Norwegian Institute of Public Health

Basics of

Infectious Disease Epidemiology

Course «Infections control in a global perspective» at NRSGH at NTNU

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Based on a lecture from EPIET by Mike Catchpole, Bernadette Gergonne, James Stuart, Outi Lyytikäinen, Viviane Bremer

Introduction

Basic infectious disease epidemiology is simple!

- To understand the dynamics of infectious diseases is important for prevention and control
- Pandemics can be explosive → Smallpox, plague, cholera, measles, influenza, COVID-19
- Pandemics can be slow and go under the radar for a long time → Aids, TB, leprosy, AMR
- The difference between epidemiology for infections and other diseases

Infectious vs. non-infectious disease epidemiology

Same

- general rationale
- terminology (mostly)
- study methods
- ways of collecting data
  - blood samples, questionnaires, registries …
- analysis (statistics)

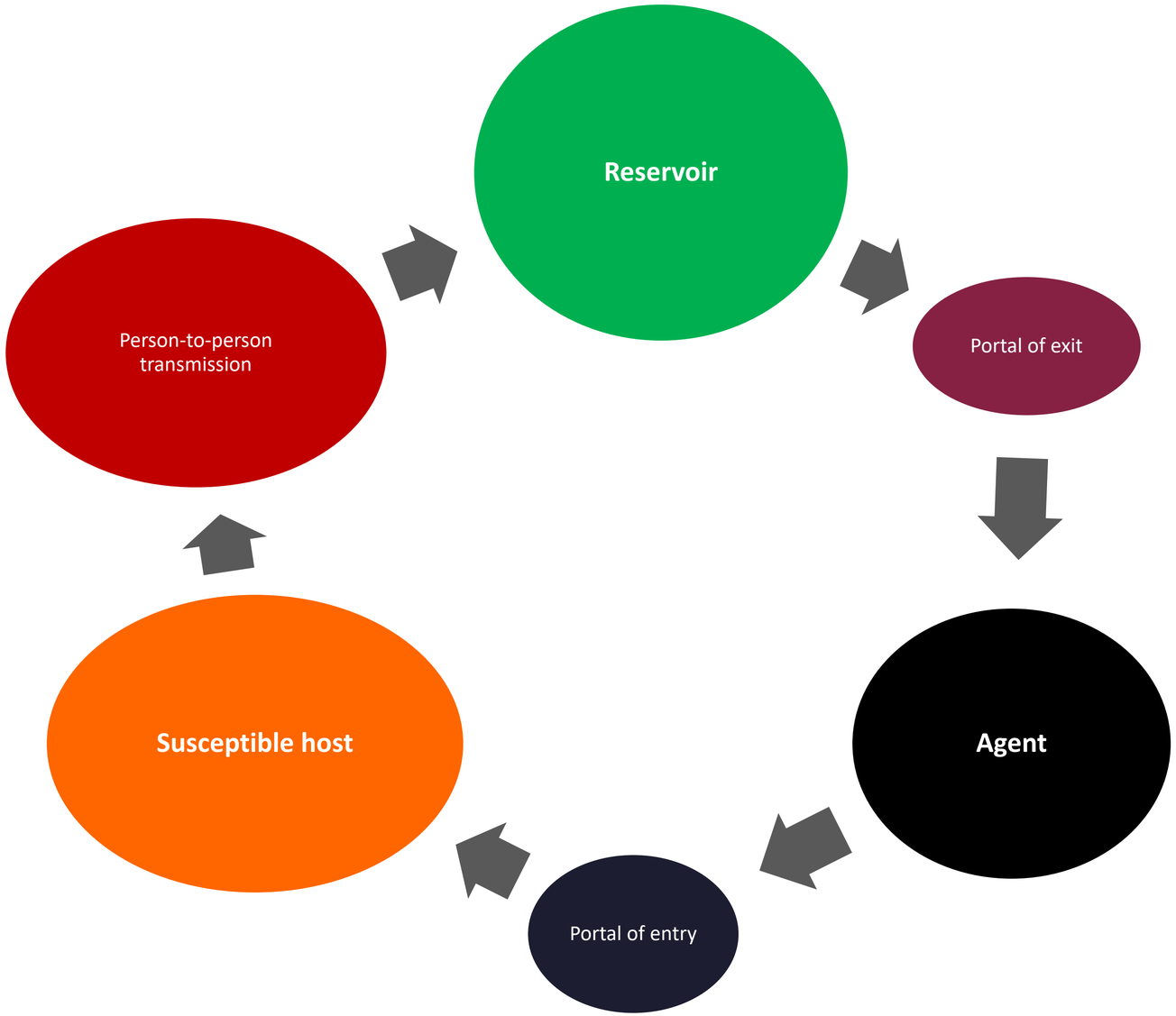
– but some special features

- A case may also be a risk factor
  - Person with infection can also be source of infection
- People may be immune
  - Having had an infection or disease could result to resistance to an infection (immunity)
- A case may be a source without being recognized
  - Asymptomatic/sub-clinical infections
- There is sometimes a need for urgency
  - Epidemics may spread fast and require control measures
- Preventive measures (usually) have a good scientific evidence

Case = exposure

- Primary case
  - Person who brings the disease/infection into a population
- Secondary cases
  - Persons who are infected by primary case
- Generation of infections (waves)
  - Secondary cases are infected at about the same time and consequently tertiary cases
- Index case
  - First case discovered during an outbreak
- Reproductive rate
  - Potential of disease to spread in a population

Chain of Transmission



Reservoir and source of infection

Reservoir of infection

- Ecological niche where the infectious agent survives and multiplies
- Person, animal, arthropod, soil, or substance

