FAO/ASTF Project: GCP/RAF/510/MUL:

## Enhancing capacity/risk reduction of emerging Tilapia Lake Virus (TiLV) to African tilapia aquaculture: Intensive Training Course on TiLV

4-13 December 2018. Kisumu, Kenya

in cooperation with Kenya Marine Fisheries Research Institute (KMFRI) and Kenya Fisheries Service (KeFS)

# Epidemiology Session
# **Patterns of Diseases**


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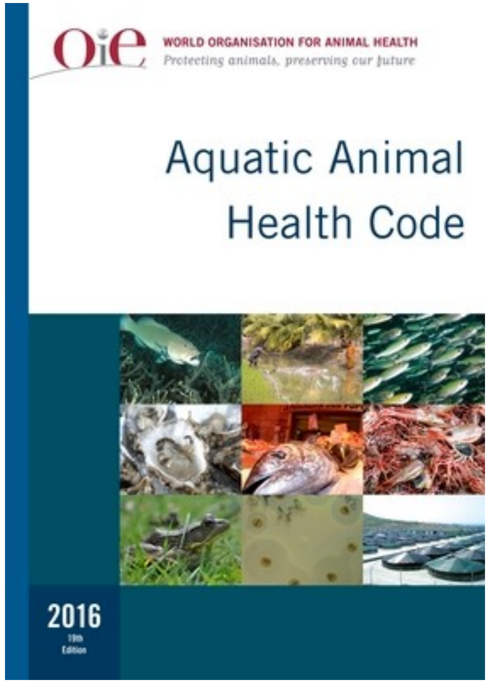
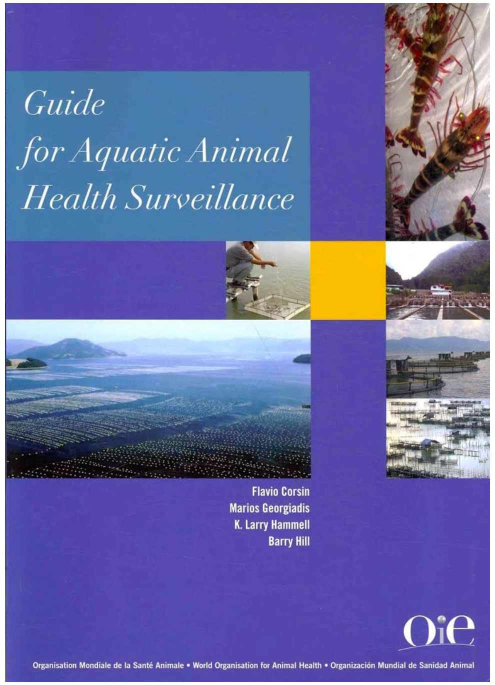
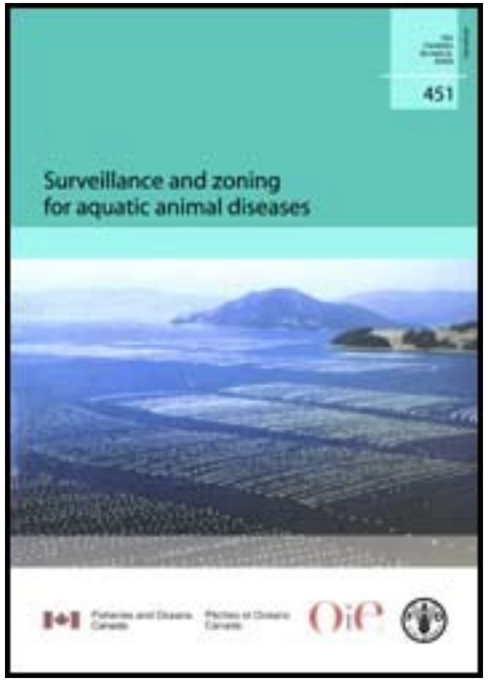
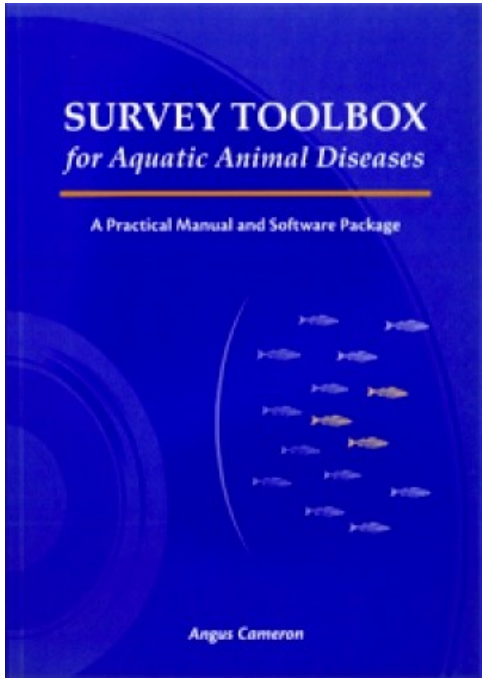
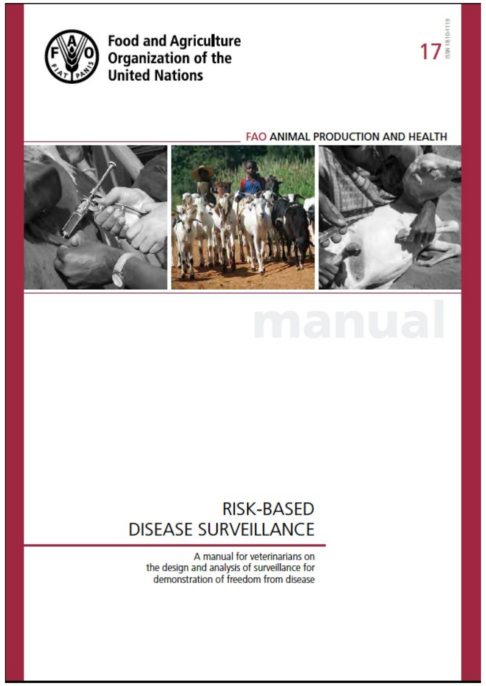
# Available resources & useful references



# Overview

- Disease does not occur randomly in animal groups, over time or in space
- Why we see patterns at the population level, must understand:
  - Behavior of disease in the individual animal and,
  - How disease agents move from animal to animal and farm to farm.
- In this chapter we will explore some basic disease principles that result in the patterns that are seen in populations.

