
بسم الله الرحمن الرحيم

Principles of Infectious Disease Epidemiology

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Infectious disease

Definition

An illness due to a specific infectious agent or its toxic products that arises through transmission …. from an infected person, animal or reservoir to a susceptible host, either directly or indirectly through an intermediate plant or animal host, vector or inanimate environment.

Last JM, *Dictionary of Epidemiology, 1988*

Infectious disease epidemiology

- Some special feature
  - A case may also be a risk factor
  - People may be immune
  - A case may be a source without being recognized as a case
  - There is sometimes a need for urgency
  - preventive measure usually have a good scientific basis

Infectious disease epidemiology

- All diseases caused by micro-organisms
- Diseases can be transmitted from one infected person to another, directly or indirectly
- Disease can be transmitted from one person to another by unnatural routes

What is *infectious disease epidemiology*?

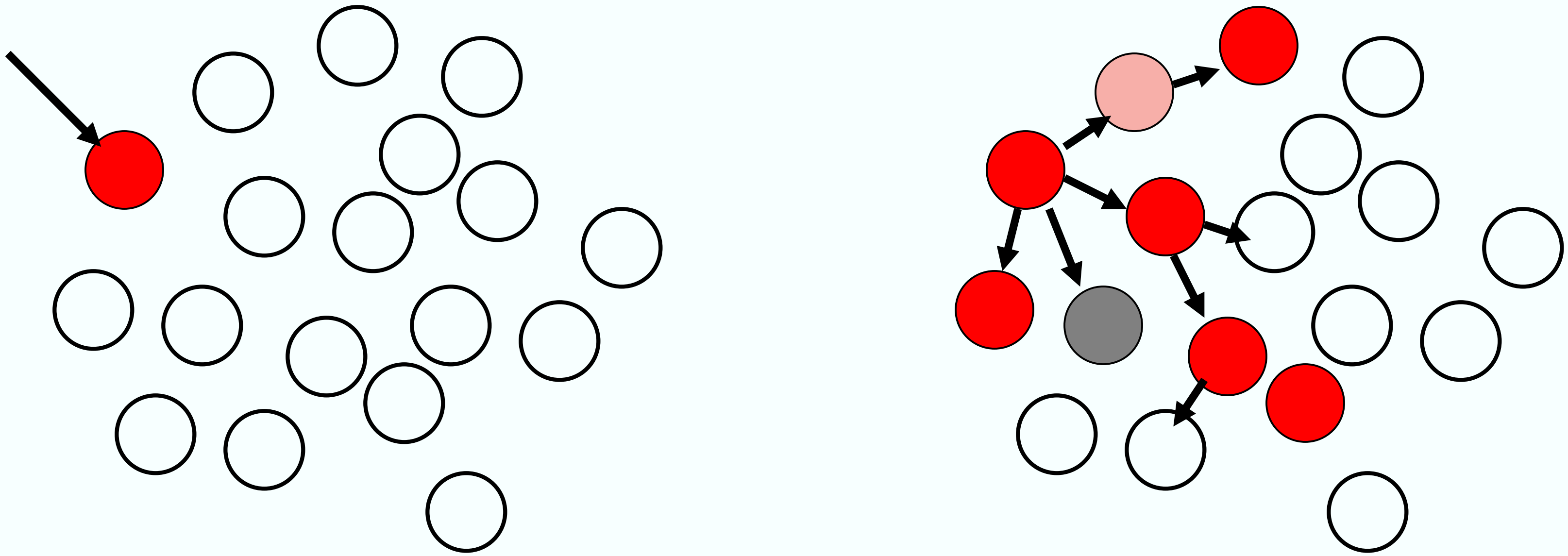
Epidemiology		Infectious disease epidemiology
❖ Deals with one population	→	❖ Two or more populations
❖ Risk case	→	❖ A case is a risk factor
❖ Identifies causes	→	❖ The cause often known

What is *infectious disease epidemiology*?

- Two or more populations
  - Humans
  - Infectious agents
    - Helminths, bacteria, fungi, protozoa, virus, prions
  - Vectorer
    - Mosquito (protozoa-malaria), snails (helminths-schistosomiasis)
    - Blackfly (microfilaria-onchocerciasis) – bacteria?
  - Animals
    - Dogs and sheep/goats – *Echinococcus*
    - Mice and ticks – *Borrelia*

What is *infectious disease epidemiology*?

- A case is a risk factor …
  - Infection in one person can be transmitted to others



What is *infectious disease epidemiology*?

The cause often known

- An infectious agent is a necessary cause

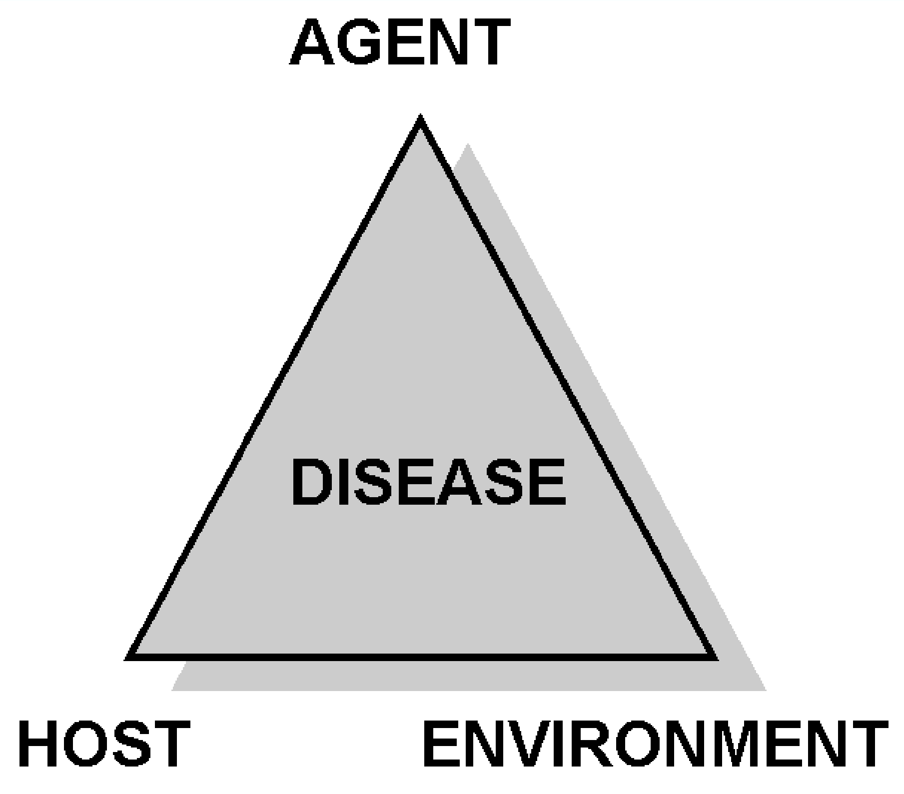
What is infectious disease epidemiology then used for?