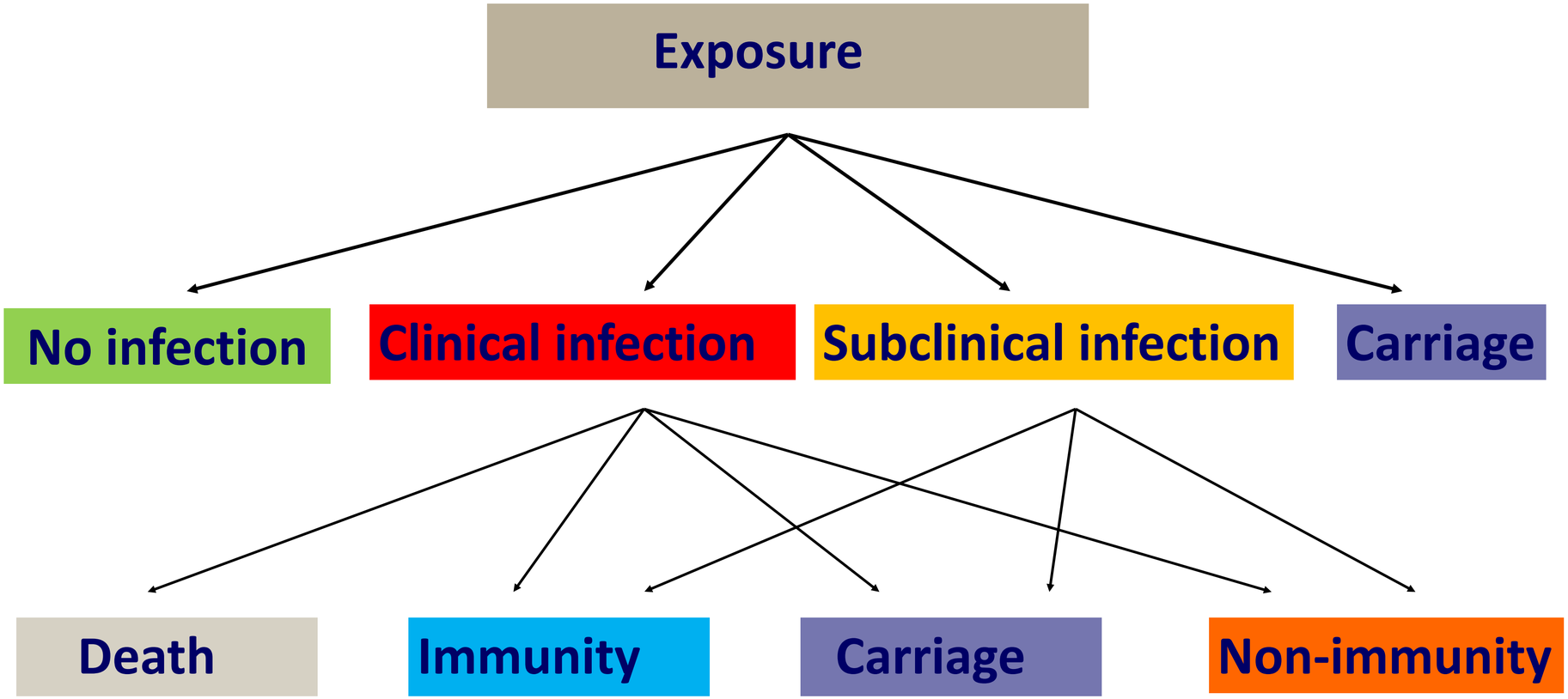
Source

- Human
- Animal
- Environment

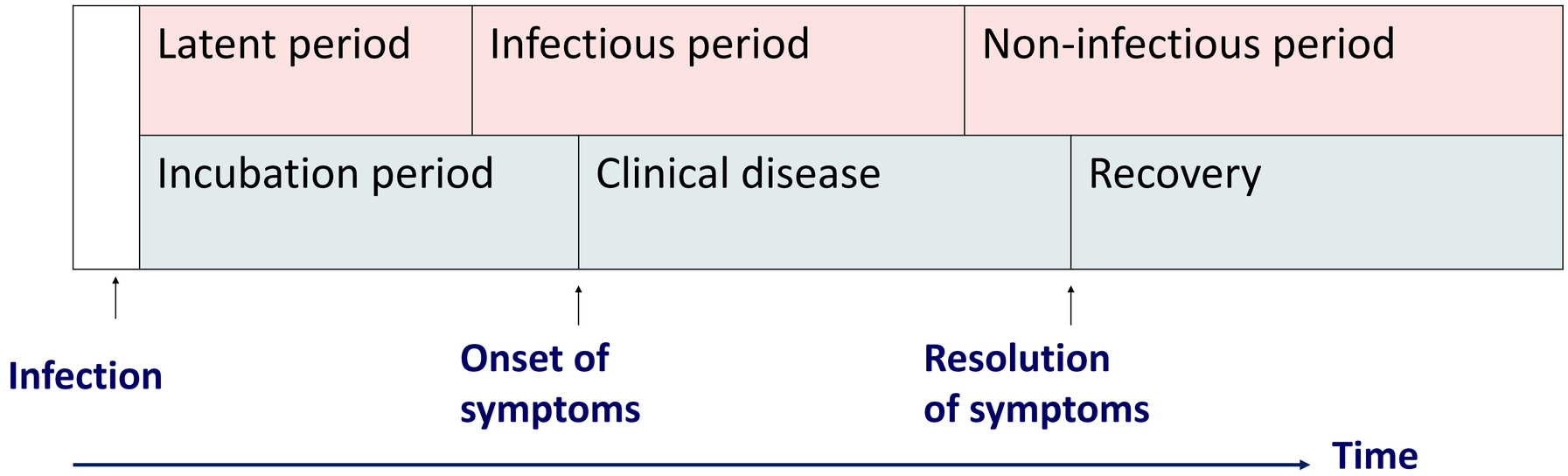
Transmission routes

Direct transmission	Indirect transmission
Mucous to mucous membrane	Waterborne
Across placenta	Airborne
Transplants, blood	Foodborne
Skin to skin	Vectorborne
Sneezes, cough	Objects/Fomites