# Unit of study

- We can examine patterns of disease by looking at individual animals or some other unit of study that is an aggregation of animals (an animal group)
- Examples: farm, herd, flock, shed, tank, cage, pond, village, district, province, state, etc.

# Unit of study

- In medical epidemiology and with many livestock and aquatic animal diseases, the unit of study may be the individual person or animal. Focus on identifying factors that make some animals more susceptible to TiLV than others.
- However, in many cases, the unit of study can be aggregations of individuals, so that an epidemiologist might be interested in risk factors for the occurrence of TiLV at the farm or village level, rather than in individual animals.
- The unit of study is the biological unit of primary concern in an epidemiological investigation and may be individual animals or aggregations of animals at various levels.

# Example

- It may be observed that in a particular village outbreak of foot-and-mouth disease (FMD), disease appears to be more common in young cattle than in older cattle.
- Here the unit of study is the individual animal and the characteristic that seems to be associated with disease is the age of the animal.

# Example

- Extending the FMD example, it may be observed that some villages experience a greater number of cases than others.
- An epidemiologist is interested in identifying factors associated with a higher prevalence of disease.
- These factors can then be manipulated to help control the disease in future outbreaks.

# Characteristics of the unit of study

- When describing patterns of disease and relating those patterns to factors of the unit of study, it is important that the chosen characteristics <u>are relevant to the chosen unit of study</u>.

- For example, the characteristics of species, sex and age are relevant where the unit of study is the individual animal but are not relevant where the unit of study is the farm or pond.

# Possible units of study in hierarchical order

| Unit of study | Examples of relevant characteristics (livestock) |
| --- | --- |
| Animal | Species, sex, age, breed, weight |
| Management unit: pen, pond, cage, mob, paddock | Size, soil type, stocking density, stage of production, pasture type |
| Farm | Location, size, source of stock, production method, other enterprises |
| Village/locality | Location, number of farms, geographic and climatic factors, farming practices |
| District/region | Location, state, size, government services, geographic and climatic factors |

# Population Matters

- The <u>population at risk</u> is the population of individuals susceptible to a particular disease and who have some likelihood of exposure.
- The population at risk <u>includes</u> non-diseased individuals as well as diseased, and provides the denominator for prevalence and incidence calculations.
- The population at risk <u>does no</u>t include individuals that are not at risk of the disease, because of either innate or acquired immunity.

# Example

- In an outbreak of pregnancy toxemia in sheep, the population at risk is all pregnant female sheep on the farm. Male sheep, desexed males and non-pregnant females are not part of the population at risk.

- If the unit of study is defined as a pen or farm of animals, then the population at risk is the population of farms (or management units) that are susceptible to the disease, not the individual animals.

# Example

- When investigating a particular disease within a single farm, the at-risk population may be all the animals on that particular farm or it may be limited to a particular subset of animals on the farm such as animals of a particular age or management group.

- On the other hand, if an outbreak of classical swine fever were to occur in Australia, the at-risk population would be regarded as the entire pig population in Australia (including feral pigs)

# Natural History of Disease in Individuals and Populations

- The progress of disease in an individual animal over time (without intervention) as it occurs in the natural situation (rather than a controlled situation such as in a laboratory or tank experiment).
- It begins with exposure of the host to the disease agent and progresses through to either recovery or death.
- The epidemiologist is interested in using population-based methods to identify the important factors affecting this natural history, with the intention of identifying possible methods of prevention and control.

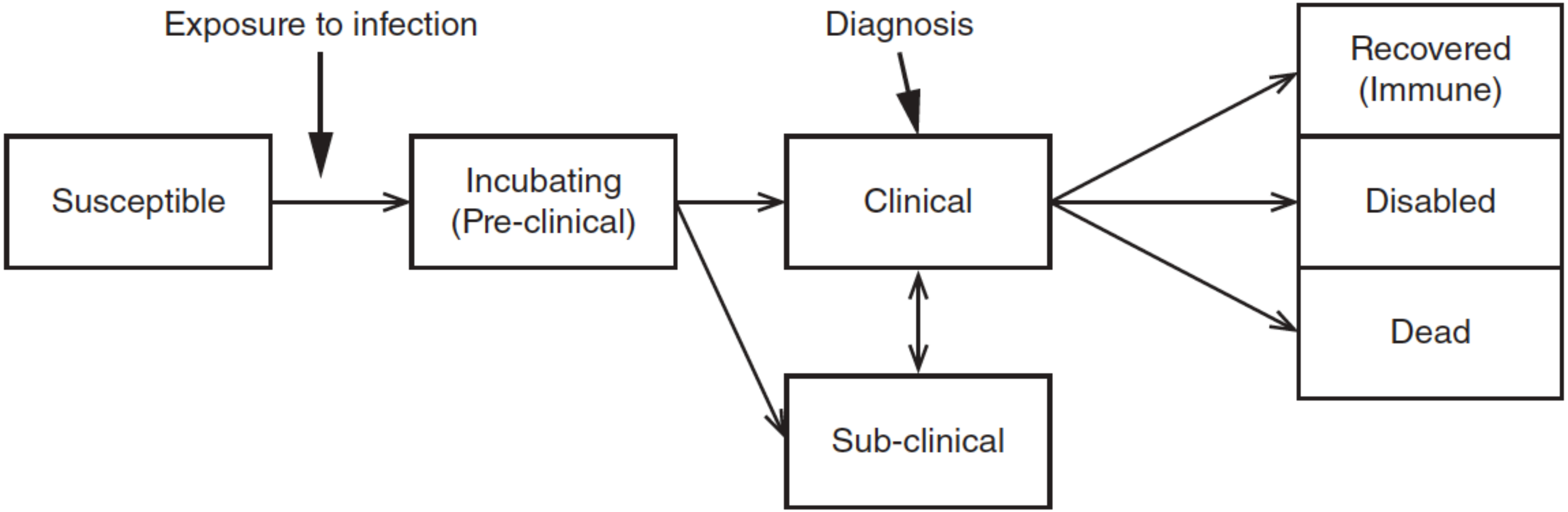
# Natural History of Disease

- Exposure refers to interaction or contact between the infectious agent and the host.
- Not every animal that is exposed will get infected.
- Infection typically means that the infectious agent is present on or within the host animal and is capable of surviving and replicating.
- Once an animal is infected there is usually a period of time before the animal develops any clinical signs of disease (incubation period).
- Animals that develop signs of disease may recover, become a carrier, or die depending on the disease.

