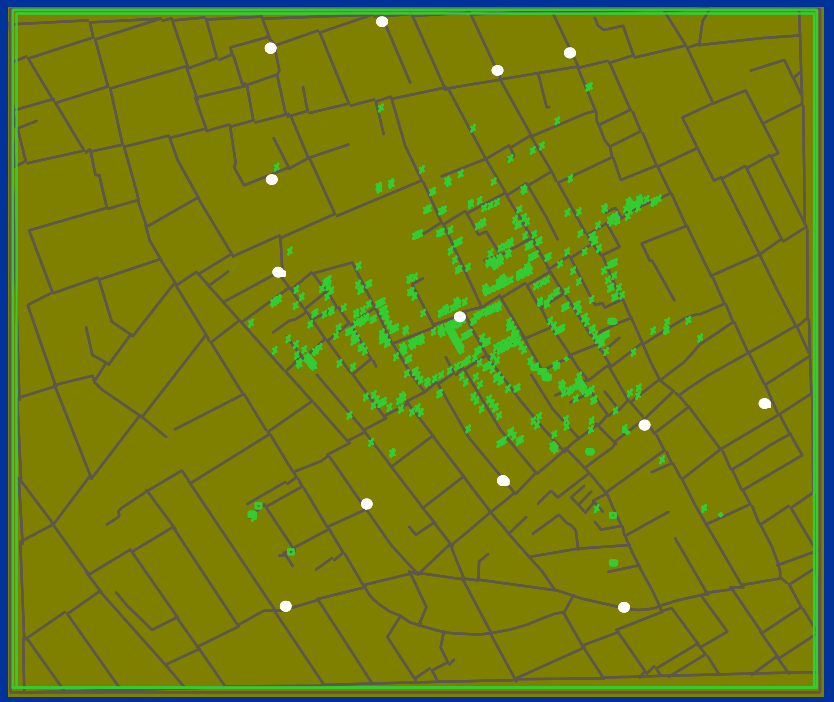
٢. Basic Concepts of Disease in Populations

Basic epidemiological concepts

- Disease is not random
- Disease the result of complex interaction of many factors
- ‘Agent’ is one of many factors



Epidemiological perspective
Web of Causation

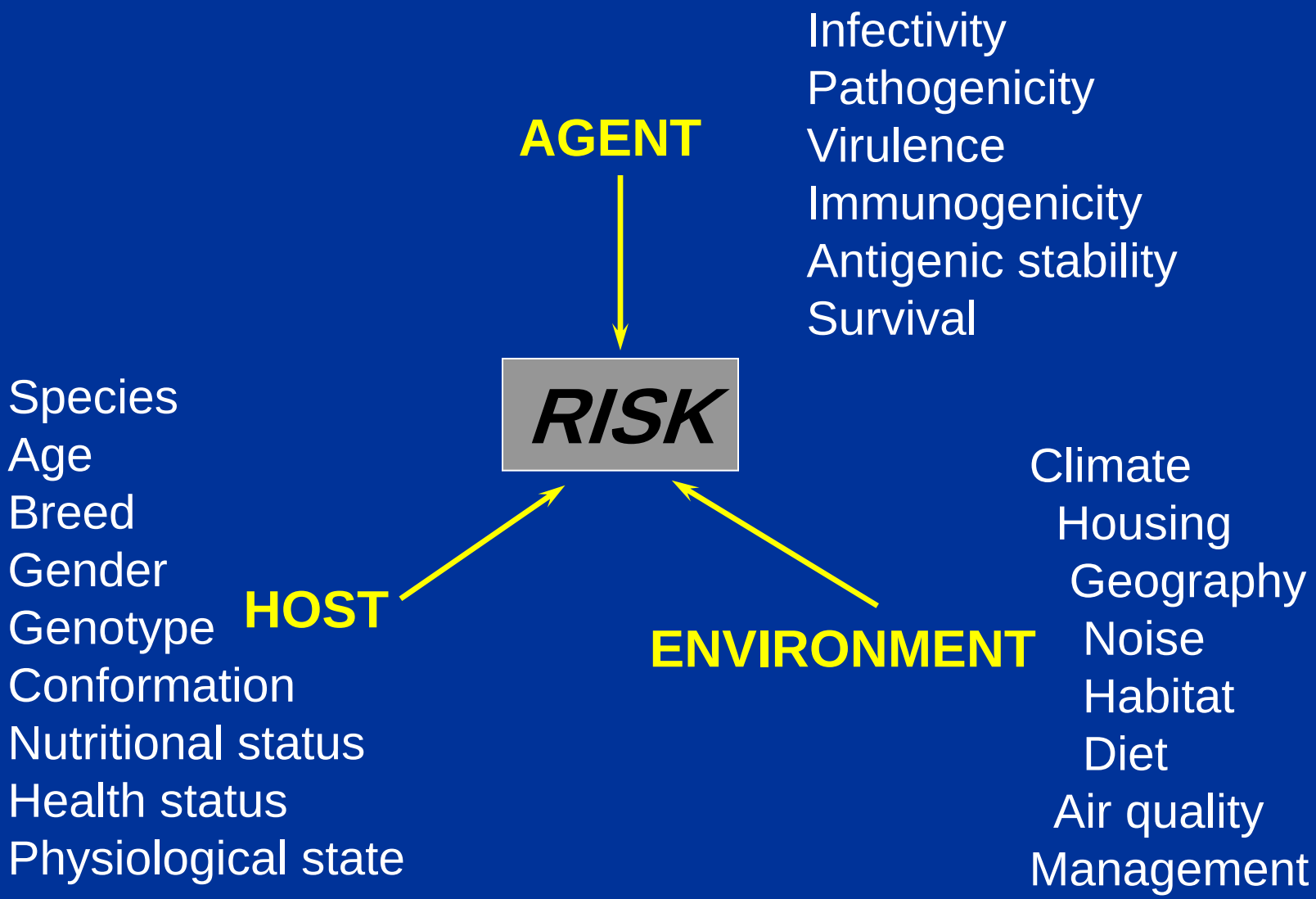
- Presence or absence of disease depends on factors other than the presence of the ‘agent’
- Disease occurrence determined by complex web of interacting factors involving
  - agent
  - host
  - environment
- Multifactorial aetiology

Multifactorial nature of disease

- **What causes sunburn?**
- **Risk factors for sunburn:**
  - **Species (Mad dogs vs. Englishmen)**
  - **Genotype**
  - **Season**
  - **Time of day**
  - **Behaviour**
  - **Location**
  - **Previous exposure**

Epidemiological Triangle

Determinants of disease



Changing patterns of disease

- Decline in importance of infectious diseases in Western countries over the last century
- Change in age distribution
- Intensification of food production and trade
- Refrigeration
- Nutrition
- Global warming and vector-borne agents (e.g. malaria, Rift Valley fever, West Nile virus)
- Destruction of habitat - old agents/new niches.

Changing patterns of mortality in USA

Rank	1900	1990
1	Pneumonia	Heart Disease
2	Tuberculosis	Cancer
3	Enteritis	Accidents
4	Heart disease	COPD
5	Nephritis	Pneumonia
6	Accidents	Diabetes
7	Cancer	Suicide
8	Senility	Homicide
9	Diptheria	AIDS

‘Agents’ of disease

- Microorganisms and parasites
- Toxins (OP, Pb)
- Deficiencies?
- Genetic diseases?
- Metabolic disorders?

Diseases without ‘agents’

- Deficiencies (scurvy)
- ‘Cardio-vascular disease’
- Genetic diseases (haemophilia)
- Metabolic disorders (obesity, diabetes)
- Some neoplasia (cancers)

What is an ‘agent’

- An organism, substance, or force whose relative presence or absence is necessary for a particular disease process to occur
- Car accidents or child abuse
- vs.
- Infectious organisms

Infectious disease epidemiology

- Transmission - survival strategy for agent
- Risk depends on events in other individuals
- Agent factors
- Host ‘infectiousness’
- Transmission probability
- Contact patterns
- Host susceptibility (immunity, siccel cell anaemia/malaria)

Threats to agent survival

- Availability of susceptible hosts
  - host range and population density
  - population immunity
- Host environment
  - natural resistance (skin, gastric pH)
  - non-specific and specific immunity
  - competition for nutrients (Fe)
- External environment
  - dessication, UV light, temperature and pH

Determinants of agent survival strategy

- Host range
- Survival in environment
- Infectivity
  - ability of an agent to establish itself in host
  - ID_{50} = number of agents required to infect ٥٠% of exposed susceptible animals under controlled conditions
  - highly dependent on host (behaviour, susceptibility)
- Genetic stability

Determinants of agent survival strategy

- Pathogenicity:
  - ability of agent to produce pathogenic changes
- Virulence
  - ability of agent to cause severe disease
  - LD_{50} = quantity of agent required to kill ٥٠% of exposed susceptible animals under controlled conditions

Roles of hosts

- Maintenance host
  - maintains infection within endemic area
- Secondary host
- Amplifier host
  - increases disease risk
  - pigs and Japanese B encephalitis

Roles of hosts

- Incidental (dead-end or accidental) host
  - man and hydatids
- Vector (mechanical or biological)
  - hydatids (dog, ant)
  - malaria (mosquitos)
  - lyme disease (ticks)
  - utensils (fomites)

Exit routes - mouth and nose

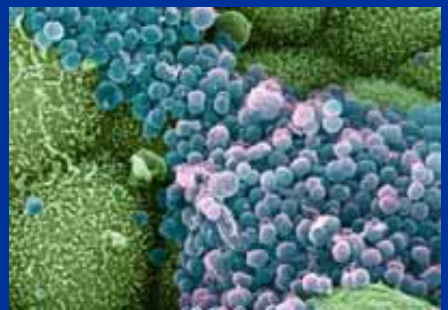
- Saliva on solids and liquids (fomites)
  - Common cold
- Saliva direct to new host
  - Rabies (bite)
  - Close contact
  - Glandular fever
- Excessive nasal/salivary secretion
  - Droplet shower with expiration, cough or sneeze
- Lacrimal

Exit routes - gastrointestinal

- Faeces on solids and liquids (fomites)
  - *Salmonella*, Rotavirus, intestinal parasites
- Aerosolised faeces in dust
  - enteric organisms that resist dessication
  - dust distributed more widely than moist faeces
  - *Toxoplasma gondii*
- Vomitus

Exit routes - urogenital

- Organism established in urinary tract
  - leptospirosis
  - splash droplets
  - meat works
- Semen
- Ova (*Salmonella enteritidis)*
- Venereal
  - organisms often not resilient in environment
  - *Treponema pallidum* (syphilis)
  - Neisseria gonorrhoeae:



Exit routes - skin and hair

- Direct contact - skin and hair
  - Lice, mites
- Skin detritus, scabs
  - Pox viruses
  - Herpes simplex
- Vector-borne transfer
  - Malaria
- Secondary skin contamination (faeces)

Exit routes - products

- Milk - Bovine TB, brucellosis
- Meat/offal
  - life cycle: hydatids
  - contamination: *Salmonella, Campylobacter etc.*
  - food/by-products: prions (BSE/vCJ)
- Cadavers, products of disease processes
  - effusions, discharges from lesions e.g. draining abscesses
  - anthrax, clostridiosis (gaseous oedema)

Exit routes: vertical transmission

- Genotype - retroviruses
- Semen/ovum
- Placenta
- Milk (?)