- Identification of causes of new, emerging infections, e.g. HIV, vCJD, SARS
- Surveillance of infectious disease
- Identification of source of outbreaks
- Studies of routes of transmission and natural history of infections
- Identification of new interventions

Epidemiologic Triad

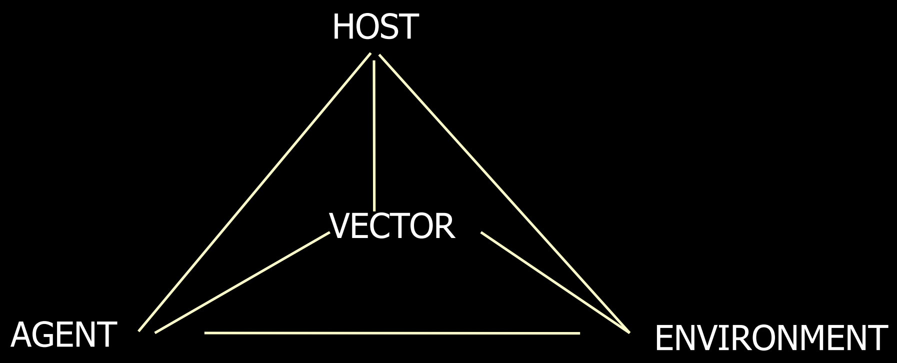
Disease is the result of forces within a dynamic system consisting of:

- agent of infection
- host
- environment



Dynamics of Disease Transmission

Epidemiologic Triad



- Human disease results from interaction between the host, agent and the environment. A vector may be involved in transmission.
- Host susceptibility to the agent is determined by a variety of factors, including:
  - Genetic background
  - Nutritional status
  - Vaccination
  - Prior exposure

Factors Influencing Disease Transmission

Agent

- Infectivity
- Pathogenicity
- Virulence
- Immunogenicity
- Antigenic stability
- Survival

Environment

- Weather
- Housing
- Geography
- Occupational setting
- Air quality
- Food

Host

- Age
- Sex
- Genotype
- Behaviour
- Nutritional status
- Health status

Epidemiologic Triad Concepts

- **Infectivity – ability to invade a host**
  (# infected / # susceptible) X 100
- **Pathogenicity – ability to cause disease**
  (# with clinical disease / # of infected) X 100
- **Virulence – ability to cause death**
  (# of deaths / # with disease (cases)) X 100
- **All are dependent upon the condition of the host**
  - Immunity (active, passive)
  - Nutrition
  - Sleep
  - Hygiene

Routes of transmission

Direct

- Skin-skin
  - Herpes type 1
- Mucous-mucous
  - STI
- Across placenta
  - toxoplasmosis
- Through breast milk
  - HIV
- Sneeze-cough
  - Influenza

Indirect

- Food-borne
  - Salmonella
- Water-borne
  - Hepatitis A
- Vector-borne
  - Malaria
- Air-borne
  - Chickenpox

Exposure

- A relevant contact – depends on the agent
  - Skin, sexual intercourse, water contact, etc

Some Pathogens that Cross the Placenta

Table 14.3 Some Pathogens that Cross the Placenta

	Pathogen	Condition in the Adult	Effect on Embryo or Fetus
Protozoan	*Toxoplasma gondii*	Toxoplasmosis	Abortion, epilepsy, encephalitis, microcephaly, mental retardation, blindness, anemia, jaundice, rash, pneumonia, diarrhea, hypothermia, deafness
Bacteria	*Treponema pallidum*	Syphilis	Abortion, multiorgan birth defects, syphilis
	Listeria monocytogenes	Listeriosis	Granulomatosis infantiseptica (nodular inflammatory lesions and infant blood poisoning), death
DNA viruses	*Cytomegalovirus*	Usually asymptomatic	Deafness, microcephaly, mental retardation
	Parvovirus B19	Erythema infectiosum	Abortion
RNA viruses	*Lentivirus* (HIV)	AIDS	Immunosuppression (AIDS)
	Rubivirus rubella	German measles	Severe birth defects or death

Mode of Transmission

- Person-to-person (respiratory, urogenital, skin)
  - Examples: HIV, measles
- Vector (animals, insects)
  - Examples: rabies, yellow fever
- Common vehicle (food, water)
  - Examples: salmonellosis
- Mechanical vectors (personal effects) such as doorknobs, or toothbrushes

