Introduction to Infectious Disease Modelling and its Applications

Course Description

Intensive course: 2nd – 13th July, 2012





Introduction

Infectious diseases remain a leading cause of morbidity and mortality worldwide, with HIV, tuberculosis and malaria estimated to cause 10% of all deaths each year. New pathogens continue to emerge in animal and human populations, as demonstrated by the emergence of SARS in 2003, of Highly Pathogenic Avian Influenza (HPAI) in poultry and humans in 2004/2005, and swine flu in 2009.

Mathematical models are being increasingly used to elucidate the transmission of infections and to evaluate the potential impact of control programmes in reducing morbidity and mortality. This two week intensive course is intended to introduce professionals with an interest in infectious diseases in either developing or developed countries or in veterinary questions to this exciting and expanding area. The emphasis will be on developing a conceptual understanding of the basic methods and on their practical application rather than the manipulation of mathematical equations.

The level of difficulty is similar to that of the recently published book "An Introduction to Infectious Disease Modelling" which was written by two of the course organizers (Emilia Vynnycky and Richard White), and which is based on material from this popular and successful course. For further details about the book, see www.anintroductiontoinfectiousdiseasemodelling.com.

Course structure

The course comprises 4 sections, as follows:

Section 1: Basic methods and motives for developing infectious disease models

This section is designed to introduce participants both to the basic methods for developing models of the transmission dynamics of infectious diseases and to the applications of these models. It starts with an introduction to the major concepts used for studying the epidemiology of infectious diseases (the basic reproduction number, incubation periods, serial intervals, herd immunity) and continues with an introduction to the main types of models that can be employed.

Participants learn about the basic methods for setting up deterministic models (difference and differential equations) and will gain practice and confidence in setting up simple models using spreadsheets and a specialist, user-friendly modelling package (Berkeley Madonna). Examples of diseases discussed in this section include influenza, measles, mumps and rubella. Participants will gain an understanding of the insights into infectious disease dynamics that models can provide, such as the factors influencing the periodicity of disease incidence for immunizing infections (e.g. the incubation period, basic reproduction number, seasonal transmission, vaccination and control programmes) and how the models can be applied to determine optimal control strategies for outbreaks involving new pathogens as well as for endemic infections.

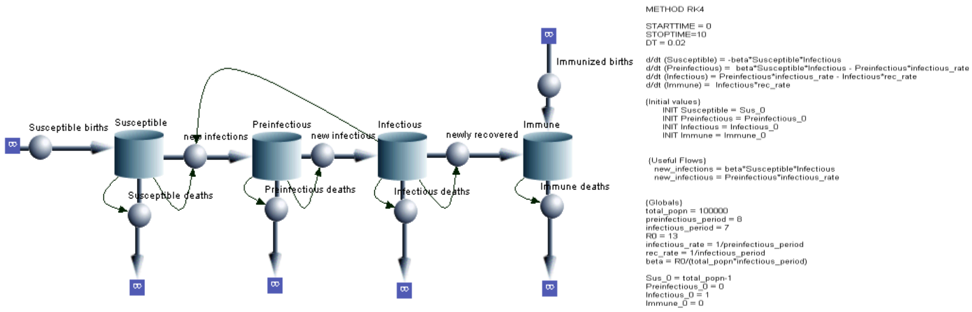


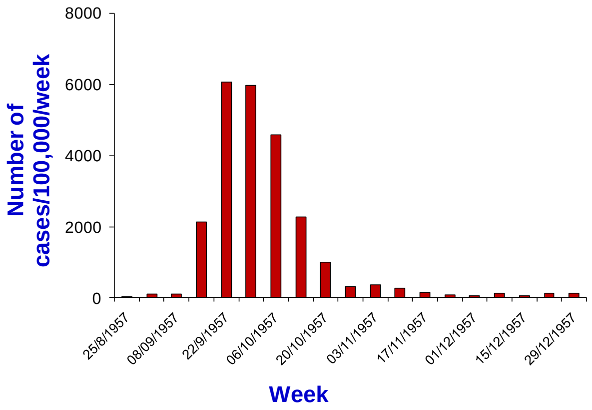
Figure 1: Example of different approaches which can be used to set up models using Berkeley Madonna. Models can be set using either flow diagrams or equations. Participants can work with the approach that they prefer during the course.