Transfer routes

- Passive carriage
  - Fortuitous carriage by species that is not necessary for life cycle and is not infected
  - Usually skin or digestive tract
  - Cutaneous anthrax
- Tissue transfer:
  - Blood, body fluid, transplantation, xenotransplantation
  - Inadvertent consquence of deliberate procedure
  - EBL, babesia in vaccines

Transfer routes

- Inanimate objects - equipment
  - bovine mastitis, erysipelas in sheep
  - iatrogenic – injection/blood sampling, skin
  - cars, cloth, slurry
- Plants/feed
  - faecal - oral
  - Intestinal nematodes, *Toxoplasma* oocysts
- Water - *Cryptosporidia, Campylobacter*

Routes of Entry

- Mouth and nose
  - airborne
  - food, water contaminated with agent
- Skin and hair
- Injury to skin or membranes
  - AIDS, rabies leptospirosis

Stages of infection

- Establishment in/on host
- Pathogenesis - lesions in target tissues
- Multiplication of agent
- Final outcome
  - dissemination and exit of agent
  - carrier state (persistence of viable agent)
  - vertical transmission
  - ‘quenching’ without transmission
  - death of host

Relationship with host

- Commensal - gut flora
- Symbiosis – gut flora
- Parasitic - pathogenic
- Commensal at one site, opportunistic pathogen at another
  - E.coli and UTI, S. aureus and mastitis
  - S.suis type ٢ meningitis
- Commensal in one host, pathogen in another
  - E.coli ٠١٥٧:H٧
- Pathogen in primary host(s), but otherwise absent

Establishment - agent factors

- Strain/infectivity
- Pathogenicity/virulence
- Host preference
- Exposure dose and route
- Establishment in/on host
- Agent interactions
  - Synergism (Atrophic rhinitis)
  - Antagonism (cross-protection)

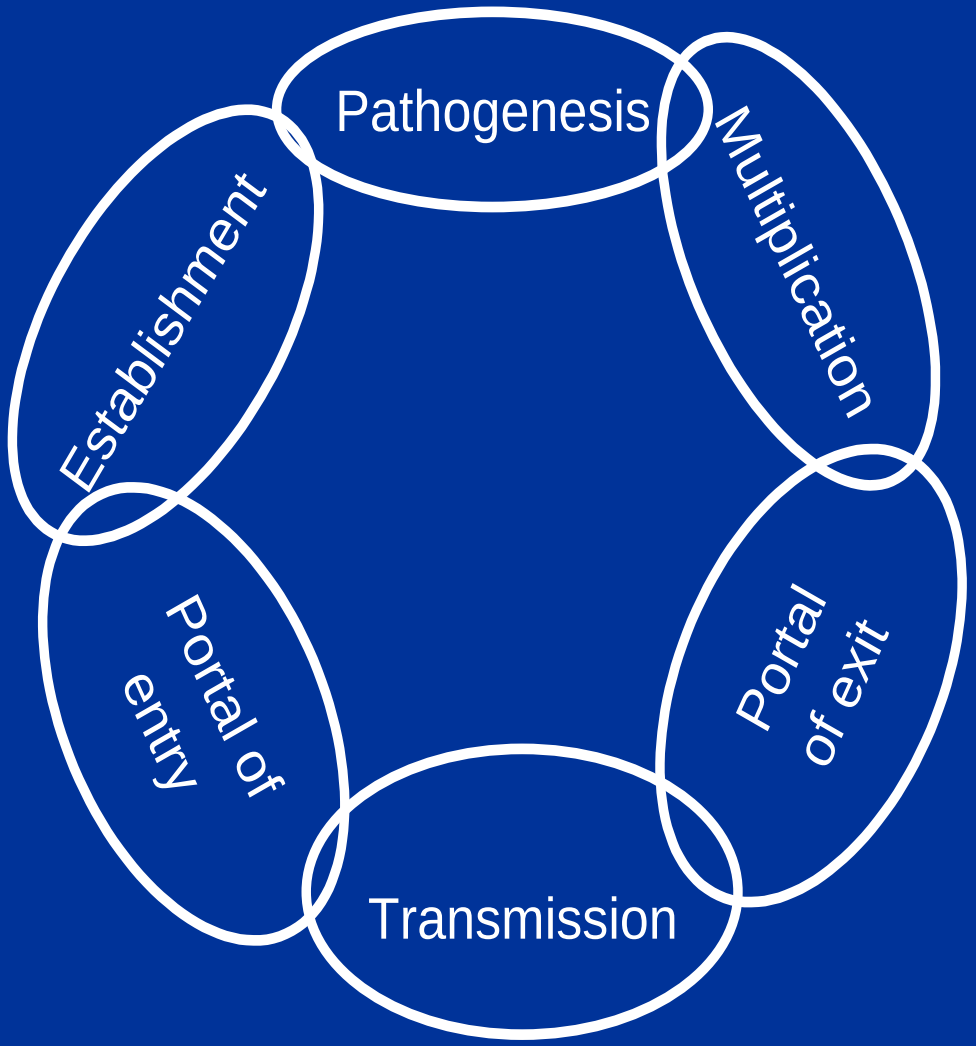
Time course of clinical disease

- *Peracute* - very rapid onset and progress of symptoms (٢٤ - ٤٨ hours)
- *Acute* - rapid onset and progression (days)
- *Sub-acute* - slower
- *Chronic* - slow prolonged course of disease over months or years

