Chapter 3

Dynamics of Disease Transmission

Human disease does not arise in a vacuum. It results from an interaction of the host (a person), the agent (e.g., a bacterium), and the environment (e.g., polluted air). Although some diseases are largely genetic in origin, virtually all disease results from an interaction of genetic, behavioral, and environmental factors, with the proportions differing for different diseases

- Disease has been classically described as the result of the epidemiologic triad shown in Figure 2.1. According to this diagram, it is the product of an interaction of the human host, an infectious or other type of agent, and the environment that promotes the exposure
- A vector, such as the mosquito or the deer tick, may be involved. For such an interaction to take place,the host must be susceptible.,

- Human susceptibility is determined by a variety of factors including genetic background and behavioral, nutritional, and immunologic characteristics.

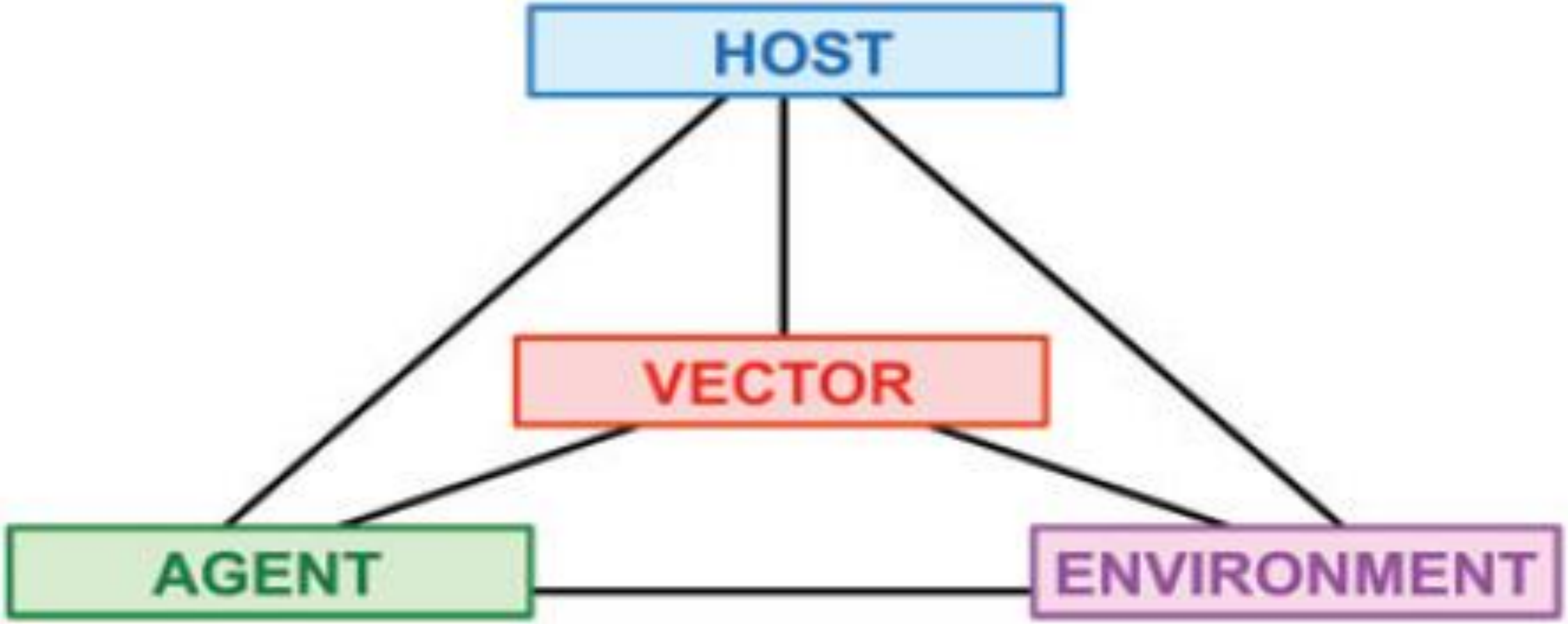
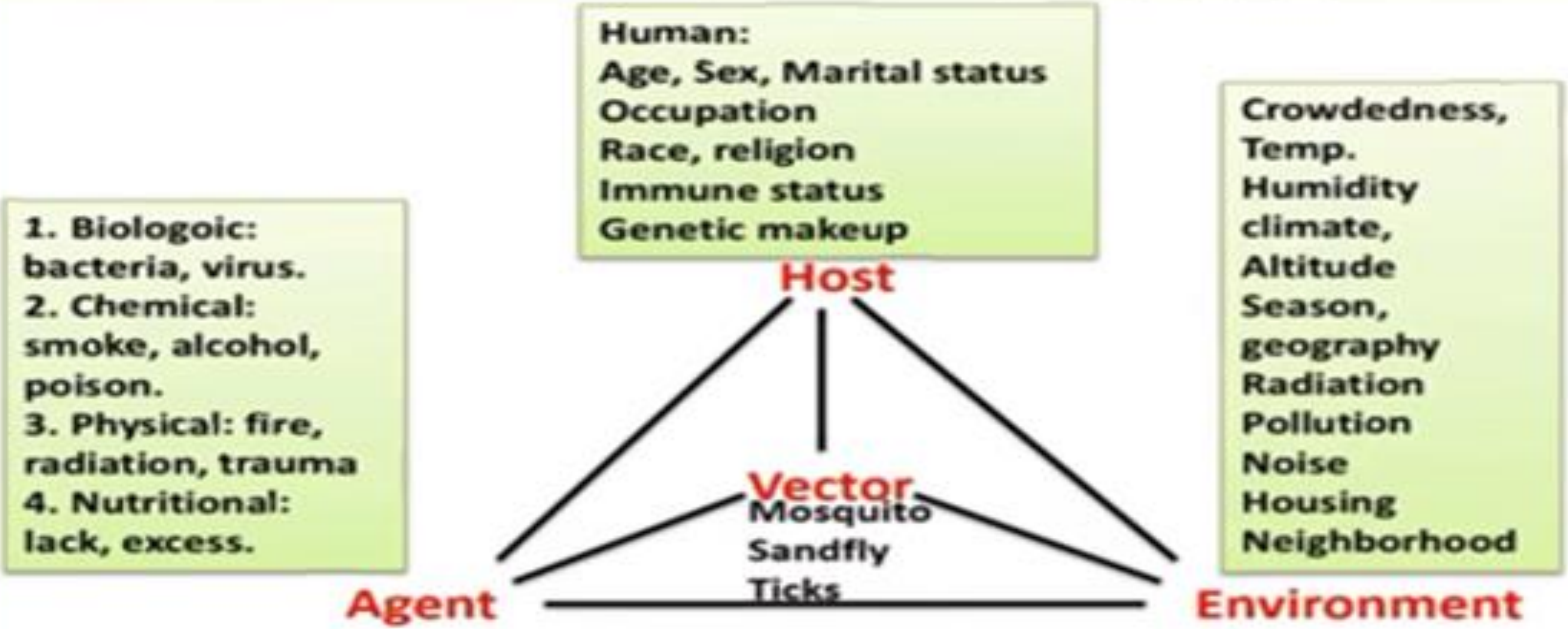


Fig. 2.1 The epidemiologic triad of a disease.