Section 2: Analysis of data and applications of modelling of seroprevalence data

Section 2 deals with the methods for analysing seroprevalence or other data on past infection, how they can be used for elucidating past trends in infection incidence and for studying the transmission dynamics and predicting the control of infections. The section starts with a lecture on how to analyse and interpret seroprevalence data and during the subsequent practicals, participants will examine different data sets and estimate (age-dependent) infection incidences ("forces of infection") for high and low infection transmission settings, using rubella as an example.

These estimates are then used to analyse how control policies can lead to a reductions in transmission but increases in infection incidence in adult life (and other unexpected events), depending on the study setting. Participants will also study how seroprevalence data can be used to estimate mixing patterns of subgroups in given populations and how different contact patterns between individuals affect the impact of control.

The section includes two sections of a groupwork exercise, whereby participants use modelling to analyse data for influenza or Ebola and predict the impact of different interventions, such as school closures, vaccination.



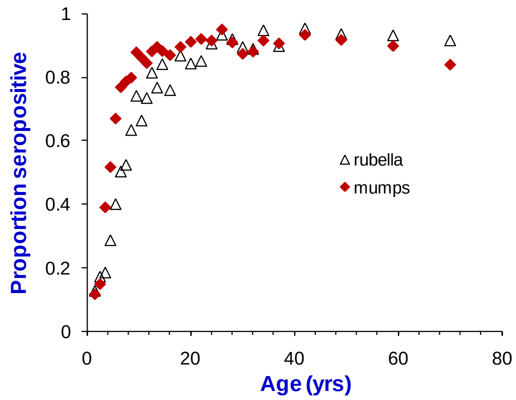


Figure 2: Examples of the kinds of datasets that course participants learn to analyse and use in models in this section. A. Data on the epidemic curve for influenza (from an outbreak during the 1957 influenza pandemic) B. Age-specific serological data for mumps and rubella.

Section 3: Additional methods and dynamics - stochastic and network modelling, model-fitting and sensitivity analyses

This section provides an introduction to several methodological aspects of modelling, namely stochastic and network models, sensitivity analyses and methods for fitting models to data.

Stochastic models are often used to describe the transmission dynamics of infections in small populations, for example, for predicting the course of outbreaks and critical population sizes for the persistence of infection. This section introduces participants to the basic methods for setting up stochastic models of outbreaks and the long-term dynamics of directly transmitted infections. It also illustrates how distributions of outbreak sizes may be used to infer the success of elimination programmes and extent of ongoing transmission e.g. for pandemic influenza or measles. It also illustrates the application of stochastic models in describing nosocomial transmission.

Modelling studies increasingly need to fit models to data and use sensitivity analyses to determine the effect of different assumptions or inputs on predictions of the incidence or control of an infection. This is especially important when using models to guide policy. The subsequent lecture in this section discusses the methods for fitting models to data and there is an additional lecture on the interpretation and applications of sensitivity analyses.

The success of control programmes greatly depend on the extent to which different individuals are connected, for example, the individuals that each person contacts and the contacts of those persons. These issues are illustrated in a lecture and practical on network models, which try to capture such detailed contact patterns and have been used in modelling the transmission and control of sexually transmitted infections and Foot and Mouth Disease.

The section concludes with a lecture reflecting on the different approaches for setting up models, and discussing their relative merits.

