Book proposal: Infectious Disease Epidemiology - A modern systems approach

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# Author

* Andreas Handel1, Department of Epidemiology and Biostatistics, The University of Georgia, Athens, GA, USA

# Working book titles

* Infectious Disease Epidemiology - A modern systems approach
* Modern Infectious Disease Epidemiology - A (dynamical) systems approach

# Rationale and scope

## Overview

Modern infectious disease (ID) epidemiology makes heavy use of computational model-based approaches and a dynamical systems perspective. The importance of analyzing infectious diseases in such a way keeps increasing. However, infectious disease epidemiology is still often taught mainly from a medical and classical epidemiological study design (e.g., cohort, case- control) perspective. A number of textbooks exist that approach infectious disease epidemiology from a classical epidemiological and medical perspective (e.g. (Magnus 2008; Nelson and Williams 2013; Giesecke 2017)).

While textbooks that teach a systems/model based approach to infectious diseases exist (e.g. (Anderson and May 1991; Diekmann and Heesterbeek 2000; Keeling and Rohani 2008; Vynnycky and White 2010)), those books are meant to teach students how to become modelers. As such the books require students to work with mathematical models and write computer code. This is a significant barrier for students who do not have a strong mathematical background or prior coding experience, which applies to many students in public health and related biomedical disciplines. It limits the number of students who can or want to engage with infectious disease epidemiology by using modern, systems modeling-based approaches.

There is currently (as far as I am aware) no book that teaches infectious disease epidemiology from a systems perspective while at the same time being approachable to students without the need of doing a good bit of math and/or computer programming.

Thus the idea for this book. In this book, ID topics are discussed from a dynamical systems perspective, and make use of dynamical models. At the same time, students are not required to know advanced mathematics or coding and model building is not taught.

I believe that anyone working on infectious disease related topics in public health nowadays needs to have some familiarity with models. As such, this book contains and shows some models and equations. However, it introduces those models as tools for understanding infectious disease concepts, and does not try to teach the student to become a modeler. The focus is on understanding the modeling perspective and becoming an educated consumer of models.

## Learning Objectives

The main goal of the book is to equip students with the knowledge to think about ID Epi in a systems way and to 'consume/interpret' results from infectious disease modeling studies. If students, after having worked through this book, want to proceed toward becoming modelers themselves, they could continue with the modeling textbooks mentioned above.

The proposed book is meant to address the following main learning objectives (more detailed objectives are listed at the beginning of each book chapter):

* Explain the importance of system dynamical thinking for the study and control of ID
* Understand how different stages of an infection play different roles influencing medical versus public health interventions
* Interpret the meaning of specific dynamic patterns seen in ID incidence and prevalence
* Explain and compute important epidemiological measures, such as reproductive number and level of herd immunity
* Know about main differences in ID transmission and how that affects control strategies
* Choose optimal ID intervention strategies based on features of specific IDs and predict the impact of different ID intervention strategies
* Understand how host heterogeneity impacts ID dynamics
* Appreciate the complexities of multi-pathogen dynamics
* Assess the role of stochasticity on ID extinction
* Understand the mechanisms and drivers of pathogen evolution and the emergence of new infectious diseases
* Evaluate the impact of connection structure between hosts on ID dynamics

## Specific Use Case Examples

I envision several target groups and use cases for this book:

For graduate (masters and PhD) students/courses in public health, epidemiology and related areas who have an interest in ID Epi without necessarily wanting to become modelers:

* The main book for a course on ID Epi (to replace e.g. (Nelson and Williams 2013)), possibly supplemented with additional reading from the primary literature. This would be for a course that teaches ID Epi from a modern, dynamical systems perspective.
* One of the books used for a course on ID Epi, together with more classical books (e.g. (Nelson and Williams 2013)), to teach ID Epi in a mix of standard and model-thinking approach.
* The main book for an ID Modeling course, supplemented with further material (reading or exercises, especially the DSAIDE R package described below), to teach model building.
* One of the books used for an ID Modeling course, alongside e.g. (Keeling and Rohani 2008; Vynnycky and White 2010)). For non-student individuals, e.g. health professionals working in places like health departments, CDC, etc.
* As self-contained reading outside a course for individuals who have learned ID Epi from a classical perspective and are increasingly exposed to model-based studies in the literature and want to better understand that approach, without wanting to become active modelers.