Epidemiologic disease triad: HAE



Disease is an interactions of the four components of the triad

TABLE 2.1 Factors That May Be Associated With Increased Risk of Human Disease

Host Characteristics	Types of Agents and Examples	Environmental Factors
Age	Biologic	Temperature
Sex	Bacteria,	Humidity
Race	viruses	Altitude
Religion	Chemical	Crowding
Customs	Heavy metals,	Housing
Occupation	alcohol,	Neighborhood
Genetic profile	smoke	Water
Marital status	Physical	Milk
Family	Trauma,	Food
background	radiation,	Radiation
Previous	fire	Air pollution
diseases	Nutritional	Noise
Immune status	Lack, excess	

Modes of Transmission

- Diseases can be transmitted *directly* or *indirectly.*
- *For example, a disease can be transmitted from person to person (direct transmission) by means of direct contact (as in the case of sexually transmitted infections).*

➢ Indirect transmission can occur through a common vehicle such as a *contaminated air or water supply* or by a vector such as the mosquito

BOX 2.1 MODES OF DISEASE TRANSMISSION

1. Direct
   a. Person-to-person contact
2. Indirect
   a. Common vehicle
      1) Single exposure
      2) Multiple exposures
      3) Continuous exposure
   b. Vector

Modes of Transmission

1 Direct

1. Person-to-person contact such as TB, Swine flu, STDs

2 Indirect No human-to-human contact

a. **Common vehicle** (single, multiple and continous exposure): contamiated air > 2 meters (TB), contaminated water supply (Cholera) or food (salmonellosis)

b. **Vector**: *Anopheles* for malaria, Sandfly for *Leishmania*, *Aedes Egyptae* for West Nile fever

Mode of transmission

TB, tuberculosis;
HIV, human immunodeficiency;
CMV, cytomegalovirus;
HBV, hepatitis B virus;
TP, tranplacental;
BF, breastfeeding

Mode of transmission

Direct

1. Air-borne: TB, Flu, Aspergellosis.
2. Physical: scabies, leprosy...touch
3. Sexual: HIV, syphilis

Indirect

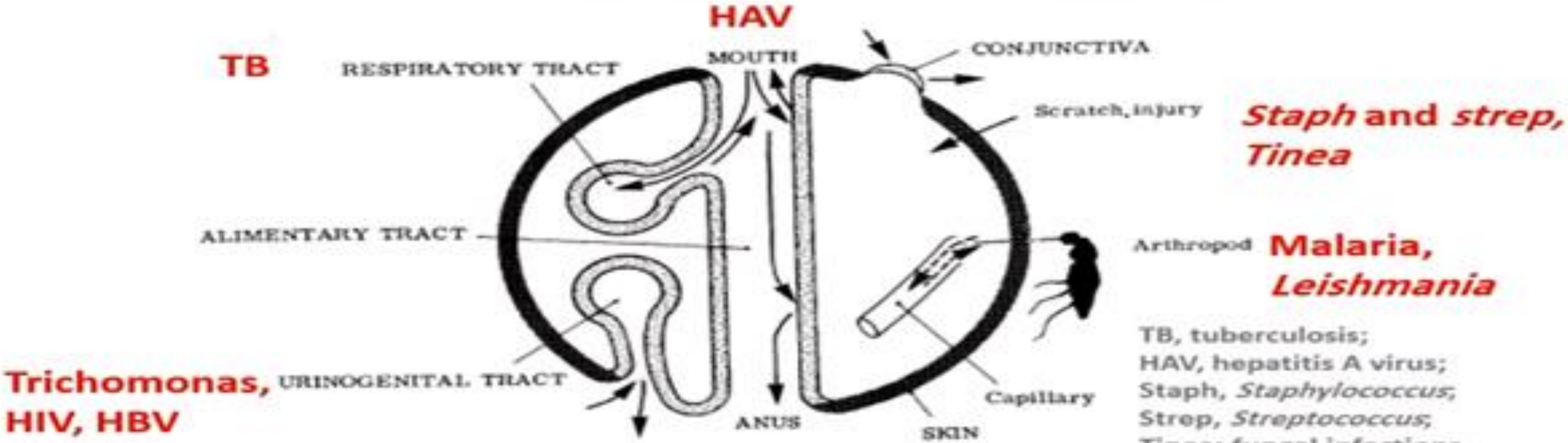
1. Blood: HIV, HBV
2. Oral-fecal (food/water-borne: Cholera, Amebiasis, Typhoid
3. Transcutaneous: bite

Vertical

1. Maternal-fetal (TP/BF): HIV, HBV, Rubella, Syphilis.
2. Congenital (from birth): CMV, leprosy.

Modes of Transmission

Human body sites of infection



TB, tuberculosis;
HAV, hepatitis A virus;
Staph, *Staphylococcus*;
Strep, *Streptococcus*;
Tinea; fungal infections
HIV, human immunodeficiency virus
HBV, hepatitis B virus