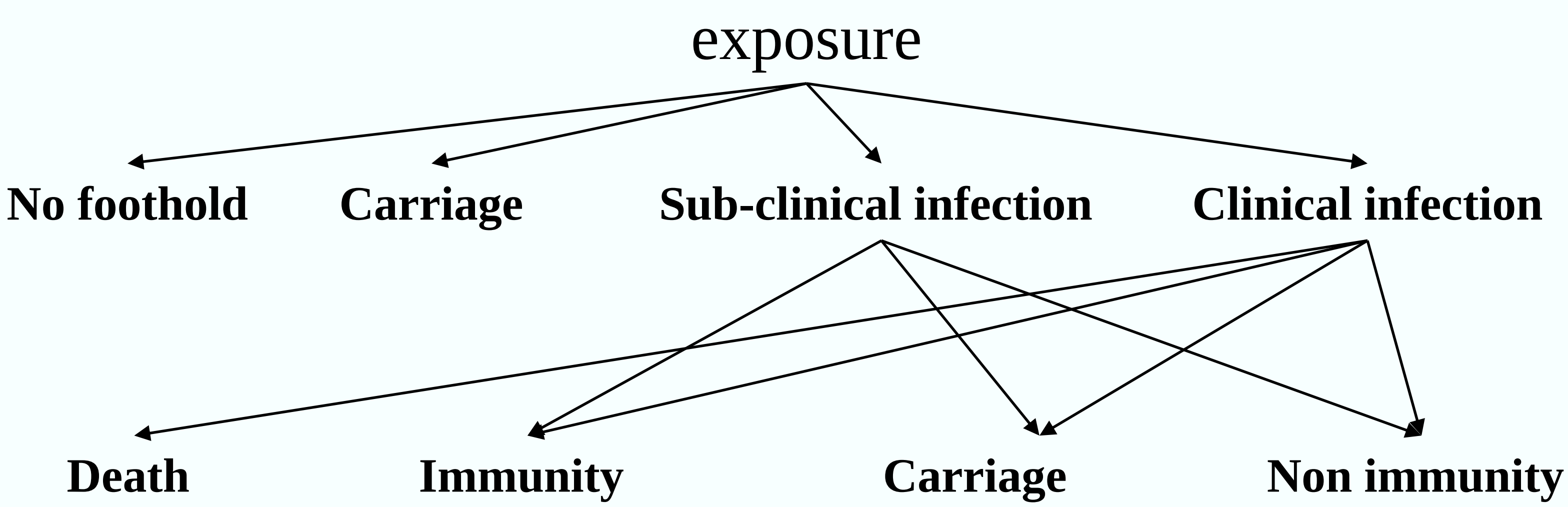
Modes of Disease Transmission

Table 14.10 Modes of Disease Transmission

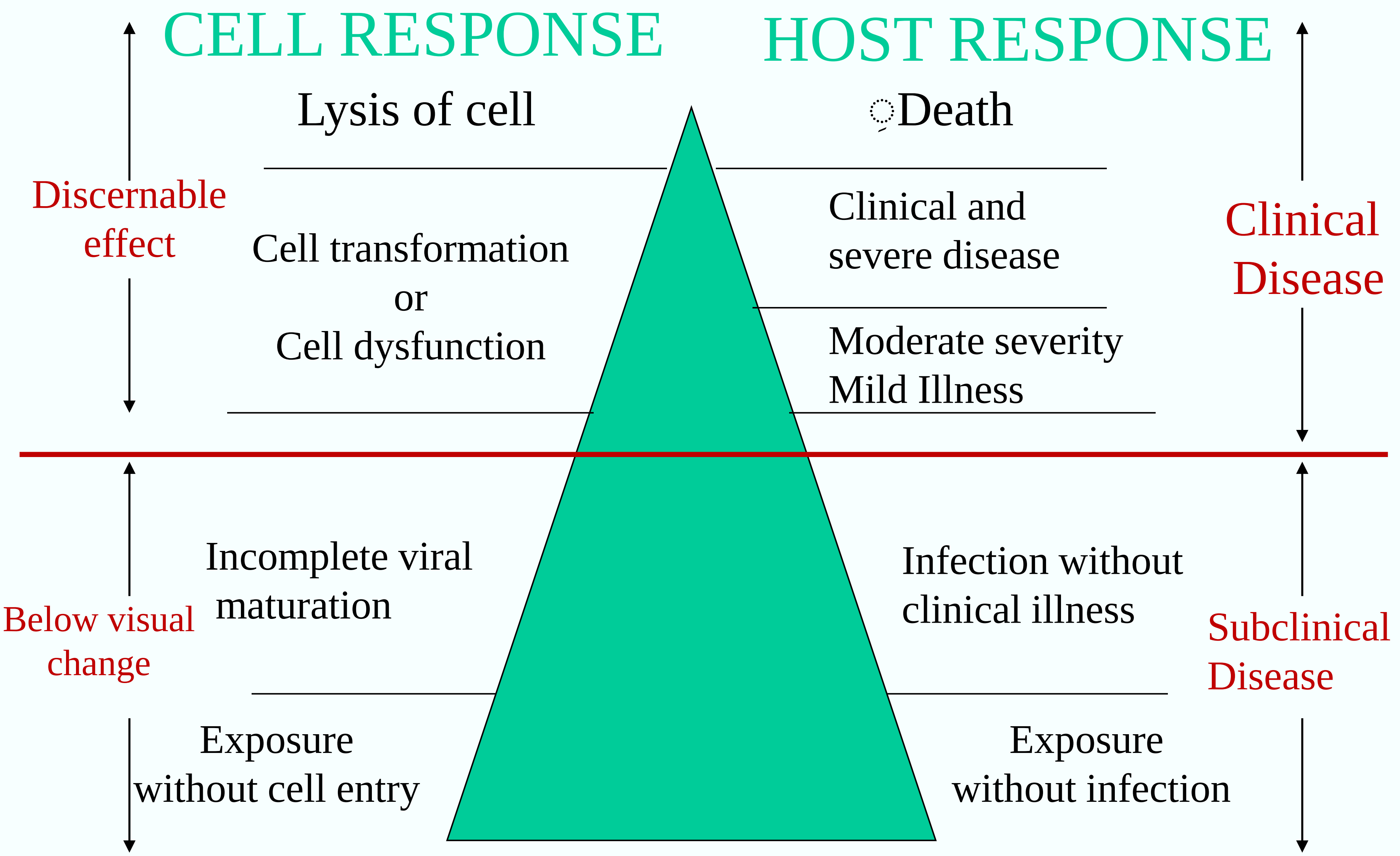
Mode of Transmission	Diseases Spread Include:
Contact Transmission	
Direct Contact: *e.g.* handshaking, kissing, sex, bites	cutaneous anthrax, genital warts, gonorrhea, herpes, rabies, staphylococcus infections, syphilis
Indirect Contact: *e.g.* drinking glasses, toothbrushes, toys, punctures, droplets from sneezing and coughing (within one meter)	common cold, enterovirus infections, influenza, measles, Q fever, pneumonia, tetanus, whooping cough
Vehicle Transmission	
Airborne: *e.g.* dust particles	chicken pox, coccidiomycosis, histoplasmosis, influenza, measles, pulmonary anthrax, tuberculosis
Waterborne: *e.g.* streams, swimming pools	*Campylobacter* infections, cholera, *Giardia* diarrhea
Foodborne: *e.g.* poultry, seafood Mec	food poisoning (botulism, staphylococcal); hepatitis A, listeriosis, tapeworms, toxoplasmosis, typhoid fever
Vector Transmission	
Mechanical: *e.g.* (on insect bodies) flies, roaches	*E. coli* diarrhea, salmonellosis, trachoma
Biological: *e.g.* lice, mites, mosquitoes, ticks	Chagas' disease, Lyme disease, malaria, plague, Rocky Mountain spotted fever, typhus fever, yellow fever

Infectious disease epidemiology

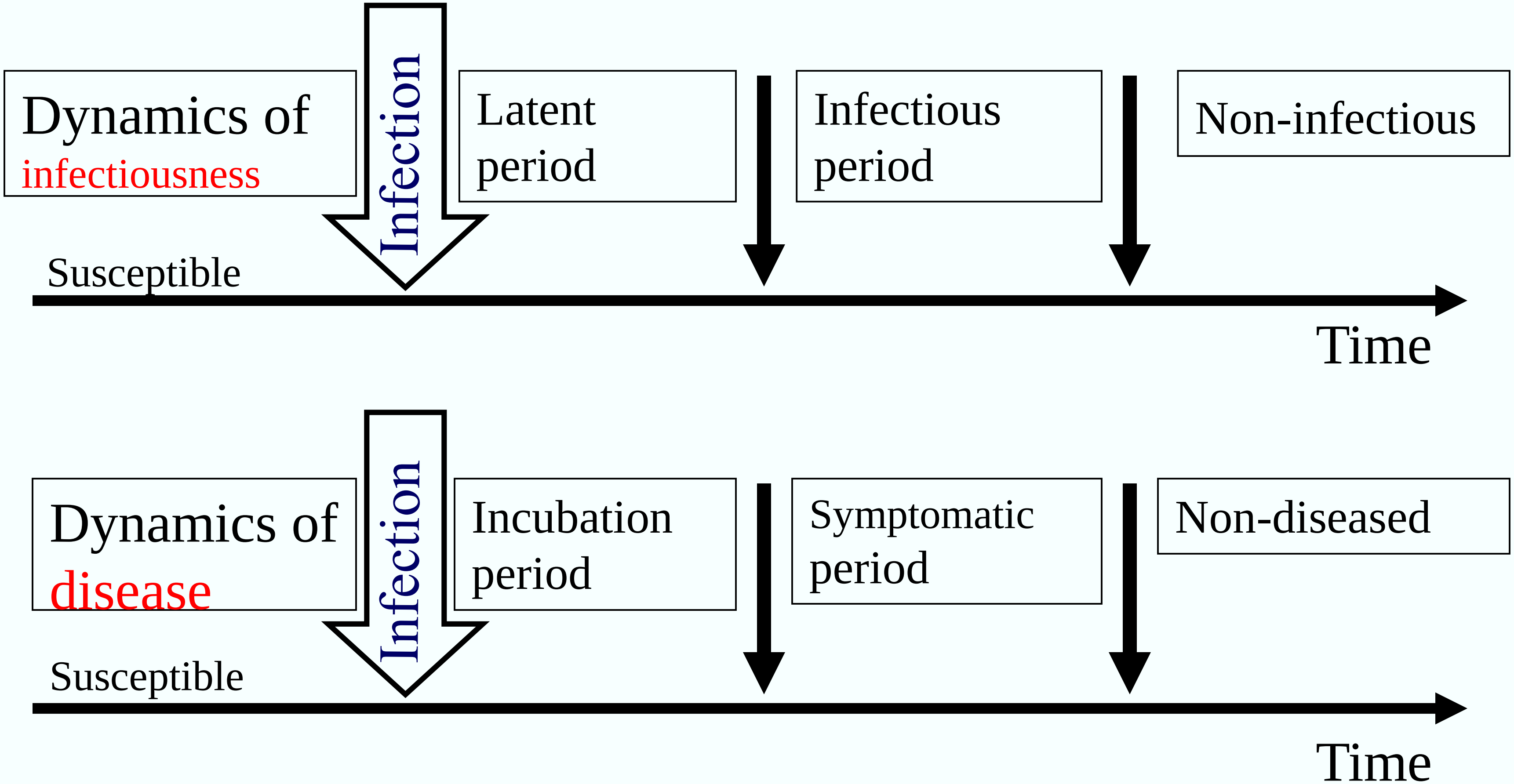
The possible outcomes of exposure to an infectious agent



