Communicable Diseases Epidemiology

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March,2023

1. Introduction

- **Communicable diseases continue to account for a major proportion of disease burden**

- **Occur in epidemic forms**

- **The problem is exacerbated by:**
  - ***Poor socio-economic status***
  - ***Poor personal and environmental hygiene***
  - ***Inadequate health service coverage, etc.***

Components of Infectious Disease Process

- **Infectious diseases result from the interaction between the infectious agent, host/reservoir and environment.**

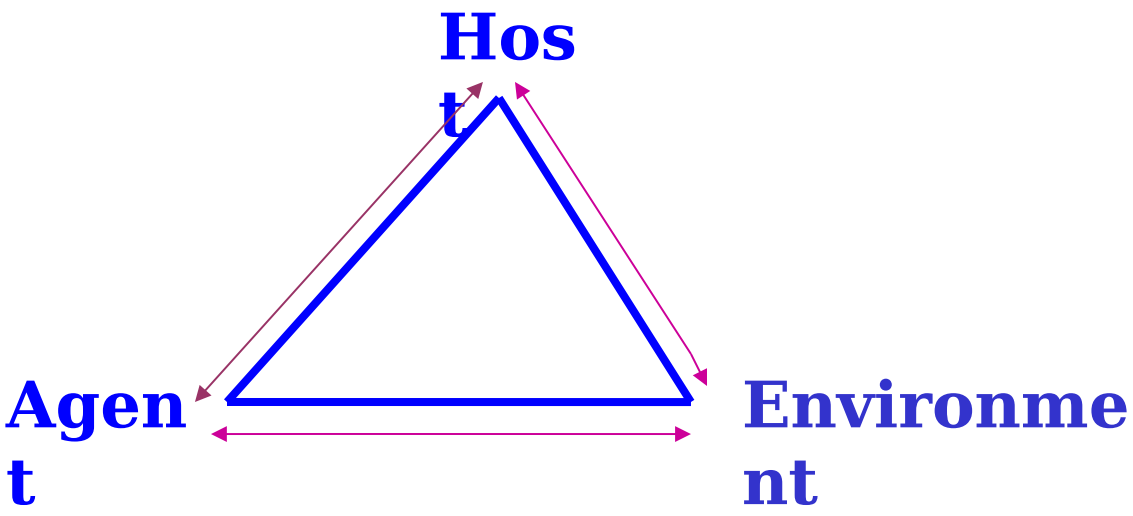


Fig 2. Components of infectious diseases

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- **Agent**: **An infectious micro-organism depends on:**
  - ***Pathogenicity,*** ***-- infectivity,***
  - ***infective dose,*** ***-- immunogenicity,***
  - ***Virulence***

- **Host**: Related to human factors.
  - ***Influences individual's exposure, susceptibility or response to a causative agent, and it depends on:***
    - ***Age, - gender,***
    - ***race, - habits,***
    - ***sexual activities, - immunization,***
    - ***contraception, - diet,***
    - ***nutrition, -etc.***

Cont….

- **Environment**: encompasses all extrinsic of the human host
  - **Physical**: **describes the geography and climate, tropical/temperate, urban/rural;**
  - **Biological**: **made up of plants, animals, and other life forms;**
  - **Socioeconomic**: **includes factors like housing, sanitation, population density, crowding, education, occupation, public health resources.**

Causal Concepts of Disease

- Not all associations between exposure and disease are causal.

- ***A cause***: ***A factor that preceded the disease and without which the disease would not occur.***

- **If disease does not develop without the factor, then the causative factor is *"necessary"***.

- ***No specific factor is sufficient to***

Cont....

- **A *"sufficient cause"* : defined as a set of conditions and events that inevitably produce disease;**

- **The occurrence of all of the conditions or events is necessary.**

- ***For example,***

  Tobacco smoking is a cause of lung cancer, but by itself it is not a sufficient cause.

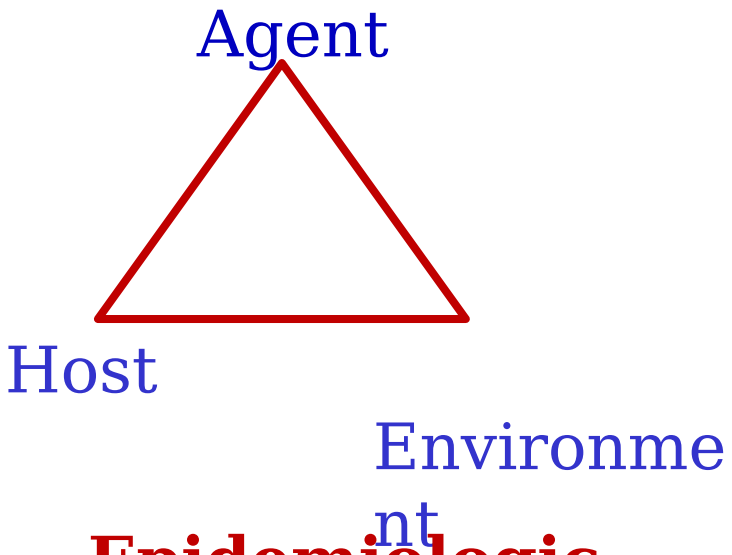
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- **If a single factor alone become sufficient to develop the disease, then we term the causative factor as both “Necessary” and *“sufficient”.***

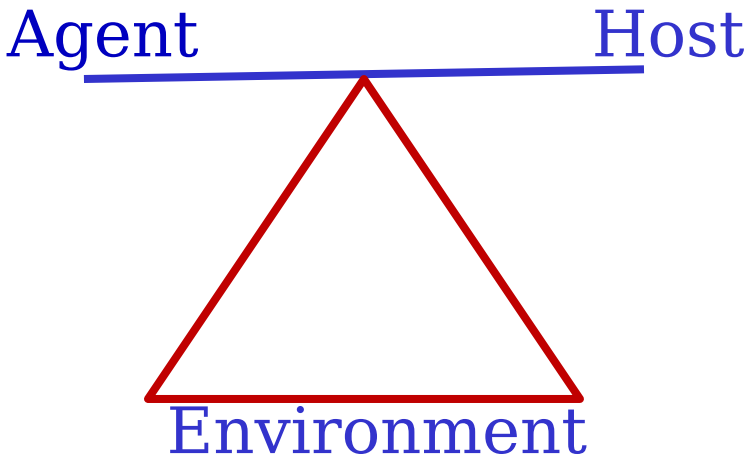
- ***Example:***
  - ***Tubercle bacilli is a necessary factor for TB***
  - ***Rabies virus is sufficient for***

Epidemiologic triangle and triad (balance beam).

- ***Traditional model of infectious disease causation***



Epidemiologic triangle



Balance beam

Multi-causality of Diseases

- **Developed in response to the idea that an infectious agent is a unique and sufficient cause of a disease.**

- **In the traditional model, each cause is seen as necessary and sufficient in itself to produce the effect.**

- ***However, a specific necessary disease agent is not recognized for non-infectious diseases.***

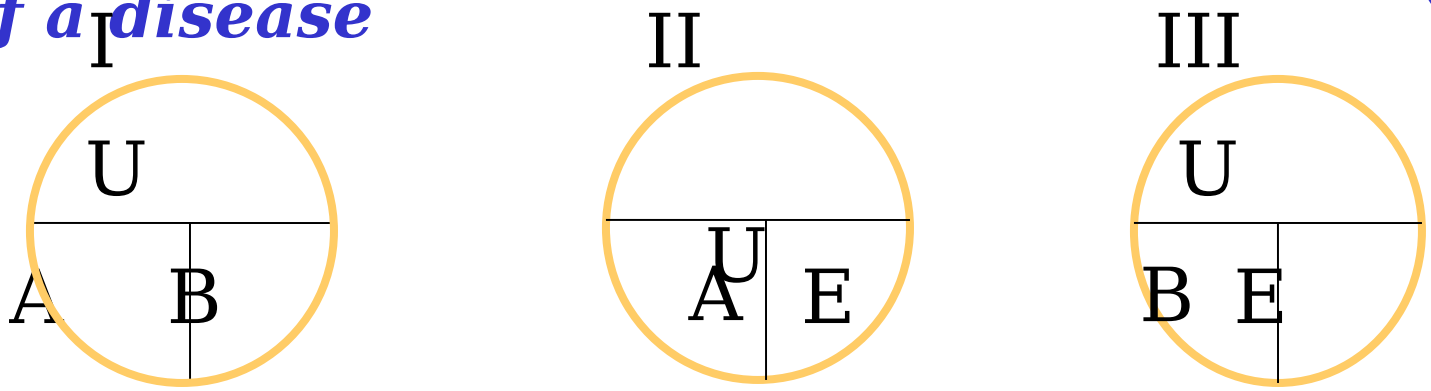
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- **In this approach, the causes of disease are considered to be agents, exposures, or risk factors.**