As example, here is how we currently cover ID Epi at our institution (College of Public Health at the University of Georgia). We currently have 3 graduate level courses (with usually a mix of MPH/MS/PhD student enrolled) that broadly cover infectious diseases:

1. Infectious Disease Epidemiology (taught by one of my colleagues for the last 5+ years), which uses a classical epidemiological/medical/disease centric approach with Nelson as textbook;
2. A course on Dynamical Systems Approaches to Infectious Disease Epidemiology which I have taught online for the last 2 years. This book originates from this class and is the main reading used there.
3. A course on Infectious Disease Modeling, also taught by myself for the last 5+ years, which in the past used (Keeling and Rohani 2008; Vynnycky and White 2010) as recommended reading. Unfortunately, I found that both books require mathematical knowledge that many of my students could not handle. Thus the books were only recommended and I mostly relied on my own materials. I have not taught the course since I wrote this book, but I plan to use this book and supplement with modeling exercises in the future, while continuing to recommend (Keeling and Rohani 2008; Vynnycky and White 2010) for those students that can handle the material.

# Readership

The main audience are students in public health and related biomedical disciplines who want to learn about infectious disease epidemiology from a modern, systems-based perspective, while not (yet) wanting to engage deeply with the math and computational aspects related to the topic.

We assume readers are familiar with basic epidemiological and public health ideas such as incidence and prevalence, basic study design such as cohort and case-control studies and clinical trials, and other basic epidemiological concepts. We also assume readers have at least some passing knowledge of many infectious diseases, which make appearances in the book but are not described in much detail.

It is likely that most readers will have some gaps (e.g. not being familiar with a specific disease or a specific epidemiological concept). Filling such gaps does not require anything beyond some basic reading on main sources such as Wikipedia, the CDC website, or similar.

# Competing/related books

The rationale and scope sections above describe how I believe this book differs from existing classical ID EPi books ((Magnus 2008; Nelson and Williams 2013; Giesecke 2017)) and ID Modeling books ((Anderson and May 1991; Diekmann and Heesterbeek 2000; Keeling and Rohani 2008; Vynnycky and White 2010)) and is positioned in the gap that I think exists between these two categories of currently existing ID Epi books.

Another book worth mentioning is (Krämer, Kretzschmar, and Krickeberg 2010), which is an edited volume. It is a mix of ID topics, more conceptual/less medical than (Nelson and Williams 2013). Since each chapter is written by a different set of authors, it has the usual problem of edited books that each chapter/topic is somewhat stand-alone, with authors writing at different levels of difficulty and discussing whatever they find relevant for a given topic. Thus the whole book is not that cohesive and I consider it suitable to assign specific chapters as additional reading but wouldn't use it as a stand-alone book for teaching/learning.

A somewhat older book similar to (Krämer, Kretzschmar, and Krickeberg 2010) seems to be (Thomas and Weber 2001). It is also an edited volume and based on the TOC, convers broadly similar ground to (Krämer, Kretzschmar, and Krickeberg 2010). I do not own (Thomas and Weber 2001), thus have not yet seen/reviewed the full text.

To my knowledge, the resources that are most similar to the book in content/spirit are not textbooks but 2 online courses on Coursera, one called 'Epidemics - the dynamics of infectious diseases' developed by faculty from Penn State (State 2014), and one called 'Epidemics', developed by faculty from Hong Kong University (University 2015).

The Penn State course is 8 week long, features many very good and short videos, and is somewhat broader regarding content and discusses topics than my book. For instance 1 week of the course is devoted to within-host infection and immune response processes, something I do not cover explicitly. Almost all content is taught through the videos, with some optional reading drawn from the primary literature

The Hong Kong Course is 10 weeks long and also mainly video-based, with some optional reading drawn from the primary literature. The course discusses some topics my book doesn't touch on (e.g. communication strategies for ID interventions) while conversely I discuss topics (e.g. extinction and evolution) that are not/barely covered in the course.

I consider the relation between these courses and my proposed book somewhat complementary, i.e. those are 2 different ways of teaching similar material. In fact, in my course on this topic (see below), for every topic I cover I assign both a chapter of my book and suitable videos, many of which come from these online courses.

# Content

A draft version of the book is already written and is currently available on Github at:

<https://ahgroup.github.io/DSAIDEbook/>

The current form of the book was written as part of my teaching of a course on this topic (the Dynamical Systems Approaches to Infectious Disease Epidemiology course mentioned above). This is an online graduate level course at the University of Georgia with mostly public health students and some students from other disciplines (e.g. Ecology, Veterinary Infectious Disease, Forestry, etc.). I have taught the course twice so far. The first year (fall 2016), I modified my previous lecture notes (based on the ID Modeling class I've been teaching for a while, as well as a short-term ID Epi class I taught previously at Emory) and turned them into short readings for each topic. For the fall 2017 course, I combined those short readings and further expanded them, leading to the currently existing book draft.

