INFECTION PROCESS

Aim: To acquaint the students with the infection process

- In every infectious disease, a series of more or less distinct events occurs in succession which leads to the development of the disease. This chain of events is called **Pathogenesis** or disease cycle.
- A **disease cycle** sometimes corresponds fairly closely to the life cycle of the pathogen, and refers primarily to the appearance, development and perpetuation of the disease as a function of the pathogen rather than to the pathogen itself.
- The **life cycle** of a pathogen refers to the stage or successive stages in the growth and development of the pathogen (or any organism) that occurs between the appearance and reappearance of the same stage (e.g. spore) of the organism.
- Disease cycle involves changes in the plant and its symptoms as well as those in the pathogen; and spans periods with in a growing season and from one growing season to the other.

Primary Events in the Disease Cycle

i) Inoculation

ii) Penetration

iii) Establishment of the infection

iv) Colonization (invasion)

v) Growth and reproduction of the pathogen

vi) Dissemination of the pathogen

vii) Survival of the pathogen in the absence of the host i.e. overwintering and over- summering (over-seasoning) of the pathogen

- In some cases, there may be several infection cycles within one disease cycle.

Inoculum and Inoculation

- **Inoculum**- The infective pathogen propagules coming in contact with the host constitutes the inoculum.
- **Inoculation** is the initial contact of the pathogen with the site of the plant where infection is possible.

- In fungi, the inoculum may include the spores, sclerotia (compact mass of mycelium) or fragments of the mycelium.
- In bacteria, phytoplasmas, protozoa, viruses and viroids, the inoculum is always their whole individuals.
- In nematodes, it may be adult nematodes, juveniles or eggs. In parasitic flowering plants, the inoculum may be plant fragments or seeds.
- **Primary inoculum -**The inoculum that survives dormant in the winter or summer and brings about original infections in the spring and autumn is called **primary inoculum,** and the infections it causes are called **primary infections**.
- **Secondary inoculum-** The inoculum produced from primary infections is called **secondary inoculums,** and it, in turn causes **secondary infections**.
- Generally, the amount of inoculum and prevalence of favourable environmental conditions determine the success of infection.
- **Inoculum potential** has been defined as the 'energy of growth of parasite available for infection of host at the surface of the host organ to be infected'.
- It is the resultant of action of the environment, the vigour of the pathogen to establish an infection, the susceptibility of the host and amount of the inoculum present.
- The inoculum, which survives whether on perennial plants, plant debris or soil, or on the propagative planting material is carried to the host plants mostly by wind, water, insects or man.
- Only a tiny fraction of the potential inoculum produced actually lands on the susceptible host plants.
- The bulk of the produced inoculum lands on the things that cannot become infected.
- Some types of inoculum, in the soil, e.g., zoospores and nematodes may be attracted to the host plant by chemical substances like sugars and amino acids diffusing out of the plant roots. This process is known as **chemotaxis**.
- Vector transmitted pathogens are usually carried to their host plants with an extremely high efficiency.

Pre-penetration Activities of the Pathogen on the Host Surface

- Almost all fungi, bacteria and parasitic higher plants, must be first attached to the host surfaces.
- This attachment takes place through their adhesive materials which are composed of water insoluble polysaccharides, glycoproteins, lipids and fibrillar materials, which when moistened become sticky and help the pathogens to adhere to the plant.

- Pathogens, such as phytoplasmas, fastidious bacteria, protozoa and most viruses are placed directly into the cells of the plants by their vectors.
- Many fungal pathogens first grow on the surface of the host to get proper mechanical, morphological and chemical strength to bring out the penetration of the barriers.
- In *Rhizoctonia solani,* the fungus first forms infection cushions and appressoria and from their multiple infections take place by means of infection pegs.
- In *Armillariella mellea,* the fungus hyphae form the **rhizomorphs** (aggregation of hyphae forming rope like/root like structures), which produce desired amount of enzymes required for direct penetration of the host.
- In other fungi, the spores landed on the host surfaces germinate producing germ tubes, which cause penetration, directly or indirectly or they first produce **appressoria** from which infection threads develop and penetrate the host.
- **Appressoria** are swollen structures formed on the tips of the germ tubes and facilitate in attachment and penetration of the host, which are produced by their thigmotropic (contact) response to the hard surfaces, and in turn produce infection hyphae or infection pegs and exert pressure to affect the direct penetration of the host.
- Seeds of parasitic flowering plants germinate by producing a radical which either penetrate the host plant directly or first produces a small plant that subsequently penetrates the host plant by means of specialized feeding structures called **haustoria**.
- Nematode eggs also require conditions of favourable temperature and moisture to become activated and hatch.