- ***The factors may include microbes, chemicals, nutrients, physiologic, genetic characteristics, as well as behaviors, mental states, race or socioeconomic status.***

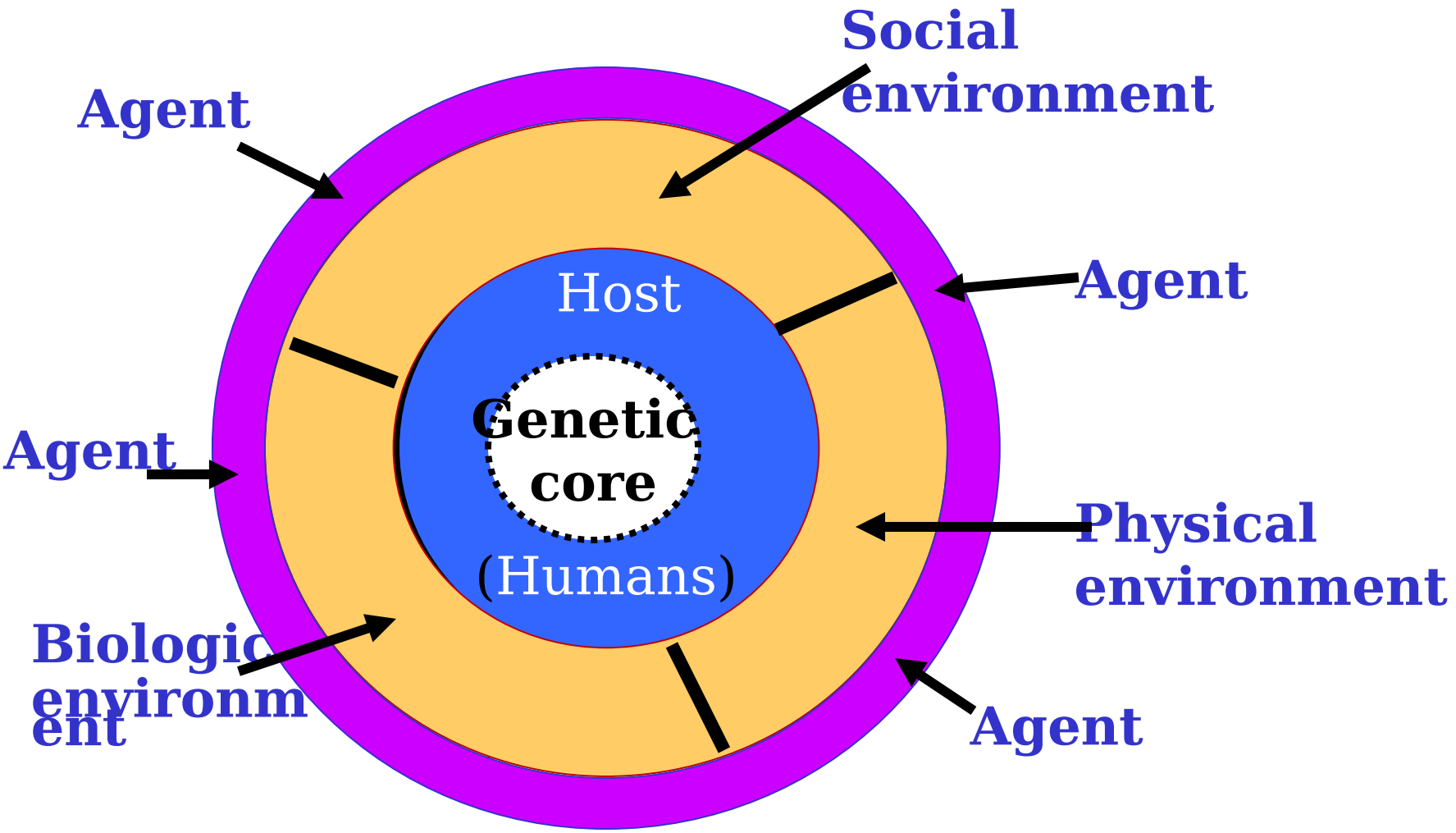
An example of three sufficient causes of a disease

Cont...



- ***Assume that these three causes are operating in the diagram***
- ***Without U, there is no disease. U is considered as necessary cause, but all disease is not due to U alone.***
- ***E causes disease through two mechanisms, II and III, all diseases arising from II and III are due to E.***

Wheel model of infectious diseases



- ***The interaction of humans with infectious agents and their environment, a person's state of health represents a dynamic equilibrium – a balance of forces.***

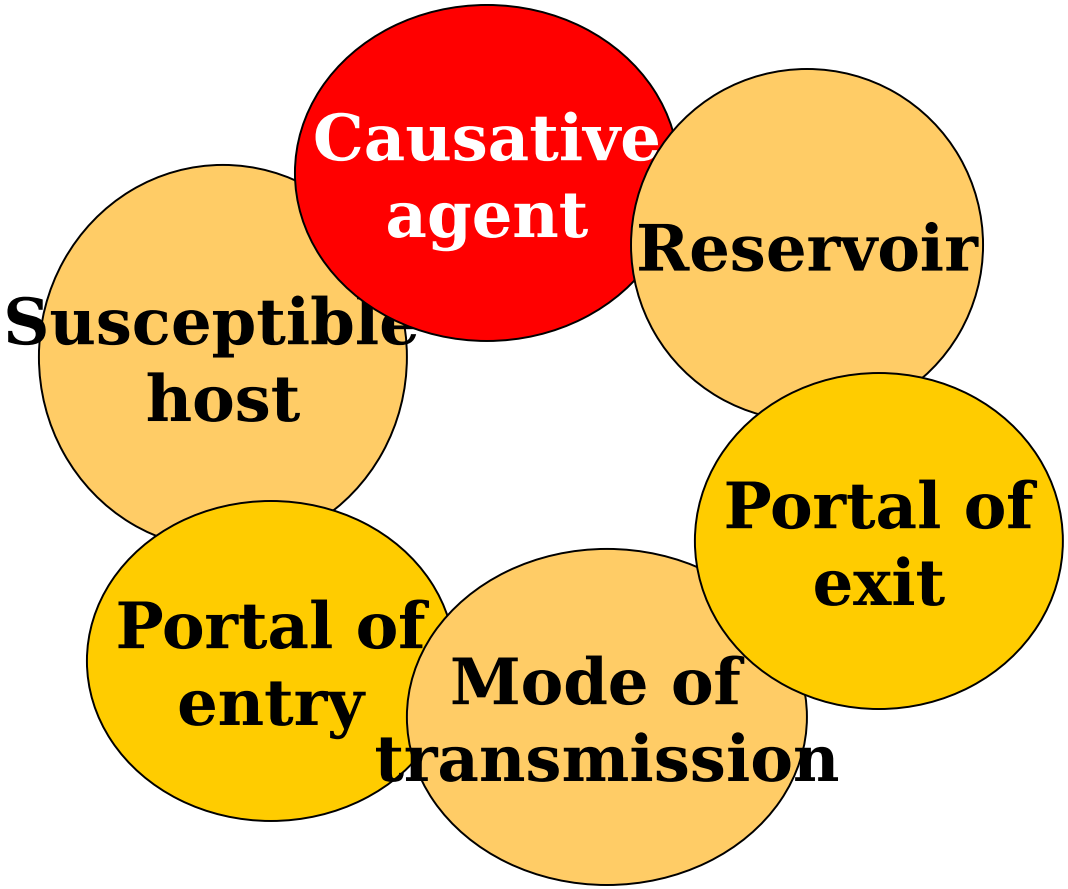
Chain of Infection

- **Infection: implies that the agent has achieved entry and begun to multiply in the host and leads to disease.**

- **This is sometimes called the *chain of infection, or transmission cycle.***

- **For infection to occur a chain of events must take place.**

Chain model of infectious diseases



Cont....