Section 4: Applications of modelling

The lectures in this section are designed to illustrate several major current areas of applications of mathematical models, namely modelling the transmission of sexually transmitted infections (STIs) and HIV, tuberculosis, real-time modelling, zoonoses and other veterinary diseases. Most of the sessions on the applications of modelling comprise two parallel streams and participants can attend sessions from either stream at any time.

This section starts with an introduction to real-time modelling, and how it was used during the 2009 swine flu pandemic in the UK for monitoring the extent of ongoing transmission at regular intervals (e.g. daily).

The first stream continues the theme of real-time modelling, starting with a lecture on the methods and a computer practical illustrating the implementation of these methods. It then continues with a lecture and practical on modelling *M tuberculosis* transmission and predicting the impact of control. The stream concludes with a with a lecture on modelling sexually transmitted infections, covering the early mathematical models for STIs and the role of core groups in sustaining infections in populations. This is followed by a lecture covering the development of models to understand the spread and control of HIV.

The second stream starts with a lecture and practical on backcalculation and modelling the vCJD epidemic in the UK. This is followed by a lecture discussing the general issues relating to modelling problems in veterinary epidemiology, illustrating the principles using avian influenza in the UK. The stream concludes with a lecture and practical describing the transmission of malaria and the Ross Macdonald model, which is followed by a lecture discussing general issues in developing models for vector-born diseases.

Teaching methods

Lectures and practicals

A typical day lasts from 9.15-5.30 (with breaks for lunch and coffee/tea), with each half-day session consisting of a lecture and an accompanying practical. There will also be review lectures on Wednesday morning of week 1 and on Monday morning of week 2, which will go over the material covered until then. Attendance at these sessions is optional.

Guest Lectures

Lunch-time and evening guest seminars by modellers from outside LSHTM are scheduled during the course. Speakers in the past have included Neil Ferguson (Imperial College), Hans Heesterbeek (University of Utrecht), Roy Anderson (Imperial College, London), Geoff Garnett (Imperial College, London), Robert May (University of Oxford), Eduardo Massad (University of Sao Paulo), Brian Williams (WHO), Jon Read (Warwick University), Liz Miller (Health Protection Agency), Angela Maclean (University of Oxford), . These seminars are designed to provide further perspectives on the areas of application of modelling and attendance is entirely optional.

Paper discussions

A paper discussion is scheduled on Friday of week 1, which is designed to familiarize participants with the mathematical modelling literature and to introduce some of the areas of applications of modelling. The topics covered in these papers include HIV, avian influenza and pandemic influenza.

Groupwork/Problem–based learning exercise

During the course, there is a problem-based learning exercise, which is designed to highlight the way modelling methods may be used to solve "real" problems and to give practice in thinking about how models are designed and used to make policy decisions. Participants will be divided into small groups and will work on a problem relating to pandemic influenza or Ebola. Participants are required to discuss and work on the problem in these groups during allocated sessions. The exercise culminates with a poster presentation on the final day.

Modelling clinic

Tutors are available during the course to discuss questions that participants may have on the course material. In addition, a short "clinic" is scheduled for the final Thursday of the course, during which tutors are available to discuss questions relating to the participants' own work in more depth.

Social arrangements

Finally, there are several opportunities for social interaction during the course, including a reception on the first day, a guided walk around the sites of special medical interest in London, and a meal and a trip on the London Eye.

Backgrounds of previous students

The course aims to bring a conceptual understanding of mathematical modelling and its applications in infectious disease research to individuals who have not had any advanced training in mathematics. It is also suitable for individuals with a background in mathematical disciplines who wish to obtain an understanding of the broad range of applications of mathematical models in infectious disease epidemiology and who

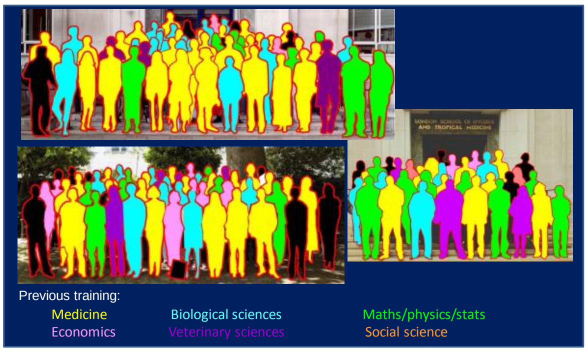


Figure 3: Illustration of the backgrounds of past course participants.

may wish to specialize in this area in the future.