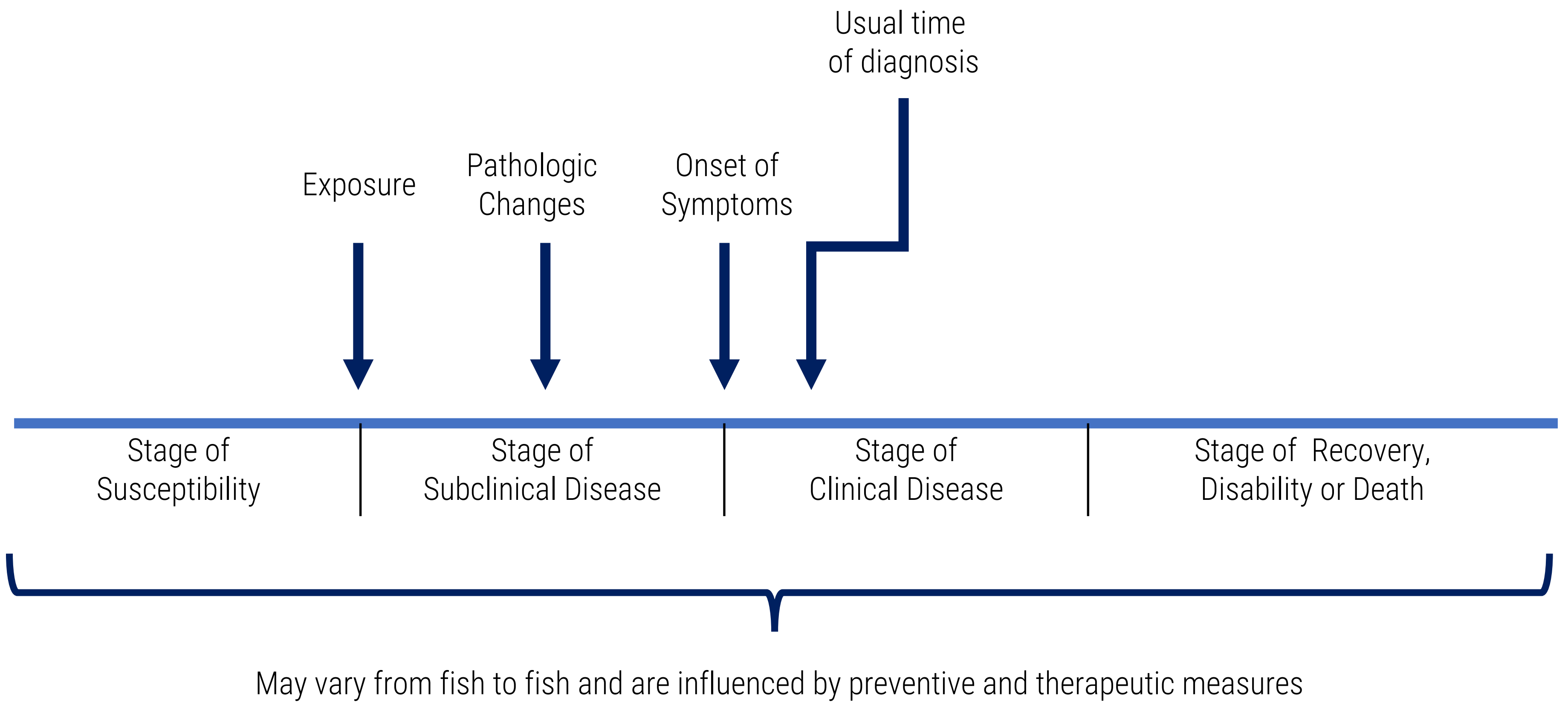
# Natural History of Disease

- Infected animals may never develop clinical signs of disease while in other diseases almost all infected animals may develop signs of disease.
- Some diseases are capable of producing <u>persistent infection or carrier states</u> in infected animals.
- Animals may show little or no signs of infection but may be capable of shedding the infectious agent posing a risk to susceptible animals.
- <u>Recovered</u> animals may develop immunity to the infectious agent so that if exposed again they do not become infected.
- <u>Immunity</u> may last a lifetime for some diseases while for other diseases it may be shorter and as immunity wanes, animals may become susceptible to infection again.