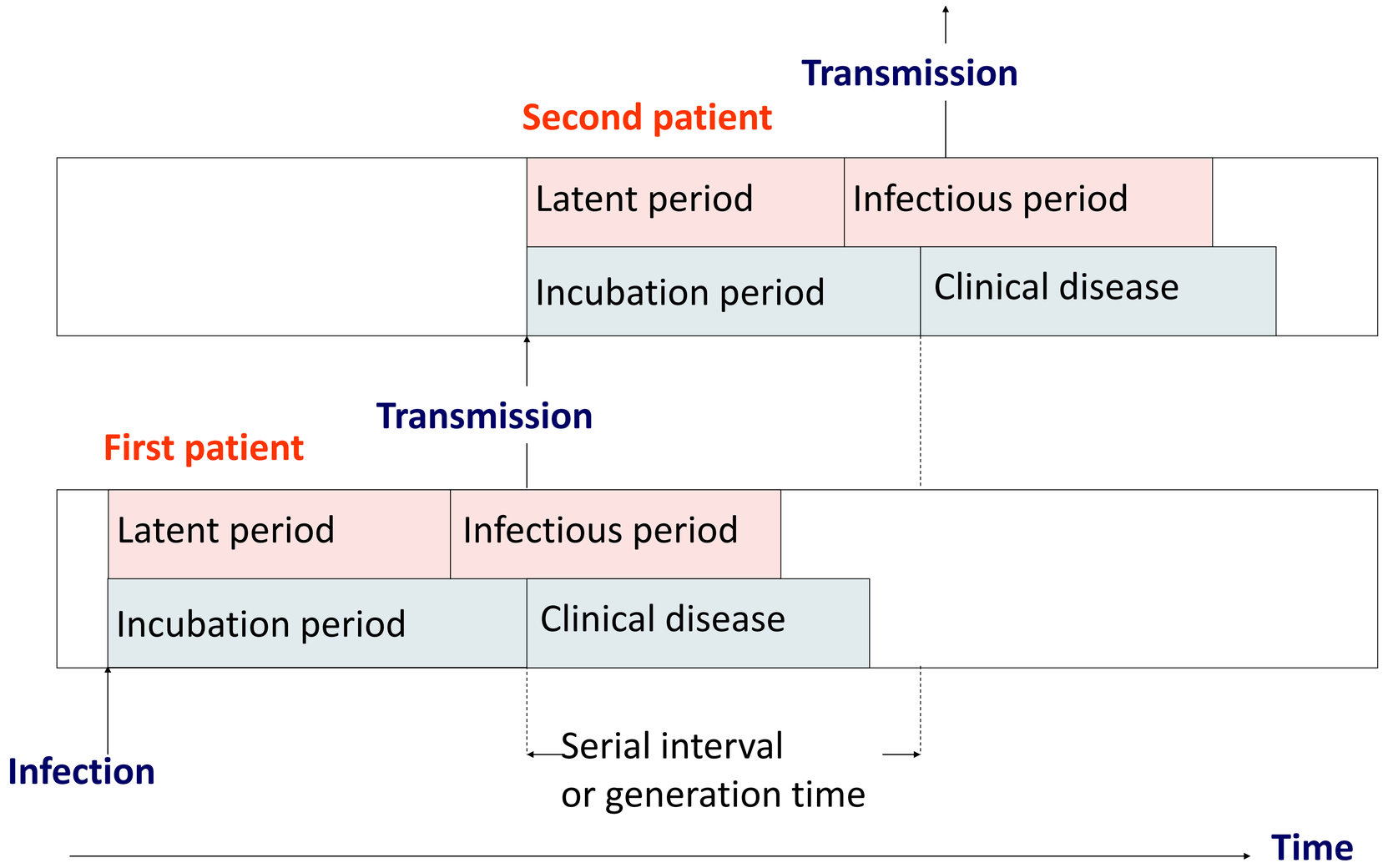
Possible outcomes after exposure



Dynamics of disease and infectiousness



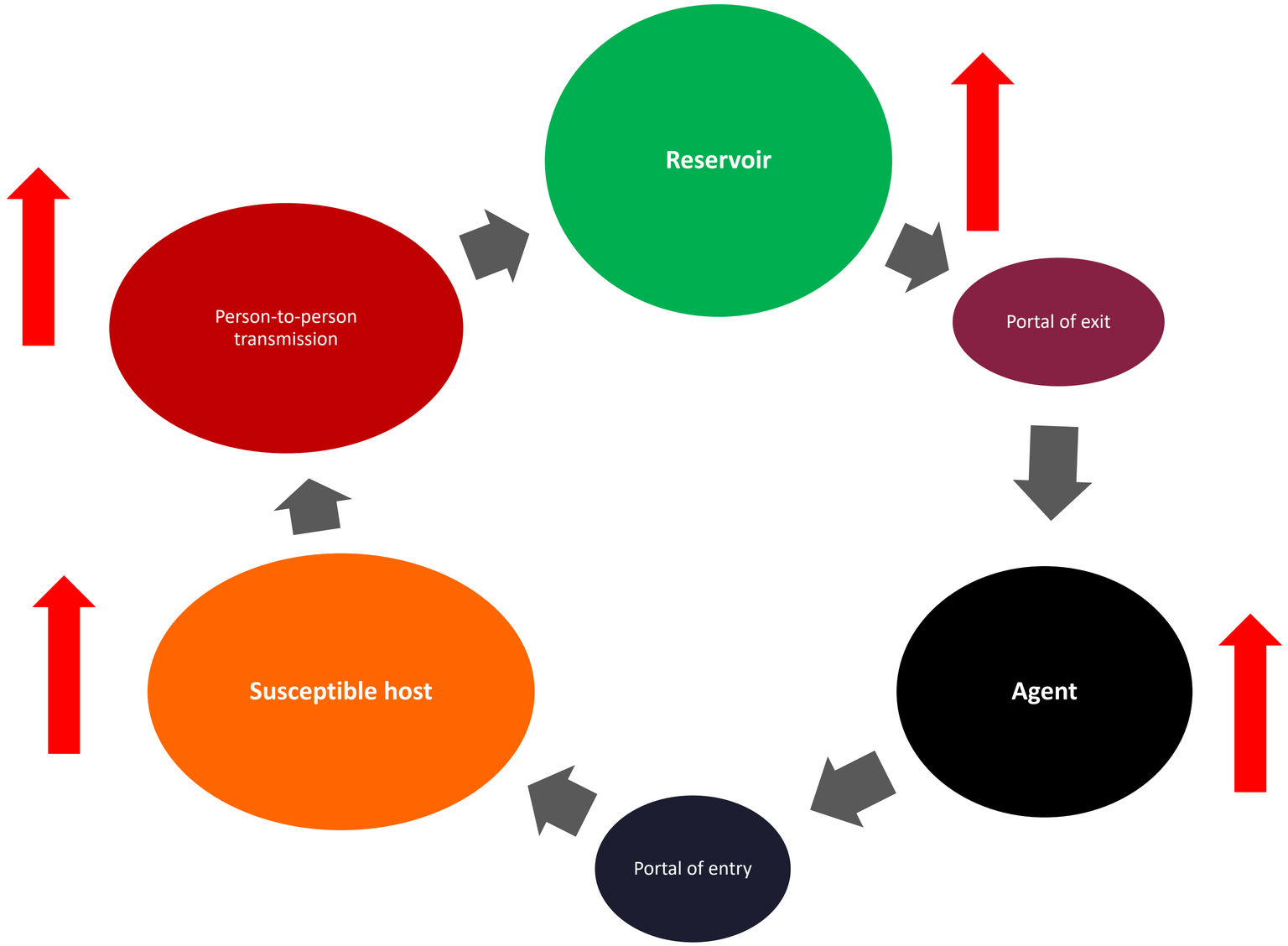
Relationships between time periods



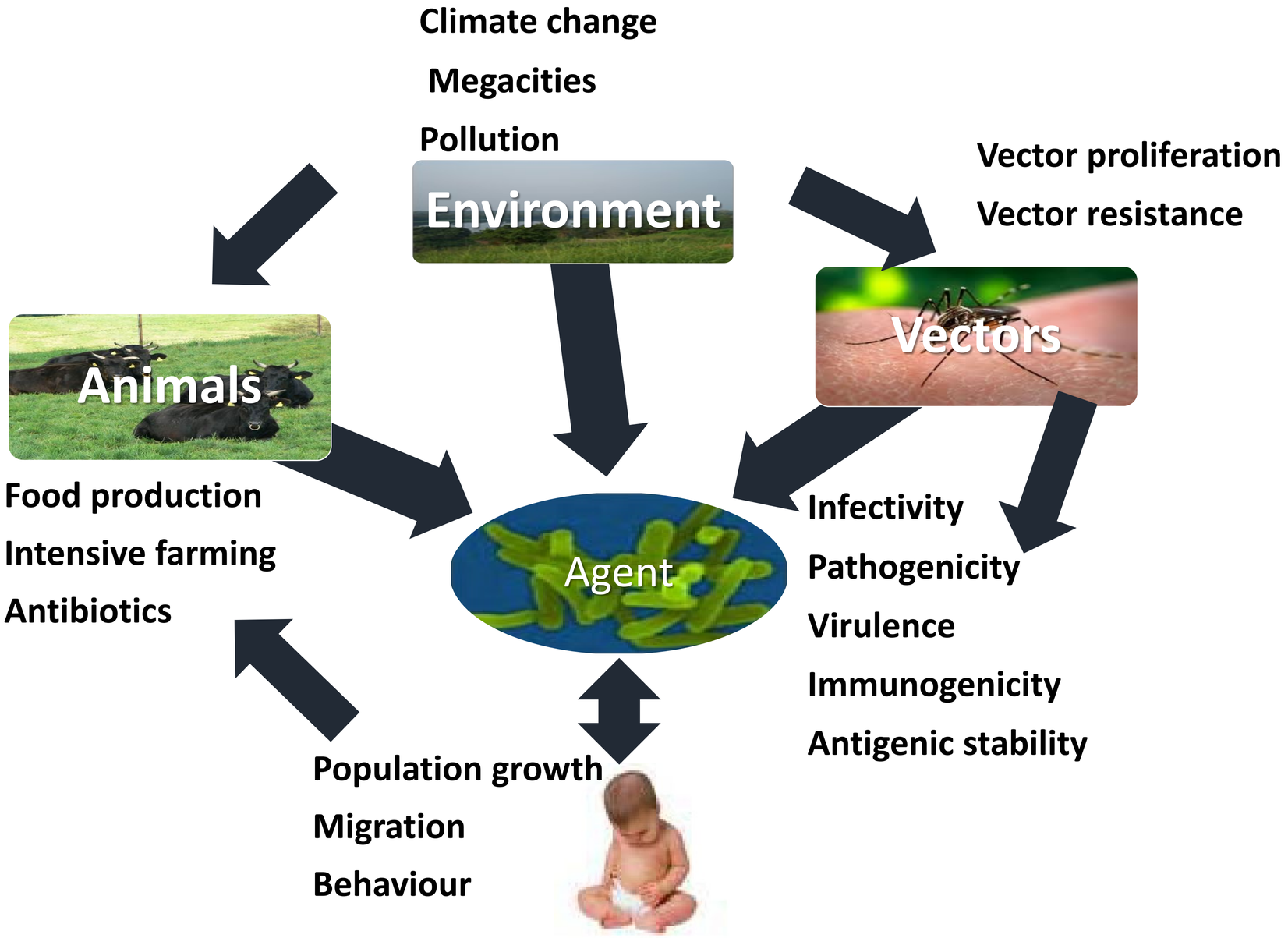
Disease occurrence in populations

- **Sporadic**
  - Occasional cases occurring at irregular intervals
- **Endemic**
  - Continuous occurrence at an expected frequency over a certain period of time and in a certain geographical location