- **Reservoir: The habitat of an infectious agent where it normally lives, grows and multiplies.**
  - **Eg dog for rabies, - Cattle for anthrax**

- **Carrier: A person without apparent disease who is capable of transmitting the agent to others.**
  - ***Asymptomatic carrier*: transmitting infection without ever showing signs of the disease.**

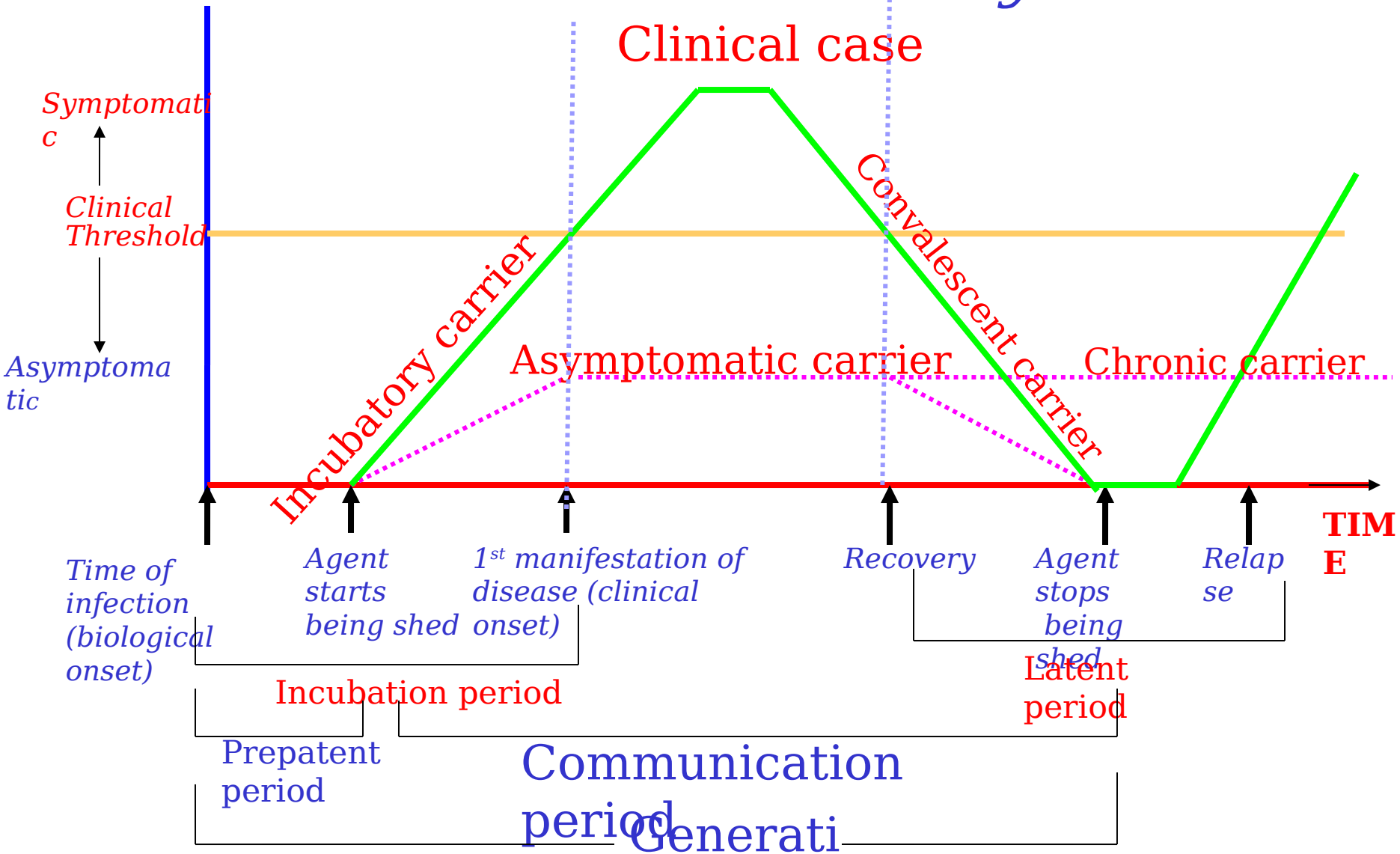
Cont…

- ***Incubatory carrier*: transmitting infection by shedding the agent before the onset of clinical manifestations.**

- ***Convalescent carrier*: Transmitting infection after the time of recovery from the disease**

- ***Chronic carrier*: Shed the agent for a long period of time, or even**

Fig 9. Time course of a disease in relation to its clinical expression and communicability



Modes of Transmission

- **The transfer of an infectious agent from an infected host (reservoir) to a susceptible host.**

- **Direct transmission: Immediate transfer of the agent from a reservoir to a susceptible host.**

- **Indirect transmission: Transmission of an infectious agent to a susceptible host through the aid of a vehicle, a vector or suspended air particles.**

Cont…

- **Direct transmission**
  - Touching
  - Kissing
  - Biting
  - Direct projection
  - Blood transfusion
- **Indirect transmission**
  - Airborne
  - Vehicle-borne
  - Vector-borne
  - Non-vector intermediate host

Disease Classification

1. Time Course

- **Acute**: **rapid onset and short duration**
- Chronic: **characterized by prolonged duration**
- **A chronic disease can have both acute and chronic manifestations**

2. Cause

- **Infectious**
- **Non-infectious**

Infection and Disease Outcome

- **Exposure to an infectious agent does not necessarily lead to infection, and**
- **An infection does not necessarily lead to disease**
- **Infection may remain asymptomatic or sub-clinical, or may lead to overt clinical disease**

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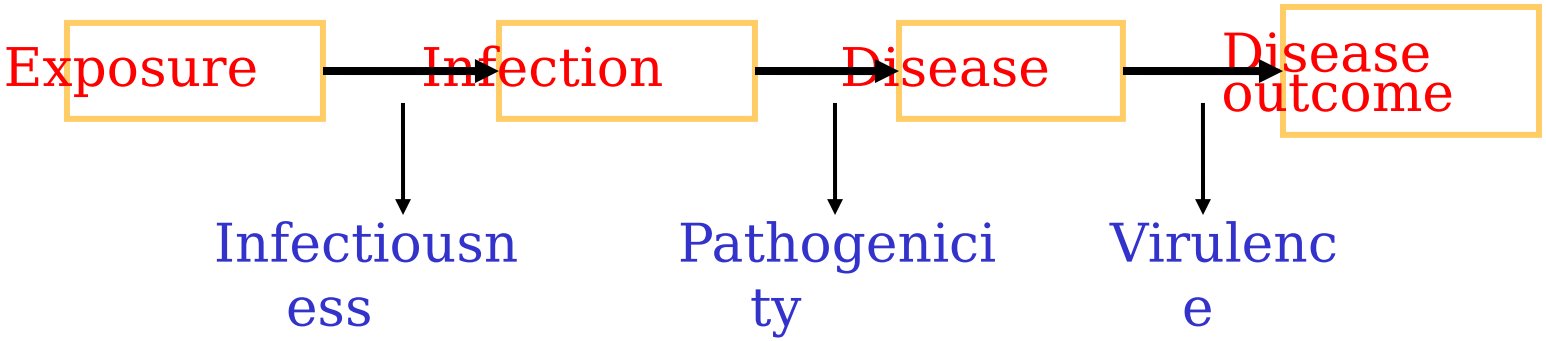


Fig 10. Outcomes at each stage of infection

Cont…

- **The progress of an infectious agent and disease outcome can be quantified as follows:**

1. From exposure to infection

- Infectiousness: **the proportion of an exposed susceptible host who become infected (measured by infection rate), as:**

$$\frac{\textit{No. infected}}{\textit{No. susceptible and exposed}} \times 100$$

Example-----1

- Let’s say you have a population of 10,000 and 50 new cases of a disease have been reported. calculate the infection rate and interpret the result?
- Answer:- IR=no of new cases/total popn x100
- IR=50/10000x100 = 5
- **Interpretation:-** for every 100 people in the populations, 5 new cases of disease has been reported.