# These different stages of disease are collectively referred to as the spectrum of disease

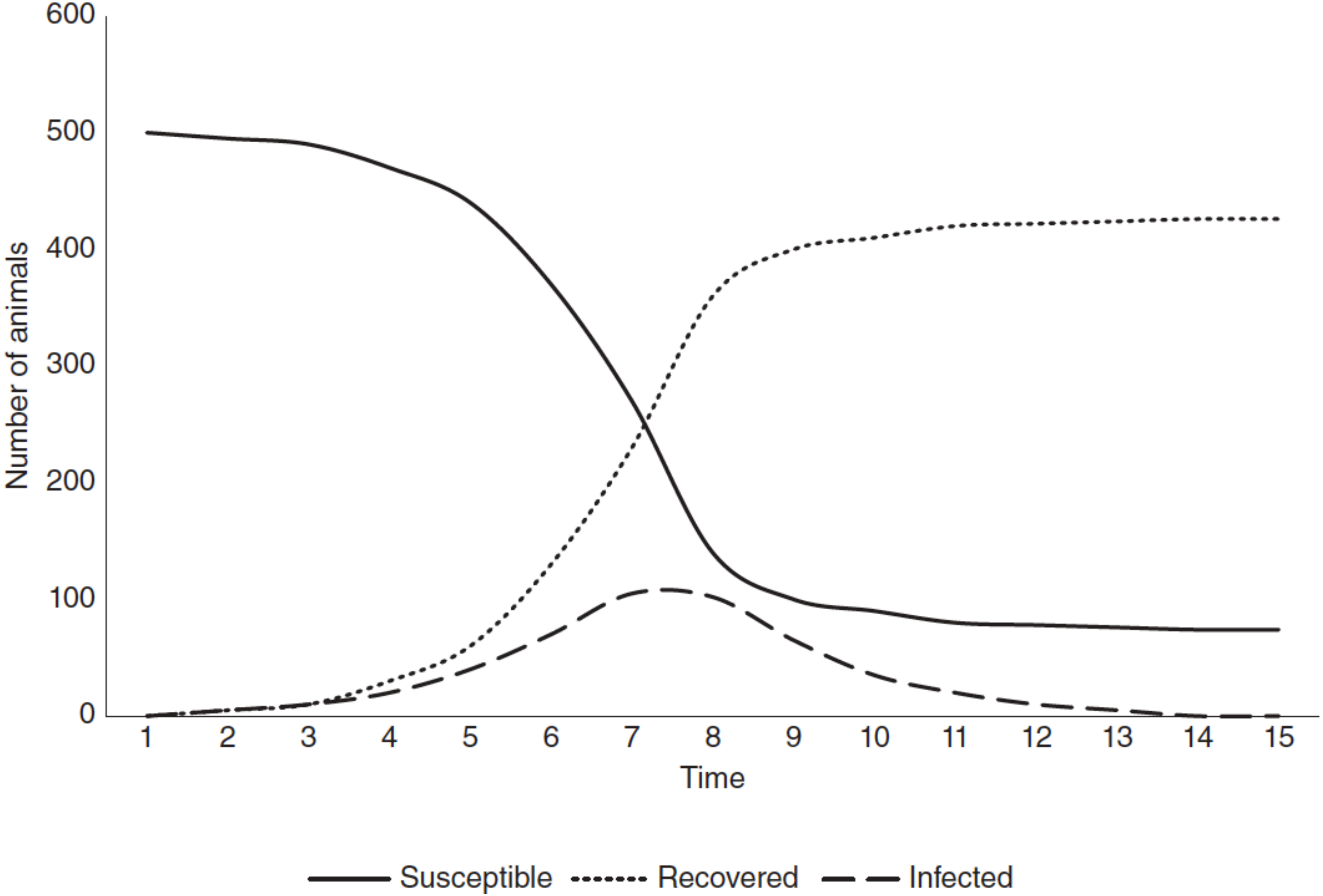


# Exercise
# Define the natural history of TiLV



# Incubation period

- The time period from exposure to infection through to when clinical signs are first manifested.
- When an infectious disease agent is first introduced into a susceptible population, there will be very few animals in the clinical and subsequent states.
- As the epidemic progresses, the number of animals with clinical disease will increase and then slowly decrease while the number of susceptible animals will decrease and the number of recovered animals will increase (assuming no mortality).

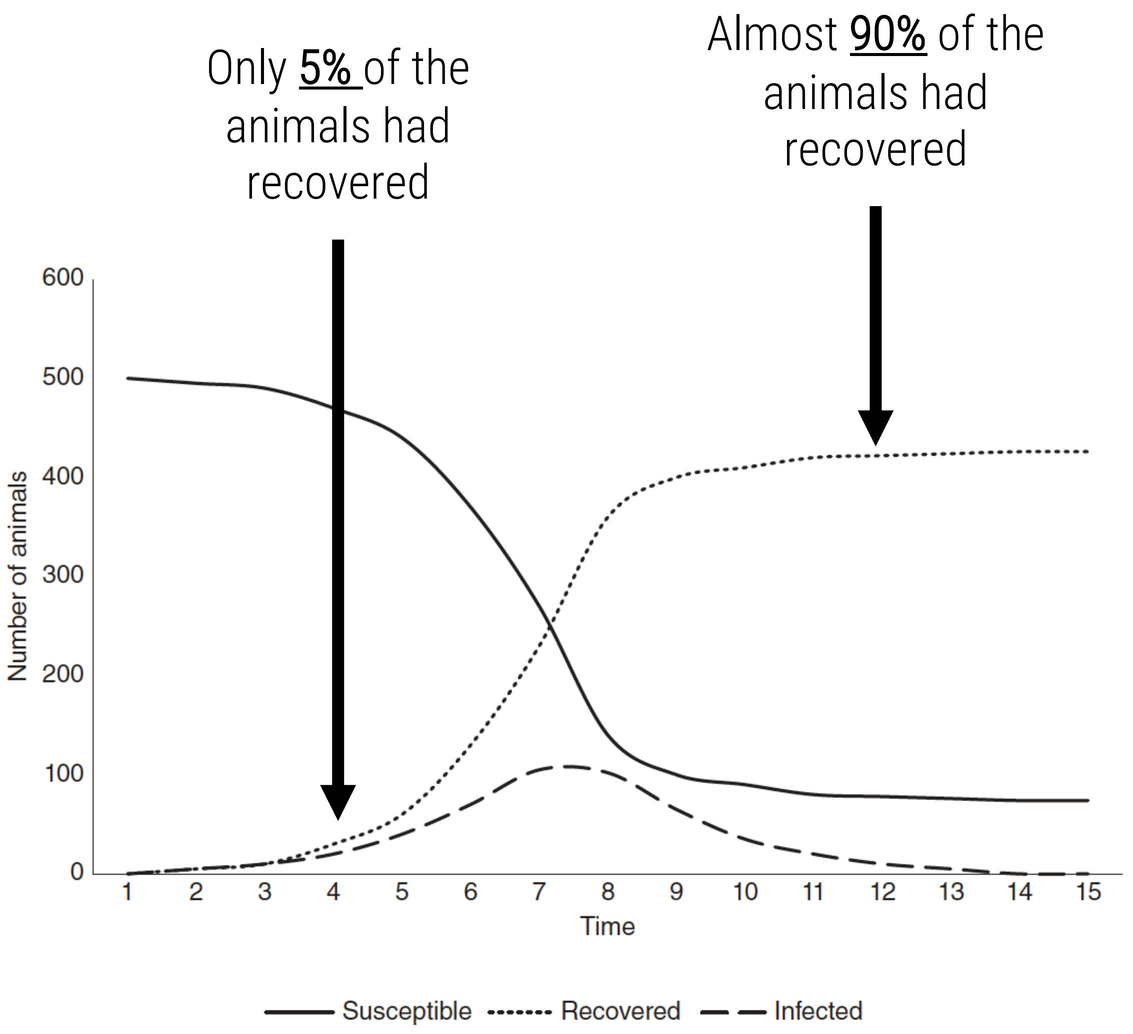


600
500
400
300
200
100
0
Number of animals
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time
Susceptible
Recovered
Infected

# Relevance

- Often a particular test is useful to detect an infected animal at one stage of disease but not another.

