

FOURTH EDITION

ESSENTIALS OF

# Epidemiology

IN PUBLIC HEALTH

**Ann Aschengrau, ScD**

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

**George R. Seage III, DSc**

Professor of Epidemiology  
Harvard T.H. Chan School of Public Health  
Boston, Massachusetts



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](http://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](mailto:specialsales@jblearning.com).

Copyright © 2020 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, Fourth 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.

12843-7

#### Production Credits

VP, Product Management: David D. Cella  
Director of Product Management: Michael Brown  
Product Specialist: Carter McAlister  
Production Manager: Carolyn Rogers Pershouse  
Associate Production Editor, Navigate: Jamie Reynolds  
Senior Marketing Manager: Sophie Fleck Teague  
Manufacturing and Inventory Control Supervisor: Amy Bacus

Composition: codeMantra U.S. LLC  
Cover Design: Kristin E. Parker  
Rights & Media Specialist: John Rusk  
Media Development Editor: Shannon Sheehan  
Cover Image (Title Page, Chapter Opener):  
© Smartboy10/DigitalVision Vectors/Getty Images  
Printing and Binding: Bang Printing  
Cover Printing: Bang Printing

#### Library of Congress Cataloging-in-Publication Data

Names: Aschengrau, Ann, author. | Seage, George R., author.  
Title: *Essentials of epidemiology in public health* / Ann Aschengrau, ScD,  
Professor of Epidemiology, Boston University School of Public Health,  
George R. Seage III, ScD, Professor of Epidemiology, Harvard T.H. Chan  
School of Public Health.  
Description: Fourth edition. | Burlington, MA : Jones & Bartlett Learning,  
[2020] | Includes bibliographical references and index.  
Identifiers: LCCN 2018023772 | ISBN 9781284128352 (paperback)  
Subjects: LCSH: Epidemiology. | Public health. | Social medicine. | BISAC:  
EDUCATION / General.  
Classification: LCC RA651 .A83 2020 | DDC 614.4–dc23  
LC record available at <https://lccn.loc.gov/2018023772>

6048

Printed in the United States of America

22 21 20 19 18 10 9 8 7 6 5 4 3 2 1

# Contents

**Preface** .....vii

**Acknowledgments** ..... xi

**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..... 5

Historical Development of Epidemiology ..... 8

Modern Epidemiology.....27

Summary.....29

References .....30

Chapter Questions.....31

**Chapter 2 Measures of Disease Frequency**.....33

Introduction.....33

Definition of a Population.....34

Definitions of Health and Disease.....36

Changes in Disease Definitions .....37

Measuring Disease Occurrence .....39

Types of Calculations: Ratios, Proportions, and Rates .....40

Measures of Disease Frequency.....41

Commonly Used Measures of Disease Frequency in Public Health.....51

Summary.....52

References .....53

Chapter Questions.....54

**Chapter 3 Comparing Disease Frequencies** .....57

Introduction.....57

Data Organization .....58

Measures of Comparison .....61

Direct Standardization.....69

Summary.....72

References .....73

Chapter Questions.....73

**Chapter 4 Sources of Public Health Data** .....77

Introduction.....77

Census of the U.S. Population.....78

Vital Statistics.....79

National Survey of Family Growth.....84

National Health Interview Survey .....84

National Health and Nutrition Examination Survey.....85

Behavioral Risk Factor Surveillance System .....85

National Health Care Surveys .....86

National Notifiable Diseases Surveillance System.....87

Surveillance of HIV Infection .....87

Reproductive Health Statistics .....88

National Immunization Survey.....89

Survey of Occupational Injuries and Illnesses .....89

National Survey on Drug Use and Health.....90

Air Quality System ..... 90  
 Surveillance, Epidemiology and  
 End Results Program ..... 91  
 Birth Defects Surveillance  
 and Research Programs ..... 91  
*Health, United States* ..... 92  
*Demographic Yearbook* ..... 92  
*World Health Statistics* ..... 92  
 Cancer Incidence on Five Continents ..... 93  
 Other Resources ..... 93  
 Summary ..... 94  
 References ..... 96  
 Chapter Questions ..... 97

**Chapter 5 Descriptive Epidemiology .... 99**

Introduction ..... 99  
 Person ..... 100  
 Place ..... 102  
 Time ..... 104  
 Disease Clusters and Epidemics ..... 105  
 Ebola Outbreak and Its Investigation ..... 110  
 Uses of Descriptive Epidemiology ..... 116  
 Generating Hypotheses About  
 Causal Relationships ..... 116  
 Public Health Planning and  
 Evaluation ..... 117  
 Example: Patterns of Mortality  
 in the United States According to Age ..... 118  
 Overall Pattern of Mortality ..... 121  
 Examples: Three Important Causes  
 of Morbidity in the United States ..... 129  
 Summary ..... 144  
 References ..... 145  
 Chapter Questions ..... 150