Same agent can be acquired through more than one route

Non-infectious (toxins) can also enter through these routes

Clinical and Subclinical Disease

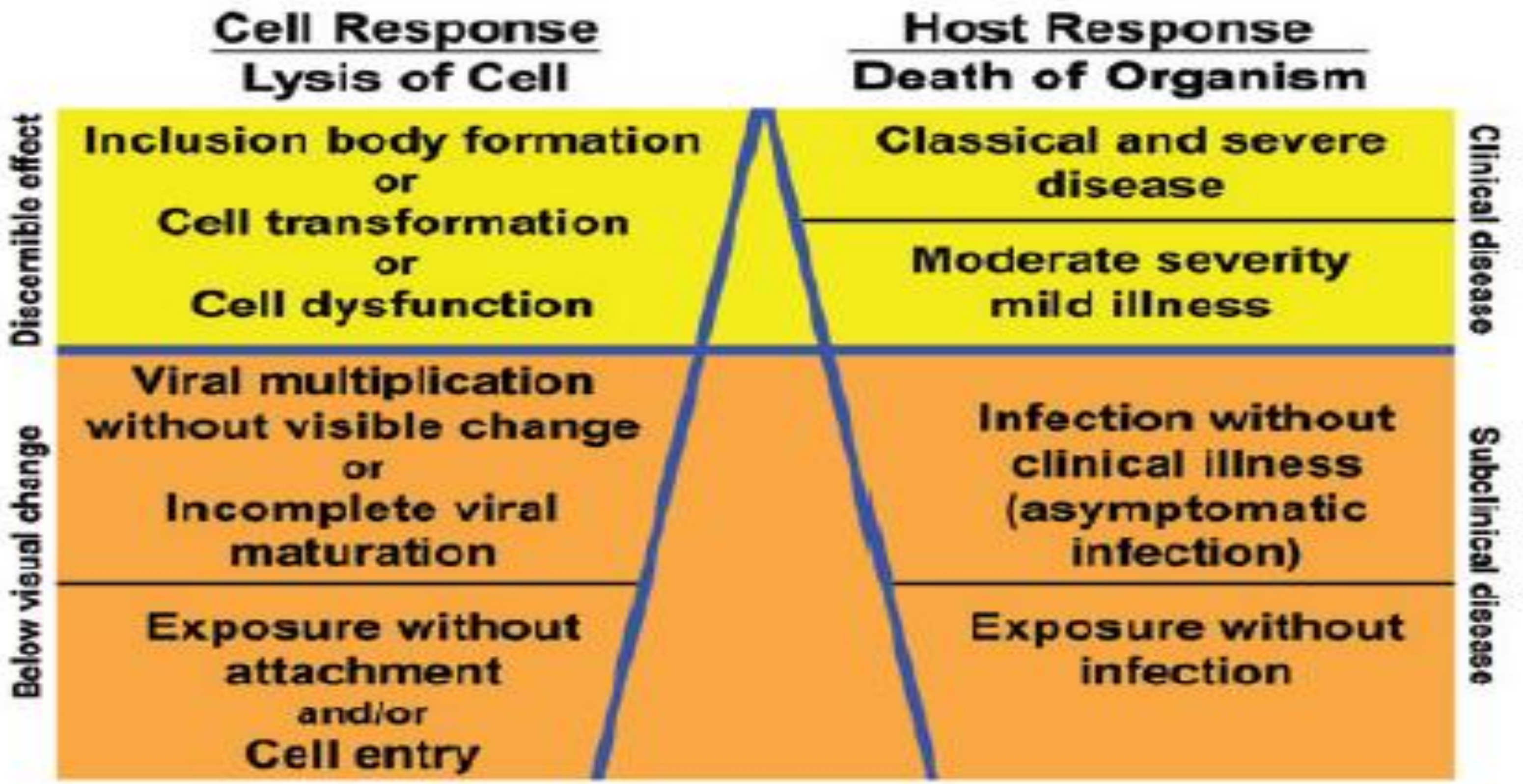


Fig. 2.4 The "iceberg" concept of infectious diseases at the level of the cell and of the host. (Modified from Evans AS, Kaslow RA, eds. *Viral Infections of Humans: Epidemiology and Control*. 4th ed. New York: Plenum;

- As clinical and biologic knowledge has increased over the years, so has our ability to distinguish different stages of disease. These include clinical and nonclinical disease.

CLINICAL DISEASE

- Clinical disease is characterized by signs and symptoms

NONCLINICAL (INAPPARENT) DISEASE

Nonclinical disease may include the following:

1. **Preclinical disease:** Disease that is not yet clinically apparent but is destined to progress to clinical disease.

2. **Subclinical disease:** Disease that is not clinically apparent and is not destined to become clinically apparent. This type of disease is often diagnosed by serologic (antibody) response or culture of the organism.

3.Persistent (chronic) disease*:* infection persists for years, at times for life. In recent years, an interesting phenomenon has been the manifestation of symptoms many years after an infection was thought to have been resolved. Some adults who recovered from poliomyelitis in childhood report severe chronic fatigue and weakness; this has been called postpolio syndrome in adult life.

- These have thus become cases of clinical disease, albeit somewhat different from the initial illness.

4. *Latent disease* *:* An infection with no active multiplication of the agent, as when viral nucleic acid is incorporated into the nucleus of a cell as a provirus. In contrast to persistent infection, only the genetic message is present in the host, not the viable organism.

Stages of Disease

1. Clinical Disease: with signs and symptoms
2. Nonclinical (inapparant) Disease: include the following:

Nonclinical (inapparant) Disease

1. **Preclinical:** so far not clinically apparant but destined to clinical signs
2. **Subclinical:** not clinically apparant and not destined to be so. Only positive by serology /culture
3. **Chronic:** a person fails to ‚shake off‘ or ‚get rid of‘ the disease and persists for years or for life time. Can manefiest symptoms years after recovery like post-polio syndrome
4. **Latent:** Infection with no active multiplication i. e viral DNA remains in DNA of host cell

Carrier Status

- A carrier is an individual who harbors the organism but is not infected as measured by serologic studies (no evidence of an antibody response) or shows no evidence of clinical illness. This person can still infect others, although the infectivity is generally lower than with other infections. Carrier status may be of limited duration or may be chronic, lasting for months or years.

Endemic, epidemic and Pandemic

Endemic

Habitual/usual presence of a disease in a certain geographic area or population group...hyperendemic

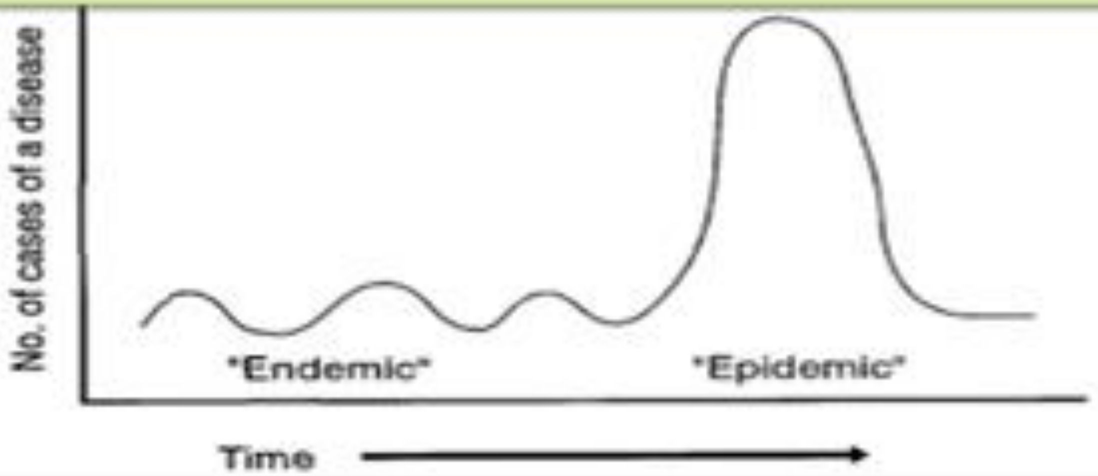
persistance

Epidemic

The occurance in a community or population group of a number of cases of a disease excess of usual or exepcted numbers