- **Epidemic or outbreak**
  - Occurrence in a community or region of cases of an illness with a frequency clearly in excess of normal expectancy
- **Pandemic**
  - Epidemic involves several countries or continents, affecting a large population

What causes incidence to increase?



Factors influencing disease transmission



Reproductive rate – **R**

- Potential of an infectious disease to spread in a population
- Dependent on 4 factors:

- Probability of transmission in a contact between an infected individual and a susceptible one
- Frequency of contacts in the population - contact patterns in a society
- Duration of infectiousness
- Proportion of the population/contacts that are already immune, not susceptible

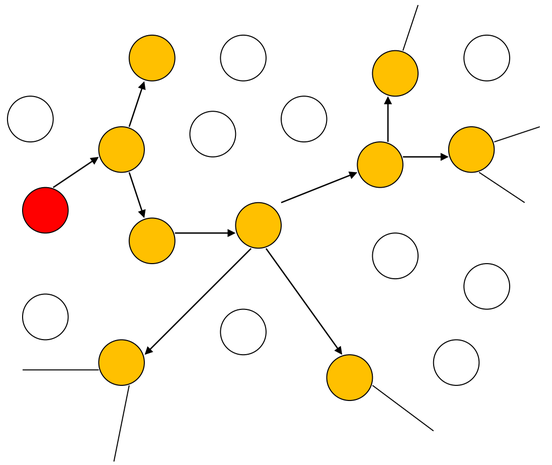
Basic reproductive rate (R_0)

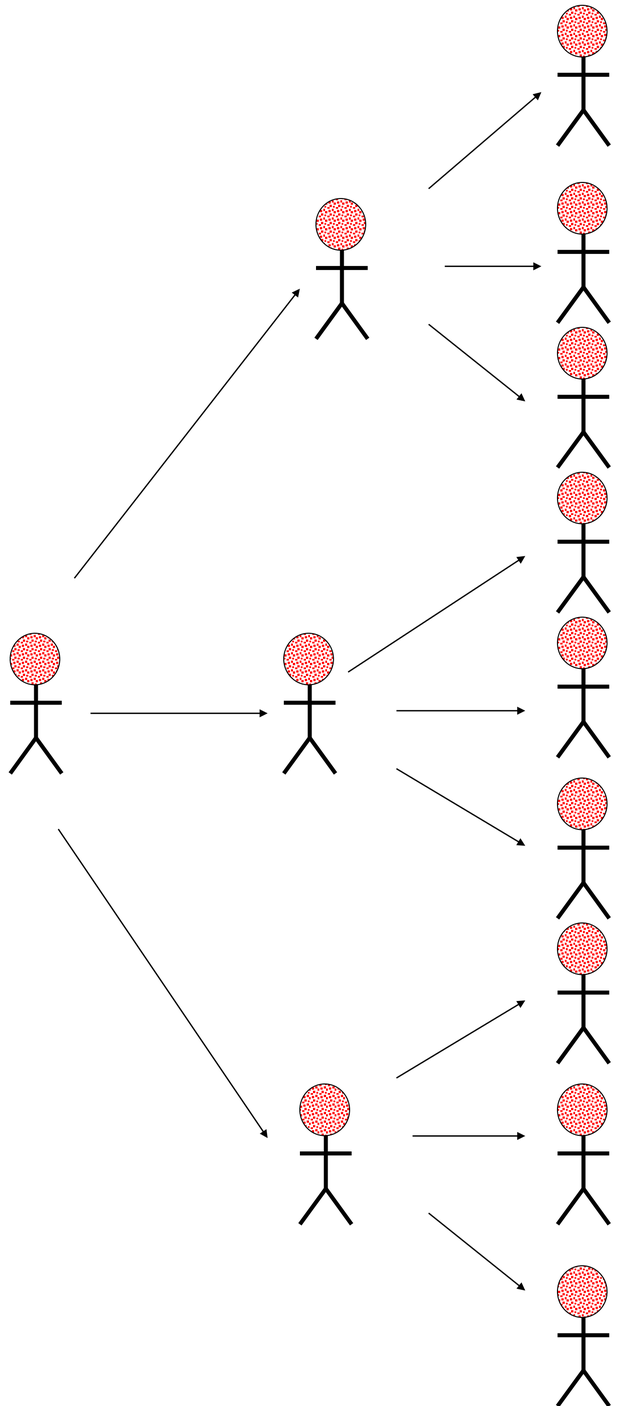
Basic formula for the actual value: $R_0 = \beta * \kappa * D$