**Chapter 6 Overview of Epidemiological  
 Study Designs ..... 153**

Introduction ..... 153  
 Overview of Experimental Studies ..... 156  
 Overview of Cohort Studies ..... 159

Overview of Case–Control Studies ..... 163  
 When Is It Desirable to Use a  
 Particular Study Design? ..... 168  
 Other Types of Studies ..... 170  
 Summary ..... 177  
 References ..... 178  
 Chapter Questions ..... 179

**Chapter 7 Experimental Studies ..... 181**

Introduction ..... 181  
 Overview of Experimental Studies ..... 182  
 Types of Experimental Studies ..... 185  
 Study Population ..... 190  
 Sample Size ..... 191  
 Consent Process ..... 192  
 Treatment Assignment ..... 192  
 Use of the Placebo and Masking ..... 196  
 Maintenance and Assessment  
 of Compliance ..... 197  
 Ascertaining the Outcomes ..... 200  
 Data Analysis ..... 202  
 Generalizability ..... 205  
 Special Issues in Experimental Studies ..... 205  
 Summary ..... 207  
 References ..... 207  
 Chapter Questions ..... 209

**Chapter 8 Cohort Studies ..... 211**

Introduction ..... 211  
 Cohort Study Definitions and Overview ..... 212  
 Types of Populations Studied ..... 213  
 Characterization of Exposure ..... 215  
 Follow-Up and Outcome  
 Assessment ..... 215  
 Timing of Cohort Studies ..... 216  
 Issues in the Selection of Cohort  
 Study Populations ..... 218  
 Sources of Information ..... 224  
 Analysis of Cohort Studies ..... 229  
 Special Types of Cohort Studies ..... 231

Strengths and Limitations of Cohort Studies ..... 232  
 Summary ..... 233  
 References ..... 234  
 Chapter Questions ..... 235

**Chapter 9 Case–Control Studies .....237**

Introduction ..... 237  
 The Changing View of Case–Control Studies ... 238  
 When Is It Desirable to Use the Case–Control Method? ..... 242  
 Selection of Cases ..... 244  
 Selection of Controls ..... 247  
 Sources of Exposure Information ..... 252  
 Analysis of Case–Control Studies ..... 255  
 The Case–Crossover Study: A New Type of Case–Control Study ..... 258  
 Applications of Case–Control Studies ..... 260  
 Strengths and Limitations of Case–Control Studies ..... 261  
 Summary ..... 262  
 References ..... 263  
 Chapter Questions ..... 265

**Chapter 10 Bias .....267**

Introduction ..... 267  
 Overview of Bias ..... 268  
 Selection Bias ..... 270  
 Information Bias ..... 278  
 Summary ..... 291  
 References ..... 292  
 Chapter Questions ..... 292

**Chapter 11 Confounding .....295**

Introduction ..... 295  
 Definition and Examples of Confounding ..... 295  
 Confounding by Indication and Severity ..... 301  
 Controlling for Confounding: General Considerations ..... 302  
 Controlling for Confounding in the Design ..... 302

Controlling for Confounding in the Analysis ..... 305  
 Residual Confounding ..... 309  
 Assessment of Mediation ..... 310  
 Summary ..... 311  
 References ..... 312  
 Chapter Questions ..... 313

**Chapter 12 Random Error .....315**

Introduction ..... 315  
 History of Biostatistics in Public Health ..... 316  
 Precision ..... 317  
 Sampling ..... 319  
 Hypothesis Testing and P Values ..... 320  
 Confidence Interval Estimation ..... 326  
 P-Value Function ..... 329  
 Probability Distributions ..... 330  
 Hypothesis-Testing Statistics ..... 336  
 Confidence Intervals for Measures of Disease Frequency and Association ..... 339  
 Sample Size and Power Calculations ..... 345  
 Summary ..... 346  
 References ..... 348  
 Chapter Questions ..... 349

**Chapter 13 Effect Measure Modification .....351**

Introduction ..... 351  
 Definitions and Terms for Effect Measure Modification ..... 352  
 Effect Measure Modification Versus Confounding ..... 353  
 Evaluation of Effect Measure Modification ..... 354  
 Synergy and Antagonism ..... 359  
 Choice of Measure ..... 360  
 Evaluating Effect Measure Modification and Confounding in Stratified Analyses ..... 361  
 Summary ..... 362  
 References ..... 363  
 Chapter Questions ..... 363