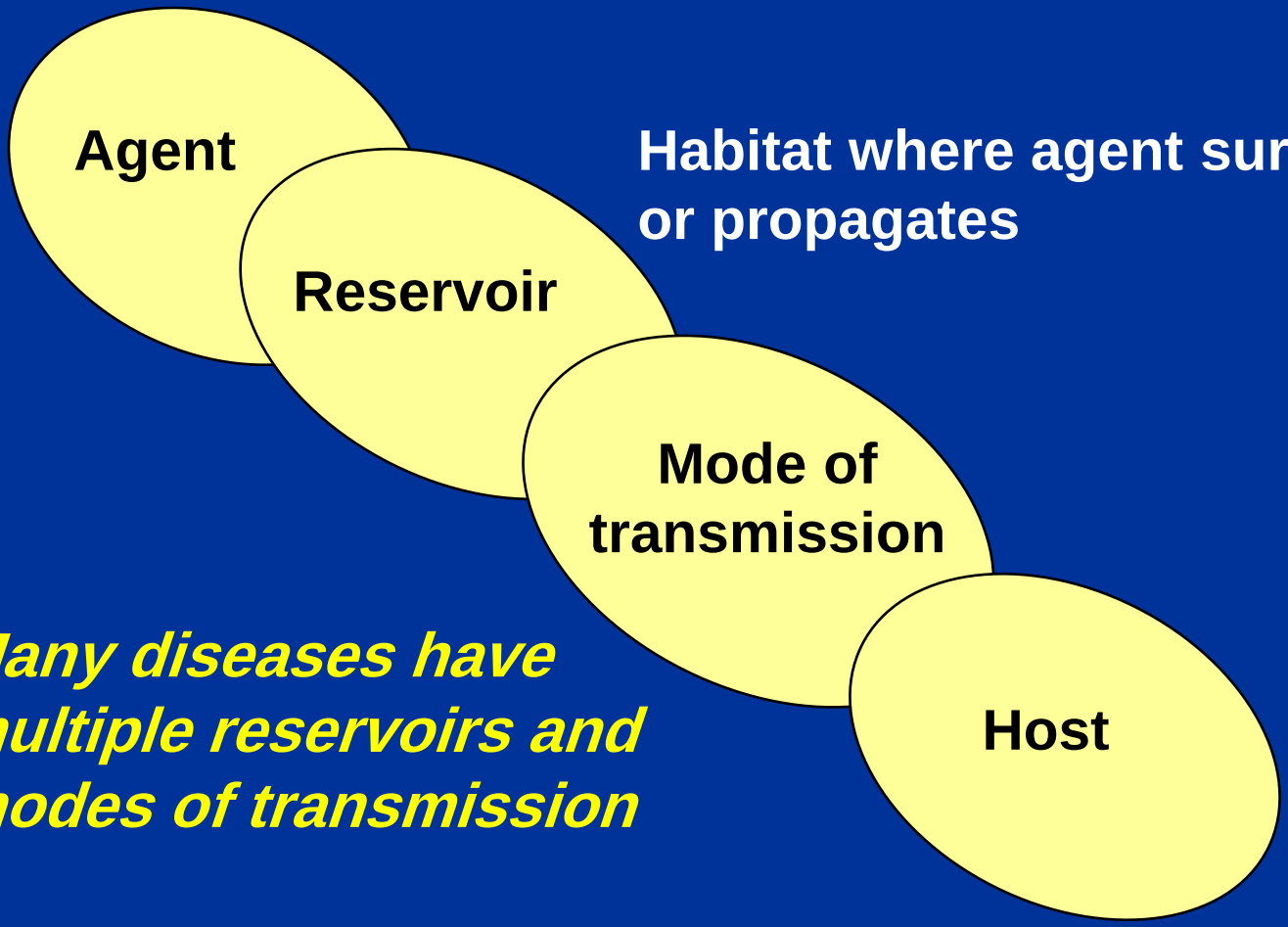
Variability between diseases

Variability within ‘host-agent’ pairs

Chain of infection



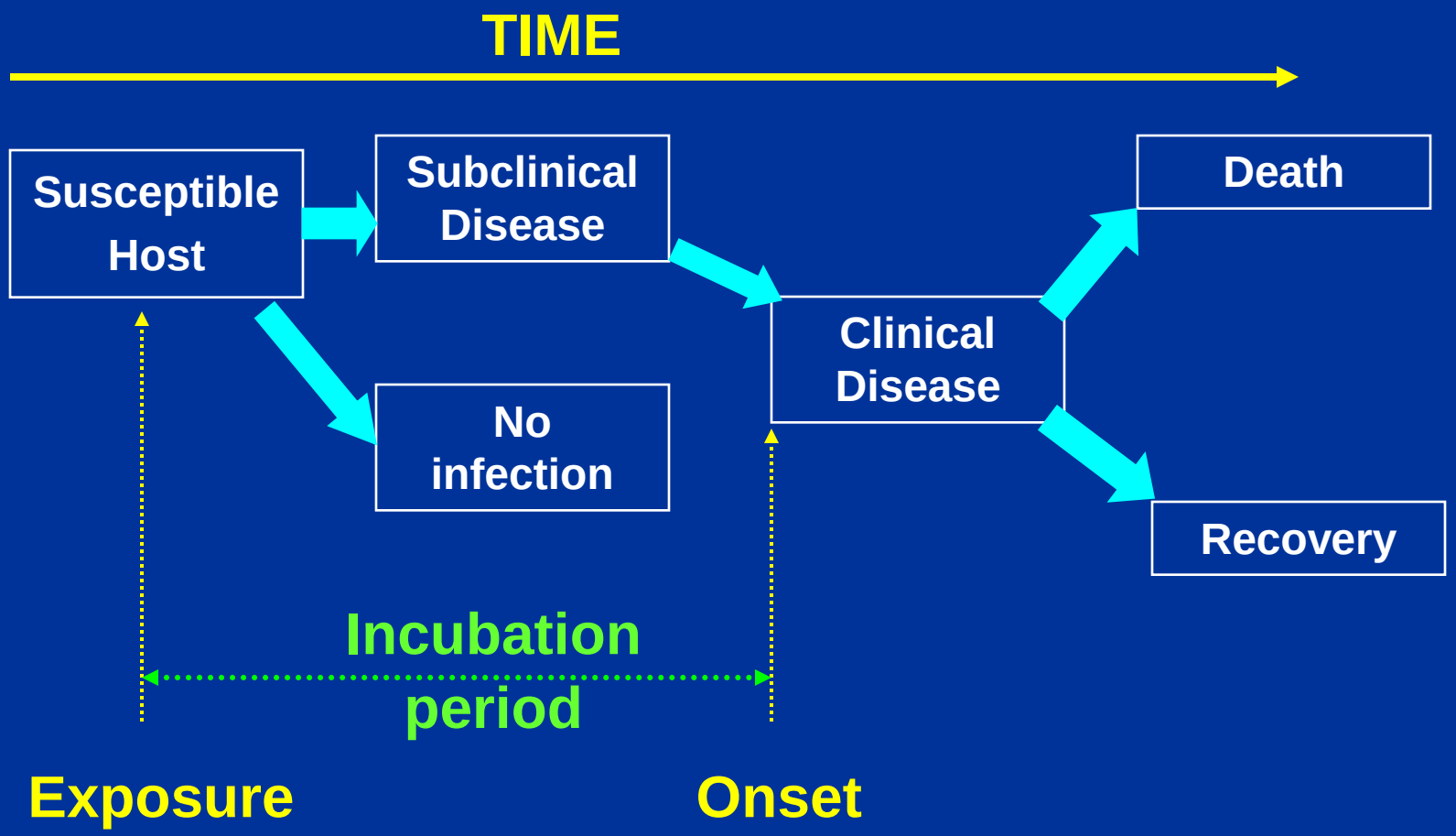
Agent - host relationship



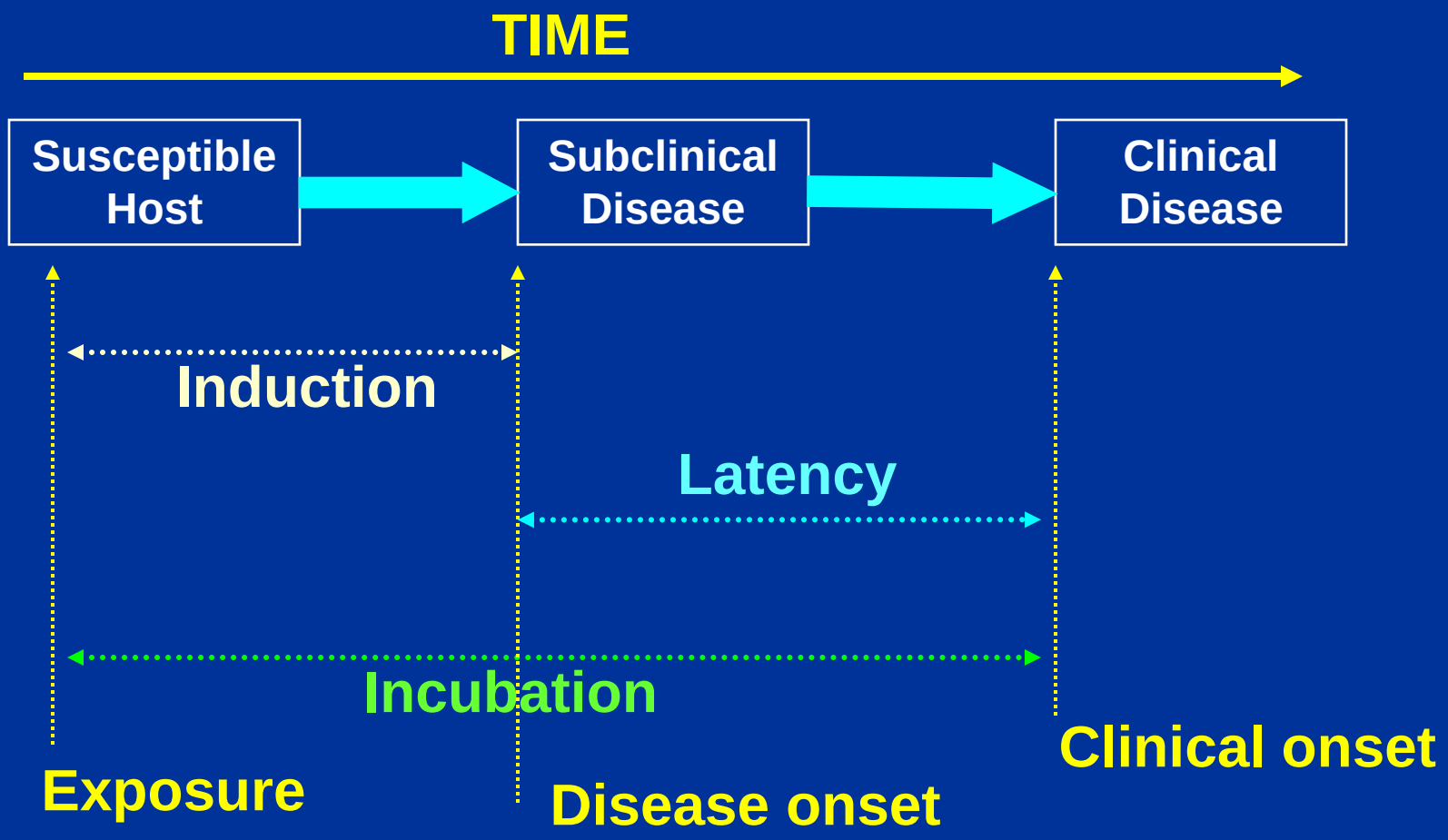
Habitat where agent survives or propagates

