PRE REQUISITES FOR TRANSMISSION OF INFECTIOUS DISEASES

Objective of this section is to introduce students to the mechanism of the transmission of communicable diseases and the pre-requisites for such transmission to take place.

Specific objectives:

At the end of this section, students should be able to

i. List the six pre-requisites for the perpetuation of infectious diseases
ii. Describe the mechanism by which diseases occur and the factors affecting development of a disease in relation to infectious agent.
iii. List the three types of reservoir of infection
iv. Classify carriers and to explain their public health importance in disease transmission
v. Illustrate with examples the different modes of transmission of communicable diseases
vi. Define intrinsic and extrinsic incubation period and state the importance of the knowledge of the intrinsic incubation period
vii. Classify and differentiate between the types of immunity
viii. State and give examples of the types of immunizing agents
ix. Outline the measures for the control of communicable diseases

For communicable diseases to be perpetuated in a community, there are six pre-requisites namely presence of microbiological agent, presence of reservoir, portal of exit, mode of transmission, portal of entry (inlet), and presence of susceptible host.

1. MICROBIOLOGICAL AGENT

Microorganisms responsible for the causation of communicable diseases are classified into:

- **Viruses**: These are the causative agents for a large number of diseases such as *influenza, mumps, chicken pox &, poliomyelitis*
- **Bacteria**: Cocci (*streptococci, staphylococci & diplococci*), Bacilli (*diphtheria, salmonella & shigella*) and vibrio (*classical vibrio & Eltor vibrio*).
- **Rickettsia**: The causative agents of a group of infectious diseases including the *typhus* group of fever
- **Fungi**: Including *Candida* and *Aspergillus*.
- **Protozoa**: Unicellular organism such as *entameba* causing dysentery, *plasmodia* causing malaria and *leishmania* causing tropical sore & kala azar.

- **Parasites**: Such as *schistosoma* & *ancylostoma*

1.1. Mechanism of disease production (pathogenesis)

- **Invasiveness** refers to the ability of the organisms to invade the tissues and multiply.
- **Toxigenicity** refers to the ability of the organism to produce toxins. Toxins are either
  - **Exotoxins** which are released by living organisms. Exotoxin are destroyed rapidly by heat (above 60°C), highly immunogenic and converted to antigen or toxoid by formalin, heat and acid. They are diffusible and don't produce fever such as Neurotoxins produced by Clostridium tetani and Clostridium botulinum; Erythrogenic toxins produced by group A beta hemolytic streptococci causing *scarlet fever*; Enterotoxins produced by *staphylococci* causing staphylococcal food poisoning.
  - **Endotoxins** which are released after disintegration of microorganisms. Endotoxins are heat stable i.e. withstand heating above 60°C, poorly immunogenic and not converted to toxoid. Endotoxins usually produce pathophysiologic effects such as fever, leukopenia, hypotension, hypoglycemia and shock. Shigella dysentery, E-coli, Salmonella typhi and paratyphi, Vibrio cholera both classical and Eltor are organisms that release endotoxin.

Each pathogen possesses the power of invasiveness and toxigenicity with variable degree. *Treponema pallidum* as well as *salmonella typhi and paratyphi* have a high power of invasiveness but they have low toxigenicity. In contrast, *clostridium tetani* has a low invasive power and high degree of toxigenicity.

1.2. Factors affecting development of diseases in relation to the infectious agent

- **Pathogenecity** is the ability of the organism to produce specific clinical reaction after infection has occurred. However, it doesn't refer to the severity of the clinical reaction.
- **Virulency** is the ability of the organism to produce severe pathological reaction; it refers to severity of the clinical reaction. Virulency is measured by

$$\boldsymbol{Ratio\ of\ clinical\ to\ subclinical\ cases} = \frac{Number\ of\ clinical\ cases}{Number\ of\ subclinical\ cases}$$

$$\boldsymbol{Case\ fatality\ rate} = \frac{Number\ of\ deaths\ due\ to\ a\ particular\ disease\ in\ a\ specific\ year\ and\ locality}{Total\ number\ of\ cases\ of\ this\ particular\ disease\ in\ the\ same\ year\ and\ locality} x\ 100$$

