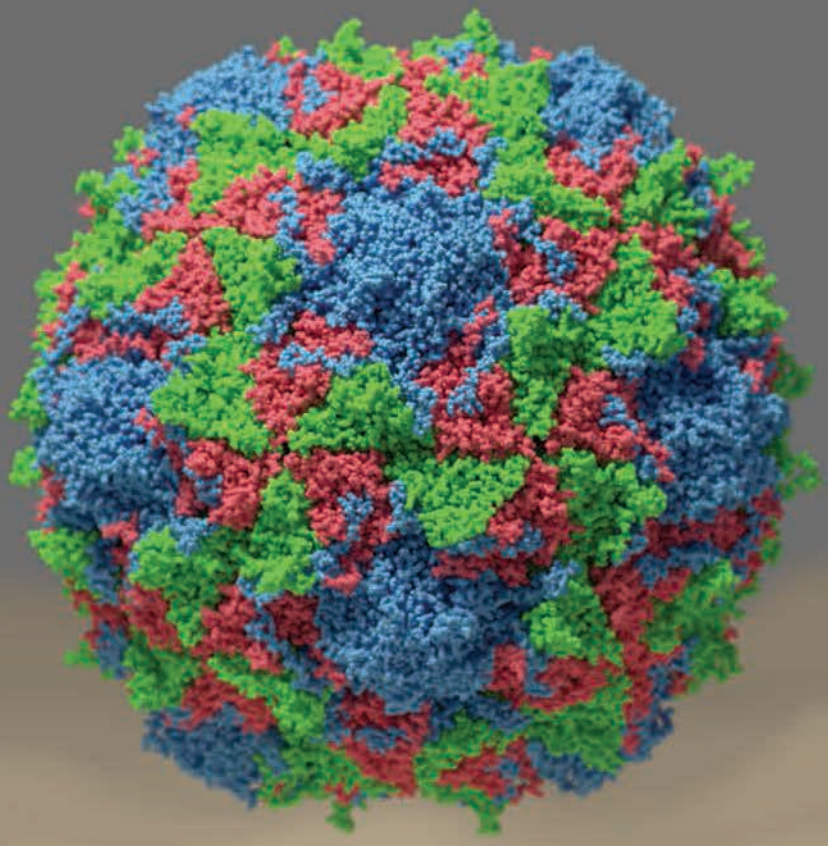
VOLUME I *Molecular Biology*

PRINCIPLES OF Virology

4TH EDITION



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WITH LYNN W. ENQUIST

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We dedicate this book to the students, current and future scientists, physicians, and all those with an interest in the field of virology, for whom it was written.
We kept them ever in mind.

We also dedicate it to our families:
Jonn, Gethyn, and Amy Leedham
Doris, Aidan, Devin, and Nadia
Eileen, Kelsey, and Abigail
Rudy, Jeanne, and Chris
And
Kathy and Brian

Oh, be wiser thou!
Instructed that true knowledge leads to love.

William Wordsworth
Lines left upon a Seat in a Yew-tree
1888

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Preface

The enduring goal of scientific endeavor, as of all human enterprise, I imagine, is to achieve an intelligible view of the universe. One of the great discoveries of modern science is that its goal cannot be achieved piecemeal, certainly not by the accumulation of facts. To understand a phenomenon is to understand a category of phenomena or it is nothing. Understanding is reached through creative acts.

A. D. HERSHEY
Carnegie Institution Yearbook 65

All four editions of this textbook have been written according to the authors' philosophy that the best approach to teaching introductory virology is by emphasizing shared principles. Studying the phases of the viral reproductive cycle, illustrated with a set of representative viruses, provides an overview of the steps required to maintain these infectious agents in nature. Such knowledge cannot be acquired by learning a collection of facts about individual viruses. Consequently, the major goal of this book is to define and illustrate the basic principles of animal virus biology.

In this information-rich age, the quantity of data describing any given virus can be overwhelming, if not indigestible, for student and expert alike. The urge to write more and more about less and less is the curse of reductionist science and the bane of those who write textbooks meant to be used by students. In the fourth edition, we continue to distill information with the intent of extracting essential principles, while providing descriptions of how the information was acquired. Boxes are used to emphasize major principles and to provide supplementary material of relevance, from explanations of terminology to descriptions of trail-blazing experiments. Our goal is to illuminate process and strategy as opposed to listing facts and figures. In an effort to make the book readable, rather than comprehensive, we are selective in our choice of viruses and examples. The encyclopedic *Fields Virology* (2013) is recommended as a resource for detailed reviews of specific virus families.

What's New

This edition is marked by a change in the author team. Our new member, Glenn Rall, has brought expertise in viral immunology and pathogenesis, pedagogical clarity, and down-to-earth humor to our work. Although no longer a coauthor, our colleague Lynn Enquist has continued to provide insight, advice, and comments on the chapters.