**Chapter 14 Critical Review of Epidemiological Studies ...367**

Introduction..... 367  
 Guide to Answering the Critique Questions .... 369  
 Sample Critiques of Epidemiological Studies ... 378  
 Summary..... 391  
 References ..... 391

**Chapter 15 The Epidemiological Approach to Causation .....393**

Introduction..... 393  
 Definitions of a Cause..... 395  
 Characteristics of a Cause..... 397  
 Risk Factors Versus Causes ..... 398  
 Historical Development of Disease Causation  
     Theories ..... 399  
 Hill's Guidelines for Assessing Causation ..... 402  
 Use of Hill's Guidelines by Epidemiologists .... 407  
 Sufficient-Component Cause Model ..... 408  
 Why Mainstream Scientists Believe That  
     HIV Is the Cause of HIV/AIDS..... 411  
 Summary..... 414  
 References ..... 415  
 Chapter Questions..... 416

**Chapter 16 Screening in Public Health Practice .....419**

Introduction..... 419  
 Natural History of Disease..... 420  
 Definition of Primary, Secondary, and  
     Tertiary Prevention..... 421  
 Appropriate Diseases for Screening ..... 423  
 Characteristics of a Screening Test ..... 426  
 Lead Time ..... 430

Predictive Value: A Measure of  
     Screening Program Feasibility ..... 431  
 Evaluating a Screening Program ..... 434  
 Bias..... 434  
 Selecting an Outcome..... 437  
 Study Designs to Evaluate  
     Screening Programs..... 438  
 Examples of the Effect of Screening on Public  
     Health ..... 440  
 Summary..... 442  
 References ..... 444  
 Chapter Questions..... 445

**Chapter 17 Ethics in Research Involving Human Participants .....449**

(Contributed by Molly Pretorius Holme)

Introduction..... 449  
 Historical Perspective..... 450  
 International Ethical and Research  
     Practice Guidelines..... 457  
 The U.S. Regulatory Framework for Human  
     Subjects Research..... 458  
 Limitations Posed by Ethical Requirements..... 460  
 Contemporary Examples ..... 460  
 The Informed Consent Process..... 461  
 Summary..... 466  
 References ..... 466  
 Chapter Questions..... 467

**Chapter 18 Answers to Chapter Questions (Chapters 1–17) ... 469**

**Glossary .....493**  
**Index.....503**

# 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 affects 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 epidemiological research and analysis, causal inference, and the role of statistics (especially P values) in research.

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 nearly three 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 epidemiological 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 epidemiological literature and those who will be practicing epidemiologists. The first five chapters cover basic epidemiological 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 epidemiological 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 epidemiological 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 epidemiological study critiques.

Chapter 15 covers the epidemiological 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 epidemiological literature on diseases of public health importance are used throughout the book. In addition, nearly 50 new study questions were added to the fourth 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, Associate Chair for Education, and Co-Director of the Master of Science Degree Program in Epidemiology. For the past 30 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 substance use.

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. He is currently Professor of Epidemiology at the Harvard T.H. Chan School of Public Health and Director of the Harvard Chan Program in the Epidemiology of Infectious Diseases. For over 30 years, he has taught courses in HIV epidemiology to master's and doctoral students. His research focuses on the biological and behavioral determinants of adult and pediatric HIV transmission, natural history, and treatment.

Drs. Aschengrau and Seage are happy to connect with instructors and students via email (aaschen@bu.edu and gseage@hsph.harvard.edu). Also check out Dr. Aschengrau's Twitter feed @AnnfromBoston.



## ► **New to This Edition**

---

- Completely updated with new examples and the latest references and public health statistics
- New section on process of investigating infectious disease outbreaks
- New section on the Ebola outbreaks and their investigation in Africa
- Introduction of the latest epidemiological terms and methods
- New figures depicting epidemiological concepts
- Expanded ancillary materials, including improved PowerPoint slides, an enlarged glossary, and new in-class exercises and test questions
- Over 50 new review questions



# 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 numerous 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 dispensing many doses of encouragement during the time it took to write all four editions of this book. Among these individuals are Bob Horsburgh, Herb Kayne, Dan Brooks, Wayne LaMorte, Michael Shwartz, Dave Ozonoff, Tricia Cogan, 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 Krystal Cantos for her many contributions to this edition, particularly the new sections on disease outbreaks, and 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 quickly. Finally, we thank our son Gregory, an actor, for his patience and for providing many interesting and fun diversions along the way. Break a leg!