- **Antigenic power of the organism** is the ability of the infectious agent to stimulate the immune system to produce antibodies or antitoxin with subsequent immunity. Antigenic power of the organism is measured by the second attack frequency of the disease which refers to the possibility of re-infection. In certain diseases second attacks are rarely recorded as in case of *measles, mumps* and *chicken pox*. In other diseases, re-infection or second attacks occur as in case of *common cold*, upper *respiratory tract infections*, *syphilis* and *gonorrhea*.
- **Ease of communicability** is measured by the secondary attack rate, which is the number of secondary cases, occurring within the range of incubation period following exposure to a primary case. Secondary attack rate is expressed as a percentage of the number of exposed susceptible.
- **Dose of infection (inoculum);** The higher the dose of infection, the more likely is the development of apparent clinical illness and severe disease
- **Tissue selectivity (tropism)** which is the inherent capacity of the pathogen to invade some particular tissues. This is the factor that gives each disease its characteristic symptoms and signs. *Hepatitis viruses* are hepatotropic i.e. have affinity to the liver cells.
- **Spore formation** which is the ability of some bacteria to change to spores under unfavorable environmental conditions that maintain their viability for a long period. *Clostridium tetani and clostridium botulinum* are examples of organisms capable of spore formation.
- **Viability of the organism (the resistance of the organism)** which is the ability of the organism to live outside the body, the longer the duration, the more the chance to come into contact with a new host causing infection and possibly initiate a disease process.

2. RESERVOIR OF INFECTION

Reservoir of infection is the place or the depot where the infective agent survives, grows and multiplies in such a manner that it can be transmitted to a susceptible host. Reservoir of infection may be man, animal, plant or soil or combination of these. Man is the most common reservoir of infection followed by animals.

Human reservoir of infection is classified into case and carrier. The case is either clinically manifested or unapparent. In unapparent cases, the disease process is taking place but without any apparent signs or symptoms; they are identifiable only by laboratory or skin tests. A carrier is as a person who harbors the infectious agent, without the presence of a

disease process (no signs or symptoms) and capable to transmit the infection to healthy community members.

Severe cases are not necessarily more infectious than mild or subclinical cases. From the public health perspective, mild and subclinical cases may be more important in the spread of infection since they are unrecognized and always overlooked. Carriers are particularly dangerous as they do not show any clinical manifestation and their contacts are not aware of their condition. Carriers are difficult to be identified and hence, not possible to deal with them.

Carriers are classified according to the place of carriage of the organism, duration of carrier state or chronologically according to the spectrum of infection.

- According to the place of carriage, carriers are classified into upper respiratory carriers (in case of *diphtheria, streptococcal* and *meningococcal* infections), fecal carriers (in case of *typhoid, paratyphoid, cholera, amebic cyst, infectious hepatitis), u*rinary carriers (in case of *typhoid* and *paratyphoid)* and skin carriers (in case of *staphylococcal* infection).
- According to the duration of carrier state, carriers are classified into temporary carriers; harbor and excrete infectious organisms up to 3 months (except for enteric which may reach one year), chronic carriers; harbor and excrete the organisms for more than 3 months (more than one year for enterica) and permanent carriers; harbor and excrete the organism for life. Most of the carriers (about 95%) are of the temporary type.
- Chronologically, carriers are classified into incubatory carriers; harbor and excrete the organism during the incubation period (in case of *infectious hepatitis, mumps, measles* and *poliomyelitis), c*ontact carriers; acquire the organism by being in contact with an infectious person as family members, classmates, physicians and nurses. Contact carriers are of transient type and usually the carrier state is terminated as soon as the patient is cured or the contact is terminated. Contact carriers are common in *typhoid* and *cholera. C*onvalescent carriers are those who continue to excrete the organism during the convalescence period as in *typhoid*. Here there will be a need for carrying out 3 consecutive bacteriological examinations before the release of the case.

Animals can act as reservoirs, whether in the form of case or carrier. The important animal reservoir are cattle in *bovine tuberculosis;* goats in *brucellosis (undulant fever)*; dogs in *rabies;* and rats in *plague*; mice, rodents, ducks and cows in *salmonella food poisoning;* and apes in *yellow fever.* Soil is an inanimate reservoir as in case of *tetanus*.