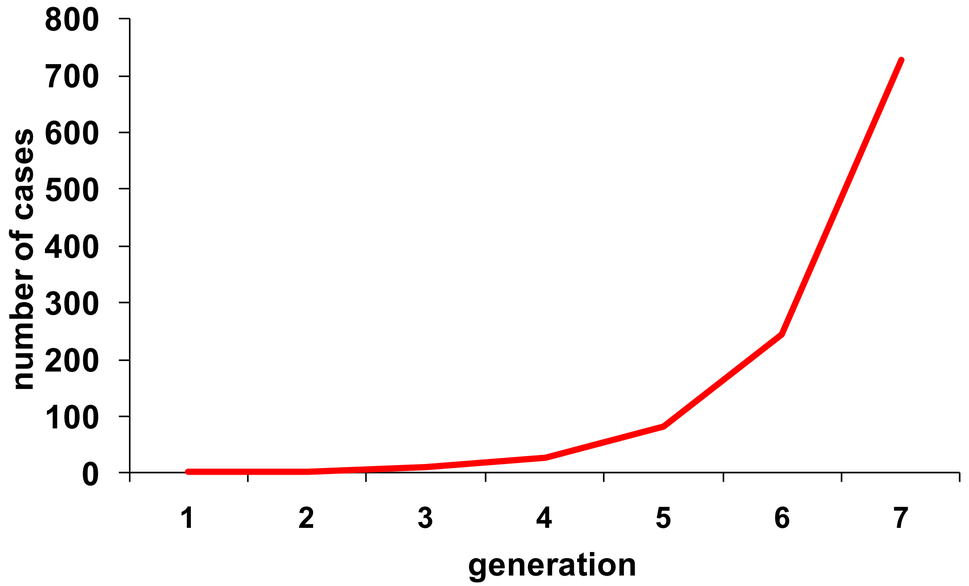
- **β** - risk of transmission per contact (i.e. attack rate)
  - Condoms, face masks, hand washing → β ↓
- **κ** - average number of contacts per time unit
  - Isolation, closing schools, public campaigns → κ ↓
- **D** - duration of infectiousness measured by the same time units as κ
  - Specific for an infectious disease
  - Early diagnosis and treatment, screening, contact tracing → D ↓

Basic reproductive rate (R_0)

- Average number of individuals directly infected by an infectious case (secondary cases) during her or his entire infectious period, when she or he enters a totally susceptible population
- (1+2+0+1+3+2+1+2+1+2)/10 = 1.5
  - $R_0 < 1$ - the disease will disappear
  - $R_0 = 1$ - the disease will become endemic
  - $R_0 > 1$ - there will be an epidemic



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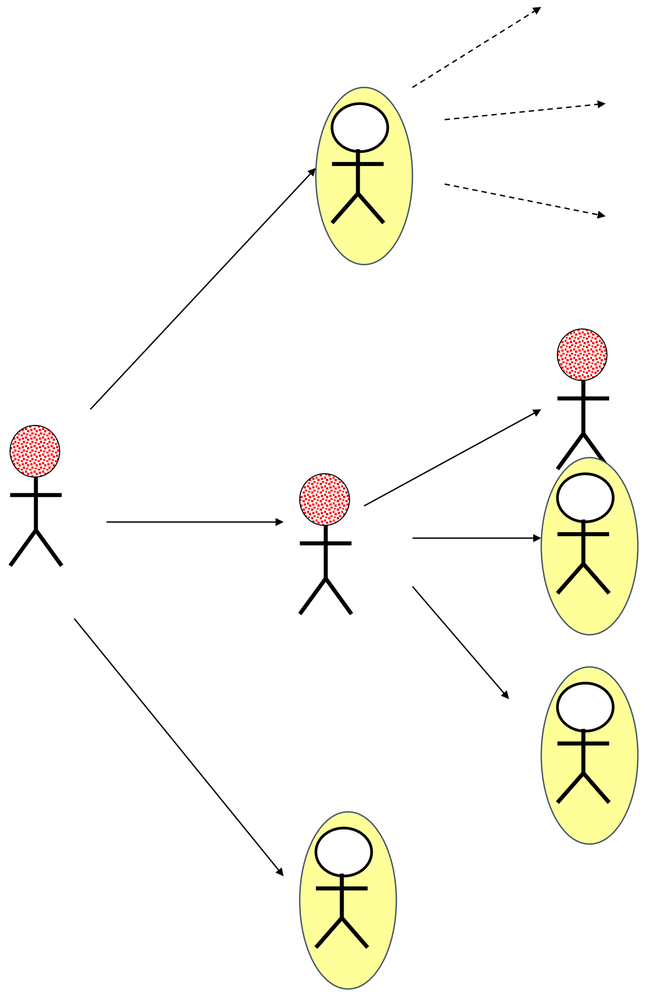