Many diseases have multiple reservoirs and modes of transmission

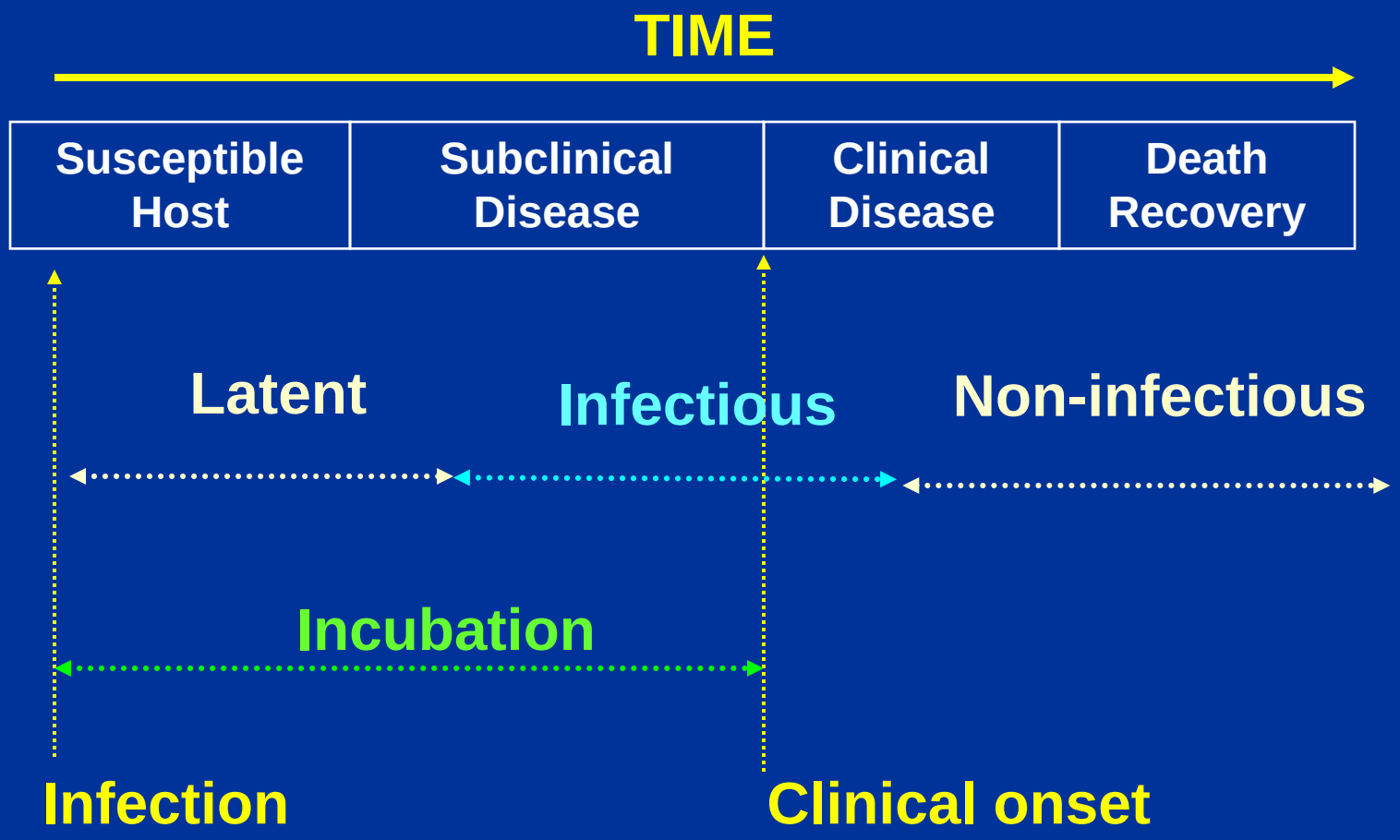
Typical course of infectious disease



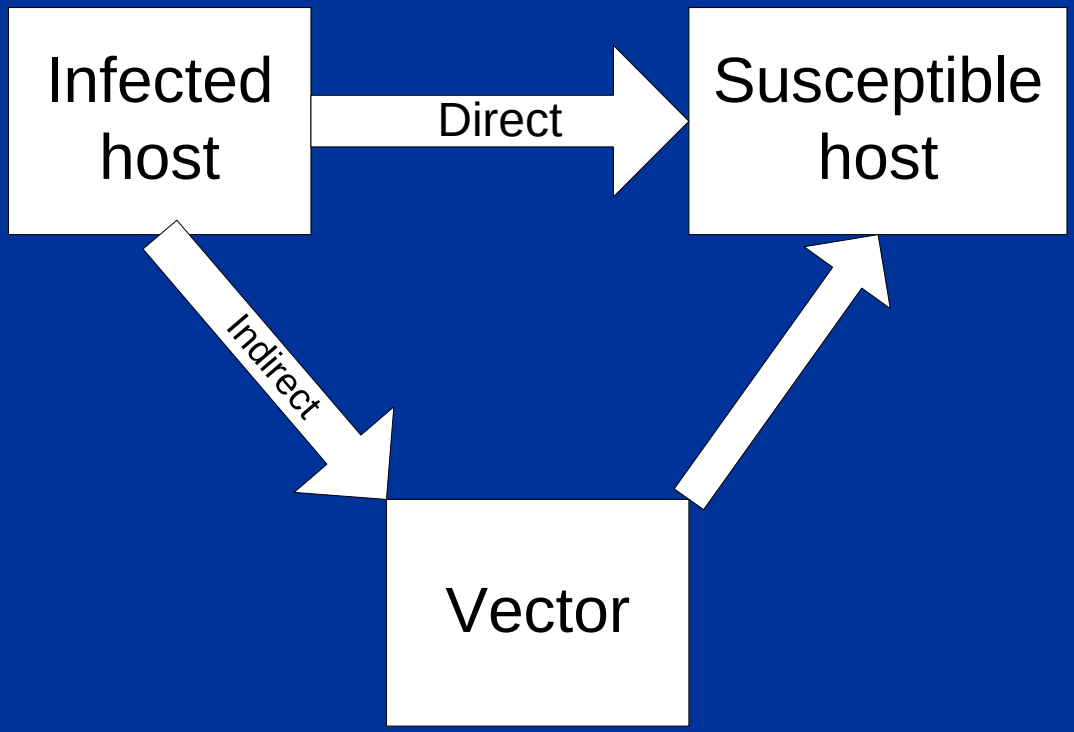
Induction + latency = incubation



Latency and infectiousness



Transmission Mechanisms



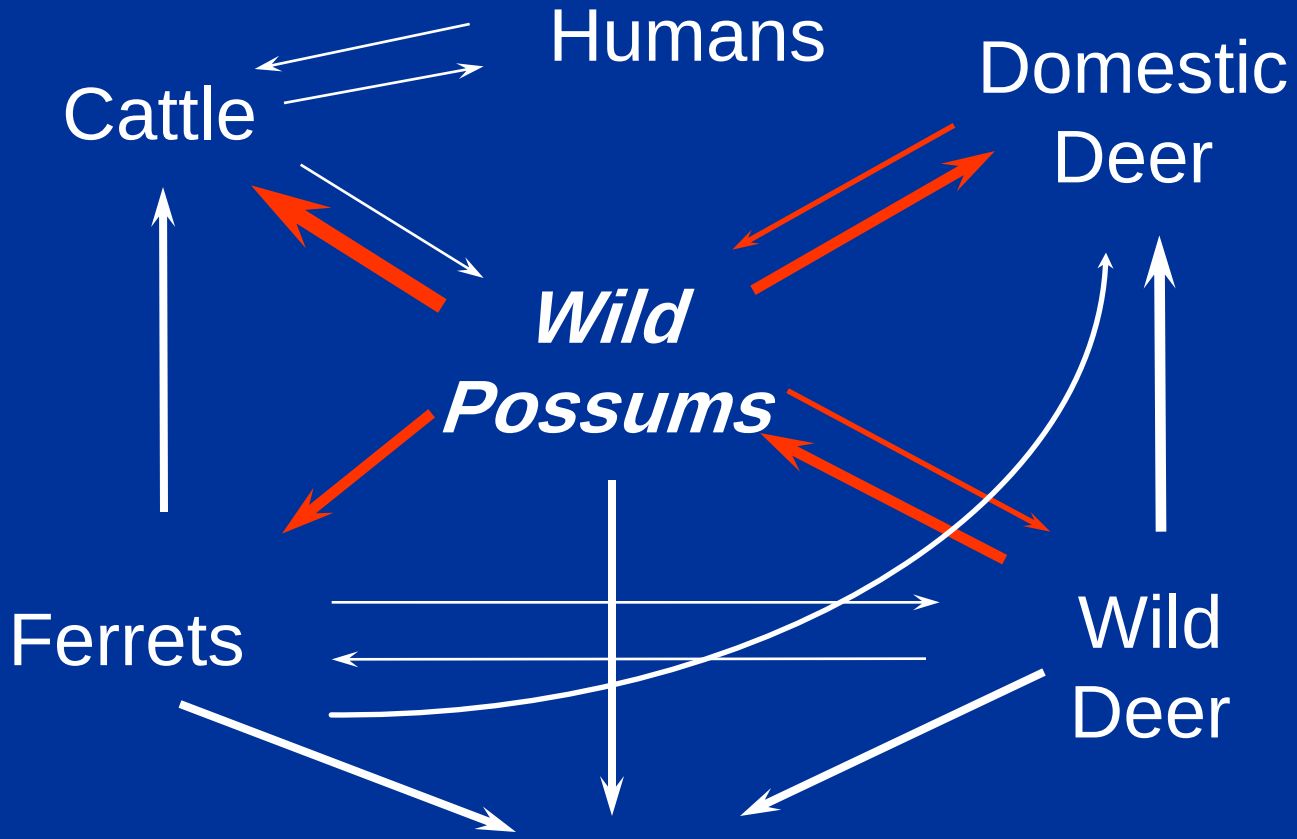
Vertical transmission

- **Through placenta / milk**
- **Infectious and non-infectious**
- **AIDS**
- **Toxoplasmosis**
- **Cocaine addiction**