Example---2

- Population of 20,000 with 200 new cases
- **Calculate the IR and interpret the result**

Cont…

2. From infection to disease

- **Pathogenicity**: the proportion of infected people who develop clinical disease, and measured by the clinical-to sub-clinical ratio, as:

$$\frac{\textit{No. of clinical cases}}{\textit{No. of sub-clinical cases}} \times 100$$

Example---1

- Let’s say that there is an out break of Bacterial infections in small town with a population of 1000 people. So far, 50 people have been infected with bacteria.
- **Calculate the pathogenicity and interpret the result?**
- Pathogenicity= no of infected individuals/Total population x100 =50/1000x100
- **Pathogenicity=5**
- **Interpretation:-** For every 100 people in the town, 5 are currently infected with the bacteria

Cont....

3. From disease to disease outcome

- ✓ Virulence: the proportion of persons with clinical disease who become severely ill or die, and measured by **Case-fatality-rate and hospitalization rate**

$$\text{Case-fatality-rate} = \frac{\text{No of death of a specific disease}}{\text{Total No of cases of that specific disease}} \times 100$$

$$\text{Hospitalization rate} = \frac{\text{No of hospitalized persons of a specific disease}}{\text{Total No of cases of that specific disease}} \times 100$$

Example--1

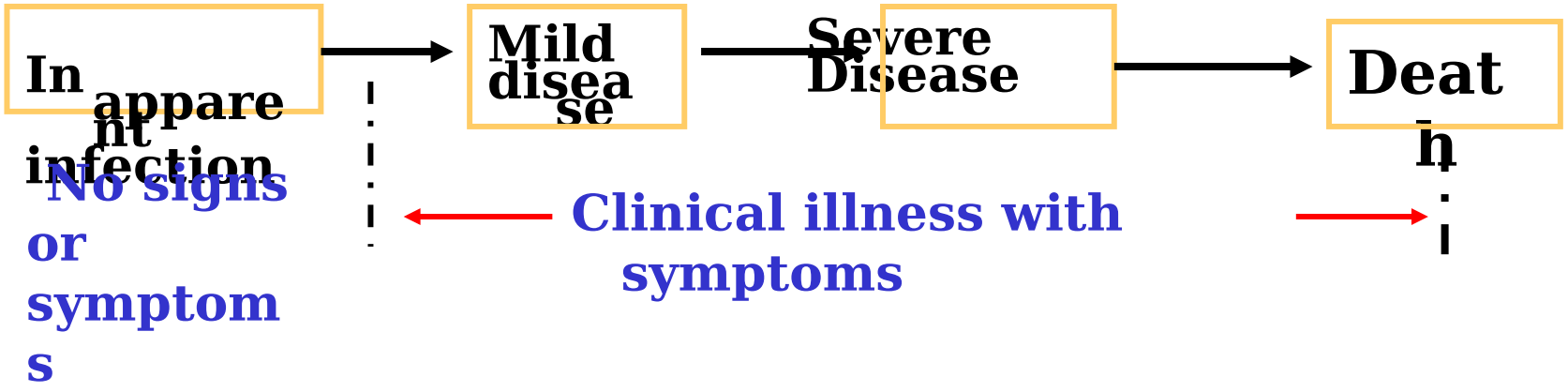
- If there were 50 confirmed cases of a disease and 10 deaths, calculate CFR and interpret the result?
- CFR=10/50X100%=20%
- **Interpretations:-** 20% of the people who contracted the disease died from it

Example---2

- If there were 50 confirmed cases of a disease and 5 required hospitalizations
- Calculate HR and interpret the result?
- HR=5/50X100 =10%
- **Interpretation:-** 10% of the people who contracted the disease required hospitalizations

Variation in Severity of Illness

- Infectious disease has a wide spectrum of clinical effects.



The spectrum of disease from communicable disease

Cont….

2ry attack rate (SAR):

- Measures spread of disease among contacts of an index case.

- ***The index cases are excluded from numerator and denominator***

- ***Index case:*** ***The case that brings a people (household) to the attention of the public health personnel.***

$$\text{SAR} = \frac{\text{New cases among contacts of index cases during the period}}{\text{Total number of contacts with the index cases}} \times 100$$

Example---1

- Let’s say there was an index case of measles in school. The index case infected 10 students out of 100 exposed contacts. After some time, 5 out of the remaining 90 exposed contacts also developed measles. The number of new cases among contact is therefore,5, and the total number of exposed contact is 90.
- **Calculate the secondary attack rate for measles in this school and interpret the result?**

Secondary Attack rate---

- **SAR**=Number of new cases among contacts/Total number of exposed contacts)x100

  SAR=(5/90)X100=5.6%

- **Interpretation:-** This means that 5.6% of exposed contacts developed measles after being in contact with an index case.