Each of the two volumes of the fourth edition has a unique appendix and a general glossary. Links to Internet resources such as websites, podcasts, blog posts, and movies are provided; the digital edition provides one-click access to these materials.

A major new feature of the fourth edition is the incorporation of in-depth video interviews with scientists who have made a major contribution to the subject of each chapter. Students will be interested in these conversations, which also explore the factors that motivated the scientists' interest in the field and the personal stories associated with their contributions.

Volume I covers the molecular biology of viral reproduction, and Volume II focuses on viral pathogenesis, control of virus infections, and virus evolution. The organization into two volumes follows a natural break in pedagogy and provides considerable flexibility and utility for students and teachers alike. The volumes can be used for two courses, or as two parts of a one-semester course. The two volumes differ in content but are integrated in style and presentation. In addition to updating the chapters and Appendices for both volumes, we have organized the material more efficiently and new chapters have been added.

As in our previous editions, we have tested ideas for inclusion in the text in our own classes. We have also received constructive comments and suggestions from other virology instructors and their students. Feedback from students was particularly useful in finding typographical errors, clarifying confusing or complicated illustrations, and pointing out inconsistencies in content.

For purposes of readability, references are generally omitted from the text, but each chapter ends with an updated list of relevant books, review articles, and selected research papers for readers who wish to pursue specific topics. In general, if an experiment is featured in a chapter, one or more references are listed to provide more detailed information.

Principles Taught in Two Distinct, but Integrated Volumes

These two volumes outline and illustrate the strategies by which all viruses reproduce, how infections spread within a host, and how they are maintained in populations. The principles of viral reproduction established in Volume I are essential for understanding the topics of viral disease, its control, and the evolution of viruses that are covered in Volume II.

Volume I The Science of Virology and the Molecular Biology of Viruses

This volume examines the molecular processes that take place in an infected host cell. It begins with a general introduction and historical perspectives, and includes descriptions of the unique properties of viruses (Chapter 1). The unifying principles that are the foundations of virology, including the concept of a common strategy for viral propagation, are then described. An introduction to cell biology, the principles of the infectious cycle, descriptions of the basic techniques for cultivating and assaying viruses, and the concept of the single-step growth cycle are presented in Chapter 2.

The fundamentals of viral genomes and genetics, and an overview of the surprisingly limited repertoire of viral strategies for genome replication and mRNA synthesis, are topics of Chapter 3. The architecture of extracellular virus particles in the context of providing both protection and delivery of the viral genome in a single vehicle are considered in Chapter 4. Chapters 5 through 13 address the broad spectrum of molecular processes that characterize the common steps of the reproductive cycle of viruses in a single cell, from decoding genetic information to genome replication and production of progeny virions. We describe how these common steps are accomplished in cells infected by diverse but representative viruses, while emphasizing common principles. Volume I concludes with a new chapter, "The Infected Cell," which presents an integrated description of cellular responses to illustrate the marked, and generally, irreversible, impact of virus infection on the host cell.

The appendix in Volume I provides concise illustrations of viral life cycles for members of the main virus families discussed in the text; five new families have been added in the fourth edition. It is intended to be a reference resource when reading individual chapters and a convenient visual means by which specific topics may be related to the overall infectious cycles of the selected viruses.

Volume II Pathogenesis, Control, and Evolution

This volume addresses the interplay between viruses and their host organisms. The first five chapters have been reorganized and rewritten to reflect our growing appreciation of the host immune response and how viruses cause disease. In Chapter 1 we introduce the discipline of epidemiology, provide historical examples of epidemics in history, and consider basic aspects that govern how the susceptibility of a population is controlled and measured. With an understanding of how viruses affect human populations, subsequent chapters focus on the impact of viral infections on hosts, tissues and individual cells. Physiological barriers to virus infections, and how viruses spread in a host, invade organs, and spread to other hosts are the topics of Chapter 2. The early host response to infection, comprising cell autonomous (intrinsic) and innate immune responses, are the topics of Chapter 3, while the next chapter considers adaptive immune defenses, that are tailored to the pathogen, and immune memory. Chapter 5 focuses on the classic patterns of virus infection within cells and hosts, the myriad ways that viruses cause illness, and the value of animal models in uncovering new principles of viral pathogenesis. In Chapter 6, we discuss virus infections that transform cells in culture and promote oncogenesis (the formation of tumors) in animals. Chapter 7 is devoted entirely to the AIDS virus, not only because it is the causative agent of the most serious current worldwide epidemic, but also because of its unique and informative interactions with the human immune defenses.