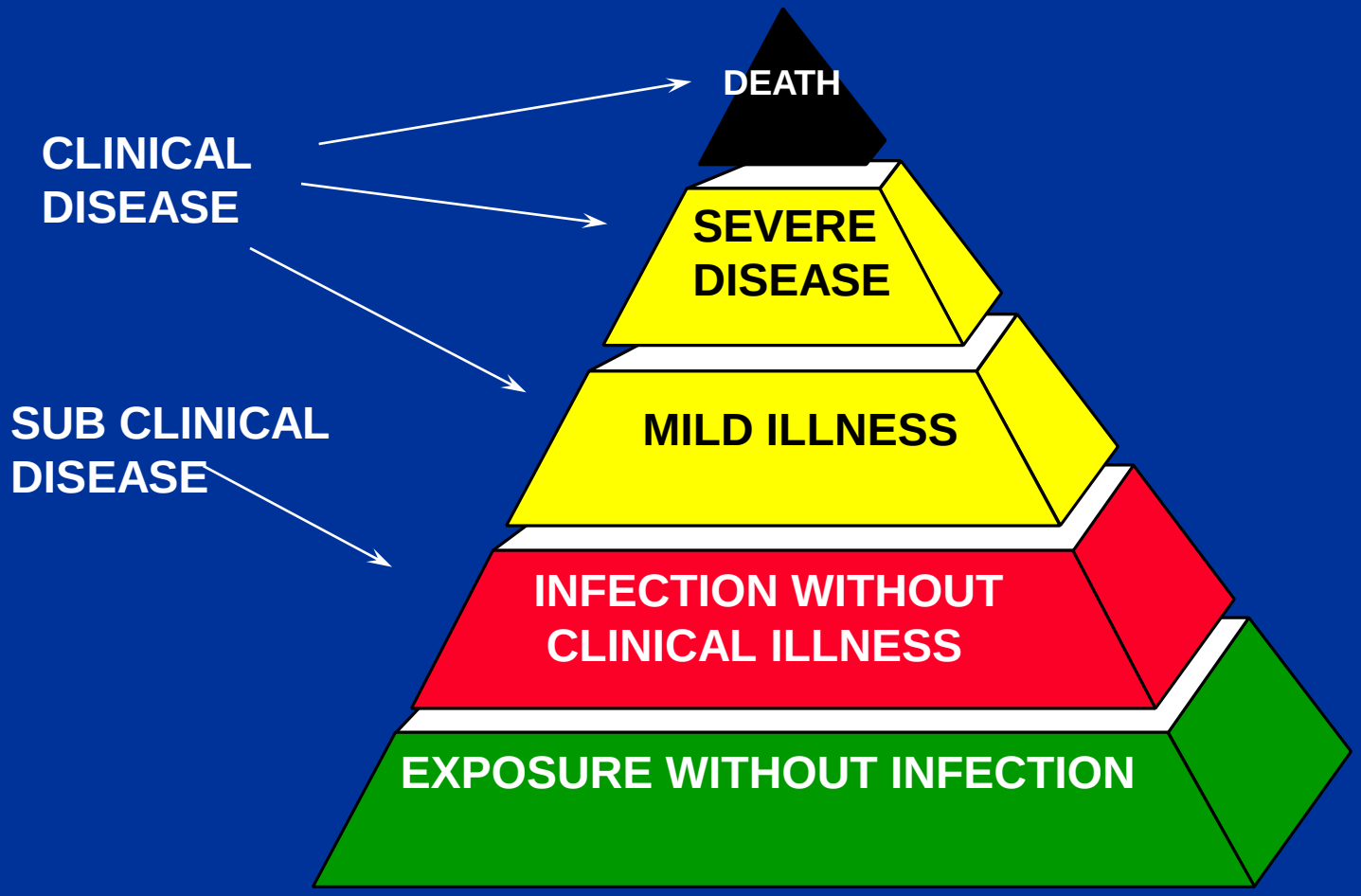
Horizontal transmission

- Direct contact
  - physical contact between susceptible and infected
  - rabies and scabies
  - venereal transmission
- Indirect contact
  - excretions, secretions, exhalations
- Vectors (mechanical, biological)
- ‘Vehicular’
  - food, water, fomites, iatrogenic

Mycobacterium bovis in New Zealand



“Iceberg” concept of infectious disease in populations



Population structure and time

- Population factors influence patterns of disease
  - Age structure
  - Distribution of genotypes
  - Population immunity
  - Population dynamics and migration

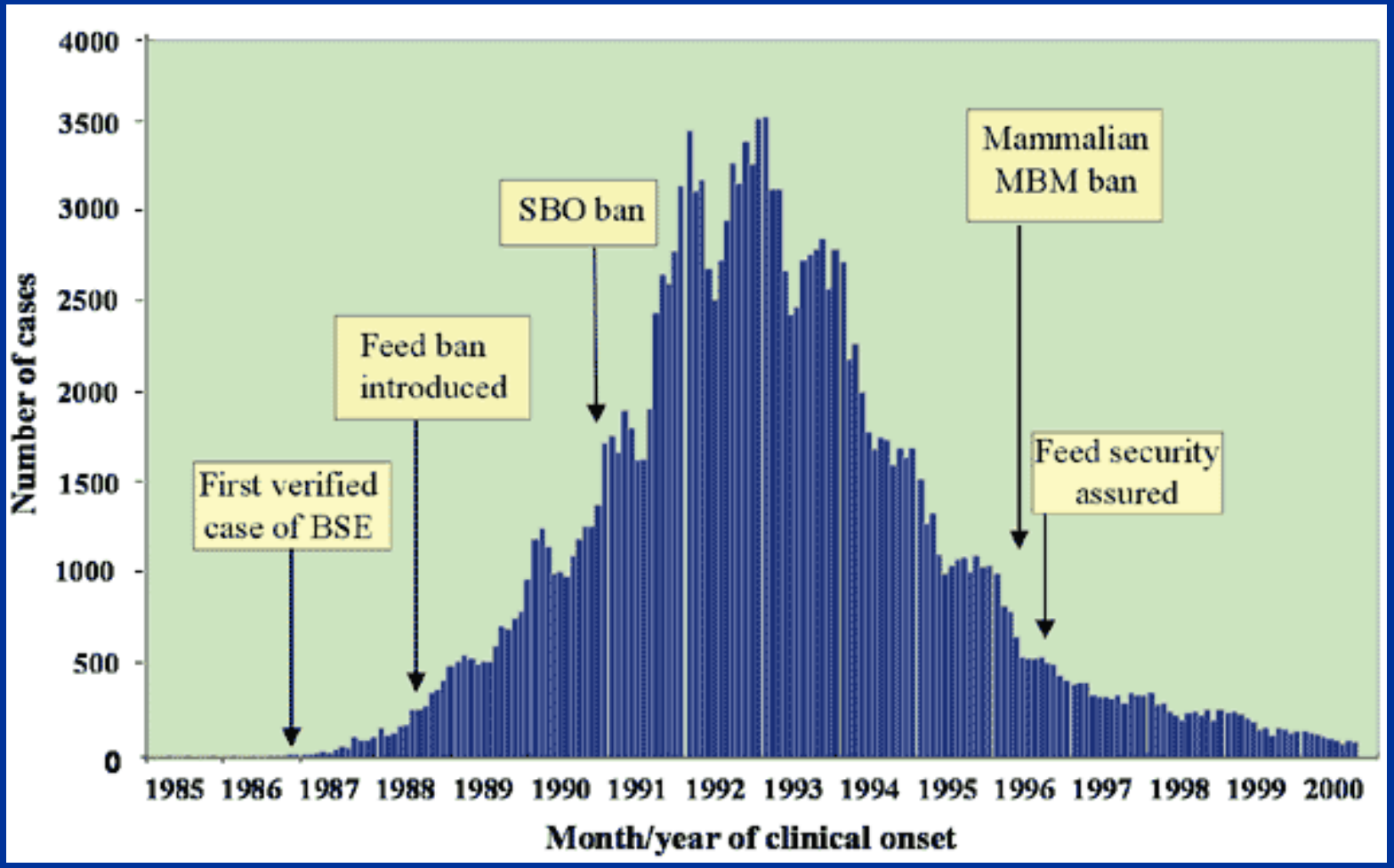
- Temporal relationships between determinants of disease can be important

Temporal patterns of disease in populations

Epidemic Curves

- Describe disease occurrence over time
- Plot as frequency histogram
- y-axis = number of cases in population
- x-axis = time interval
  - hours (food poisoning)
  - days (influenza)
  - months (seasonal diseases)
  - years (AIDS, rabies)

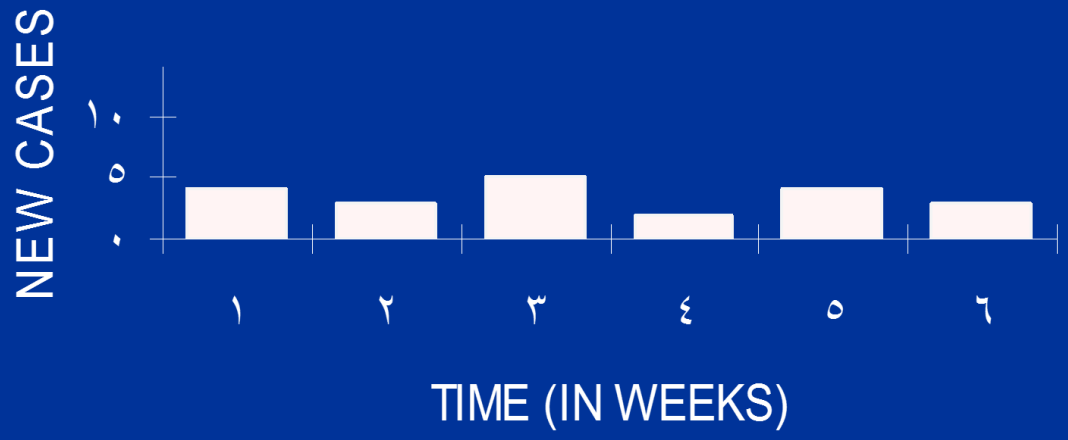
Epidemic curve for BSE in UK



Temporal patterns of disease

- **Endemic**
  - **disease occurs at greater than expected frequency**
- **Epidemic**
  - **disease occurs at greater than expected frequency**
- **Pandemic**
  - **huge epidemic (international)**
- **Sporadic**
  - **single case or cluster of cases**