Penetration

Plant pathogens penetrate the plant surfaces by direct penetration of the cell walls, natural openings or through wounds.

Direct penetration

- Direct penetration through intact plant surfaces is probably the most common type of penetration by fungi, oomycetes and nematodes and only type of penetration through parasitic flowering plants. None of the other pathogens can enter plants by direct penetration.
- Hemibiotrophs or non-obligate parasitic fungi do so through a fine hyphae produced directly by the spore or the mycelium.
- The obligate parasites do so through a penetration peg produced by an appressorium.
- They are formed at the point of contact of the germ tube or mycelium with a plant surface.

- The fine hyphae growing towards the plant surface pierces the cuticle and the cell wall through mechanical force and enzymatic softening of the cell wall substances.
- Most fungi form an appressorium at the end of germ tube, it being bulbous or cylindrical with a flat surface in contact with the surface of the host plant.
- Then a penetration peg grows from the flat surface of the appressorium towards the host and pierces the cuticle and cell wall.
- The penetration peg grows into the small hyphae generally much smaller in diameter than the normal hyphae of the fungus and regains its normal diameter once inside the cell.
- Parasitic higher plants also form an appressorium and penetration peg and the point of contact of the radical with the host plant; and penetration is similar to that in fungi.
- Direct penetration in nematodes is accomplished by repeated back and forth thrusts of their stylets. Such thrusts finally create fine opening in the cell wall. It then inserts its stylet into the cell so the entire nematode enters the cell.

Indirect penetration (through wounds)

- All bacteria, most fungi, some viruses and all viroids can enter through various kinds of wounds.
- Some viruses and all mollicutes, fastidious vascular bacteria and protozoa enter plants through wounds made by their vectors.
- The bacteria and fungi may grow briefly on the lacerated or dead tissues before they advance in to the healthy tissues.
- The penetration of viruses, phytoplasmas, fastidious bacteria and protozoa through wounds depends on their deposition by the vector on fresh wounds created at time of inoculation.
- Some viruses and viroids penetrate through wounds made by human hands and tools.

Indirect penetration through natural openings

Stomata are natural openings and are more in number on lower leaf surfaces; measuring about 10-20 x 5-8 µm, and are open in the day time; but are more or less closed at night.

- Bacteria which are present in a film of water over stomatal openings, swim through it easily and reach the sub-stomatal cavity when they can multiply and start infection.
- Fungal spores generally germinate on the plant surface and germ tubes may grow through stomata.
- The germ tubes form an appressorium that fits tightly over one stomata and normally one fine hypha grows from it into the stoma.

- It enlarges through sub-stomatal cavity giving rise to several small hyphae that actually invade the cells of the host plants directly or through hasutoria.
- Although some fungi can penetrate through closed stomata, others penetrate stomata only while they are open, e.g., *Puccinia graminis tritici*, the cause of stem rust of wheat.

Hydathodes are more or less permanently open pores at the margins and tips of the leaves. They are connected to the veins and secrete droplets of liquids called guttation drops containing various nutrients.

- Some bacteria, e.g., the one which causes black rot of cabbage (*Xanthomonas campestris* pv. *campestris*) use these pores as means of entry into the leaves.
- *Erwinia amylovora* causing fire blight of apple and pear also enter blossoms through the **nectarthodes** or **nectaries** which are similar to hydathodes but are present on the receptacle or other parts of the flower.

Lenticels are openings on the fruits, stems and tubers that are filled with loosely connected cells to allow passage of air and seem to offer little resistance to pathogen entry.

- Lenticel and wound penetration are quite similar. Many lenticel invaders can also enter through wounds, particularly soil borne pathogens like *Streptomyces scabies* (causing potato common scab), *Erwinia carotovora* (soft rot of vegetables), *Armillariella mellea* (root rot), *Spongospora subterranea* (potato powdery scab), , *Penicillium expansum* (causing blue mould rot), *Monilinia fructicola* (causing brown rot of apple) and *Nectria galligena* (causing apple canker).
- The germ tubes or hyphae of invading fungi grow between the lenticel cells and enter the plant tissues.