Pandemic

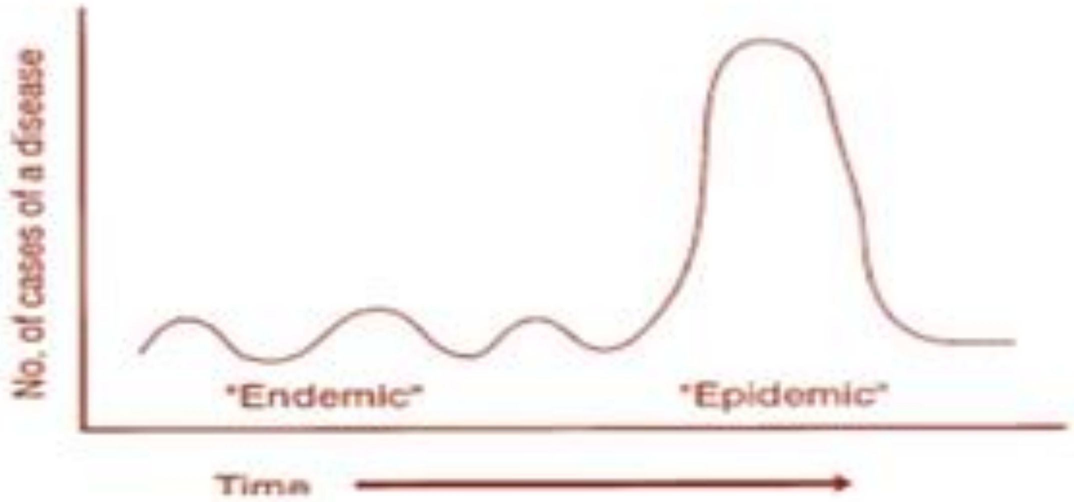
Global epidemic
COVID-19



Endemic, epidemic and Pandemic

,Usuality' of cases is determined by surveillance.

It can be a disease, a behavior (smoking) or an event (car accidents)



Disease Outbreaks

- Let us assume that a food becomes contaminated with a microorganism. If an outbreak occurs in the group of people who have eaten the food, it is called a common vehicle exposure, because all the cases that occurred were in persons exposed to the suspected contaminated food. The food may be served only once—for example, at a catered luncheon—resulting in a single exposure to the people who eat it, or the food may be served more

than once, resulting in multiple exposures to people who eat it more than once.

Disease Outbreaks

When a water supply is contaminated with sewage because of leaky pipes, the contamination can be either periodic, causing multiple exposures as a result of changing pressures in the water supply system, which may cause intermittent contamination, or continuous, in which case a constant leak leads to persistent contamination. The epidemiologic picture

that is manifested depends on whether the exposure is single, multiple, or continuous

- What are the characteristics of single-exposure, common-vehicle outbreak?
- First, such outbreaks are generally explosive— that is, there is a sudden and rapid increase in the number of cases of the disease or condition in a population.

- (Interestingly, single-exposure common-vehicle epidemics of non communicable diseases, such as the epidemic of leukemia following the explosion of an atomic bomb in Hiroshima and Nagasaki, also seem to follow the same pattern.)

- Second, the cases are limited to people who share the common exposure. This is self-evident, because in the first wave of cases we would not expect the disease to develop in people who were not exposed unless there was another independent source of the disease in the community.

- Third, in a food-borne outbreak, cases rarely occur in persons who did not eat the food—that is, those who acquire the disease from a primary case who ate the food .

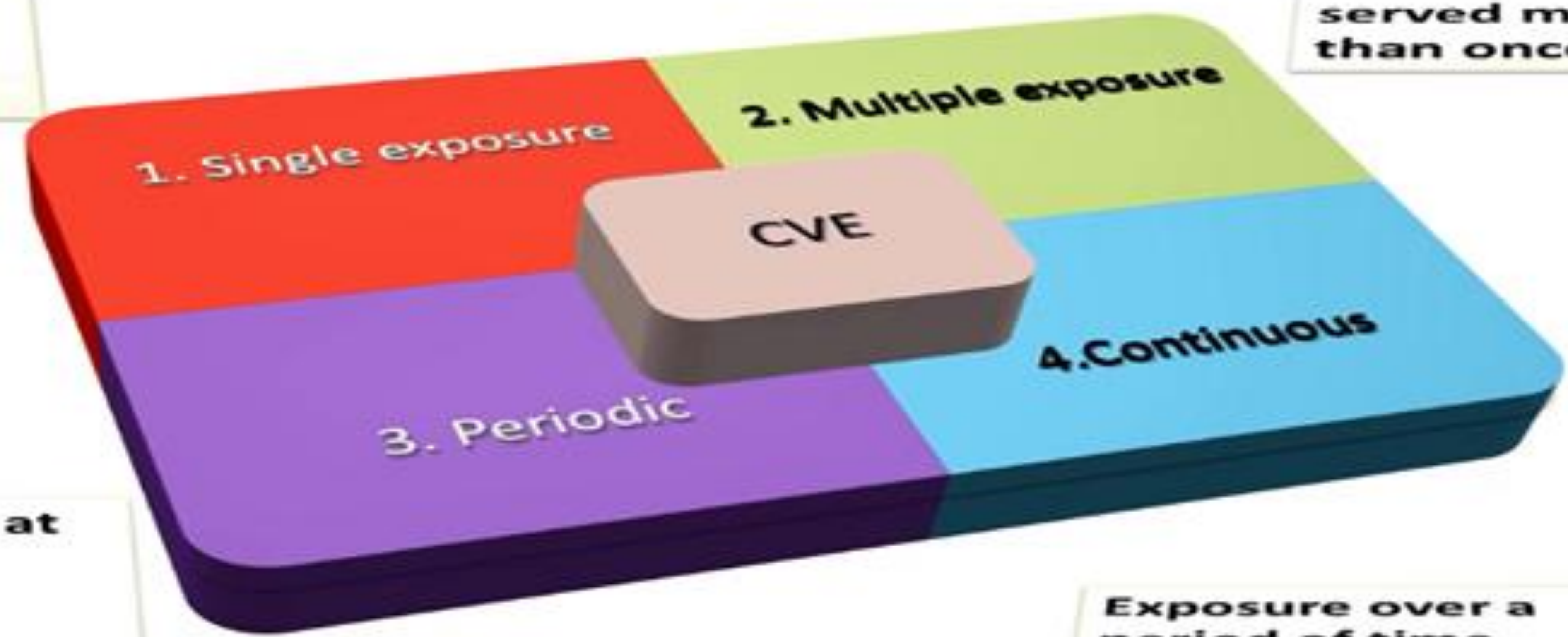
Disease Outbreaks: foodborne

Common-Vehicle Exposure:

When the group have eaten common food.