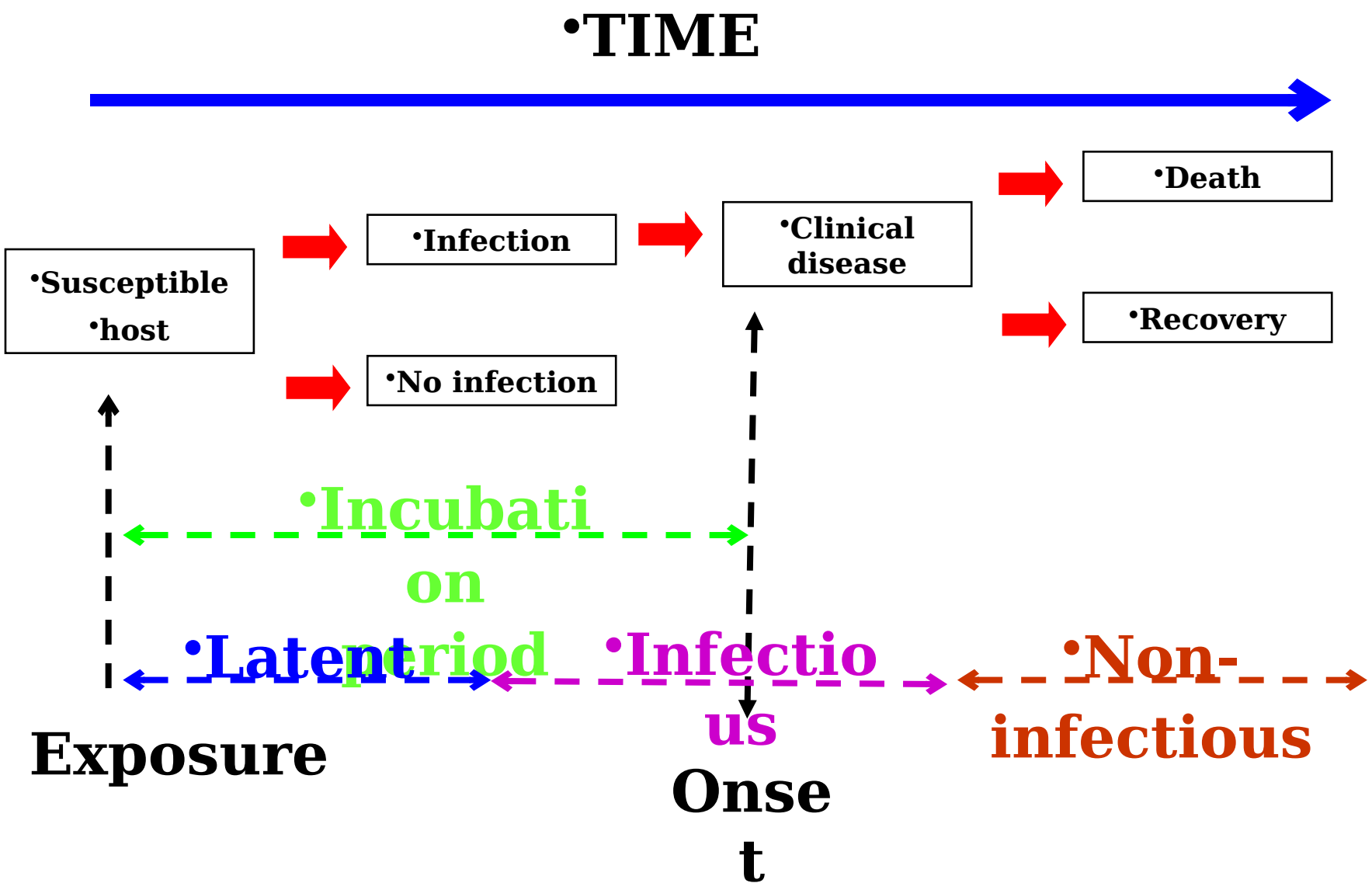
Infectious Disease Epidemiology 2

1. A generic disease model

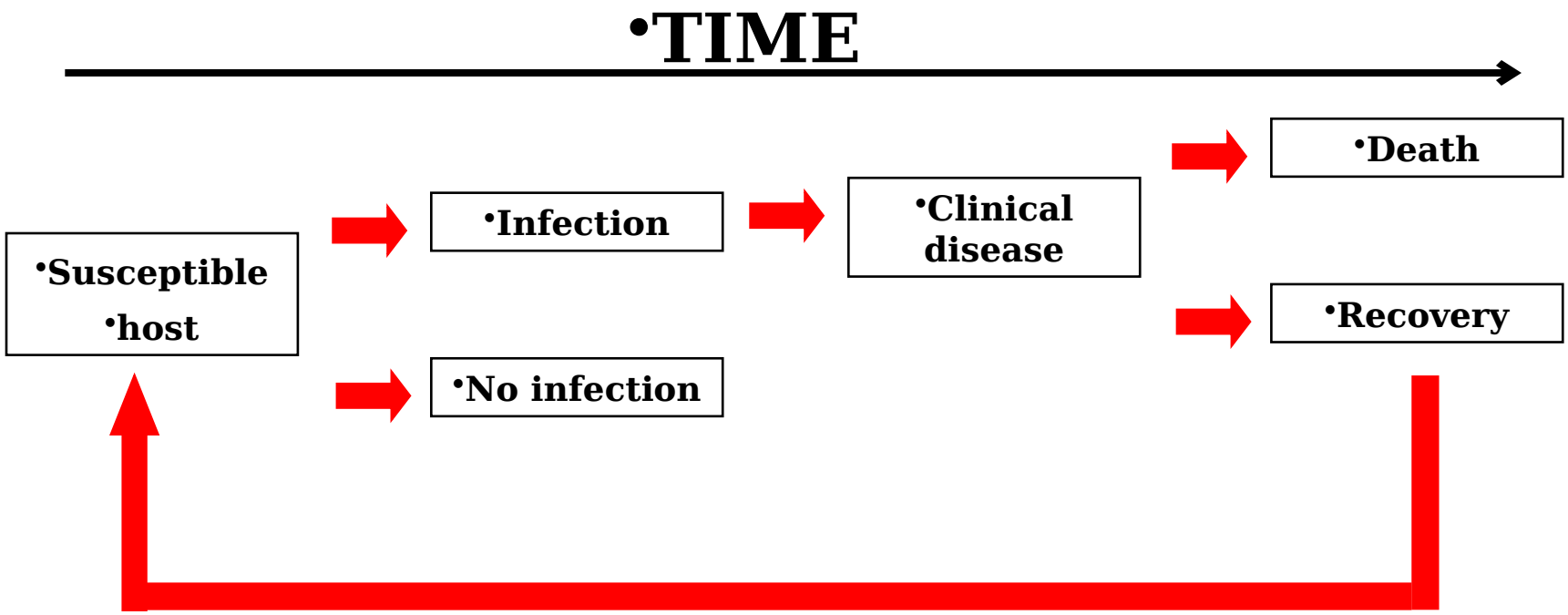
2. The Susceptible-Infectious and Recovery (SIR) model

3. Basic reproductive number

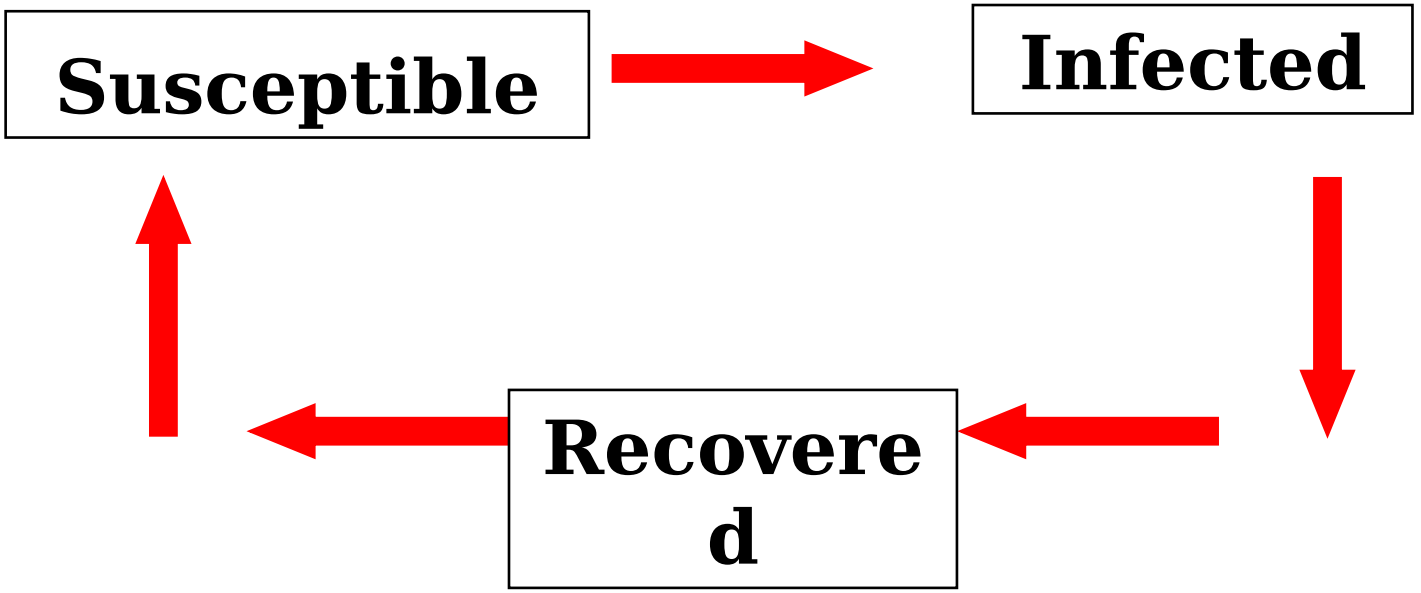
1. A generic disease model



A generic disease model



A generic disease model

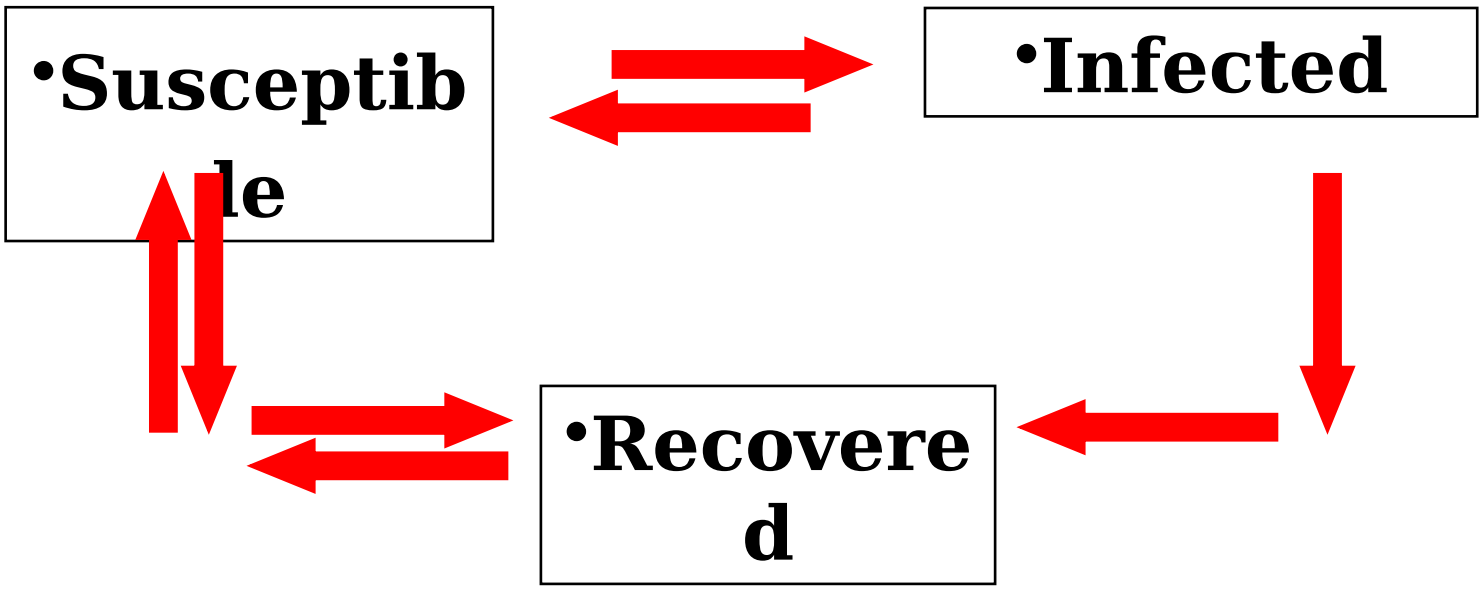


A generic disease model

- States (the boxes)
  - diseased
  - susceptible ≡ ‘at risk’
  - not susceptible ≡ ‘not at risk’
    - had disease and now immune (e.g. flu)
    - had disease and not able to catch it again (e.g. Measles)