3. PORTAL OF EXIT

The portal of exit of the infectious agent from the reservoir of infection is either

- **Respiratory tract**: Organisms leave the body via the mouth and nose during coughing, sneezing, laughing or even talking. This is the portal of exit in *measles, whooping cough, diphtheria, streptococcal sore throat*, *influenza, common cold & mumps*.
- **Gastrointestinal tract**: Organisms are liberated either in the stool as *typhoid*, *paratyphoid, cholera*, amebic dysentery & eggs of *ascaris* or through the vomitus as in case of *cholera*. In certain diseases where the primary site of infection is the intestine, organisms are excreted in stool as in *poliomyelitis* (which affects the nervous system) and *infectious hepatitis* (which affect the liver).
- **Urinary tract:** This occurs in some diseases where infection is general and the organism is found in the blood as in case of *typhoid, brucellosis (undulant fev*er), and *bilharziasis* as well as in local infection of genito-urinary tract as in case of *gonorrhea*.
- **Skin and mucous membranes**: As in case of *erysipelas*, *impetigo*, *purulent conjunctivitis*, and *venereal* diseases.
- **Insect bite**: As in case of *typhus, plague, yellow fever and malaria*.
- **Needle stick and blood transfusion**: As in case of *viral hepatitis & HIV/AIDS.*
- **Uterotransmission or transplacental** : Across the placenta from maternal blood to fetal circulation such as *HIV/AIDS, syphilis and german measles*.

4. MODE OF TRANSMISSION

The modes of transmission are classified into contact transmission, common vehicle transmission, vector transmission and air borne transmission.

4.1. Contact transmission

Contact transmission means transmission of the infectious agent when the infected person or animal and the susceptible host come together. Contact transmission is either

- **Direct contact**

  In this situation, the infectious agent passes from the infected person or animal to the host without the presence of a third party. Direct contact may occur through sexual intercourse, kissing and touching. Examples for contact transmission are

venereal diseases, *scabies and* contact of saliva of a *rabid* animal with abraded skin.

- **Indirect contact**

  In this mode of transmission, the spread of infection is through handling contaminated objects such as handkerchiefs, soiled articles as towels and toys. The organism will be transmitted from hands to mouth or from hands to abraded skin or mucous membranes. This mode of transmission is noted in *conjunctivitis, trachoma, skin infections*, and *diphtheria*. This mode of transmission plays an important role in the spread of *nosocomial infections & surgical wounds infection.*

- **Droplet transmission**

  Droplets containing the infectious agents are sprayed from the nose and/or the mouth during sneezing, coughing, spitting or talking. These droplets are usually limited to a distance of one meter or less. These droplets will pass into the nose or mouth of the host directly as in case of *measles, streptococcal infections, influenza, diphtheria* and *surgical wound infections*.

- **Trans-placental transmission**:

  In this type of contact transmission the organism is carried from mothers to fetus through the placenta, e.g. *Syphilis, AIDS*, *German measles* and *Toxoplasmosis.*

4.2. Common vehicle transmission

Vehicle of transmission can be water, milk or biological products as blood and blood products. Infectious agents are transmitted by this vehicle to the host by one of the means listed below. It is important to note that the role played by common vehicles depends on the viability of infective agents outside the body, environmental influences as dryness, temperature and sunlight.

- **Ingestion** through contaminated foods or drinks, example is *typhoid, paratyphoid, food poisoning, dysentery and cholera.*
- **Inoculation** as in case of the administration of plasma, blood or serum as in *viral hepatitis, syphilis and malaria*.
- **Deposition of disease agents** where the infectious agent is deposited on the skin or mucous membrane of the ear, nasal sinuses and conjunctiva. This mode of common vehicle transmission is of importance in the spread of a group of disease acquired in swimming pools such as *conjunctivitis*, *sinusitis* and *bilharziasis*.

4.3. Vector transmission

Various insects are known for their role in disease transmission. Vector transmission is either mechanical or biological.

- **Mechanical transmission** in which vectors carry pathogenic organisms of different infections on the feet or mouth parts, or may be ingested and pass in the insect feces or vomitus. The mechanical transmission can be either direct or indirect. Direct mechanical transmission is the case of houseflies which carry the organism from discharges of infected eyes and transmit it to healthy eyes as in case of *purulent conjunctivitis.* Indirect mechanical transmission as in houseflies and cockroaches which carry organisms then settle on human food or drink with subsequent contamination with the infectious agents as it occurs in *typhoid, dysentery* and *cholera.*
- **Biological transmission** in which the organism has to undergo biological changes inside the vector which requires a certain period of time "extrinsic incubation period". After this period, the insect is then able to transmit the infection to a new host. In some of the instances, the infectious agent may pass vertically to succeeding generations of vectors (**transovarian transmission**). The biological transmission can be either propagative, cyclopropagative or cyclodevelopmental. In propagative biological transmission, there is a simple multiplication of the causative organism in the vector as *pasteurella pestis* agent of *plague* in *flea* and *virus of yellow fever in the aedes Egypti mosquito*. In cyclopropagative biological transmission, the organism multiplies and undergoes cyclic changes within the vector as in case of *malaria.* In cyclodevelopmental biological transmission, the infectious agent undergoes developmental changes only as *filaria in mosquito.*