The book currently has 18 chapters, some longer than others. Each chapter has the same structure, with a short section of suggested exercises at the end. In the last iteration of the course (fall 2017), each book chapter (apart from the 2 I have added since which are not yet written) was covered in a week. Students were assigned some or all of the exercises listed at the end of the chapter as weekly homework. Those exercises usually involve the DSAIDE R package described in more detail below, and suggestions for reading and critically discussing papers from the primary literature.

# Special features

Color figures are likely not needed. The book contains text boxes that are set apart from the main text and that contain more advanced material (e.g. show sets of differential equations) that students can skip without losing the ability to understand the rest.

# Description of ancillary material

I have written an R package called DSAIDE that allows students to actively explore the topics covered in the book. This R package is freely available on CRAN (<https://cran.r-project.org/package=DSAIDE>). It consists of multiple simulations, wrapped into a graphical user interface (implemented in R/Shiny). Each app addresses a specific ID topic and comes with a description of the underlying model and a list of tasks for the user to do. The tasks are meant to explore and thus further learn the topic covered by an app.

This R package is fully developed and available on CRAN, I published a (freely available) paper in PLoS Comp Bio describing the package and its use (Handel 2017). I have used this package in my previous teaching of the course, and know of at least 2 other colleagues (one at Virigina Tech, one at GA Southern) who have used the package as part of their ID Epi courses.

While both the DSAIDE package and the book are designed such that they could be used on their own, in my opinion the combination of the 2 makes for the best learning experience. The idea is for a student to start by reading the material in the book. In the exercise section of each book chapter, the students are pointed toward the appropriate simulation in the DSAIDE package. Using the package and performing the given tasks for each app provides hands-on learning and further strengthens understanding of the material.

An important aspect of DSAIDE is its modular structure. The main intended use is through the graphical interface, which allows students with no coding experience to interact and explore infectious disease topics from a dynamical systems perspective. In addition, each app is written such that students have direct access to the underlying simulation code. This allows more advanced exploration by writing a few lines of their own code wrapped around the supplied simulation function, or even more advanced, by modifying the supplied simulation functions to suit their needs. As such, the package is useful for both students who wish to explore ID models but do not want to start writing code and building models, and those students who want to get a (gentle) introduction toward becoming active modelers. All of these details are described in more details in the PLoS Comp Bio paper mentioned above (Handel 2017).

Note that there are currently no apps in DSAIDE that directly deal with data (e.g. fitting dynamical models to time-series). This might change in the future, but fitting data is a more advanced topic and not the main focus of the DSAIDE package.

# Proposed length of the book and its proposed completion date

A very crude word count (including TOC and references) gives around 40,000 words currently. A pdf version of the book is 106 pages. I expect the final version to grow by around 50-100% through addition of a few more chapters and adding more details to several existing chapters.

My aspirational completion date is end of summer. I have a light teaching load in spring and time over summer. This should give me enough time to finish a version that is suitable to undergo peer review. If I can't finish by end of summer, I hope to get it done at least end of year.

# Planned next steps

* I have a few topics/chapters that I want to add, I have started working on those. They are in the book draft but currently empty/incomplete.
* I want to re-visit various pertinent books/courses/resources and review them to see if there are any topics that I think should be added to my book.
* Some of the existing chapters are a bit too short, I plan to flesh them out some more.
* Everything needs further editing and cleaning up.

# Brief credentials of the author

Andreas Handel  
Associate Professor  
Assoc. Dept. Head &  
Graduate Coordinator  
Department of Epidemiology and Biostatistics  
College of Public Health, University of Georgia  
Athens, Georgia 30602, USA  
<http://handelgroup.uga.edu/>

See website for my research and further information.

# Some other comments

The book is written in bookdown (<https://bookdown.org/>) and lives in the "R ecosystem" (markdown, pandoc, bibtex, etc.)

# Current chapters of book

Some chapters are already fairly complete, most are somewhat complete but still need further additions, a few chapters still need to be written.

1. Overview of this book
2. Introduction to the Dynamical Systems Approach to Infectious Disease Epidemiology
3. Characterizing Infectious Disease States
4. Patterns of Infectious Disease Dynamics
5. Reproductive Number
6. Types of Infectious Disease Transmission
7. Modes of Direct Transmission
8. Environmental Transmission
9. Vector-borne ID Transmission
10. Infectious Disease Control
11. Infectious Disease Surveillance
12. Host Heterogeneity
13. Dynamics of Multiple Pathogens
14. Stochastic Dynamics and Extinctions
15. Evolutionary Dynamics
16. Emerging Infectious Diseases
17. Networks and ID
18. Summary

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