When food is served once.

served more than once



Exposure at several points in time-leaky sewage pipe

Exposure over a period of time Constant sewage leak

Disease Outbreaks: foodborne

Single-exposure Common-vehicle outbreak

Characterized:

1. **Explosive:**
2. sudden rapid increase of cases

2. Limited:
people who are exposed only.

3. Rarely occure in persons who acquire disease from primary case: not understood

Determinants of outbreak

Amount of disease in population depends on balance between susceptible (at risk) and immune (previous infection or vaccine)

Herd Immunity

- Herd immunity is defined as the resistance of a group of people to an attack by a disease to which a large proportion of the members of the group are immune.

- If a large percentage of the population is immune, the entire population is likely to be protected, not just those who are immune. Why does herd immunity occur ?

- It happens because disease spreads from one person to another in any community. Once a certain proportion of people in the community are immune, the likelihood is small that an infected a person will encounter a susceptible person to whom he can transmit the infection; more of his encounters will be with people who are immune.

Herd Immunity

- The presence of a large proportion of immune persons in the population lessens the likelihood that a person with the disease will come into contact with a susceptible individual.
- Why is the concept of herd immunity so important? When we carry out immunization programs, it may not be necessary to achieve 100% immunization rates to immunize the population successfully

Herd Immunity

- We can achieve highly effective protection by immunizing a large part of the population; the remaining part will be protected because of herd immunity.
- For herd immunity to exist, certain conditions must be met. The disease agent must be restricted to a single host species within which transmission occurs, and that transmission must be relatively direct from one member of the host species to another. If we have a reservoir in which the organism can exist outside the human host, herd immunity will not operate because other means of transmission may be available

Herd Immunity

: resistance of a group to disease to which large proportion of that group is immune

Due to spread of disease from one person to another until number of immune subject becomes large.

Likelihood of infected person to find a susceptible person is small.

Importance

No need to achieve 100% immunization rate as remaining part will be protected by herd immunity.

Conditions for Herd Immunity-Prerequisits

1. Single host species (i. e human)
2. Transmisson is direct from one host to another
   No reservoir
3. Infection cause solid life-long immunity.
4. Population is mixing constantly-random mixing

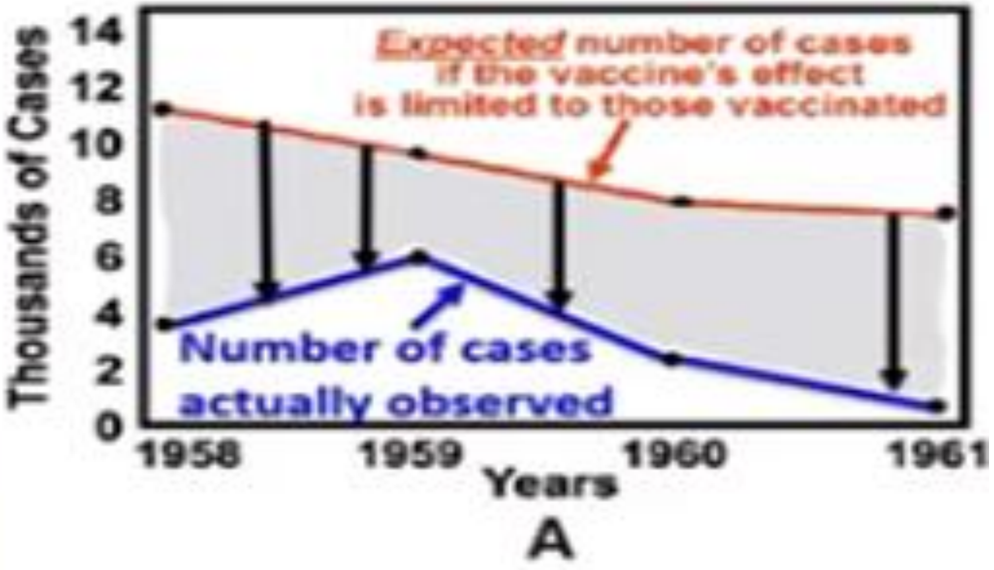
Herd immunity & Vaccination

Herd immunity for high communicable diseases should be high to interrupt the chain of transmission i. e 94% in measles

EXAMPLE

Polio vaccines:

1. OPV: Live attenuated-Salk
2. IPV: Killed-Sabin



IPV, Inactivated polio vaccine;
OPV, Oral poliovirus vaccines

OPV vaccinated person spreads vaccine virus in community- herd immunity

IPV does not spread virus in community-
Instead herd immunity can be attained by high vaccination coverage only

- The oral polio vaccine (OPV) protects not only those who are vaccinated but also others in the community through secondary immunity, produced when the vaccinated individual spreads the active vaccine virus to contacts. In effect, the contacts are immunized by the spread of virus from the vaccinated person. If enough people in the community are protected in this way, the chain of transmission is interrupted. However, even inactivated poliovirus vaccine (IPV), which does not produce secondary immunity (does not spread the virus to susceptibles), can produce herd immunity if enough of the population is immunized. Even those who are not immunized will be protected because the chain of transmission in the community has been interrupted

Herd immunity: Threshold

Herd immunity for high communicable diseases should be high to interrupt the chain of transmission i. e 94% in measles

Disease	Threshold (%)
Mumps	75–86
Polio	80–86
Smallpox	80–85
Diphtheria	85
Rubella	83–85
Pertussis	92–94
Measles	83–94

Incubation Period

: time from entry of infectious agent to time of onset of clinical illnes (symptoms)

During incubation period :

- person is well with noOrganisim is replicating to reach critical mass to cause symptoms
- disease signs

How long should a person with disease like COVID 19 be isolated?

When a person is no longer infectious
Passed incubation period

- During this time, **the *incubation period***, you feel completely well and show no signs of the disease.
- Why does disease not develop immediately at the time of infection? What accounts for the incubation period?
- It may reflect the time needed for the organism to replicate sufficiently until it reaches the critical mass needed for clinical disease to result.

- It probably also relates to the site in the body at which the organism replicates—whether it replicates superficially, near the skin surface, or deeper in the body (e.g., in the gut).