- Transitions (the arrows)
  - represent the movement from one state to another (‘events’)

A generic disease model



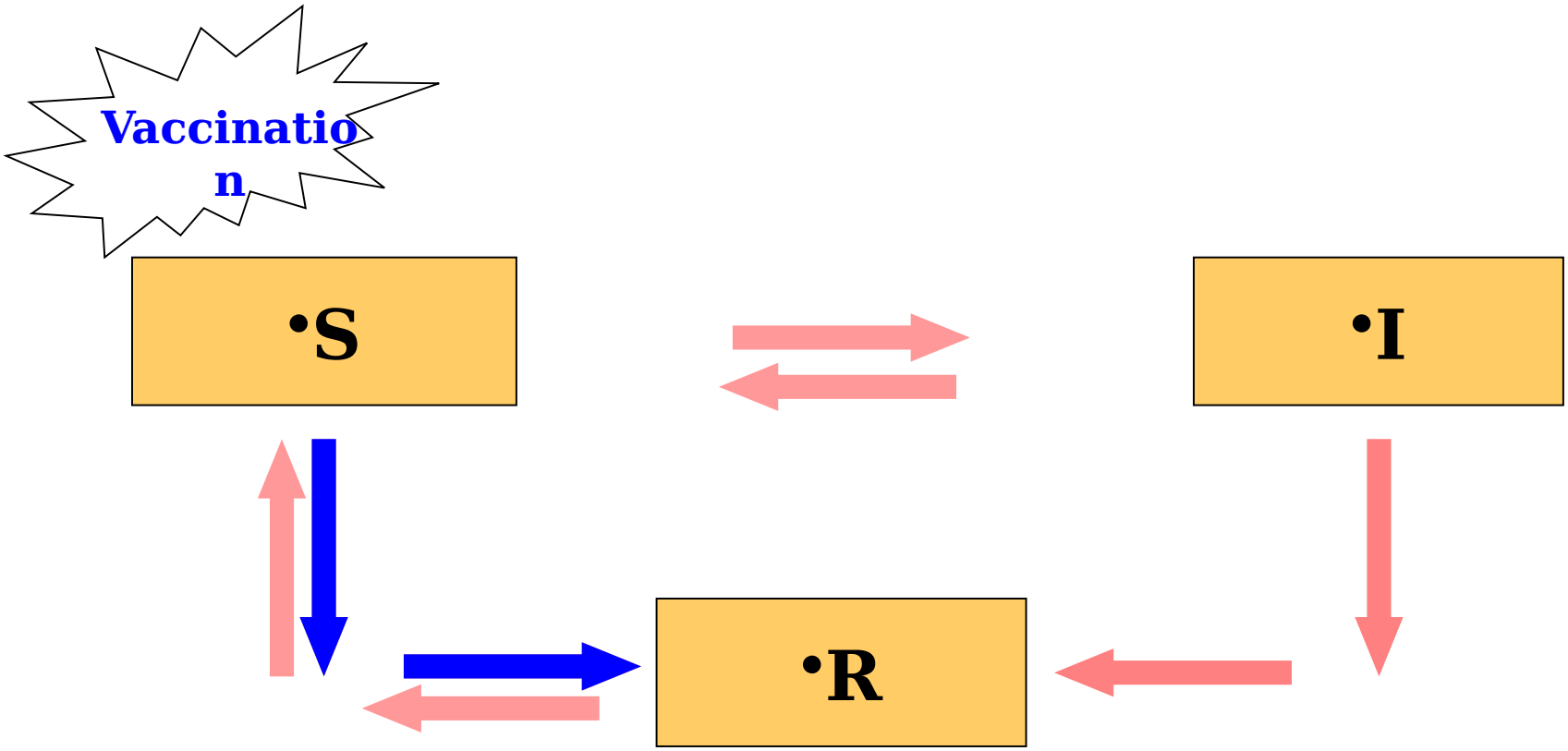
A generic disease model

- Infectious disease control
  - involves influencing the movement from one state to another
  - we aim to:
    - change an individual from one state to another, or
    - reduce the flow from one state to another

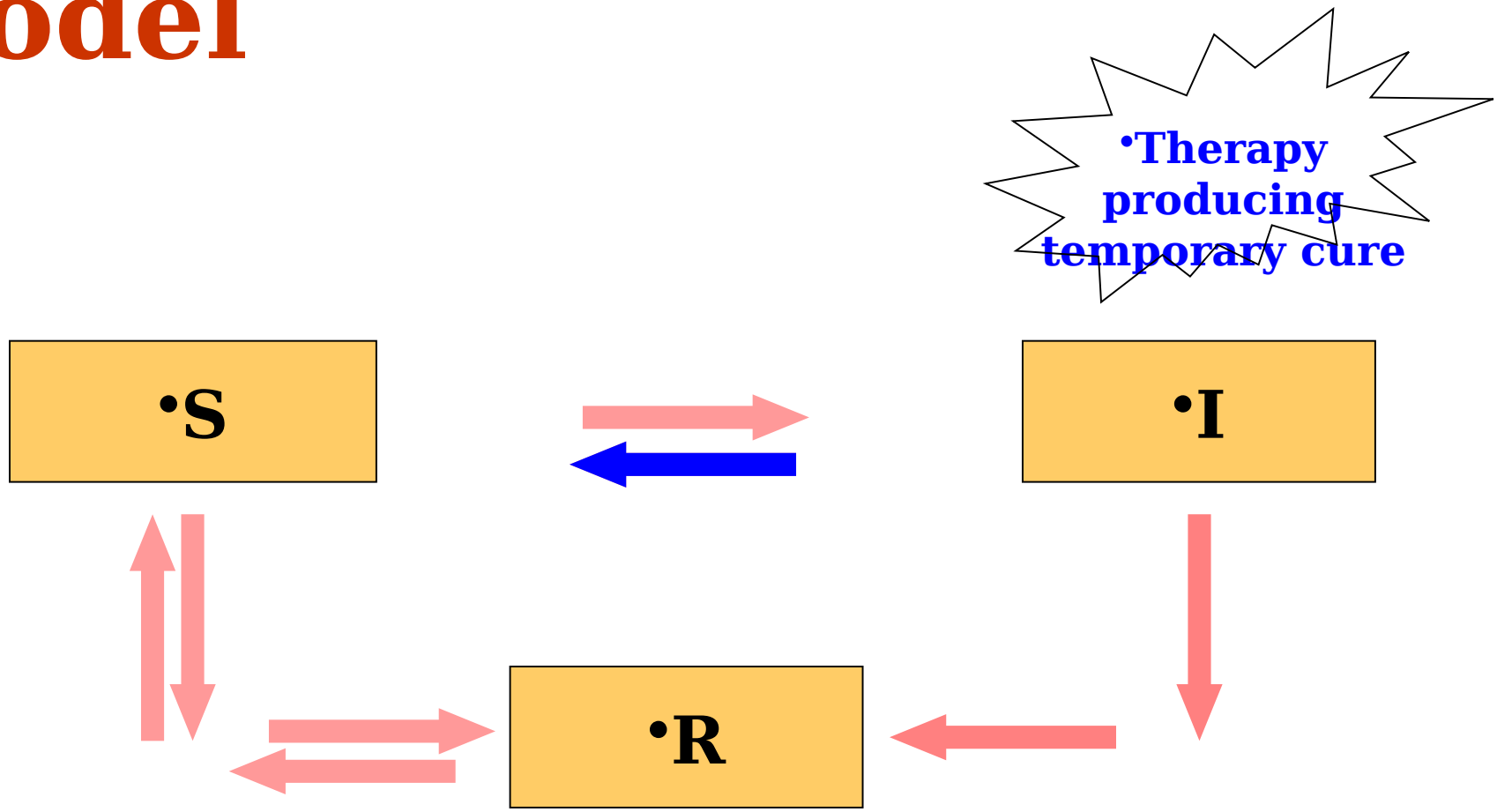
A generic disease model

- Disease control
  - vaccination
    - shifts individuals from ‘susceptible’ to ‘recovered’ state
    - for some diseases this shift is not permanent
  - therapy increases the rate of flow out of the infected state
    - permanent cure moves the individual from the infected to the recovered state
    - temporary cure moves the individual from the infected to the susceptible state

