

**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

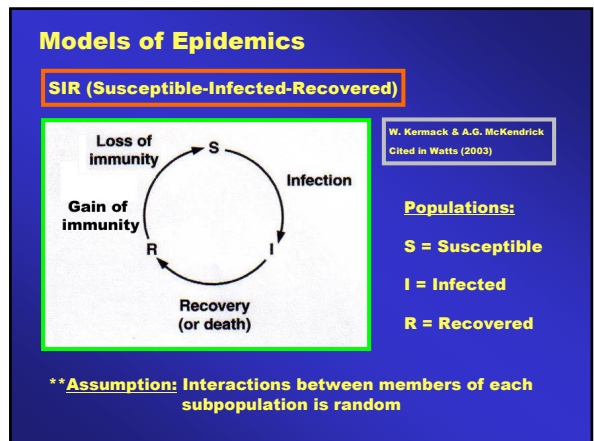
--Adapted from M-W dictionary and Watts (2003)

- ### 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)

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

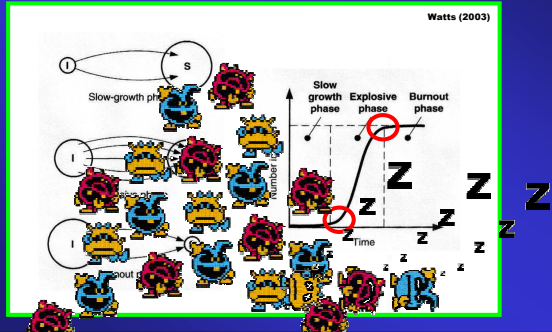
**Epidemic:**  
a disease that is spreading across a disproportionately large population of individuals in a wide geographical area

--Adapted from M-W dictionary



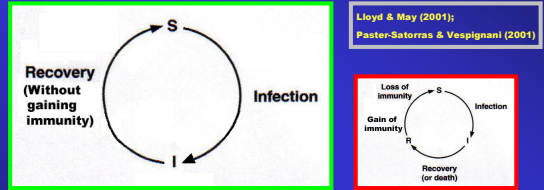
## Models of Epidemics

### SIR (Susceptible-Infected-Recovered)



## Models of Epidemics

### SIS (Susceptible-Infected-Susceptible)

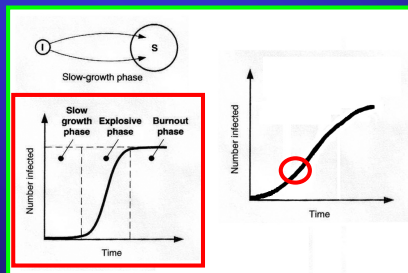


\*\*Immediate re-infection of susceptibles

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

## Models of Epidemics

### SIS (Susceptible-Infected-Susceptible)



\*\*No threshold

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

## Models of Epidemics

### 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

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

## 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)  
*Six Degrees*, D. Watts (2003)

## How do Diseases Spread?

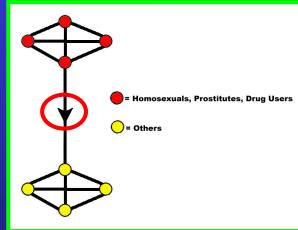
### Case #2: HIV

- Originated from African jungles
- Patient Zero = flight attendant Gaetan Dugas (Late 1970s)
- Kills slowly
- Victims often not aware that they are infected in early stages

*Six Degrees*, D. Watts (2003)

## How do Diseases Spread?

### Case #2: HIV



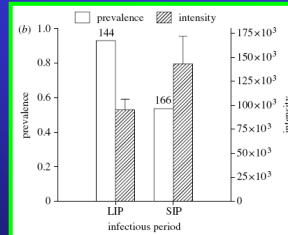
Adapted from D. Watts (2003)

- Initially thought to be confined to specific groups
- Likely to have spread by small-world networks



## How do Diseases Spread?

### Special Cases: Social Insects



### Types of Infection

#### Long Infectious Period (LIP)

- \*\* High prevalence
- \*\* Low intensity

#### Short Infectious Period (SIP)

- \*\* Low prevalence
- \*\* High intensity

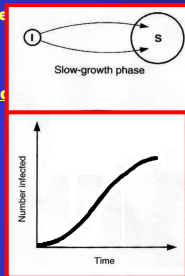
Naug & Smith (2007)

## How do Diseases Spread?

### Special Special Cases: Computer Viruses

- Computers do not have immune systems
- Computer viruses very efficient at spreading by incorporating its code into computer
- Major differences from conventional viruses

- (1.) No epidemic spread threshold
- (2.) Early stage spread is slow and non-exponential

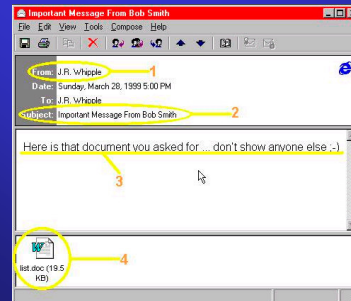


Watts (2003); Lloyd & May (2001);  
Paster-Satorras & Vespignani (2001)



## How do Diseases Spread?

### Special Special Cases: Computer Viruses



e.g., Melissa Virus (1999)

Watts (2003)

## 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

## Factors Influencing Spread of Diseases

### Summary: (Continued)

#### (6.) Reproductive rate of disease

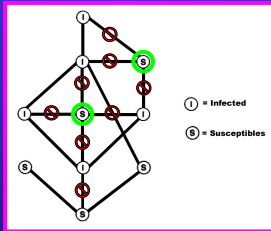
$$\frac{\# \text{ infected produced}}{\# \text{ infected removed}} \begin{cases} > 1 = \text{Exponential growth} \\ < 1 = \text{Die out (Burnout)} \end{cases}$$

#### (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



## Stopping Spread of Diseases

(3.) Recognize effects of small-world networks

Reduce infection rates in hubs

Eliminate transmission shortcuts