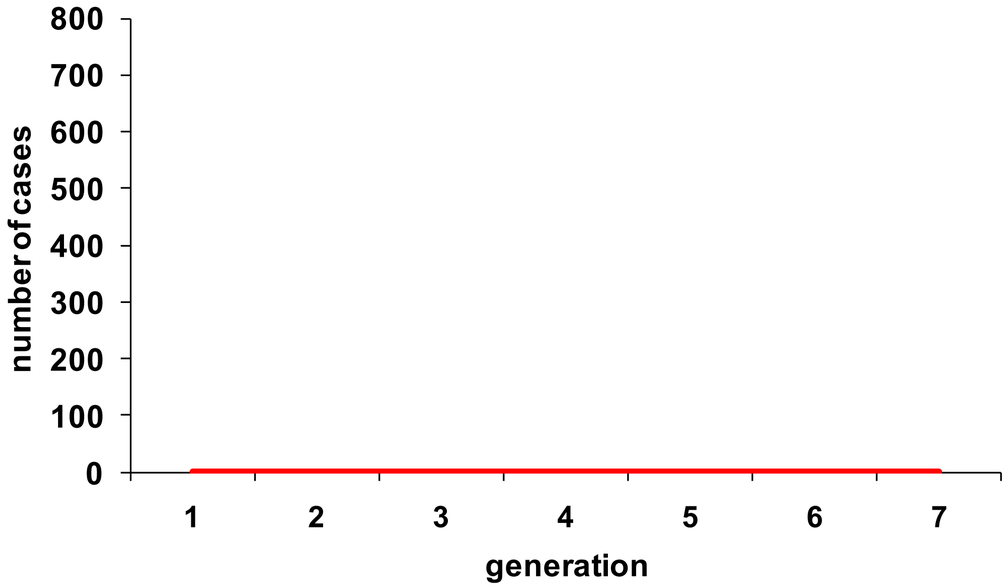
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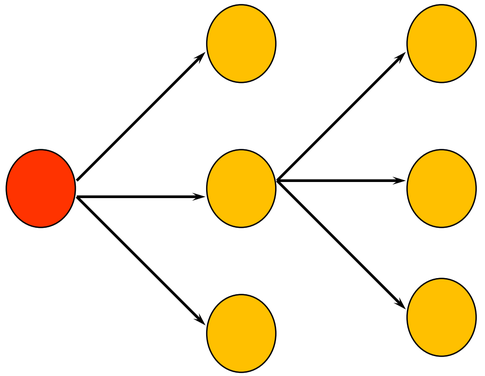
Effective reproduction number R_e

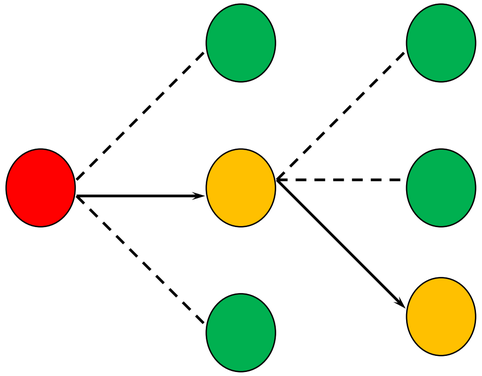
- If the population is not fully susceptible, the average number of secondary cases is less than Ro. This is the effective reproduction number, R_e.

- Epidemic in susceptible population
- Number of susceptibles starts to decline
- Eventually, insufficient susceptibles to maintain transmission. When each infectious person infects <1 persons, epidemic dies out