The diversity of academic backgrounds catered for in this course is illustrated by the course photo from recent years, shown above and from the feedback from students (see below). Each individual in the photo is shaded according to his or her academic background and region of origin. For example, medical doctors are shaded in yellow, vets are in purple, etc.

Feedback from previous students

General

- 'Great course! It's hard to bring people from different levels of knowledge together, but this course succeeded in doing so.'
- 'It would help infectious diseases doctors to develop a higher level of comprehension of how epidemics spread.'
- 'Many MDs working in tropical areas badly need these concepts...'
- 'One of the few courses where I really feel I learnt something useful.'
- ‘I would say it is a must for infectious disease epidemiologists.’

Course content and structure

- 'Really helps reinforce basic epidemiology and how that is applied and taken further.'
- 'We have lectures covering basic concepts and following that there are practicals to further digest them, that is so like me!'
- 'Is a really good course, where you really get useful outputs! Beautiful course to get in touch with modelling.'
- 'Lots of practicals for each session, lots of examples based on diseases: wide spectrum for applications.'
- ‘It gives a good picture of the problem. It is not too technical and therefore people with different backgrounds can follow and understand.’

Level of difficulty

- 'Very good for a totally 'blur' person like me on modelling - I saw the light.'
- 'Just right; could even have been more difficult (but it would take more time to explain the maths; so this might not be feasible).'
- 'Challenging but very well presented.'
- ‘This course provided a great introduction to modelling for non-mathematicians, making this important discipline accessible.

Organization and teaching

- ‘It is very well organised. Every detail seems to have been covered.’
- 'Complete use of all our time - I certainly got 'my moneys' worth! Mix of fellow students was excellent, majority of lectures were to a really high standard, as you would hope from world famous LSHTM!'
- 'Excellent teachers, very good division of time between activities.'
- 'I learnt a lot more from this course (LSHTM) than another modelling course I attended. First the lecture notes are really good. Second each lecture was followed by a practical session and is really fantastic. This helps students to consolidate the

ideas from lecture and put the theory into practice. On the whole FANTASTIC. Thank you!'

Further reading

Background reading

Course participants will find it helpful to read the following before the course:

1. J Giesecke. Modern Infectious Disease Epidemiology. 2002; Edward Arnold Press. Chapters 1, 2, 11, 16, 17, 19

The material covered during the course is complemented by the following book, which was written by the course organizers and published in May 2010:

E Vynnycky and RG White. An introduction to infectious disease modelling. 2010; Oxford University Press, Oxford.

Online files and exercises related to this book are available on the following website:
http://anintroductiontoinfectiousdiseasemodelling.com/

Course participants may find it helpful to read the first chapter of this book before the start of the course, and to read the other chapters whilst they are in London and after the course.

A maths refresher will be sent to course participants about a month before the start of the course. Participants wishing to refresh their mathematical knowledge before this time may find it helpful to read the Basic maths chapter (sections B.1-B.6 and B.7.1) in the above book.

Reading after the course

The following books are recommended for further reading after the course has finished:

1. Farrington CP. Modelling epidemics . 2008; The Open University. Milton Keynes.

2. Anderson RM (ed) (1982) The population dynamics of infectious diseases: theory and applications. Chapman and Hall.

3. RM Anderson and RM May (1991) Infectious diseases of humans: dynamics and control, Oxford University Press (paperback edition published in 1991)

4. MJ Keeling and P Rohani (2007) Modeling infectious diseases in humans and animals. Princeton University Press.