Introduction to infectious disease dynamics I

Introduction to Biomedical Sciences
BSc Honours Course in Biomathematics
African Institute for the Mathematical Sciences
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Exposure - potentially infectious contact between a parasitic organism and a potential host.

Exposed
Infectious diseases

Terminology

Exposed

Infected

Infection - a parasitic organism enters a host
Infectious diseases

**Terminology**

Transmission - a parasitic organism replicates within an infected host, and the infected host sheds infectious individuals (the host is said to be “infectious” or “transmitting”)
Terminology

Infectious diseases

Pathogenesis - a parasitic organism causes changes in the physiology of an infected host, affecting survival and/or reproduction (the host is said to be "diseased")
Infectious diseases dynamics are determined -- to a large extent -- by the duration of these states, as well as the degree and timing of overlap.
Infectious diseases

Terminology

Exposure

Exposed

Infected

Infectious

Diseased

Onset of infection

Onset of shedding

Onset of symptoms
Infectious diseases

Terminology

- Infection
- Onset of symptoms
- Incubation period
- Clinical disease
- Latent period
- Infectious period
- Onset of shedding
Infectious diseases

Transmission

Mode of transmission

Direct transmission
- Direct contact
- Droplet spread

Indirect transmission
- Airborne
- Vehicle-borne (fomites)
- Vector-borne (mechanical or biological)

Portal of entry

Portal of exit
Immunity

Infectious diseases

Active immunity
Requires stimulation of antibody production
Response to many infections
Induced by most vaccines
Long-lasting

Passive immunity
Presence of antibodies without stimulating production
Maternal antibodies
Immunoglobulin injections
Transient
Infectious disease dynamics

Traditional epidemiology
- Outbreak investigation
- Disease surveillance
- On-the-ground management

Mathematical epidemiology
- General principles
- Explanation of patterns
- Prediction of spread and control
- Assessment of necessary data
Shoe-leather epidemiology

Terminology

Endemic level of disease
("hyperendemic")

Epidemic

Disease outbreak

Pandemic

Sporadic cases and clusters
Shoe-leather epidemiology

Epidemic curves

Common source epidemics
point source exposure

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Shoe-leather epidemiology

Epidemic curves

Common source epidemics
  continuous exposure
Shoe-leather epidemiology

Epidemic curves

Common source epidemics
  intermittent exposure

Week of onset

Number of cases

0  1  2  3  4
Shoe-leather epidemiology

**Epidemic curves**

**Propagated epidemics**

Simulated epidemic with $R_0=1.2$ in a population of 1500 individuals
Introduction to infectious disease dynamics II
Infectious disease dynamics

Traditional epidemiology
- Outbreak investigation
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- On-the-ground management

Mathematical epidemiology
- General principles
- Explanation of patterns
- Prediction of spread and control
- Assessment of necessary data
Terminology

- Exposed
- Infected
- Infectious
- Diseased

Infection

Onset of symptoms

Onset of shedding
Infectious diseases

A simpler view of the world

Infected

Infectious

Diseased

Infectivity = 1

Infection

Onset of symptoms

Onset of shedding

Infectivity = 1
Infectious diseases

A simpler view of the world

Don’t worry about symptoms and disease!

Infectivity = 1

Onset of shedding
Infectious diseases

A simpler view of the world

much!

Don’t worry about symptoms and disease!

Infected = Infectious

Infectivity = 1

Onset of shedding
A simpler view of the world

Infectious diseases

much!
A simple view of the world

Infectious diseases

Susceptible

Infectious

Recovered
A simple view of the world

Infectious diseases

Susceptible → Infectious → Recovered
Infectious diseases

A simple view of the world

Susceptible → Infectious → Recovered
Health-related states

Infectious diseases

Susceptible → Infectious → Recovered
Infectious diseases

State variables

S → I → R
Infectious diseases

Transition rates

\( S \) \( \xrightarrow{\beta I} \) \( I \) \( \xrightarrow{\gamma} \) \( R \)
A simple disease model

\[
\begin{align*}
\frac{dS}{d\tau} &= -\beta SI \\
\frac{dI}{d\tau} &= \beta SI - \gamma I \\
\frac{dR}{d\tau} &= \gamma I
\end{align*}
\]
A simple disease model

\[ N = S + I + R \]

\[ \frac{dS}{d\tau} = -\beta SI \]
\[ \frac{dI}{d\tau} = \beta SI - \gamma I \]
\[ \frac{dR}{d\tau} = \gamma I \]
A simple disease model

\[ N = S + I + R \]

\[ \frac{dS}{dt} = -\frac{\beta SI}{\gamma} \]

\[ \frac{dI}{dt} = \frac{\beta SI}{\gamma} - I \]

\[ \frac{dR}{dt} = I \]
Infectious diseases

A simple disease model

\[ N = S + I + R \]

\[
\frac{dS}{dt} = -\frac{\beta SI}{\gamma}
\]

\[
\frac{dI}{dt} = \frac{\beta SI}{\gamma} - I
\]
$S = \frac{N}{R_0}$ Susceptible individuals
$S = \frac{N}{R_0}$  Susceptible individuals