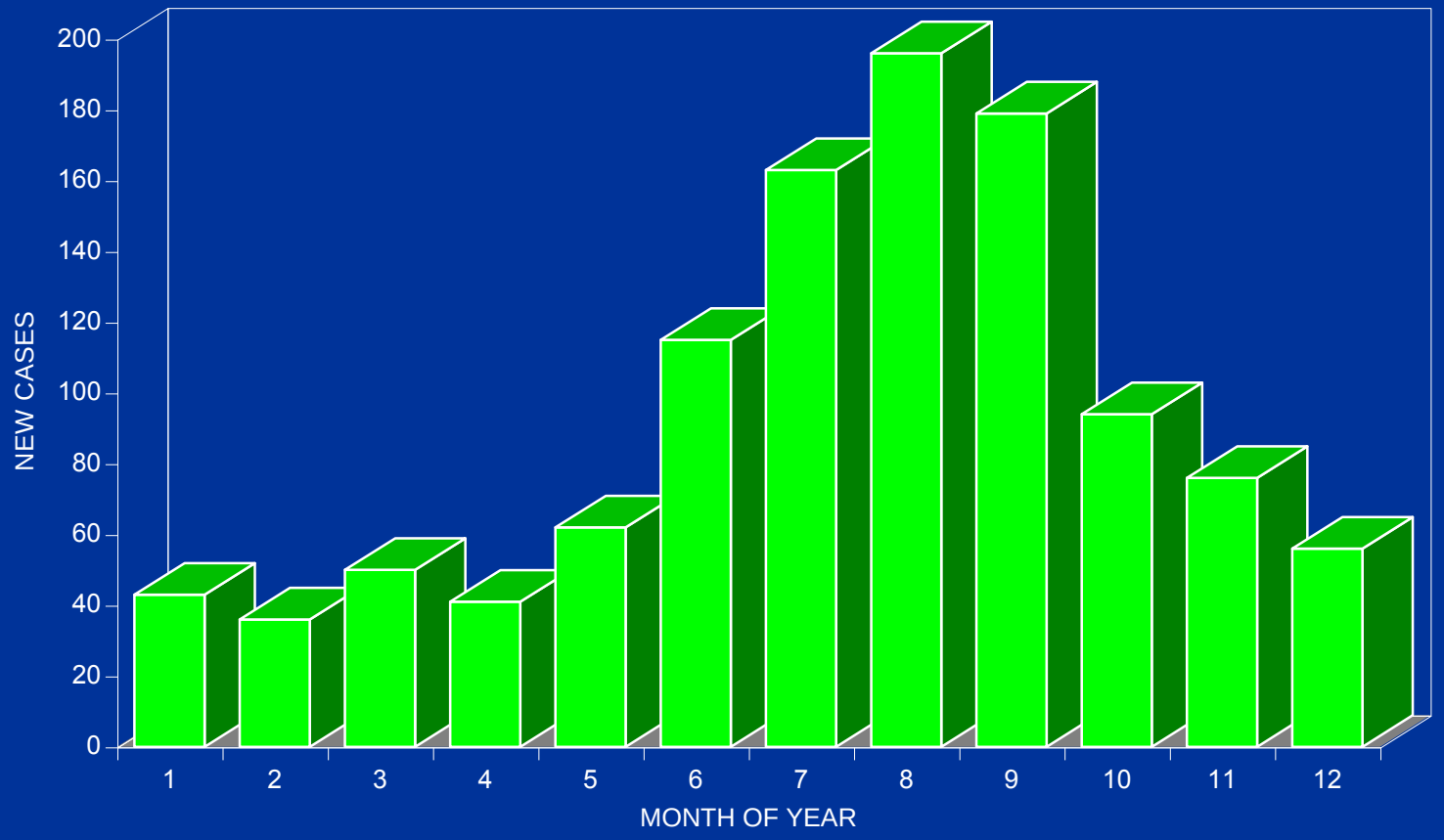
Endemic Disease



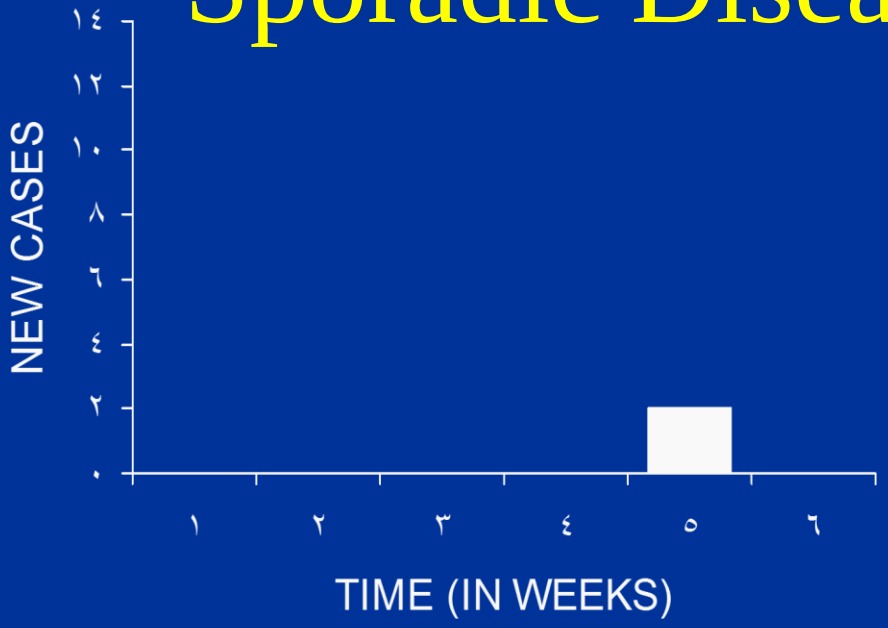
- Disease present in population or region at all times
- Usually low and predictable level
- *Enzootic* used for some animal diseases

Seaonality of disease

Human leptospirosis in U.S.A



Sporadic Disease

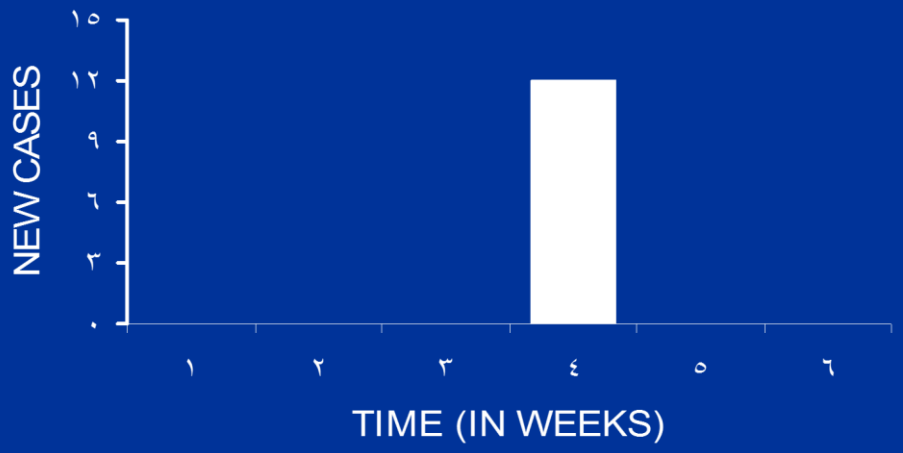


- **Infrequent disease occurrence**
- **Irregular and unpredictable**

Epidemic Disease

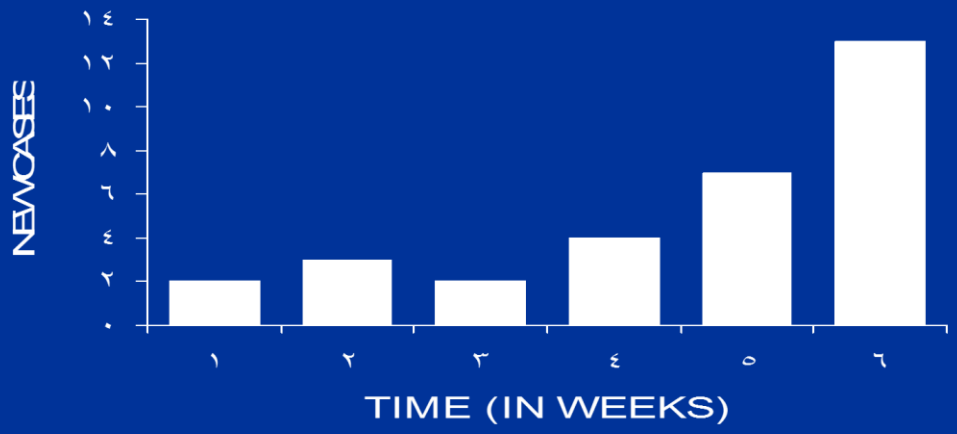
- **Incidence exceeds expected**
- **Usually infectious disease or poisoning**
- **In animals, occasionally referred as *epizootic* disease**
- **Point source or propagated**

Point Epidemic



- **Single common exposure**
- **Does not spread**
- **Foodborne disease outbreaks**