Iceberg Concept of Infection



Timeline for Infection



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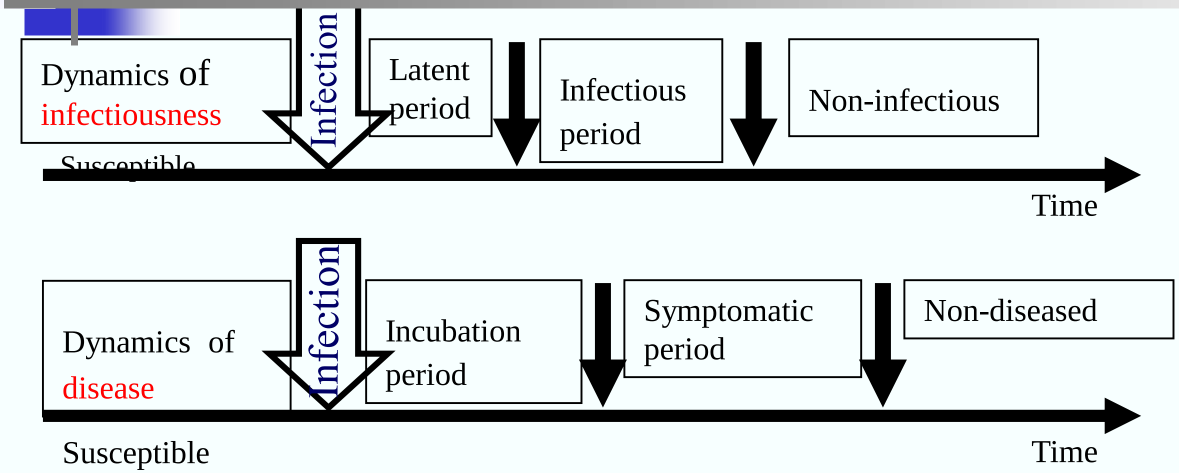
Timeline for Infection



Definitions from Previous Slide:

Latent period: time interval from infection to development of infectious (note: this definition differs from that used for non-infectious diseases).

Infectious period: time during which the host can infect another host.

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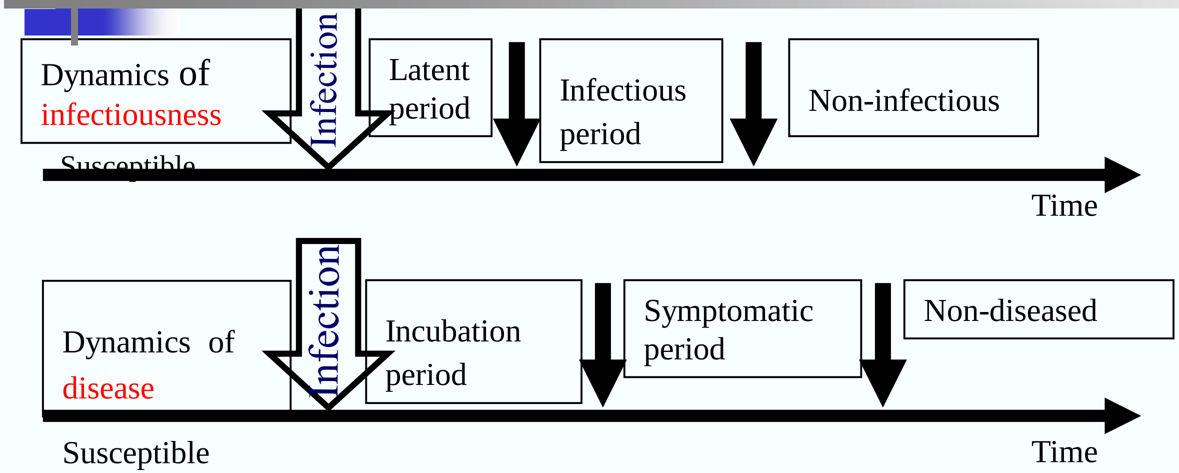
Timeline for Infection



Definitions from Previous Slide:

Incubation period: time from infection to development of symptomatic disease.

Symptomatic period: period in which symptoms of the disease are present.

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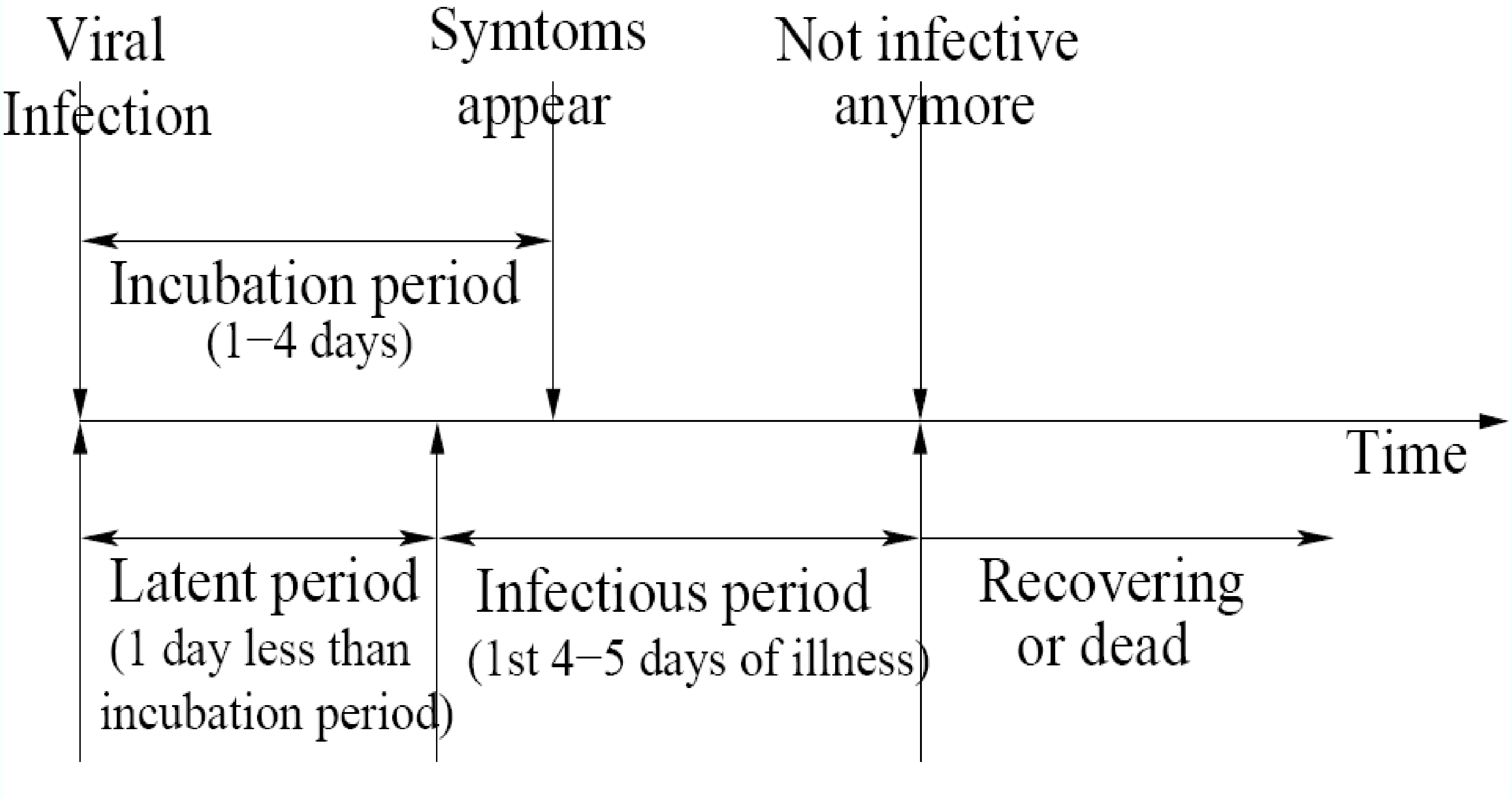
Incubation Period

- The interval between the time of contact and/or entry of the agent and onset of illness
- The time required for the multiplication of microorganisms within the host up to a threshold where the parasitic population is large enough to produce symptoms