- Its usefulness will depend on the proportion of individuals in the population in the various stages of disease at the time that samples were taken.



# Infectivity, pathogenicity and virulence

- These terms all relate to the severity of a disease in a population, but each operates at a different point in the natural history of the disease.

In epidemiology:

- Infectivity refers to the percentage (or proportion) of susceptible individuals exposed to a particular agent who become infected.
- Pathogenicity refers to the percentage of infected individuals who develop clinical disease due to the particular agent.
- Virulence refers to the percentage of individuals with clinical disease who become seriously ill or die.

# Examples

- Q fever (due to *Coxiella burnetti* infection) is highly infectious but has a generally low pathogenicity in animals (does not cause much disease).
- Foot-and-mouth disease is highly infectious in cattle and also highly pathogenic (most exposed animals develop clinical disease) but with low virulence (few cases die)
- Rabies is both highly pathogenic (most infected individuals get sick) and highly virulent (most subsequently die).
- <u>TiLV is…</u>

# Herd immunity

- Progress of a disease in a population is also affected by herd-immunity effects.

- Herd immunity is the immunologically derived resistance of a group of individuals to attack by disease based on the resistance of a large proportion, but not all, of the group.

- Herd immunity may arise from:
  - Innate immunity (although this may not always have an immunological basis)
  - Natural infection
  - Vaccination.

# Herd immunity

- Herd immunity will slow the rate of transmission of a disease within a population, with the magnitude of the effect depending on the level of herd immunity.

- If herd immunity is high, infection may fail to establish or can be eliminated from the population. It is not necessary for all individuals in a group to be immune to eliminate infection.

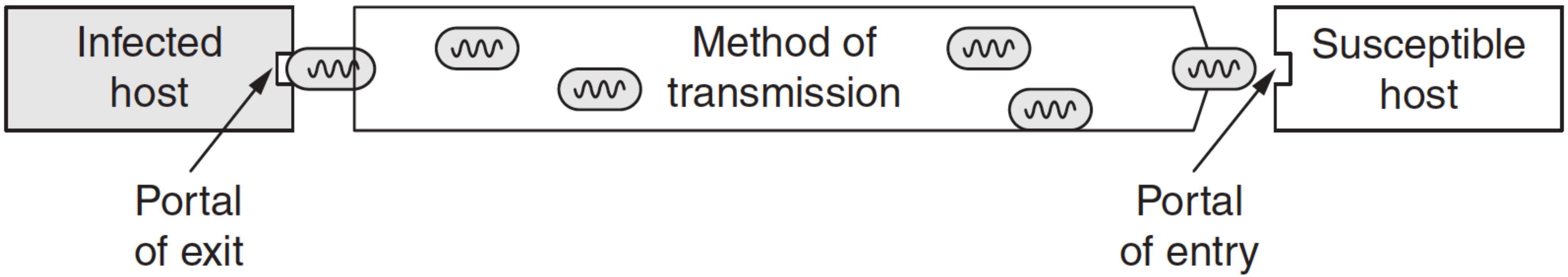
# Transmission, Spread and Maintenance of Infection

- To understand how disease patterns are created, we must understand how disease agents (organisms) move around in the population – from animal to animal, farm to farm, etc.

- We also need to know how agents can persist in a population and not be easily detected.

# Transmission and spread

- The chain of infection is the series of mechanisms by which an infectious agent passes from an infected to a susceptible host.
- To move around in a population, a disease agent must escape from infected hosts and find new susceptible hosts.




Chain of infection for infectious disease agents

# Transmission and spread

- These terms have related meanings and are often used synonymously.

- Transmission refers to the movement of infection from an infected animal to a susceptible animal within an infected population.
- Spread refers to the movement of infection from an infected population or subpopulation to a susceptible population or subpopulation.

# Methods of transmission and spread

- The most fundamental level of interest is transmission from animal to animal.
- However, within a particular farm there may be interest in methods of spread from one management group to another.
- At a higher level, the interest will be in methods of spread from farm to farm.
- Finally, quarantine authorities are interested in mechanisms of spread from country to country.

# Methods of transmission for infectious diseases

| | | |
|---|---|---|
| Direct transmission or spread | | |
| Horizontal transmission | Direct contact | |
| | Contact with discharges (vomitus, faeces, etc.) | |
| | Cannibalism | |
| Vertical transmission | Transmission through egg or sperm | |
| Indirect transmission or spread | | |
| Airborne transmission | Droplet nuclei (~<5 μm) | |
| | Dust (~>5 μm) | |
| Vector | Mechanical vector | Arthropods, birds, or other animal or aquatic species |
| | Biological vector | |
| Vehicle transmission | Fomites | Vehicles, personnel, equipment |
| | Animal products | |

# Maintenance of infection

- A pathogen must be able to survive in host animals and the external environment or vectors and reservoirs.
- Within the host, defense mechanisms will either eventually terminate the infection or the host will die.
- However, infection can persist and the host will appear relatively normal (known as carriers).
- A carrier is an animal that is capable of transmitting infection but shows no clinical signs. A carrier can be incubatory, convalescent or chronic.
- Carriers are very important in the maintenance of infectious diseases in populations

# Disease reservoirs

- Some agents can infect more than one host species. Thus, persistence of infection is facilitated by the presence of a range of host species of varying susceptibility to disease.
- An animal is said to be a reservoir host when it is the host species in which the disease agent normally lives and persists in a population and from which it can spill over to other species of hosts and cause disease.

# Example

- Hendra and Nipah viruses are both viruses that occur commonly in fruit bats with little if any disease in bats but may cause severe disease when they infect other species such as humans (Hendra and Nipah), horses ( (Hendra) and pigs (Nipah).
- Fruit bats are therefore a reservoir host for these viruses for other species.

# Disease reservoirs

- A reservoir is any animal, plant or environment or combination of these in which an infectious agent normally lives and multiplies and upon which it depends as a species for survival in nature. A disease reservoir can be a source of infection.
- An outbreak may occur when circumstances permit effective contact to be made with the reservoir of infection.
- Some pathogens can persist in a population by surviving for long periods of time within vector species.
- In the external environment, pathogens are exposed to variations in temperature, humidity, concentrations of various chemicals (e.g. oxygen, salinity) and sunlight.