Propagated Epidemic

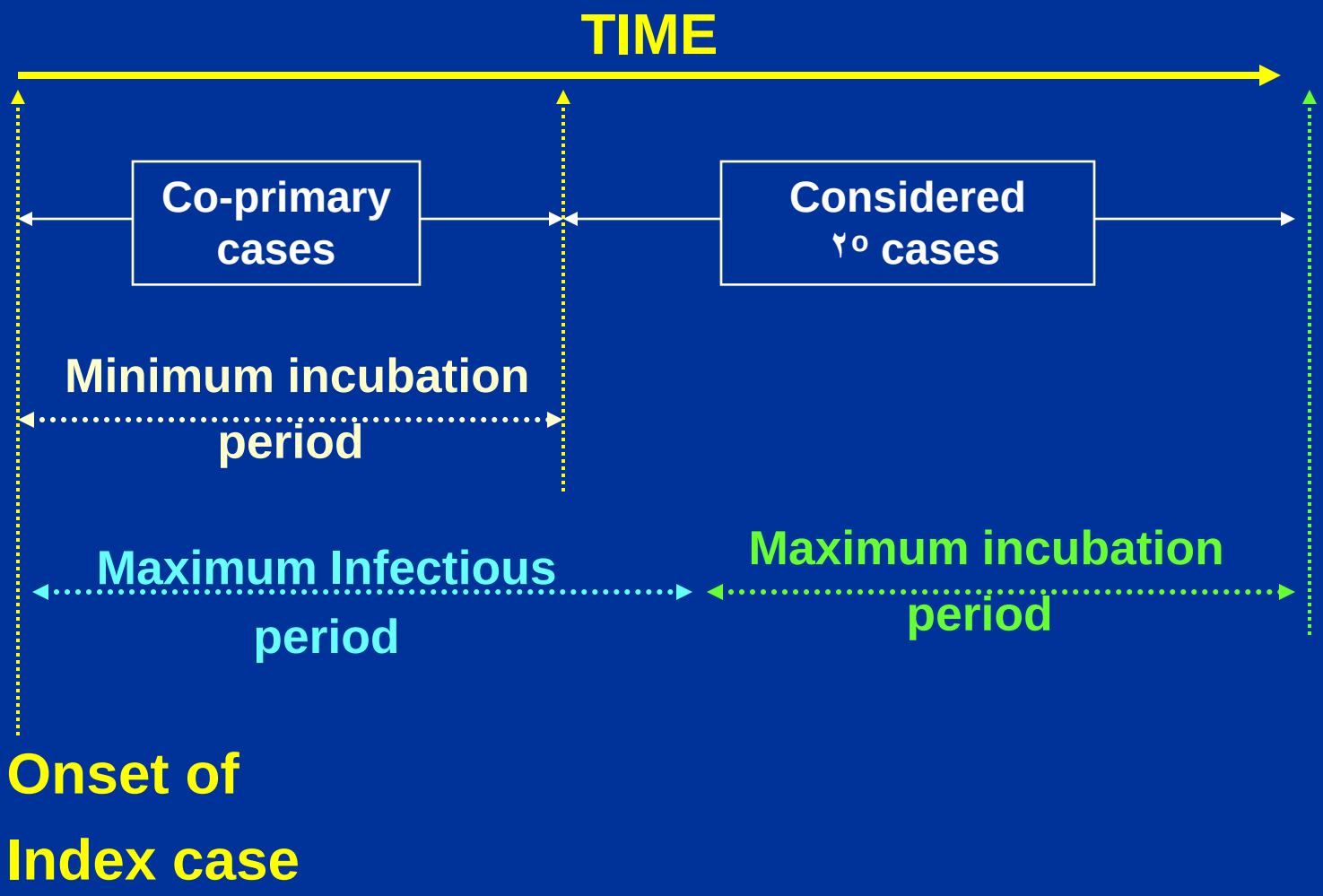


- **Spread between animals**
- **Often involves vectors or carriers**

Propagated Epidemic Curve

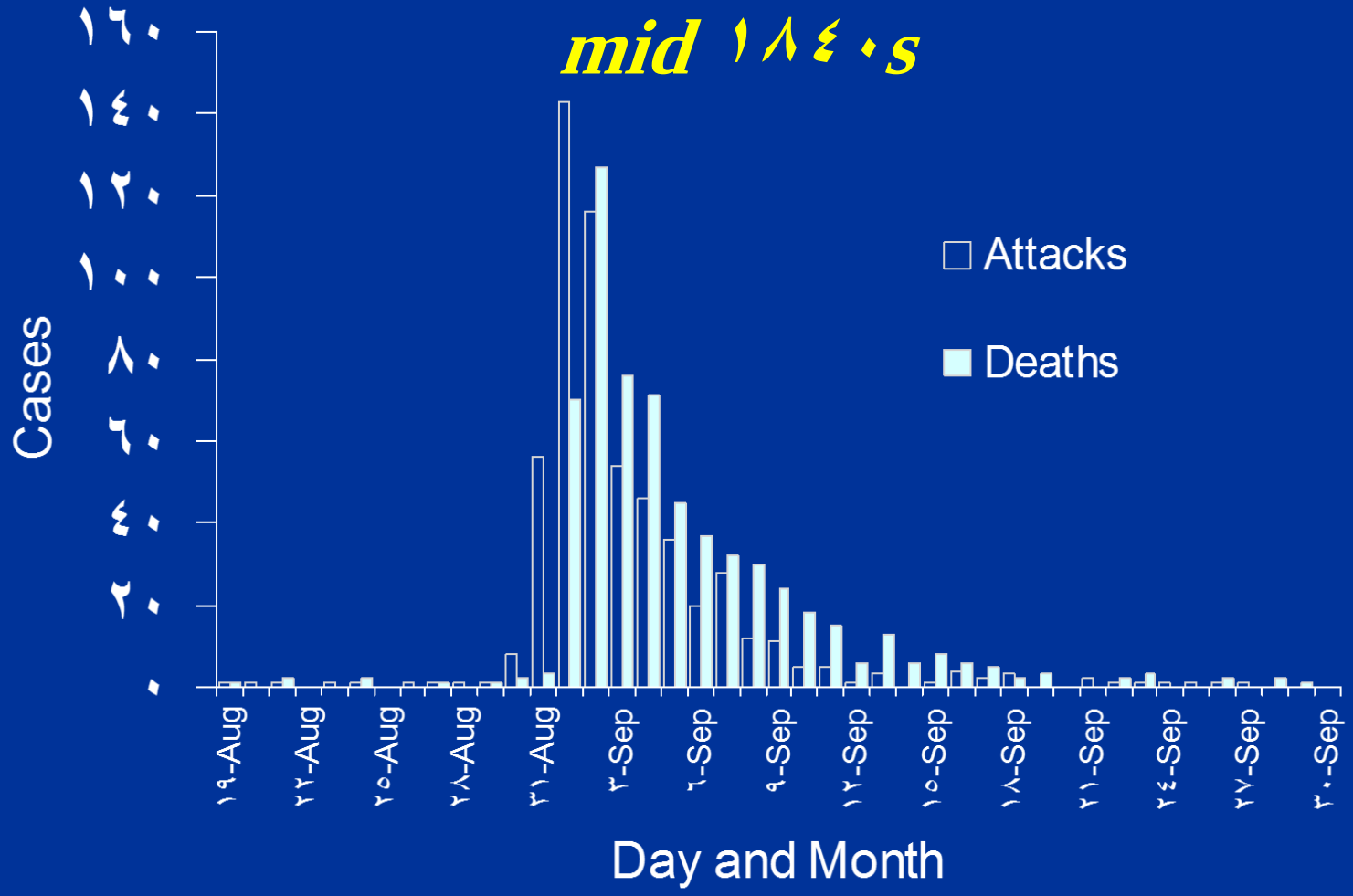
- Shape depends on
  - characteristics of agent (virulence) and host (susceptibility)
  - contact rate
  - population density etc...
- Cases may occur over prolonged period of time

Primary and secondary cases

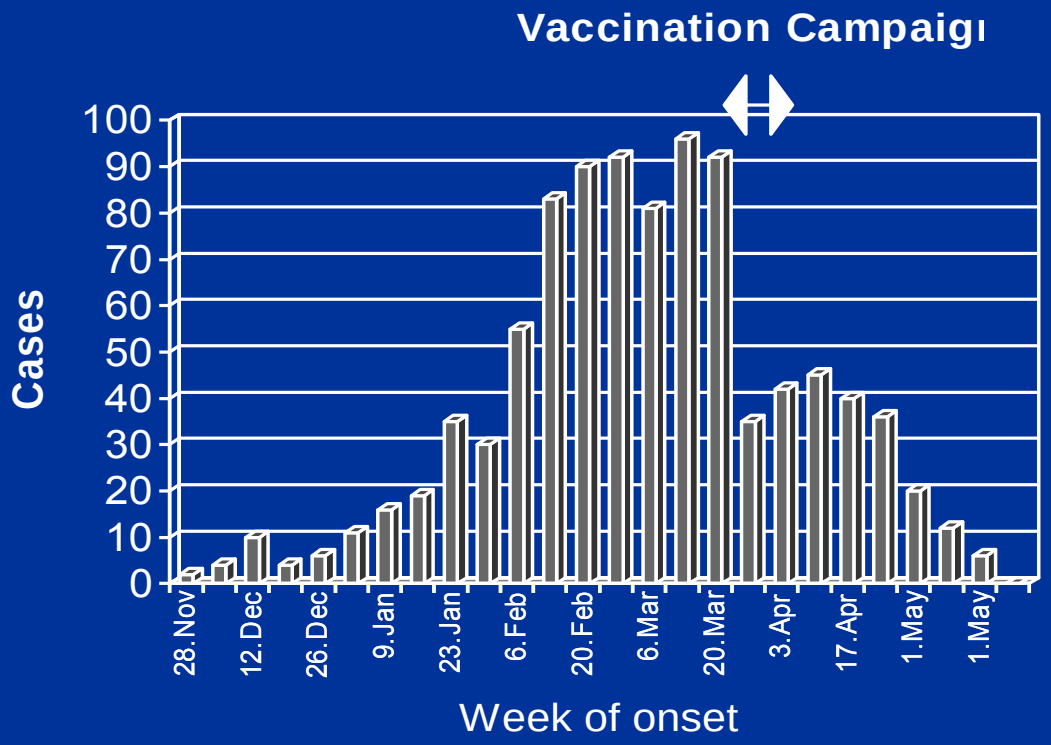


John Snow

Cases and deaths from cholera during Broad St. pump cholera epidemic in mid ١٨٤٠s