Influenza Infection Timeline

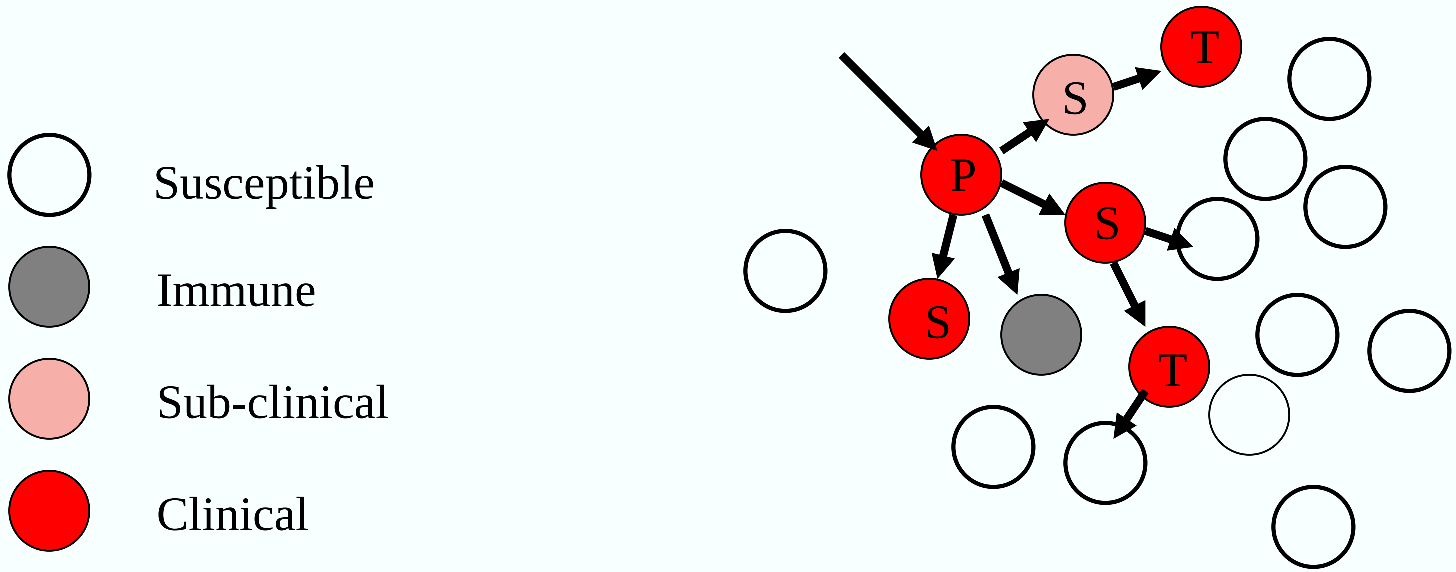


- در آبله مرغان، latent period کوتاهتر از incubation period است
  - لذا می تواند قبل از بروز علایم، دیگران را آلوده کند.
- در مالاریا فالسیپاروم، latent period طولانی تر از incubation period است
  - لذا درمان زودرس، می تواند از انتقال جلوگیری کند.
- در ایدز، latent period کوتاه (در حد چند روز تا هفته) است و incubation period طولانی(در حد چند سال)
  - لذا بیمار ایدزی می تواند برای مدت طولانی، دیگران را نیز آلوده کند بدون این که علایم داشته باشد

Transmission

Cases

- **Index – the first case identified**
- **Primary – the case that brings the infection into a population**
- **Secondary – infected by a primary case**
- **Tertiary – infected by a secondary case**



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Definitions

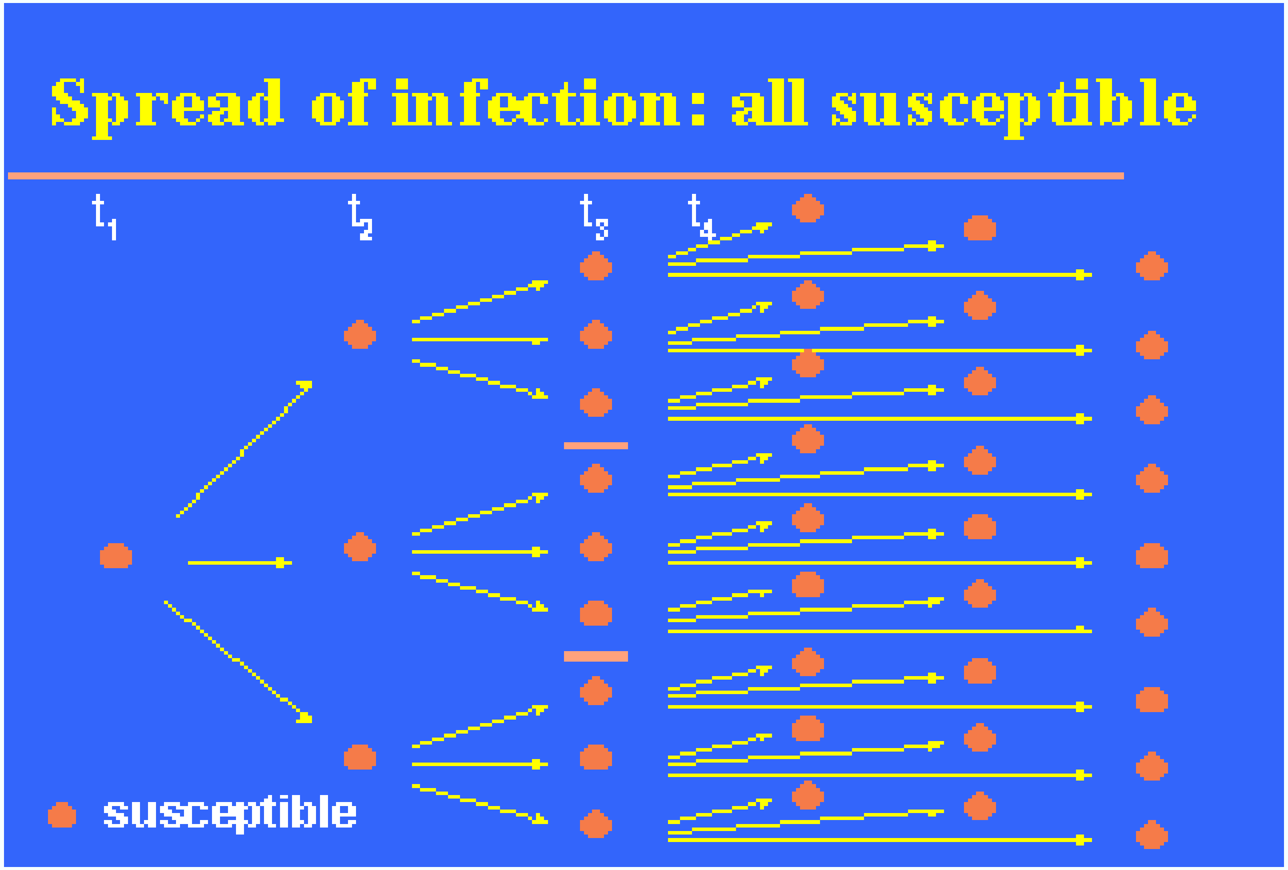
Endemic: Habitual presence of a disease in a given geographic area.

Epidemic: Occurrence of a group of illnesses of similar nature within a given community or region in excess of normal expectancy, and derived from a common or from a propagated source.