# Ecology of Disease

- To investigate disease in populations, we need to understand the relationships among the hosts, agents and environments.
- e.g., Climate
  - geographical distribution of animal species, disease agents and disease vectors
- The study of the relationship among animals, plants and their environment in nature is known as ecology.
- Ecology of disease extends this basic concept to include pathogens (agents of disease).
- Ecology of disease is the relationship among animals, pathogens and their environment in a natural situation without intervention.

# List of factors related to agent, host and environment

| Agent | Host | Environment |
| --- | --- | --- |
| Infectivity | Species | Climate/weather |
| Pathogenicity | Genotype | Water system |
| Virulence | Phenotype | Water quality |
| Immunogenicity | Age | Food |
| Antigenic variation | Sex | Geology |
| Survival | Nutritional status | |
| | Physiological status | |
| | Pathological status | |

# Patterns of Disease by Animal or Other Unit of Study

- The epidemiologist uses methods that document the patterns of disease in populations and by analyzing these patterns, a better understanding of the cause of disease can be obtained.
- Temporal and spatial patterns
- Also extended to the characteristics of the unit of study (animals, herds, farms, etc.).
- Some species, sex or age-class of animal can be more affected by disease than others even though they share a similar environment.

# Examples

| Disease | Pattern |
|---|---|
| Foot and mouth disease | Common in younger than older animals<br>Common in cattle rather than sheep and goats |
| Footrot in sheep | Common and more severe in some breeds |
| Johne’s disease in cattle | Common in dairy than in beef farms |

# Patterns of Disease by Time

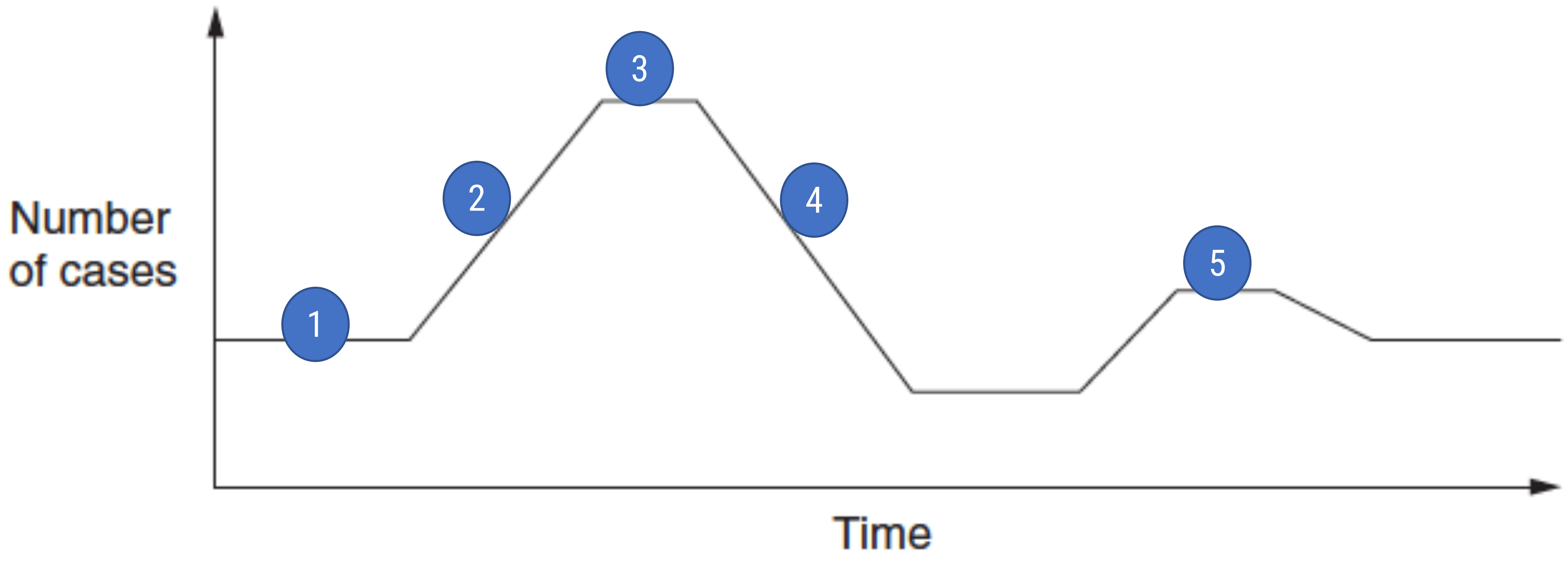
The timing of onset of cases of disease in a population tends to follow one of four patterns:

1. Cases may occur in a **sporadic** fashion
2. Cases may occur regularly at a fairly constant level. The disease is often referred to as being **endemic**.
3. Cases may occur in time clusters, a pattern typical of outbreaks or **epidemics.**
4. If an epidemic takes international proportions and affects a large proportion of the population, it is termed a **pandemic**.