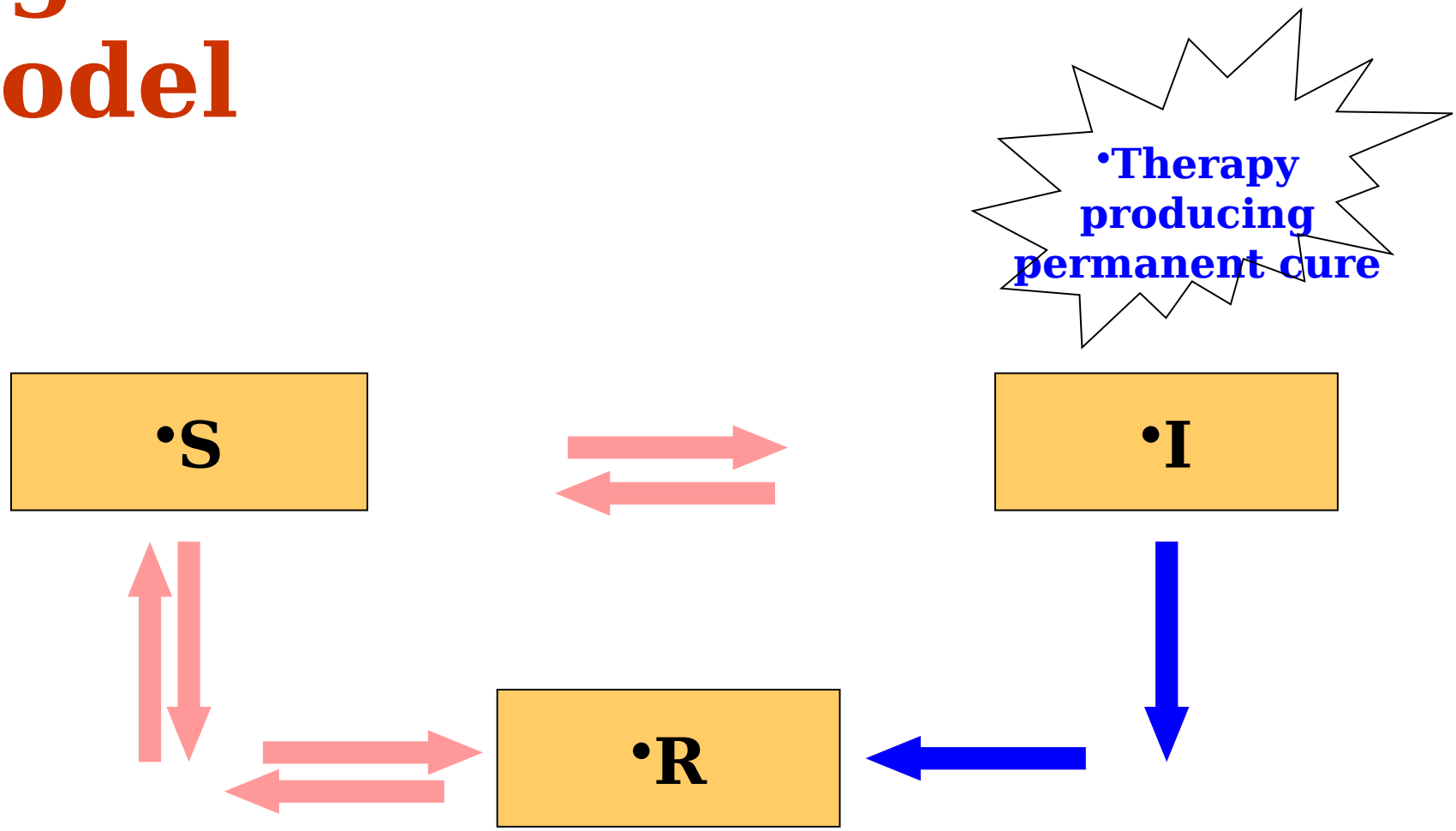
A generic disease model



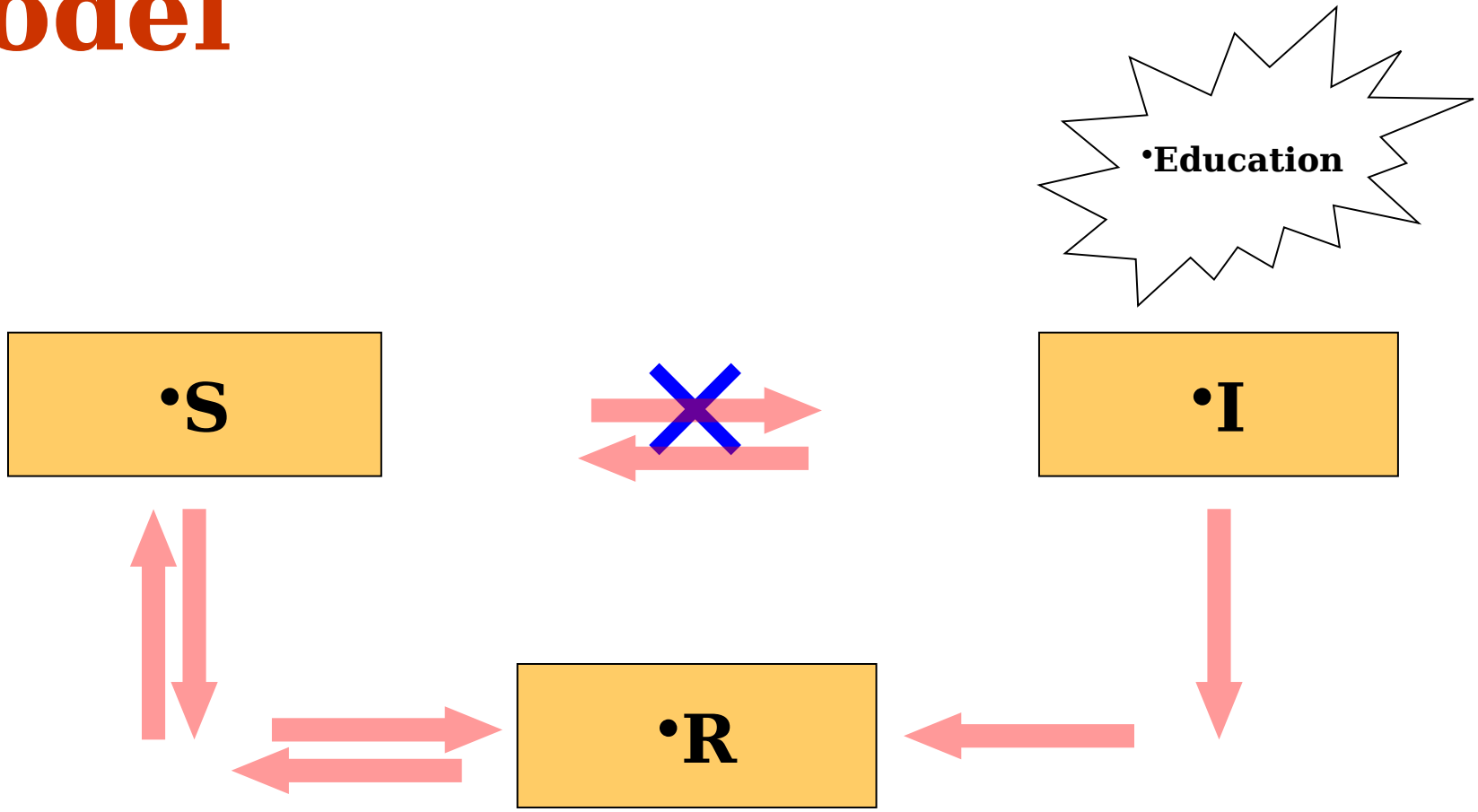
A generic disease model



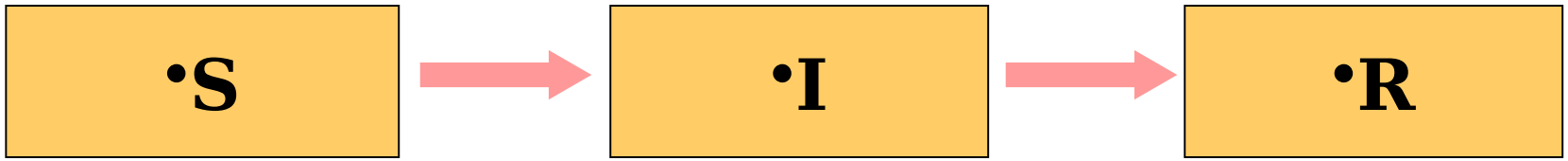
A generic disease model



A generic disease model



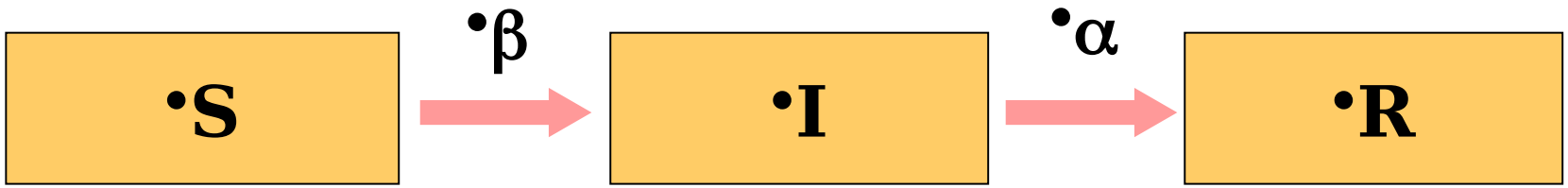
2. The SIR model



Cont…

- Rate of transfer of individuals from the susceptible to the infected state depends on β
  - β quantifies the probability of contact and infection transfer between individuals

- Rate of transfer of individuals from infected to recovered state depends on α
  - α quantifies the duration of infectivity


•S
•β
•I
•α
•R

The SIR model

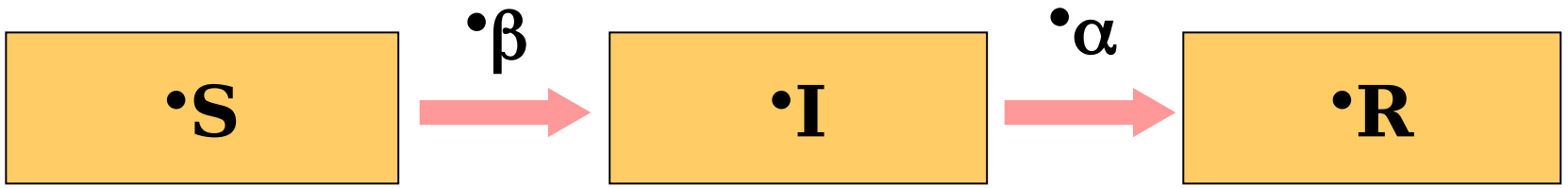
- Transmission probability, β
  - a fundamental parameter of infectious disease epidemiology
  - is the probability that, given contact between an infective source and a susceptible host, successful transfer of the disease will occur
  - depends on:
    - host, agent, and environment
    - the type and definition of contact

The SIR model

- Transmission probability
  - the concept of contact is broad and must be defined in each particular circumstance
    - **whooping cough**

      Infective contact: living in the same house during the period of presumed infectiousness of a person with whooping cough

    - HIV
      - **Infective contact**: unprotected sex with



- **β: the rate of successful transmission (per time unit)**
- **α: the speed of recovery (per time unit)**

Basic reproductive number

- **Basic reproductive number**, denoted by R_0
  - the expected number of new infected hosts that one infectious host will produce during his (or her) period of infectiousness in a large, susceptible population or
  - Used to estimate how many new infections each infected person will cause in a susceptable populations
  - Example: if **$R_0 = 9$** for measles in a

Cont…

- **Basic reproductive number, R_0**
  - for an epidemic to occur, R_0 must be **>** 1
  - if $\mathbf{R_0 < 1}$, the disease will not be reproduced, so an epidemic will not occur
  - $\mathbf{R_0}$ is a composite of three important aspects of infectious diseases:
    - the proportion of susceptible contacts, **C**
    - transmission probability **β**
    - duration of infectiousness **d**,

$$\mathbf{R_0 = C \times \beta \times d}$$

Ro----

Ro=Contact rate x transmission Probability x Duration of Infectiousness

Contact Rate-is the number of people an infected person comes in contact with each day

e.g. let’s say an infected person comes in contact with 10 people each day, the contact rate would be 10

Ro-----

Transmision Probability-the likelyhood that an infected person will transmit the disease to someone they come in contact with

e.g.if the Transmision Probability is 0.4, it means that 40% of the people who come in contact with infected person will get infected

Ro--------