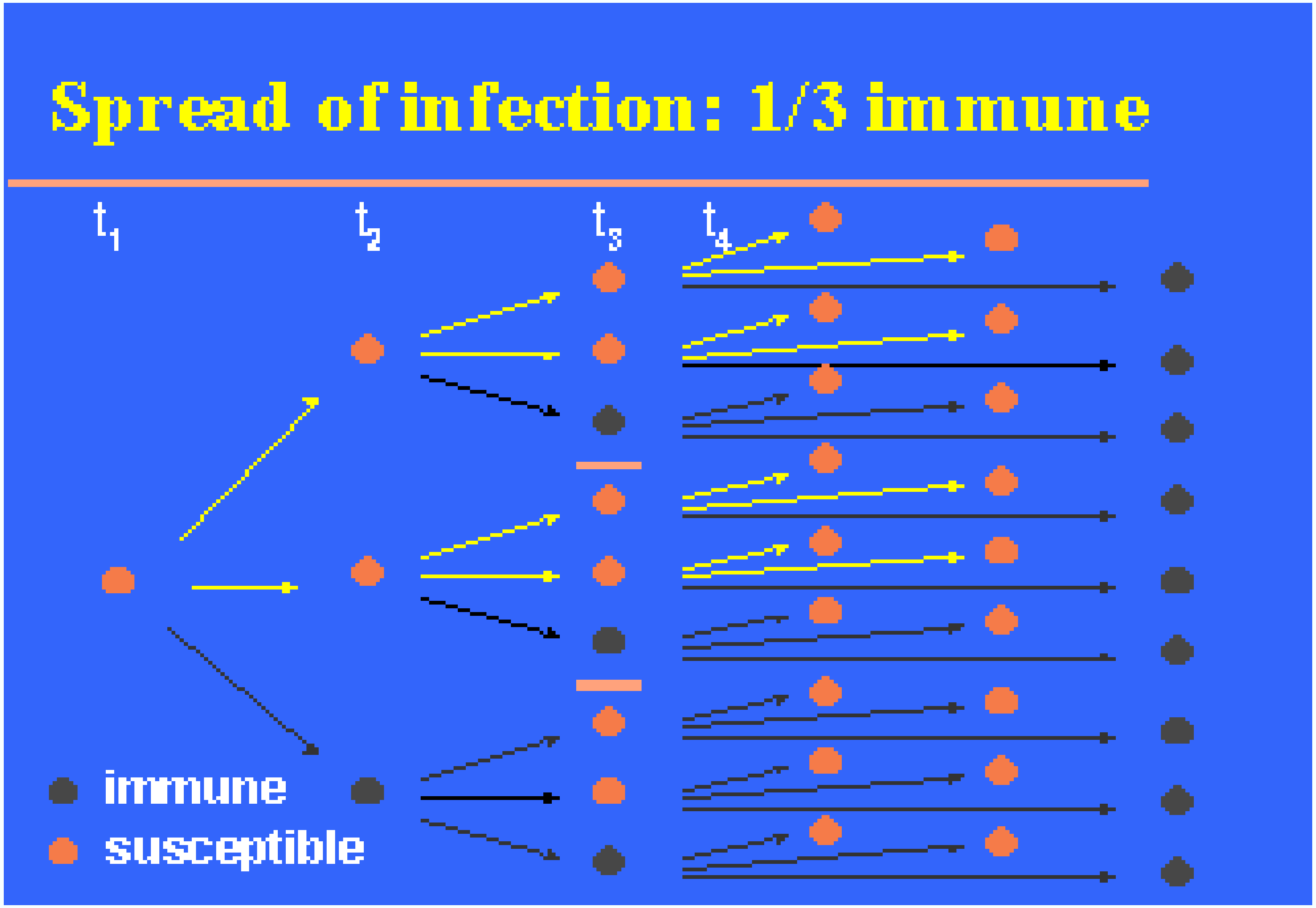
Pandemic: A worldwide epidemic.

Herd immunity: Resistance of a group to an attack by a disease to which a large proportion of members of the group are immune.

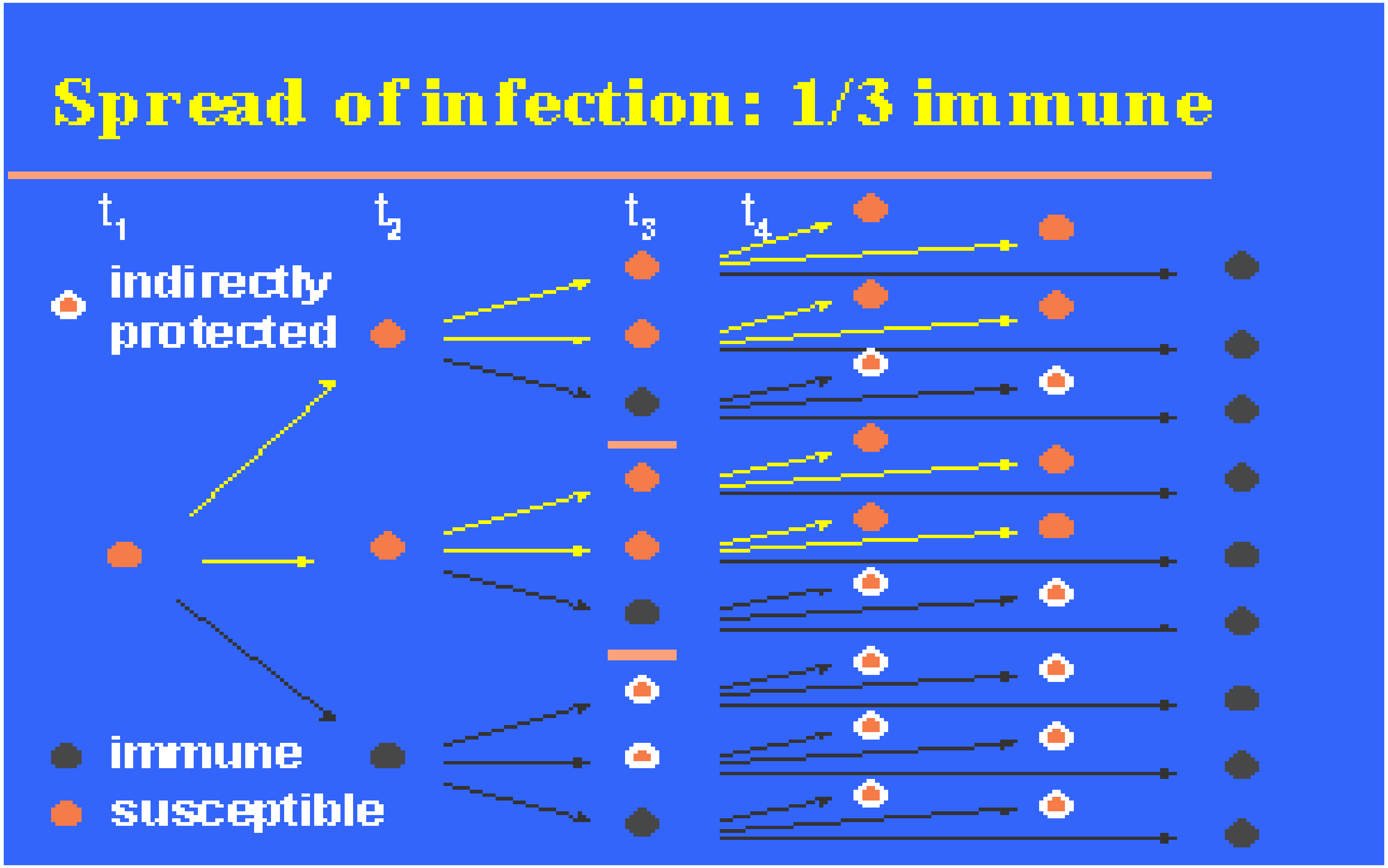
Infectious disease epidemiology



Infectious disease epidemiology



Infectious disease epidemiology



Infectious disease epidemiology

- This is HERD IMMUNITY.
- Herd immunity: The indirect protection from infection of susceptible members of a population, and the protection of the population as a whole, which is brought about by the presence of immune individuals.

Definitions (cont.)

Virulence: Severity of the disease produced by the organism.

Carrier: Individual who harbors the organism but is not infected, as measured by serologic studies or evidence of clinical illness.

Classic Example: Typhoid Mary was a carrier of *Salmonella typhi* who worked as a cook in NYC in different households over many years – considered to have caused at least 10 typhoid fever outbreaks that included 51 cases and 3 deaths.