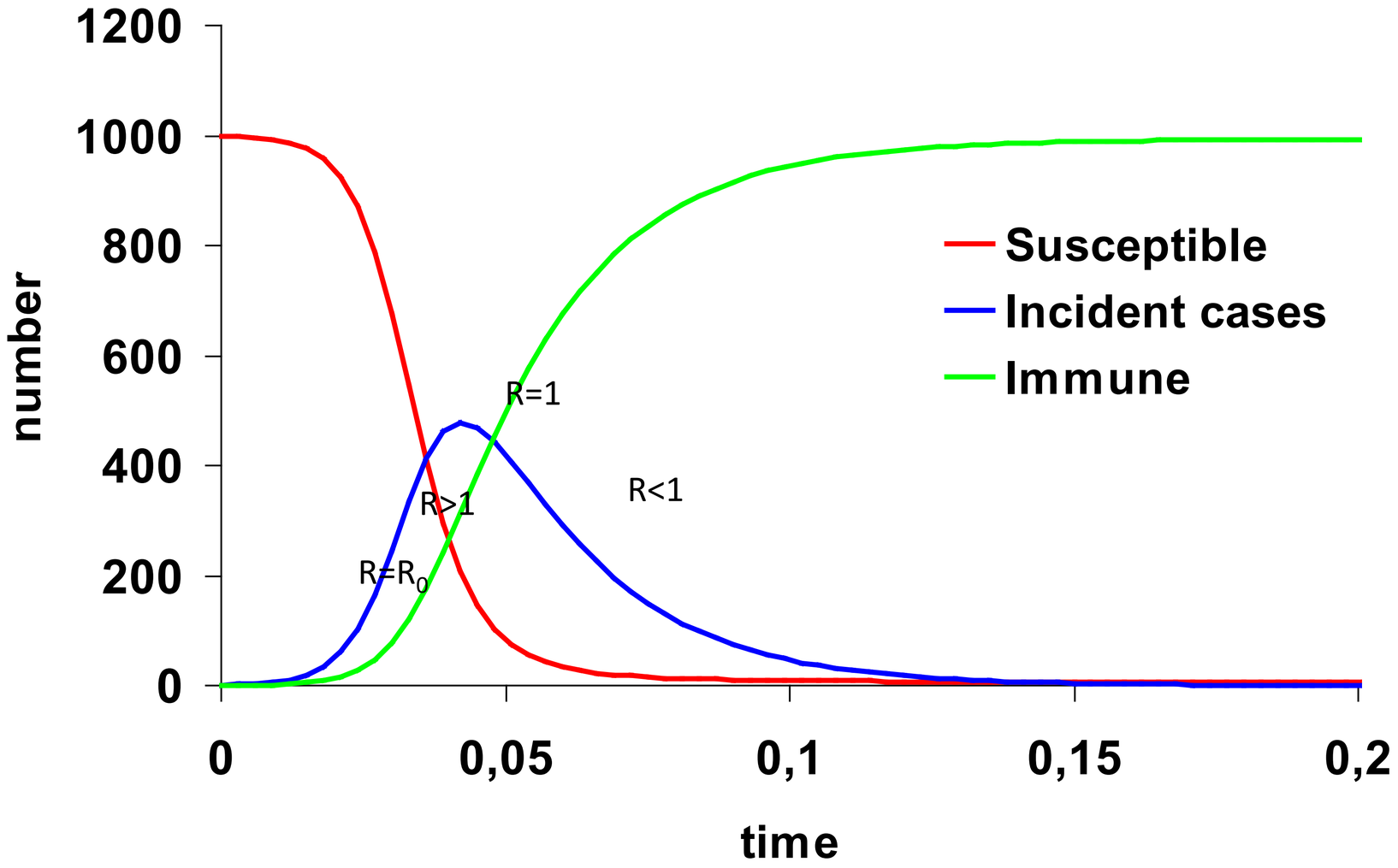
Initial phase R = R_0



Peak of epidemic R = 1



Changes to R(t) over an epidemic



R, threshold for outbreak

- If R < 1
  - infection cannot invade a population
  - implications: infection control mechanisms unnecessary (therefore not cost-effective)
- If R > 1
  - on average the pathogen will invade that population
  - implications: control measure necessary to prevent (delay) an epidemic

Herd immunity

- Level of immunity in a population which prevents epidemics even if some transmission may still occur
- Presence of immune individuals protects those who are not themselves immune

Minimum proportion (**p**) of population that needs to be immunized in order to obtain herd immunity

$p > 1 - 1/R_0$

e.g.

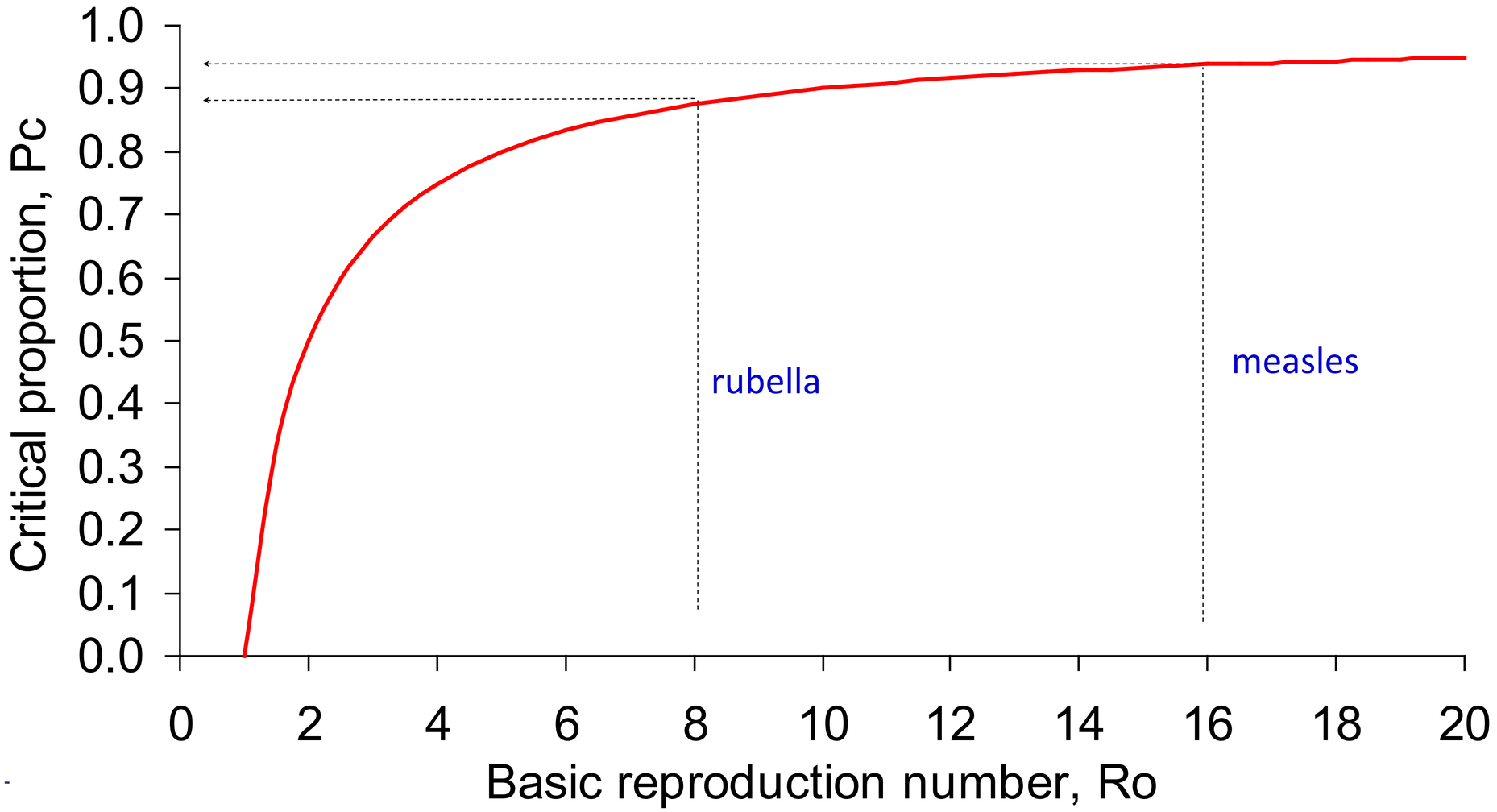
if $R_0 = 3$, immunity threshold = 67%

if $R_0 = 16$, immunity threshold = 94%

Important concept for immunization programs and eradication of an infectious disease

Vaccination coverage required for elimination

Pc = 1-1/Ro



Summary

- Infectious diseases will continue to be an important threat to humans
- Basic infectious disease epidemiology is simple and fun
- Infectious disease epidemiology is different
- Transmission dynamics important for prevention and control