- **Duration of Infectiousness:-** is the length of time that an infected person can transmit the disease
- It varies from disease to disease,but let’s say an infected person is infectious for 10 Days
- Therefore,Ro=contact rate(10)x Transmission Probability (0.4)x Duration of Infectiousness(10)=**4**
- **Interpretations:-**Each Infected Person will,on Average, infect 4 new people before recovering or dying

Effective reproductive number

- **R_o** usually assumes all contacts are susceptible
- In reality, there are some people immune of the disease under study
- In these circumstances, the number of new cases produced R are below the R_O
- This reproductive number is called

Cont…

- Effective reproductive number then will be product of R_0 and proportion of susceptible people in the community.

$$\mathbf{R = R_0 \times S}$$ (s= proportion of susceptible)

- Example:
  - let $\mathbf{R_0}$ of measles is **9**, and half the population is not immunized, then **R = 9 x ½= 4.5.**
  - A case of measles will infect about **4.5 new cases** before getting recovery

Example 2

- Suppose there were new infectious respiratory disease that has an Ro of 2.5. this means that on average, each infected individual will spread the disease to 2.5 other people . they estimate that theses measure have reduced the transmission rate by 30% (social distancing and wearing masks)
- **Formula**

-R=Ro x (1-reduction in transmission rate)

Example----

- **Calculate R and interpret the result**
- R=Ro x (1-reduction in transmission rate)
- R=2.5 x (1-0.30) =1.75
- **Interpretations:-** on Average each infected individual will now only spread the disease to 1.75 other people due to the implementation of preventive measures

Cont…

- If proportion of susceptible are very low, the probability of contact with an index case will be low (transmission may not occur).
- If immunization gives complete/ life long immunity among all the immunized, and if **‘f’** proportion of individuals are immunized, proportion of susceptible will be **(1-f)**
- **$R = R_0 \times (1-f)$**
- To eliminate the disease, R should be below 1
- **$R = R_0 \times (1-f) < 1$;** **$f = [1 - 1/R_0]$**

Cont....

- Example

  Let R_0 for measles be 9.0, proportion of immunization that is needed to stop transmission of measles in the community will be;

  $f = 1 - 1/R_0$; **$= 1 - 1/9 = 0.89$**

  If we immunize 89% of the population, we can stop transmission of illness in a community, and the condition is called *herd immunity*.

Summary Cont...

- Ro(**Pronounced “R naught**)” is a measure of the potential for disease transmission in a population that is wholly susceptable to infection
- It represents the average number of new cases of an infectious disease that would arise from a single infected individual
- **Effective Reproductive number**, denoted as Re(Pronounced “R sub e”) is a measure of disease transmission in a population that has some level of immunity

Thank you!!