Next, we consider the principles involved in treatment and control of infection. Chapter 8 focuses on vaccines, and Chapter 9 discusses the approaches and challenges of antiviral drug discovery. The topics of viral evolution and emergence have now been divided into two chapters. The origin of viruses, the drivers of viral evolution, and host-virus conflicts are the subjects of Chapter 10. The principles of emerging virus infections, and humankind's experiences with epidemic and pandemic viral infections, are considered in Chapter 11. Volume II ends with a new chapter on unusual infectious agents, viroids, satellites, and prions.

The Appendix of Volume II provides snapshots of the pathogenesis of common human viruses. This information is presented in four illustrated panels that summarize the viruses and diseases, epidemiology, disease mechanisms, and human infections.

Reference

Knipe DM, Howley PM (ed). 2013. *Fields Virology*, 6th ed. Lippincott Williams & Wilkins, Philadelphia, PA.

For some behind-the-scenes information about how the authors created the fourth edition of *Principles of Virology*, see: http://bit.ly/Virology_MakingOf

Acknowledgments

These two volumes of *Principles* could not have been composed and revised without help and contributions from many individuals. We are most grateful for the continuing encouragement from our colleagues in virology and the students who use the text. Our sincere thanks also go to colleagues (listed in the Acknowledgments for the third edition) who have taken considerable time and effort to review the text in its evolving manifestations. Their expert knowledge and advice on issues ranging from teaching virology to organization of individual chapters and style were invaluable, and are inextricably woven into the final form of the book.

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Since the inception of this work, our belief has been that the illustrations must complement and enrich the text. Execution of this plan would not have been possible without the support of Christine Charlip (Director, ASM Press), and the technical expertise and craft of our illustrator. The illustrations are an integral part of the text, and credit for their execution goes to the knowledge, insight, and artistic talent of Patrick Lane of ScEYEnce Studios. We also are indebted to Jason Roberts (Victorian Infectious Diseases Reference Laboratory, Doherty Institute, Melbourne, Australia) for the computational expertise and time he devoted to producing the beautiful renditions of poliovirus particles on our new covers. As noted in the figure legends, many could not have been completed without the help and generosity of numerous colleagues who provided original images. Special thanks go to those who crafted figures or videos tailored specifically to our needs, or provided multiple pieces: Chantal Abergel (CNRS, Aix-Marseille Université, France), Mark Andrake (Fox Chase Cancer Center), Timothy Baker (University of California), Bruce Banfield (The University of Colorado), Christopher Basler and Peter Palese (Mount Sinai School of Medicine), Ralf Bartenschlager (University of Heidelberg, Germany), Eileen Bridge (Miami University, Ohio), Richard Compans (Emory University), Kartik Chandran (Albert Einstein College of Medicine), Paul Duprex (Boston University School of Medicine), Ramón González (Universidad Autónoma del Estado

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There is little doubt in undertaking such a massive effort that inaccuracies still remain, despite our best efforts to resolve or prevent them. We hope that the readership of this edition will draw our attention to them, so that these errors can be eliminated from future editions of this text.

This often-consuming enterprise was made possible by the emotional, intellectual, and logistical support of our families, to whom the two volumes are dedicated.

About the Authors

Jane Flint is a Professor of Molecular Biology at Princeton University. Dr. Flint's research focuses on investigation of the molecular mechanisms by which viral gene products modulate host cell pathways and antiviral defenses to allow efficient reproduction in normal human cells of adenoviruses, viruses that are widely used in such therapeutic applications as gene transfer and cancer treatment. Her service to the scientific community includes membership of various editorial boards and several NIH study sections and other review panels. Dr. Flint is currently a member of the Biosafety Working Group of the NIH Recombinant DNA Advisory Committee.

Vincent Racaniello is Higgins Professor of Microbiology & Immunology at Columbia University Medical Center. Dr. Racaniello has been studying viruses for over 35 years, including poliovirus, rhinovirus, enteroviruses, and hepatitis C virus. He teaches virology to graduate, medical, dental, and nursing students and uses social media to communicate the subject outside of the classroom. His Columbia University undergraduate virology lectures have been viewed by thousands at iTunes University, Coursera, and on YouTube. Vincent blogs about viruses at virology.ws and is host of the popular science program This Week in Virology.

Glenn Rall is a Professor and the Co-Program Leader of the Blood Cell Development and Function Program at the Fox Chase Cancer Center in Philadelphia. At Fox Chase, Dr. Rall is also the Associate Chief Academic Officer and Director of the Postdoctoral Program. He is an Adjunct Professor in the Microbiology and Immunology departments at the University of Pennsylvania, Thomas Jefferson, Drexel, and Temple Universities. Dr. Rall's laboratory studies viral infections of the brain and the immune responses to those infections, with the goal of defining how viruses contribute to disease in humans. His service to the scientific community includes membership on the Autism Speaks Scientific Advisory Board, Opinions Editor of *PLoS Pathogens*, chairing the Education and Career Development Committee of the American Society for Virology, and membership on multiple NIH grant review panels.

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