Attack Rate

$$AR = \frac{\text{Number of people at risk who develop disease}}{\text{Number of people at risk during a specified period of time}}$$

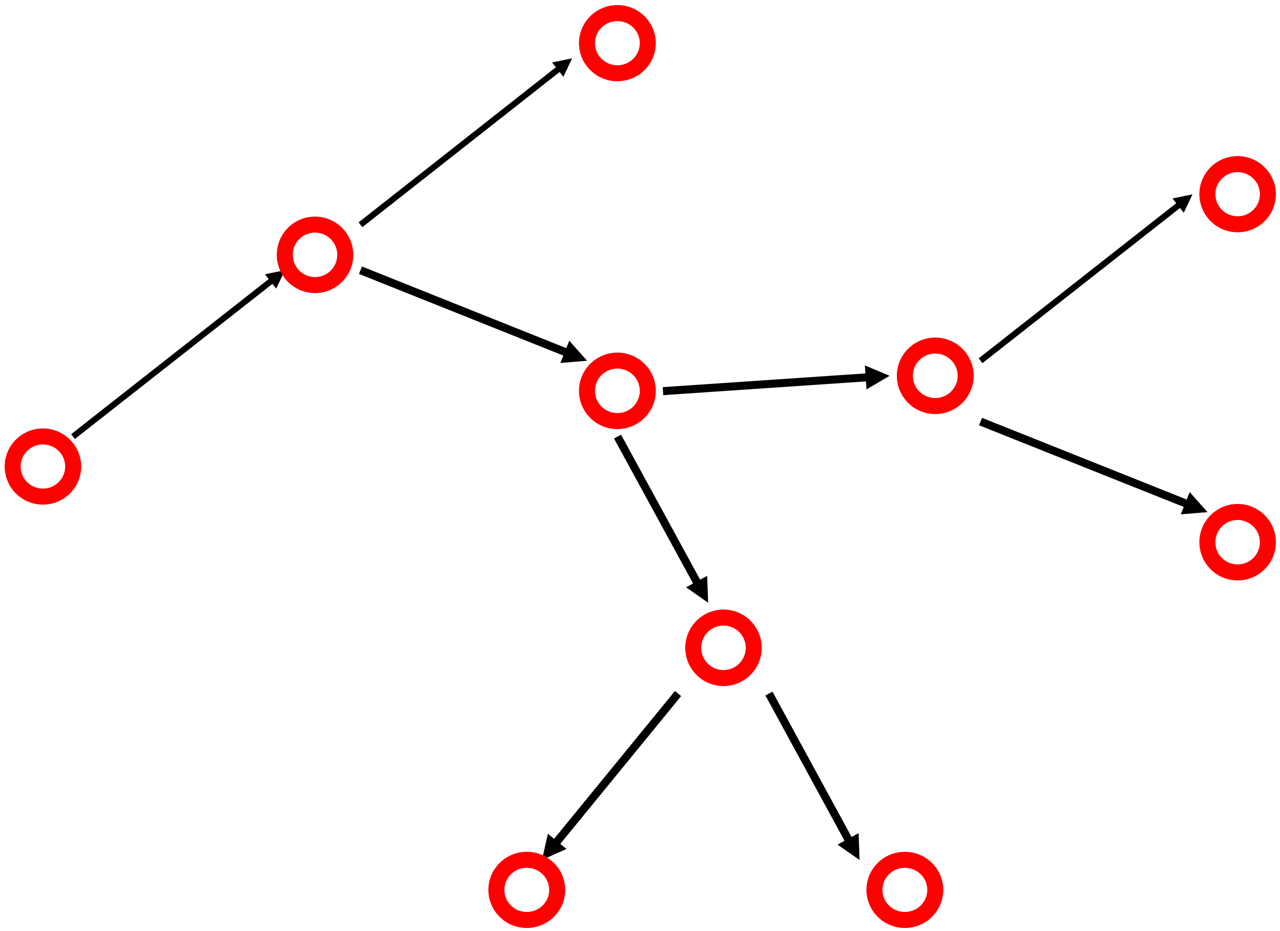
Person-to-person transmission

Data from Dr. Simpson's studies in England (1952)			
	Measles	Chickenpox	Rubella
Children exposed	251	238	218
Children ill	201	172	82
attack rate	0.80	0.72	0.38

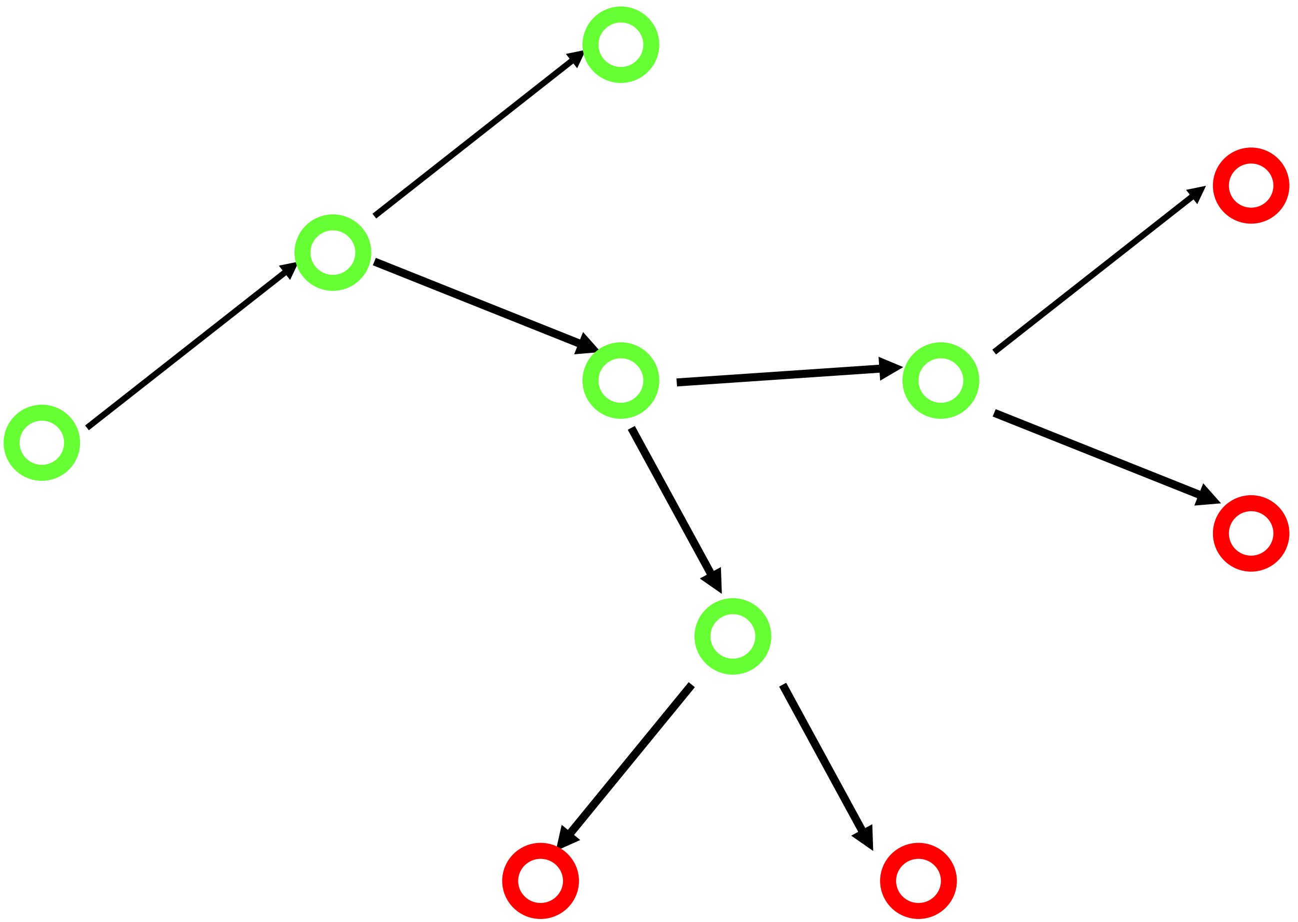
$$\text{Attack rate} = \frac{\text{ill}}{\text{exposed}}$$

The Basic Reproductive Number R_0

- R_0 is defined as "the average number of secondary cases caused by an infectious individual in a totally susceptible population".