4.4. Air borne transmission

The dissemination of suspended particles in the air consisting partially or wholly of microorganisms which remain suspended for a long period. Usually, in this mode of transmission the reservoir of infection and the host are not present at the same time. Some organisms retain their infectivity as *mycobacterium tuberculosis* while others don't as *neisseria meningitides.* Air borne transmission is either through droplet nuclei or dust transmission. Droplet nuclei are small particles which result from evaporation of the fluids from the droplets of infected person. They contain pathogens and remain suspended in air for a long period of time. When they are inhaled by a host they cause infection. In dust transmission, large particles of nuclei fall on the ground to mix with the dust and become part of it. This mode of transmission is noted for infectious agents that resist dryness as *mycobacterium tuberculosis.* The source of these particles is the discharge of infected persons, contaminating bedding, clothes, floor and soil.

5. PORTAL OF ENTRY

With some exception, the portal of entry to the host corresponds to the portal of exit from reservoir. Portal of entry is usually the natural orifices including mouth, nose, rectum, vagina, urethra and conjunctiva. Other portal of entry is skin through inoculation by blood sucking insects or by injection.

Intrinsic Incubation period:

The intrinsic incubation period is the time interval between exposure to the infectious agent and appearance of the first sign or symptom of the disease. There is an average incubation period for every disease with a range indicating the minimum and the maximum period. The length of incubation period depends on the type of the infection whether organism or toxin, the virulency of the organism, the dose of the inoculums as well as the host resistance.

Long incubation period is encountered in *leprosy*, *infectious and serum hepatitis, tuberculosis, filariasis* and *rabies*. Short incubation period is that of *staphylococcal food poisoning* where the enterotoxin is responsible for disease causation and not the organism.

Knowledge of the incubation period is important for

- Surveillance and quarantine in some diseases
- Application of preventive measures within the incubation period to abort or modify the attack. *Measles* vaccine if given to the contacts in the first three days after exposure will prevent the disease and if given in the second three days after exposure will modify the attack yielding a mild or subclinical infection with subsequent solid immunity.
- Identification of the source of infection, water borne epidemic of *typhoid* has longer incubation period than milk borne.

6. SUSCEPTIBLE HOST

Host is a person or other living animal, including birds and arthropods that afford subsistence or lodgment to an infectious agent under natural condition. Susceptibility to infection is universal but susceptibility to disease depends on host immunity and resistance.

IMMUNITY AND RESISTANCE

Resistance is the total body mechanisms which act as barriers to invasion or multiplication of infectious agents or their damaging effects. Resistance is either natural or acquired.

Natural resistance is the non-specific resistance of the body against the invading organisms which does not depend on the presence of specific antibodies or antitoxin for protection, but depends on the anatomical or physiological characteristics of the host.

Acquired resistance is what is gained and mostly specific. It is classified into passive and active immunity. **Passive immunity** is the type of resistance acquired through readymade antibodies. **Passive natural immunity** is the resistance enjoyed by the infant due to the presence of antibodies against a number of diseases which have been transferred from the mother through the placenta during intrauterine fetal life. It is important to note that the mother should have contracted the disease and/or being vaccinated to develop such antibodies. The level of the maternally acquired antibodies reaches its peak at birth then decline gradually till they become insignificant by six month of age. **Passive artificial immunity** is the immunity induced by injecting immune serum or gammaglobulin that offer readymade antibodies or antitoxins. This type of immunity is of short duration, lasting for about three weeks then gradually eliminated such as passive protection using antitetanic and antidiphtheritic sera as well as the gamma globulin for infectious hepatitis.