- The dose of the infectious agent received at the time of infection may also influence the length of the incubation period. With a large dose, the incubation period may be shorter.

Incubation Period

Factors affecting duration incubation period

1. Sufficient organism replication to reach critical mass for symptoms
2. Site in the body where organism replicates-deep or superficial
3. Dose of infectious agent-organism

- Different diseases have different incubation periods. A precise incubation period does not exist for a given disease; rather, a range of incubation periods is characteristic of that disease. Fig. 2.13 shows the range of incubation periods for several diseases. In general the length of the incubation period is characteristic of the infective organism.

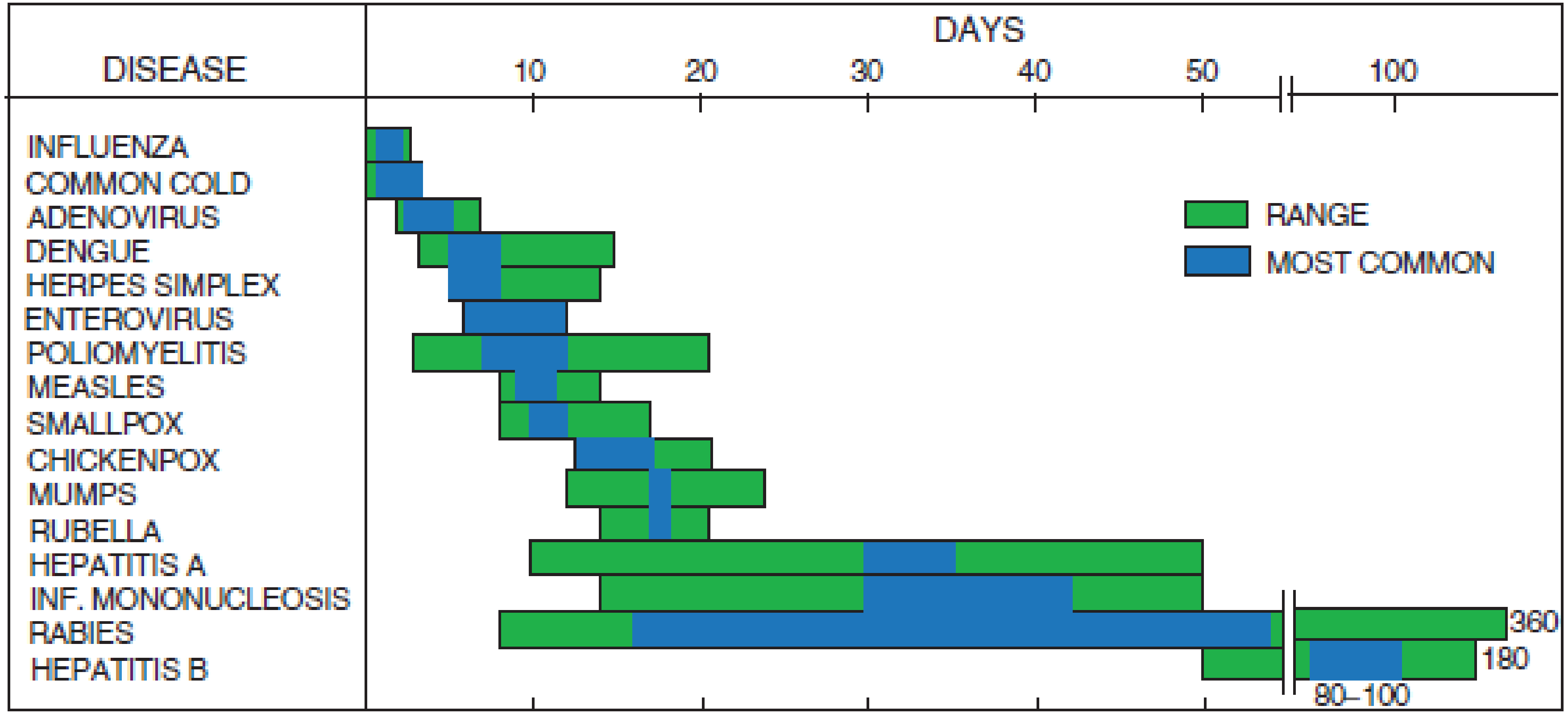
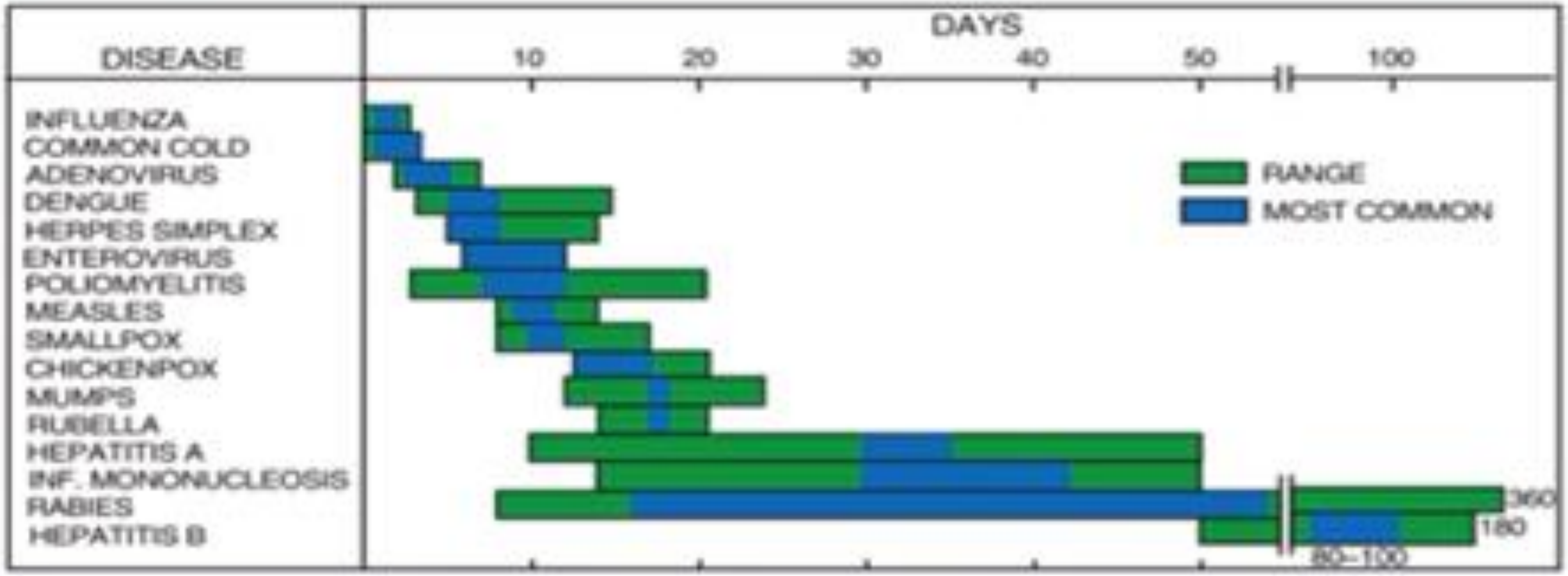


Fig. 2.13 Incubation periods of viral diseases. *INF.*, Infectious. (From Evans AS, Kaslow RA, eds. *Viral Infections of Humans: Epidemiology and Control.* 4th ed. New York: Plenum; 1997.)

