Spread of Infectious Diseases in Complex Systems

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Spring 2008

Spread of Content in Complex Systems

Conserved Spread
Non-conserved Spread

Newman et al. (2006)

Review of Robustness

What makes a complex system robust?

1. Total number of connections/nodes
2. Number of highly connected nodes
3. Duplication of pathways (e.g., genes)

Robustness:
the ability of a complex system to preserve functional connectivity under a wide range of situations when unintentional failure or directed attacks on the network occurs

---Adapted from M-W dictionary and Watts (2003)

Endemic:
a disease that is spreading within a restricted community or geographical area

Epidemic:
a disease that is spreading across a disproportionately large population of individuals in a wide geographical area

---Adapted from M-W dictionary

Models of Epidemics

SIR (Susceptible-Infected-Recovered)

W. Kermack & A.G. McKendrick

**Assumption:** Interactions between members of each subpopulation is random

Populations:
S = Susceptible
I = Infected
R = Recovered
SIR (Susceptible-Infected-Recovered) Models of Epidemics

Watts (2003)

SIS (Susceptible-Infected-Susceptible) Models of Epidemics

Lloyd & May (2001); Paster-Satorras & Vespignani (2001)

**Immediate re-infection of susceptibles**

**A brief recovery stage but no immune stage developed**

SIS (Susceptible-Infected-Susceptible) Models of Epidemics

Lloyd & May (2001); Paster-Satorras & Vespignani (2001)

**No threshold**

Homogeneous Models

-- All nodes assumed to interact with the same number of nodes

-- Best fits diseases passed on by casual contact

Heterogeneous Models

-- Some nodes have more interactions than others

-- Best fits diseases passed on by network of close friends or associates

How do Diseases Spread?

Case #1: Ebola Virus

-- Jumped from monkeys to humans (1976)

-- Multiple strains in Africa

-- Kills fast

-- Incapacitates victims

-- Initial stage not very contagious (spread through skin lesions and permeable membrane)

The Hot Zone, R. Preston (1994)


How do Diseases Spread?

Case #2: HIV

-- Originated from African jungles

-- Patient Zero = flight attendant Gaetan Dugus (Late 1970s)

-- Kills slowly

-- Victims often not aware that they are infected in early stages

How do Diseases Spread?

**Case #2: HIV**
- Initially thought to be confined to specific groups
- Likely to have spread by small-world networks

Adapted from D. Watts (2003)

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**Special Cases: Social Insects**

- **Long Infectious Period (LIP)**
  - **High prevalence**
  - **Low intensity**

- **Short Infectious Period (SIP)**
  - **Low prevalence**
  - **High intensity**

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**How do Diseases Spread?**

**Types of Infection**

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**How do Diseases Spread?**

**Special Cases: Computer Viruses**

- Computers do not have immune systems
- Computer viruses very efficient at stealthily incorporating its code into computer commands

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**Factors Influencing Spread of Diseases**

**Summary:**

(1.) Virulence
(2.) Distance traveled by victims
(3.) Level of contagiousness (airborne is most contagious)
(4.) Initial size of outbreak
(5.) Number of interactions between infected and susceptible subpopulations

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(6.) Reproductive rate of disease

\[ \frac{\text{# infected produced}}{\text{# infected removed}} \]

- \( > 1 \) = Exponential growth
- \( < 1 \) = Die out (Burnout)

(7.) Infectious period (Long or Short)
Stopping Spread of Diseases

1. Stop interactions between infected nodes and all nodes connecting to them
2. Focus on terminating or treating susceptible nodes that have the highest probability of interacting with infected nodes
3. Recognize effects of small-world networks
   - Reduce infection rates in hubs
   - Eliminate transmission shortcuts