Active immunity is the type of immunity in which the person makes or develops his own antibodies. It is either **natural active immunity** or post infection immunity which follows a disease process (clinical or subclinical). This immunity is either solid or for a long period as in case of mumps and measles or it may be of limited duration (for years) as in case of meningitis or it may be for a short period (months) as in flu. **Artificial active immunity** is produced artificially by active immunization using an immunizing agent, a specific antigen when introduced in the body stimulates the immune system for the formation of antibodies or antitoxins.

IMMUNIZING AGENTS

Immunizing agents are vaccines. The ideal immunizing agent should be antigenically stable, gives durable immunity, have minimal side effects, easy in administration, of reasonable cost as well as being available and of good keeping quality. The followings are the types of immunizing agents.

Types of immunizing agents (vaccines):

1. **Live attenuated vaccines**:
    - **Attenuated vaccines**: In these vaccines, microorganisms lose their pathogenicity but retain their power of multiplication and antigenicity. Attenuation can be done by repeated subcultures or by cultivation under unfavorable conditions, e.g. *Sabin* vaccine of *polio, measles, german measles* and *mumps* vaccines.

- **Variant forms of living organisms vaccines:** In these vaccines a milder species of the organisms closely related antigenically to the human disease agents, are used, such as *smallpox* vaccine using cow pox virus and *BCG* vaccine using bovine tubercle bacilli.

2. **Non-living vaccines**:-
   - **Killed or inactivated:** Killed bacteria by heat or chemicals as ether or formalin for the preparation of *typhoid* & *whooping cough* vaccines. Inactivated virus as *Salk* vaccine of *polio.*
   - **Products of organisms (Toxoid):** Toxoid is a toxin after losing its toxicity but retaining its antigenicity e.g. *Diphtheria,* and *tetanus toxoid.*
   - **Part of organisms:** The subunit of *hepatitis B* surface antigen (HBsAg) prepared from plasma of HBsAg positive carriers (plasma derived) or by genetic engineering (yeast derived). Part of polysaccharide capsule of *Neisseria meningitides* used as a vaccine against meningococcal meningitis.

HERD IMMUNITY

It is the state of immunity within the community. Herd immunity is the factor that decides the epidemiologic pattern of any infectious disease among that community. The incidence of the disease rises at times when the number of susceptible in the population is the highest and the herd immunity is the lowest. The best example is *measles* epidemic in Fiji in 1975 where the attack rate approached 100% and fatality rate was excessively high. The spread of the disease among all age groups equally is characteristic of the absence of immunity. Also, the well known rhythm of measles epidemic in urban communities in pre vaccination era is due to the variations in community susceptibility. Following an epidemic, immunity is at its highest level. The level of susceptibility increases as new infants are born, an epidemic will develop after accumulation of susceptible. The herd immunity could be produced artificially by immunization, or naturally after infection.

Several factors play a role in community protection namely the extent of immunization coverage, the degree of resistance to infection provided by the vaccine, duration and degree of infectivity of the organism, past experience with different infections resulting in cross immunity and overcrowding and environmental sanitation.

MEASURES FOR CONTROL OF COMMUNICABLE DISEASES

Disease control is an ongoing operation aiming at reducing the incidence of a disease, the duration of the illness and subsequently the transmissibility of the infection, the physical

and psychological sequelae as well as the financial burden of the disease. Control measures include

1. **Measures applied to disease agents** including sterilization and disinfection
2. **Measures applied to reservoir of infection**
    - Measures applied to cases include case finding, reporting to the local health authority in order to apply the appropriate control measures for contact and the environment, the isolation of cases either strict isolation or discharge/body fluid isolation for the whole period of communicability and treatment.
    - Measures applied to carriers include identification of carriers in the community, treatment and exclusion from work till the organism is eliminated especially if food handlers or working with children. It is important to note that carriers' detection is very costly. Its cost effectiveness depends on the proportion of carrier in the community as well as the sensitivity of their occupation.
    - Measures applied to animal reservoir of infection include adequate animal husbandry, immunization (if vaccine is available), treatment of infected animals and killing if treatment is not feasible.
3. **Measures applied to contact** include enlistment, surveillance for the longest incubation period of the disease, isolation (if indicated) as well as increase resistance by immunization or chemoprophylaxis.
4. **Measures applied to the host** including health education, adequate personal hygiene, **s**ound nutrition, **i**mmunization and chemoprophylaxis.
5. **Measures applied to the environment** including sanitation (water/food/sewage/refuse)