$$R_0 = \frac{1+2+2+2+2}{6} = \frac{9}{6} = 1.5$$



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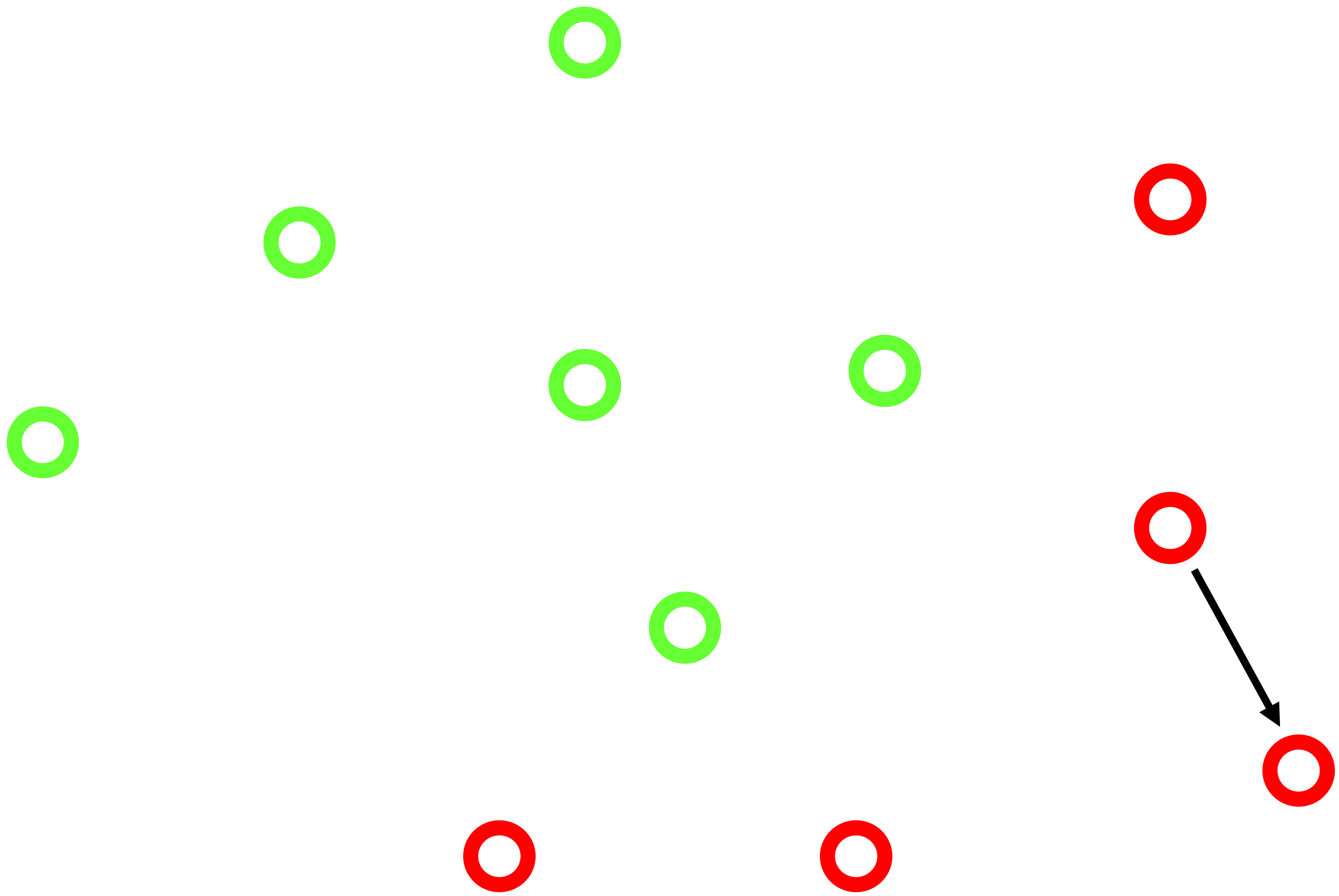

$$R_0 = \frac{1}{4} = 0.25$$

The Basic Reproductive Number R_0

- Individualistic definition: R0 = The number of infections an infected person would generate over the course of their infection if everyone they encountered were susceptible.
- Population definition: R0 = The average force for growth of infection in a population where everyone is susceptible.

The Basic Reproductive Number

- $R_0 > 1$ is also a persistence criterion

- R_0 tells us how easy or difficult it is to eradicate an infection

- Easier to eradicate an infection with low R_0 than high R_0 (e.g. smallpox: $R_0 \approx 5$, measles: $R_0 \approx 15$)

The Basic Reproductive Number R_0

- As such R_0 tells us about the initial rate of increase of the disease over a generation:

- When R0 is greater than 1, the disease can enter a totally susceptible population and the number of cases will increase,
- whereas when R_0 is less than 1, the disease will always fail to spread.

Reproductive Number, R_0

- If $R_0 < 1$ then infection cannot invade a population
  - implications: infection control mechanisms unnecessary (therefore not cost-effective)

- If $R_0 > 1$ then (on average) the pathogen will invade that population
  - implications: control measure necessary to prevent (delay) an epidemic

Infectious disease epidemiology

- If **Ro < 1**, then every new generation of infection will affect fewer individuals and eventually the disease will die out. The value of Ro and the % of the population that is vaccinated affects disease spread and die out.
- If **Ro = 1** then approximately the same number of individuals are infected with every new generation causing endemicity.
- If **Ro > 1** then there is an ever increasing number of infected individuals.

The Basic Reproductive Number R_0

AIDS	2-5
Smallpox	3 -5
Measles	16 -18

Infectious disease epidemiology

- Reproductive rate (R) (potential of spread from person to person) depend on:
  1) The probability of transmission in a contact between an infected individual and susceptible one
  2) The frequency of contacts in the population
  3) How long an infected person is infectious
  4) The proportion of the population that is already immune

Reproductive Number, R_0

A measure of the potential for transmission

The basic reproductive number, R_0, the mean number of individuals directly infected by *an infectious case* through the total infectious period, when introduced to a susceptible population

probability of transmission per contact

$$R_0 = p \cdot c \cdot d$$

duration of infectiousness

contacts per unit time

Infection will …..	disappear, if	$R < 1$
	become endemic, if	$R = 1$
	become epidemic, if	$R > 1$

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What determines R_0 ?

p, transmission probability per exposure – depends on the infection

- HIV, p(hand shake)=0, p(transfusion)=1, p(sex)=0.001
- interventions often aim at reducing *p*
  - use gloves, screene blood, condoms

c, number of contacts per time unit – relevant contact depends on infection

- same room, within sneezing distance, skin contact,
- interventions often aim at reducing *c*
  - Isolation, sexual abstinence

d, duration of infectious period

- may be reduced by medical interventions (TB, but not salmonella)

(www)

Reproductive Number, R_0

Use in STI Control

$$R_0 = p \bullet c \bullet d$$

p	condoms, acyclovir, zidovudine
c	health education, negotiating skills
d	case ascertainment (screening, partner notification), treatment, compliance, health seeking behaviour, accessibility of services

Immunity – *herd immunity*

❖If R_0 is the mean number of secondary cases in a susceptible population, then R is the mean number of secondary cases in a population where a proportion, p, are *immune*

$$R = R_0 - (p \cdot R_0)$$

❖What proportion needs to be immune to prevent epidemics?

If R_0 is 2, then $R < 1$ if the proportion of *immune*, p, is > 0.50

If R_0 is 4, then $R < 1$ if the proportion of *immune*, p, is > 0.75

❖If the mean number of secondary cases (R) should be < 1, then

$$R_0 - (p \cdot R_0) < 1$$

$$p > (R_0 - 1)/ R_0 \Rightarrow p > 1 - 1/ R_0$$

❖ If $R_0 = 15$, how large will p need to be to avoid an epidemic?

$$p > 1-1/15 = 0.94$$

❖The higher R_0, the higher proportion of *immune* required for herd immunity

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