Incubation Period

- **Different diseases have different incubation periods.**
- **No given disease has a precise incubation period**



- **Importance of incubation period? Quarantine-Quarante giorni-40 days**

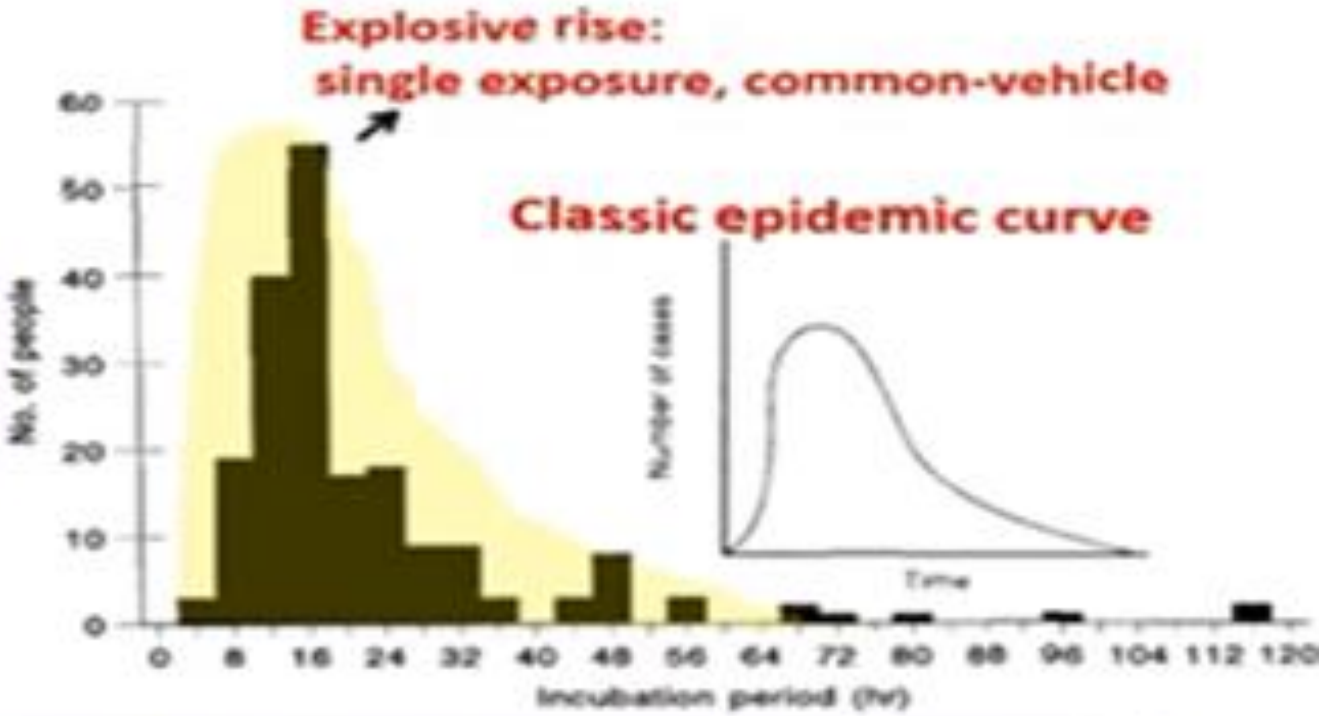
- In *a single-exposure, common-vehicle epidemic*, the epidemic curve represents the distribution of the incubation periods. This should be intuitively apparent: if the infection took place at one point in time, the interval from that point to the onset of each case is the incubation period in that person.
- As seen in Figure involving Salmonella typhimurium, there was a rapid, explosive rise in the number of cases within the first 16 hours, which suggests a single-exposure, common-vehicle epidemic. In fact, this pattern is the classic epidemic curve for a single exposure common-vehicle outbreak

- The incubation period for infectious diseases has its analogue in noninfectious diseases. Thus, even when an individual is exposed to a carcinogen or other environmental toxin, the disease is often manifest only after months or even years. For example, mesothelioma resulting from asbestos exposure may occur 20 to 30 years after the exposure. The incubation period for noninfectious diseases is often referred to as the latency period.

Estimate Incubation Period

NCDs: exposure to carcinogen or toxin
Mesothelioma: After 20-30 years of exposure to asbestos.

Salmonella typhimurium **outbreak: incubation periods for 191 person**



Epidemic curve: distribution of times of onset of diseases

- The three critical variables in investigating an outbreak or epidemic are as follows:
- 1. When did the exposure take place?
- 2. When did the disease begin?
- 3. What (how long)was the incubation period for the disease ?
- If we know any two of these, we can calculate the third.

Outbreak Investigation: 3 critical points

Know two of the above to calculate the third

Attack Rate (AR)

To compare risk of disease in a group with different exposures

$$\text{Attack rate} = \frac{\text{Number of people at risk in whom a certain illness develops}}{\text{Total number of people at risk}}$$

$$\text{Food-specific attack rate} = \frac{\text{Number of people who ate a certain food and became ill}}{\text{Total number of people who ate the food}}$$

Similar to incidence rate, but in more acute diseases

Time NOT considered

Attack Rate

Primary case (index case):

:Person acquiring disease from exposure i. e contaminated food

Secondary case:

:Person acquiring disease from exposure to primary case

Secondary attack rate :

: Attack rate in susceptible people who have been exposed to primary case, usually in family of index case