Canine Distemper in Texas, ١٩٧١

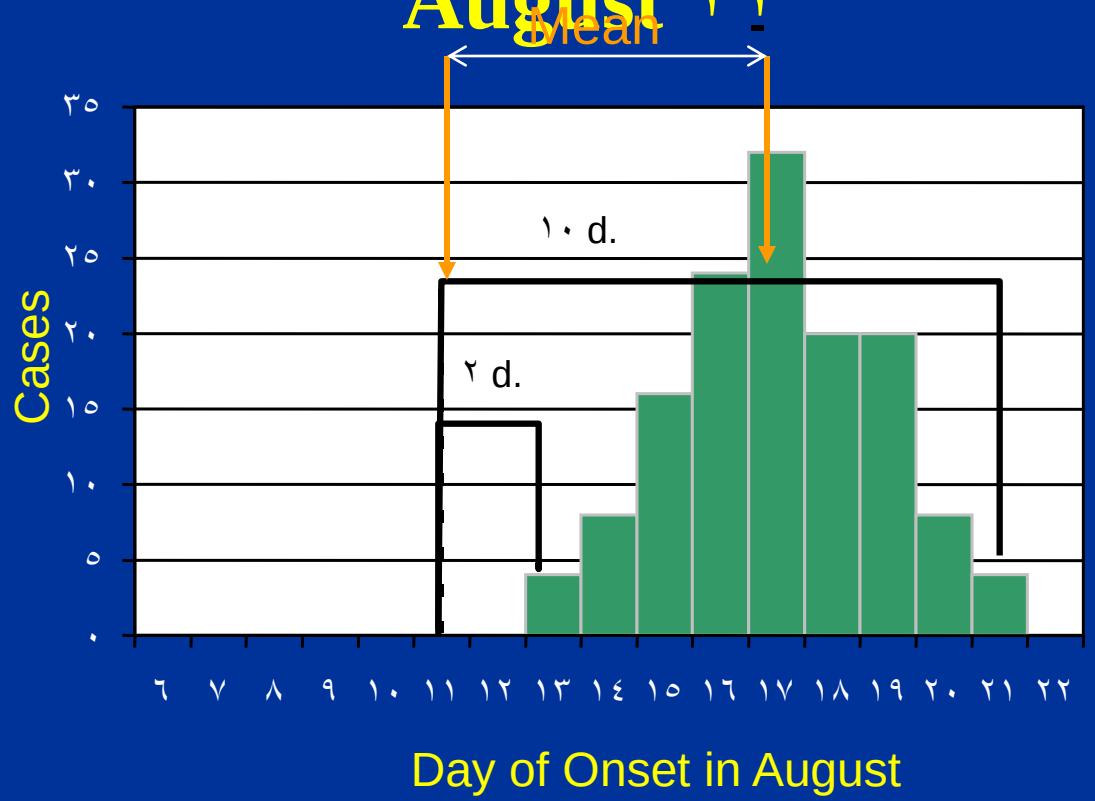


- Abrupt drop in March
- Immunization reduced # of susceptibles

Calculation of incubation period

- **Difficult for propagated epidemics**
  - **need index peak and main peak present**
- **Need to know**
  - **index case**
  - **cause**
  - **time of exposure (knowledge about common exposure helpful)**
- **Assumptions**
  - **presence of clinical signs indicates**

Estimation of incubation period **Known point exposure on August ١١**



IP: ٢ - ١٠ days; average ٦ days

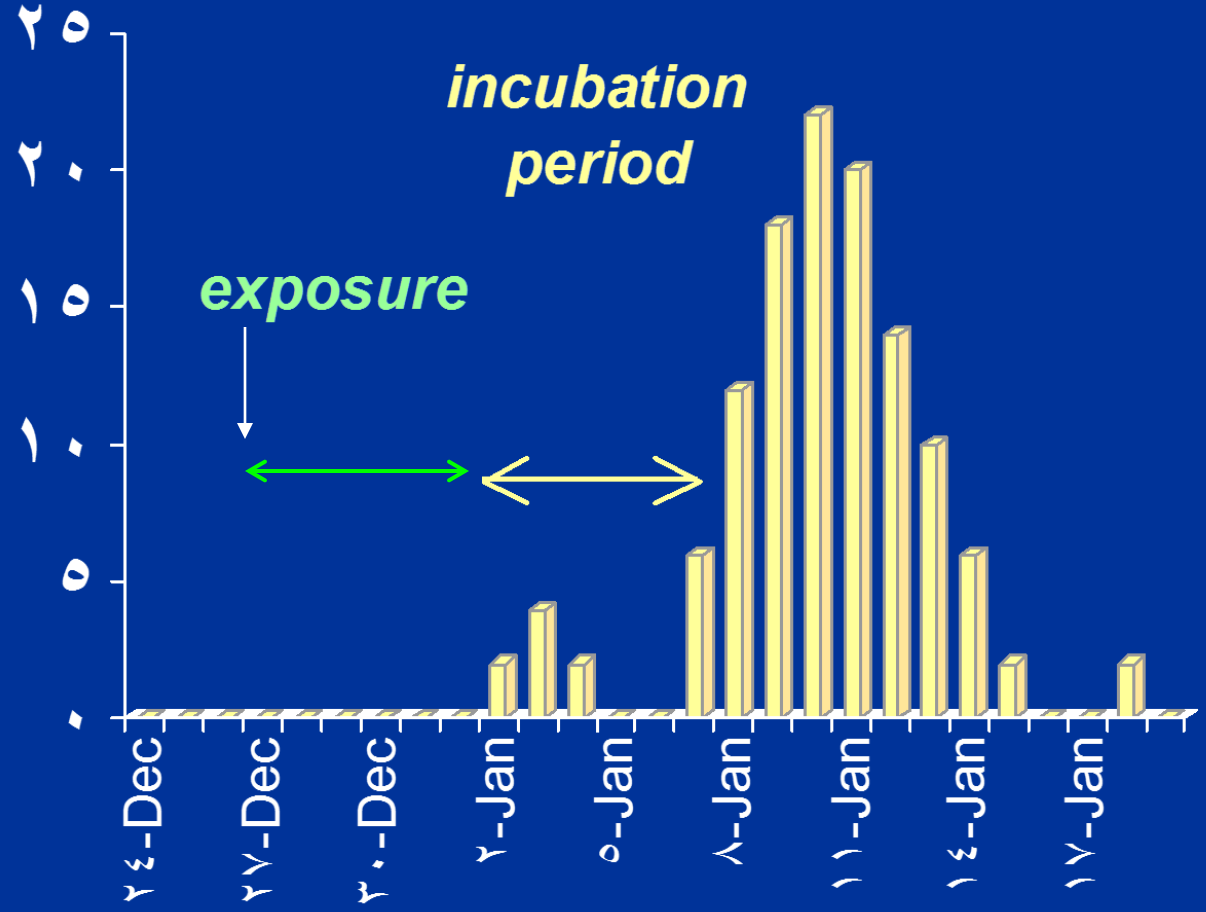
Estimation of exposure time

Propagated Epidemic

- **Cause of disease unknown**
- **Estimate exposure period from incubation period**
  - **interval from *index case* to *first case in main peak***
  - **Count back in time from index caseto estimate probable period of exposure**

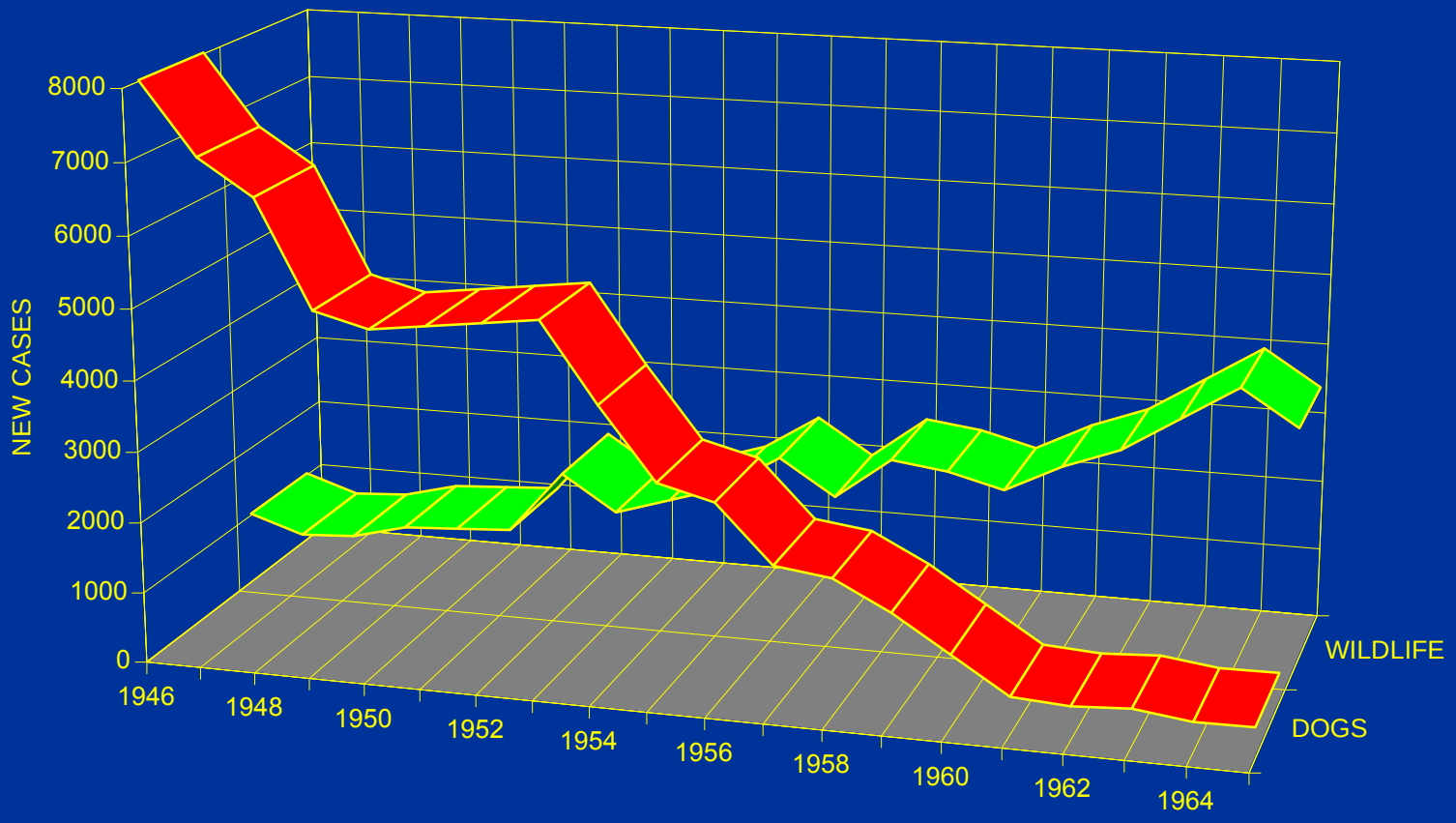
Estimation of exposure time

Propagated epidemic



Long term patterns of disease

Rabies in USA



Summary

- Simple description of disease occurrence is the first step in epidemiological investigations
- Temporal patterns
- Spatial patterns