# Epidemic curves

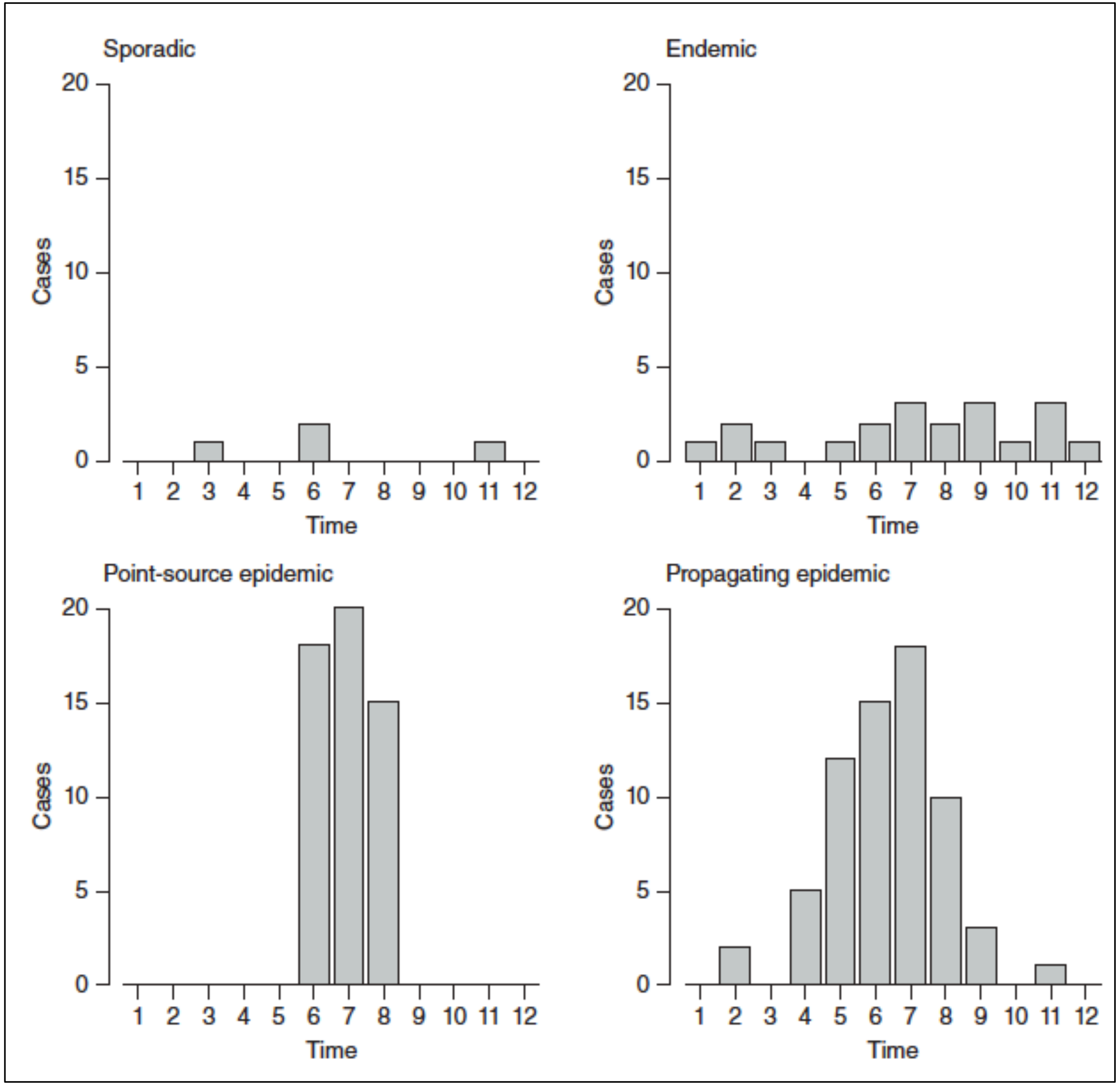
- Summary of the temporal pattern of disease events
- Provides a visual display of the scale or magnitude of the event and the rate at which new cases are occurring.
- Represents in a graphic form the onset of cases of the disease, either as a histogram, a bar graph or a frequency polygon.
- The frequency of new cases (or outbreaks) is plotted on the y-axis over a time scale on the x-axis.
- A typical epidemic curve may be conceived of as having four and occasionally five segments

# Five stages of an epidemic curve



# Different types of epidemic curve

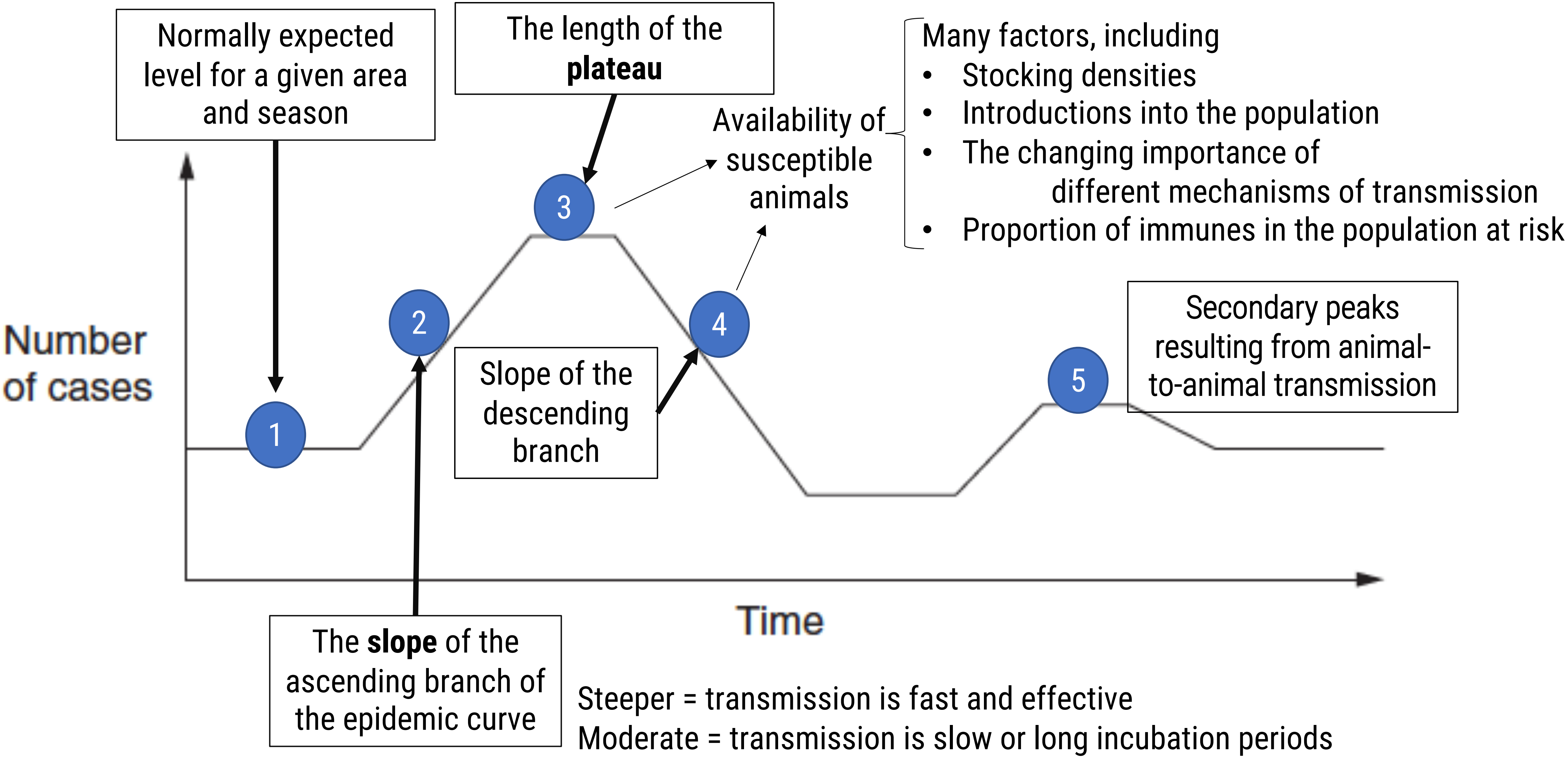
- For sporadic disease, most time periods have no cases, with occasional periods experiencing small numbers of cases.
- For the endemic disease, the number of cases fluctuates between time periods but remains at a fairly stable level.
- For the epidemic disease, the number of cases increases sharply from its initial endemic level and then declines slowly back to that level.