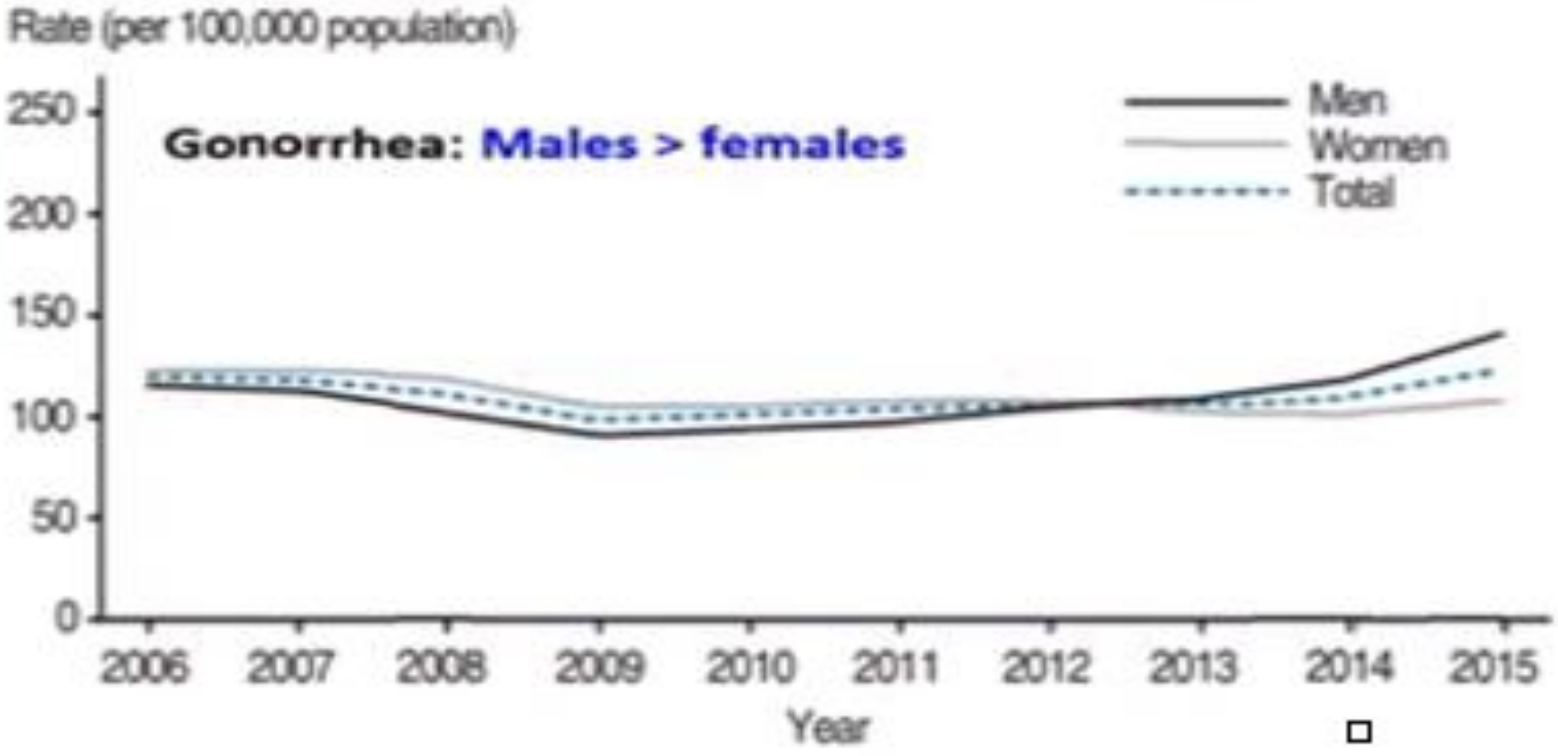
EXAMPLE

Items consumed	Ate			Did Not Eat		
	sick	total	Attack rate	sick	total	Attack rate
Beverage	179	264	179/264= 67.8	22	50	22/50= 44
Egg salad	176	226	176/226= 77.9	27	73	27/73= 37

Occurance of Disease

To investigate an epidemic:
Who was attacked?
When did the disease occure?
Where did cases arise?

PPT: Person, Place, Time



WHO- PERSON

Sex, age, race

WHO? WHEN? WHERE?

STEPS: Acute Outbreak Investigation

DEFINE outbreak:
1. Numerator?
   Cases: by symptomes and/or test
2. Denominator?
   Risk Pop
3. Attack rate?

EXAMINE PPT
P: person
P: place
T: time

Generate HYPOTHESIS: by interview and based on:
1. Knowledge
2. Analogy to same aetiology
3. Finding from investigation

TEST hypothesis
1. Lab test
2. Case-control study

STEPS: Acute Outbreak Investigation

CONTROL :
1. Current outbreak
2. Future outbreaks

REPORT , written Findings

DESSEMINATE:
to:
1. Policy makers
2. Scientific community

Cross Tabulation (Crosstabs)

A commonly used statistical tool in foodborne outbreaks.
Used to pinpoint the actual causative agent from several suspected ones

2 x 2 contingency tables

EXAMPLE

Outbreak of *Streptococcus pyogenes* (group A)

Pharyngitis in a jail in Miami in 1974

Items consumed	Ate-drank (exposed)			Did Not Eat-drink (not exposed)		
	sick	total	Attack rate	sick	total	Attack rate
Beverage	179	264	179/264= 67.8	22	50	22/50= 44
Egg salad	176	226	176/226= 77.9	27	73	27/73= 37

Exposed: Ate and drank, Not exposed: did not eat or drink

AR is higher in exposed than not exposed, but...

Is it bevaeage or egg salad that caused outbreak? Use crosstab

Crosstab Analysis

Calculate AR for those who ate and those who did not,
but, look separately at those who drank and those who did not

Vertical — Did not increase AR: 75.6 vs 80 and 26.4 vs 25

	Ate Egg Salad				Did Not Eat			
	sick	Well	Total	AR	sick	Well	total	AR
Drink	152	49	201	75.6	19	53	72	26.4
Not Drink	12	3	15	80	7	21	28	25

Horizantal

Increase AR
75.6 vs 26.4 Significant increase
80 vs 25 Significant increase

AR, attack rate

Egg salad is the main suspect

Exploring Occurrence of Disease

- The concepts outlined in this chapter form the basis for exploring the occurrence of disease. When a disease appears to have occurred at more than an endemic (usual) level and we wish to investigate its occurrence, we ask:
- *Who* was attacked by the disease?
- *When* did the disease occur?
- *Where* did the cases arise?
- It is well known that disease risk is affected by all of these factors.

- **WHO**
- The characteristics of the human host are clearly related to disease risk. Factors such as sex, age, and race as well as behavioral risk factors (e.g., smoking) may have major effects.

- **WHEN**
- Certain diseases occur with a certain periodicity. For example, diarrheal disease is most common during the summer months, and respiratory disease is most common during the winter months.

- For example, in the United States, both the incidence of and deaths from acquired immunodeficiency syndrome (AIDS) increased for many years, but it began to decline in 1996, largely as a result of new therapy and health education efforts.

- **WHERE**
- Disease is not randomly distributed in time or place.