, and carry out and evaluate health programs.

The next four chapters of the textbook focus on epidemiologic study design. Chapter 6 provides an overview of study designs—including experimental, cohort, case-control, cross-sectional, and ecological studies—and describes the factors that determine when a particular design is indicated. Each of the three following chapters provides a detailed description of the three main analytic designs: experimental, cohort, and case-control studies.

The next five chapters cover the tools students need to interpret the results of epidemiologic studies. Chapter 10 describes bias, including how it influences study results and the ways in which it can be avoided. Chapter 11 explains the concept of confounding, methods for assessing its presence, and methods for controlling its effects. Chapter 12 covers random error, including hypothesis testing, P-value and confidence interval estimation and interpretation, and sample size and power calculations. We believe this chapter provides a balanced view of the appropriate role of statistics in epidemiology. Chapter 13 covers the concept of effect measure modification, an often neglected topic in introductory texts. It explains the difference between confounding and effect measure modification and describes the methods for evaluating effect measure modification. Chapter 14 pulls together the information from Chapters 10 through 13 by providing a

framework for evaluating the literature, as well as three examples of epidemiologic study critiques.

Chapter 15 covers the epidemiologic approach to causation, including the historical development of causation theories, Hill's guidelines for assessing causation, and the sufficient-component cause model of causation. Chapter 16 explains screening in public health practice, including the natural history of disease, characteristics of diseases appropriate for screening, important features of a screening test, and methods for evaluating a screening program. Finally, Chapter 17 describes the development and application of guidelines to ensure the ethical conduct of studies involving humans. Up-to-date examples and data from the epidemiologic literature on diseases of public health importance are used throughout the book. In addition, nearly 50 new study questions were added to the third edition.

Our educational background and research interests are also reflected in the textbook's outlook and examples. Ann Aschengrau received her doctorate in epidemiology from the Harvard School of Public Health in 1987 and joined the Department of Epidemiology at the Boston University School of Public Health shortly thereafter. She is currently Professor in the Epidemiology and Director of the Master of Science Degree Program in Epidemiology. For the past 25 years, she has taught introductory epidemiology to master's-level students. Her research has focused on the environmental determinants of disease, including cancer, disorders of reproduction and child development, and neurological abnormalities.

George R. Seage III received his doctorate in epidemiology from the Boston University School of Public Health in 1992. For more than a decade he served as the AIDS epidemiologist for the city of Boston and as a faculty member at the Boston University School of Public Health. For 7 years he directed the U.S. HIV Prevention Trials Network. He is currently Professor of Epidemiology at the Harvard School of Public Health and Director of the Interdisciplinary Concentration in Infectious Disease Epidemiology. For over 20 years he has taught courses in HIV epidemiology to masters and doctoral students. His research focuses on HIV epidemiology, including the biologic and behavioral determinants of HIV transmission and prevention, HIV clinical epidemiology and outcomes research, and the long-term impact of antiretroviral therapy for prevention and treatment among children and adolescents perinatally exposed to HIV.



Acknowledgments

Our ideas about the principles and practice of epidemiology have been greatly influenced by teachers, colleagues, and students. We feel privileged to have been inspired and nurtured by many outstanding teachers and mentors, including Richard Monson, George (Sandy) Lamb, Steve Schoenbaum, Arnold Epstein, Ken Rothman, the late Brian MacMahon, Julie Buring, Fran Cook, Ted Colton, Bob Glynn, Adrienne Cupples, George Hutchison, and the late Alan Morrison. We are pleased to help spread the knowledge they have given us to the next generation of epidemiologists.

We are also indebted to the many colleagues who contributed to the first, second, and third editions of this book in various ways, including clarifying our thinking about epidemiology and biostatistics, providing ideas about how to teach epidemiology, reviewing and commenting on drafts and revisions of the text, pilot-testing drafts in their classes, and, last but not least, dispensing many doses of encouragement during the time it took to write all three editions of this book. Among these individuals are Bob Horsburgh, Herb Kayne, Dan Brooks, Wayne LaMorte, Michael Shwartz, Dave Ozonoff, Tricia Coogan, Meir Stampfer, Lorelei Mucci, Murray Mittleman, Fran Cook, Charlie Poole, Tom Fleming, Megan Murray, Marc Lipsitch, Sam Bozeman, Anne Coletti, Michael Gross, Sarah Putney, Sarah Rogers, Kimberly Shea, Kunjal Patel, and Kelly Diringer Getz. We are particularly grateful to our colleague, Molly Pretorius Holme, for contributing the chapter on ethics in human research. Ted Colton also deserves a special acknowledgment for originally recommending us to the publisher.

We thank our students for graciously reading drafts and earlier editions of this text in their epidemiology courses and for contributing many valuable suggestions for improvement. We hope that this book will serve as a useful reference as they embark on productive careers in public health. We also recognize Abt Associates, Inc. for providing George Seage with a development and dissemination grant to write the chapter on screening in public health practice. We are very grateful to the staff of Jones & Bartlett Learning for guiding the publication process so competently and so quickly. Finally, we thank our son Gregory, an aspiring actor, for his patience and for providing many interesting and fun diversions along the way. Break a leg!