Sporadic
Endemic
Point-source epidemic
Propagating epidemic
Cases
Time
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12

# The shape of the curve

- An epidemic is said to occur when the frequency of cases (or outbreaks) in a population clearly exceeds the normally expected level for a given area and season.

# Five stages of an epidemic curve



# Time interval of the epidemic curve

- Basis of the incubation or latency period and the period over which the cases are distributed.
  *e.g.*, hours in acute intoxications to months in infectious agents with a long incubation period.
- Caution: Overly long intervals obscure subtle differences in temporal patterns, including secondary peaks resulting from animal-to-animal transmission.
- Rule of thumb: use interval between one-eighth and one-quarter as long as the estimated incubation period. Also plot several epidemic curves based on different graphing intervals and then select the one that best portrays the data.

# Drivers for the duration of an epidemic

- ✓The number of susceptible animals exposed to a source of infection that become infected
- ✓The period of time over which susceptible animals are exposed to the source
- ✓The minimum and maximum incubation periods of the disease
- ✓The level of contact between infected and susceptible animals.

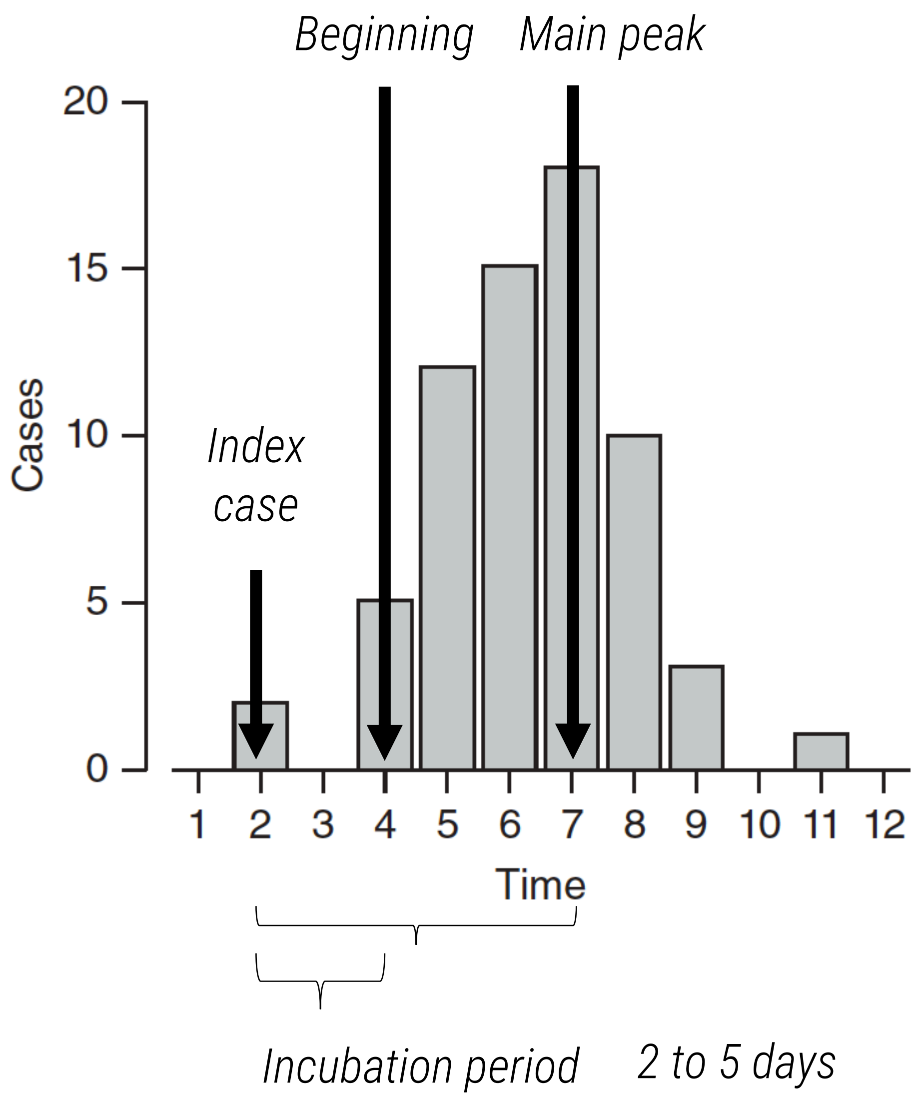
# Example

Outbreaks involving a large number of cases, with opportunity for exposure limited to a day or less, of a disease having a maximum incubation period of a few days or less, usually have an epidemic curve which approximates a ‘*normal*’ distribution.

Such epidemic curves usually indicate a common source origin with exposure over a short period relative to the maximum incubation period of the disease.

# Main and secondary peaks and index case

- Secondary peaks due to:
  - Introduction of susceptible animals into the previously epidemic area
  - Movement of infected animals from the epidemic area and contact with susceptible animals



# Why do epidemics occur?
*(some reasons)*

- Recent introduction of the agent into a susceptible population.
- Recent introduction of a susceptible group of animals into an infected area.
- Recent increase in virulence or amount of the agent.
- Change in the mode of transmission of the agent.
- Change in host susceptibility or response to the agent.
- Factors causing increased host exposure or involving new portals of entry

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# Epidemiology Session
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