Infection

Infection is the process by which pathogens establish contact with susceptible cells or tissues of the host and obtain nutrients from the tissues.

- Successful infection results in the appearance of symptoms, viz., discolouration, malformation or necrotization of the affected plant parts.
- Some infections do not produce symptoms right away, and remain **latent** but do so at a later time when environmental conditions and/or stage of plant become more favourable.
- The time interval between inoculation and the appearance of disease symptoms is called **incubation period**.
- It varies from few days to years with different pathogens-host combinations, stage of host and prevailing environmental conditions.

- During infection, some pathogens obtain nutrition from the living cells, often without killing them or at least not for a long time; others kill the cells and utilize their contents as they invade them; and still others kill cells and disorganize the surrounding tissues.
- During infection, pathogens release a number of biologically active substances (e.g., enzymes, toxins and growth regulators) that may affect the structural integrity of the host cells or their physiological processes.
- In response, the host reacts with a variety of defence mechanisms.
- For a successful infection, the host must be susceptible, the pathogen must be virulent and the environment must be favourable.
- When these conditions occurred at an optimum, the pathogen can further invade the host plant up to the maximum of its potential even in the presence of plant defenses; and in consequence the disease develops.

Invasion

Various pathogens invade hosts in different ways and to different extents.

- Some fungi, such as those causing powdery mildews produce mycelium only on the surface of the plants and send **haustoria** into the epidermal cells.
- Others such as those causing apple scab and black spot of rose produce mycelium that grows only in the area between the cuticle and epidermis showing **sub-cuticular growth**.
- Most fungi spread into the tissue of the plant organs either by growing directly through the cells as **intracellular mycelium** or by growing between the cells as **intercellular mycelium.**
- Fungi that cause vascular wilts invade the **xylem vessels** of the plants.
- Bacteria invade tissues inter-cellularly, although when parts the cell walls dissolve, they also grow intra-cellularly.
- Bacteria causing vascular wilts and fastidious bacteria (*Xylella fastidiosa*) invade the xylem vessels.
- Viruses and viroids invade all types of living cells, phytoplasma and protozoa invade phloem sieve tubes and a few adjacent phloem parenchymatous cells.
- **Local infections-** Many infections caused by fungi, bacteria, nematodes, viruses and parasitic flowering plants are local, i.e., they involve a single cell, a few cells or a small area of the plant. They may remain localized throughout the growing season or may enlarge slightly or very slowly.
- **Systemic infections-** Other infections enlarge more or less rapidly and may involve an entire plant organ, a large part of plant or even the entire plant.

- Infections caused by fastidious bacteria, phytoplasma, protozoa, and natural infections caused by viruses and viroids are **systemic,** i.e., the pathogen from one initial point spreads and invades most or all susceptible cells and tissues throughout the plant. For example, vascular wilts, some downy mildews, white rust of crucifers, loose smut and hill bunt of wheat.

Growth and reproduction (colonization) of the pathogen

- After infection, pathogens grow, multiply or both within the plant tissues and invade and colonize the plant to a lesser or greater extent.
- Growth and reproduction of the pathogen (also called colonization) in or on the infectious tissues are actually two **concurrent sub-stages of disease development**.
- Most of the fungi and parasitic higher plants generally invade and infect the plant tissues by growing on or into them.
- They continue to grow and branch out within the infected host and spread into more and more of the plant until, its spread is stopped or the plant is dead.
- All other pathogens, namely, bacteria, phytoplasmas, viruses, viroids and protozoa do not increase in size much if at all, as their size and shape remains relatively unchanged throughout their existence.
- They invade and infect the new tissues within the plants by reproducing at a rapid rate and increasing their number tremendously in the infected tissues.
- Their progeny may then be carried passively into the new cells and tissues through plasmodesmata (some viruses, viroids), phloem (viruses, viroids, phytoplasmas, some fastidious bacteria, protozoa) or xylem (some bacteria).
- Alternatively, as happens with bacteria they may move through cells on their own power.
- **Plant pathogens reproduce in a variety of ways**.

i) Fungi reproduce by means of **spores**, either asexually or sexually.

ii) Parasitic higher plants produce **seeds**.

iii) Bacteria and phytoplasma reproduce by **fission** in which one mature individual splits into two equal, smaller individuals.

iv) Viruses and viroids are **replicated** inside the host cells.