Pathogenesis

Before symptoms appear, the pathogen independently or with the host has passed through several stages. These stages, reactions and interactions arranged in a sequence that leads to disease development and the entire chain of events leading to disease development are known as pathogenesis. In brief, pathogenesis is a process or sequential chain of events by which disease development takes place.

Stages of the pathogenesis

1. Inoculation
2. Penetration
3. Establishment of infection
4. Invasion (Colonization)
5. Growth and reproduction of the pathogen
6. Exit of the pathogen i. e. dissemination of the pathogen,
   and survival of the pathogen in the absence of the host.

Success of the infection process

After landing on the host or having come in contact with the living host surface through dissemination by seed, soil, air or other means the pathogen generally initiates the process of infection. In the strict sense of the term, pathogenesis starts from this point. The success of this process, however, depends on many factors which are listed below:

- The host should be receptive or susceptible.
- The host should have disease proneness determined by environments.
- There must be proper aggressiveness in the pathogen.
- The pathogen should be capable of fast multiplication.
- It should have proper inoculum potential, environmental conditions that favour the pathogen in penetration and multiplication.

Inoculation:

Inoculation is the coming in contact of a pathogen with a host. Pathogenesis caused by an infectious agent begins as soon as the pathogen comes into contact with any portion of a susceptible plant. Most of the bacterial and fungal pathogens come into contact with their hosts accidentally in the form of windborne or water-borne spores or propagules. Some fungi, many bacteria and most of the viruses are carried to their host plants by insects, nematodes, and other vectors. Motile propagules of fungal pathogens are attracted to root exudates such as the zoospores of many plant

pathogens (Hickman and Ho, 1966). The inoculum of most plant pathogens is carried to host plants passively by wind, water, and insects.

Penetration:

Pre-penetration activities of the pathogen on host surface:

The plant viruses are absolutely passive in transmission and entry into the host. They reach the interior of host cells only with the activity of organs of their vector or by some other mechanical means. Thus there is no pre-penetration activity on the host surface. The bacteria have no dormant structures hence no pre-penetration activity except for multiplication on the natural openings. Nematodes cannot multiply outside the living host or away from the host as they depend for nutrition solely on their host. Before penetration, they do show some orientation towards the root surface and are active for some time before actual penetration.

It is only in fungi that complicated activities do occur before penetration. Many fungal pathogens first grow on the surface of the host before causing penetration. By this, they achieve the proper numerical and chemical strength to bring about the breakdown of outer defence barriers of the host. Hyphae of *Rhizoctonia solani* often aggregate to form an infection cushion from which multiple penetrations occur by means of appressoria and penetration pegs (Dodman and Flentje, 1970). A similar activity occurs in some species of root-infecting *Fusarium*. In *Armillaria mellea* the fungus hyphae must first form the infection structure called rhizomorph and then can cause infection. In other fungi, the spores germinate, either the germ tube by itself causes penetration, directly or indirectly, or it first produces an appressorium from which infection threads develop and penetrate the host.

Indirect penetration

In case of indirect penetration the germ tubes of infection threads enter the host through one or both of the following channels:

- **Wound**
- **Natural openings**

i) Entry through Wounds:

Wounds are caused by physical means such as by implements used in various operations, hail storm, improper handling by workers etc. and also the wounds or punctures caused by insects, nematodes and other members of the animal kingdom.

All bacteria, most fungi, some viruses, and all viroid can enter plants through various types of wounds, and viruses, mycoplasmas, and fastidious vascular bacteria enter plants through wounds by their vectors.

The ectoparasitic nematodes cause superficial wounds on root surface thereby helping many root rot pathogens to establish on the exposed root tissues.

The endoparasitic nematodes puncture the epidermis and move into deeper tissues. The tunnels caused by them help entry of pathogens that prefer to invade the deeper tissues such as xylem and phloem.

The vascular wilt fungi such as *Fusarium*, *Verticillium* are usually more aggressive when endoparasitic nematodes such as *Meloidogyne* (root knot) have also attacked the roots.

ii) Entry through natural opening:

Many fungi and bacteria enter plants through stomata and some enter through hydathodes, nectarthodes, lenticels and other uncovered or non-cuticularised parts of the host.

Stomata: The stem rust fungus *Puccinia graminis tritici* enters through stomata of the host.

Lenticels: *Streptomyces scabies* causing common scab of potato, enter through stomata or lenticels.

Hydathodes: *Erwinia amylovora* – enter through hydathodes of apple and pear flowers. *Xanthomonas campestris*- also enter through hydathodes.

Nectarthodes: *Erwinia amylovora* – enter through nectarthode of apple and pear flowers.

Trichomes: *Corynebacterium michiganense*-Bacterial canker of tomato often enters through trichomes.

Entry through root hairs: *Fusarium oxysporum* f. sp. *lini* (flax wilt) enter through root hairs. *Plamodiophora brassicae* (club root of crucifers).

Entry through buds: *Uromyces pisi* (Pea rust) enters through unfolding buds. *Synchytrium endobiotium* causes wart disease of sweet potato results from bud infection.

Direct penetration:

In this method of entry into the host, the pathogen exerts its own efforts to break the host barriers and directly enter through the cuticle or the epidermis without seeking the help of wounds or natural openings.

Fungi that penetrate their host plants directly do so through a fine hypha or an appressorium. The fine hypha grows toward the plant surface and pierces the cuticle and the cell wall through mechanical force and enzymatic softening of cell wall substances.

Direct penetration in nematodes is accomplished by repeated back-and-forth thrusts of their stylets. Such thrusts finally create a small opening in the cell wall, and the nematode sends its stylet into the cell or the entire nematode enters the cell

Parasitic higher plants from haustoria and penetration peg at the point of contact of the radical with the host plant, penetration is similar to that in fungi.

Infection

Infection is the process by which pathogens establish contact with the susceptible cells or tissues of the host and procure nutrients from them. During infection pathogens release in the host a number of biologically active substances (such as enzymes, toxin, and growth regulators), which may affect the structural integrity of the host cells or their physiological process. All the visible changes in the appearance of infected plants make up the symptoms of the disease.

Invasion:

Most fungi spread into all the tissues of the plant organs they infect, either by growing directly through the cells-intracellular mycelium, or by growing between the cells intercellular mycelium. The fungi that cause vascular wilt invade the xylem vessels of plants. Bacteria invade tissues intercellularly, although when parts of the cell walls dissolve, bacteria also can grow intracellularly. Bacteria causing vascular wilts invade the xylem vessels. Most nematodes invade tissues intercellularly, but some can invade intracellularly as well. Viruses, viroids, mycoplasma, and fastidious bacteria invade tissues by moving from cell to cell intracellularly.

Growth and Reproduction:

After successful establishment in the host tissues, plant pathogens reproduce in a variety of ways. Fungi reproduce by means of spores; parasitic higher plants reproduce just like all plants, that is, by seeds. Bacteria, mycoplasmas, and protozoa reproduce by fission. Viruses and viroids are replicated by the cell. Nematodes reproduce by means of eggs.

Exit of the Pathogen:

After an infection has been established the pathogen-bacteria, fungi, and nematodes multiply by reproduction in the tissues and their population increase. Since the host tissues cannot support the disease cycle and escape death due to overcrowding. Viruses can exist only with living protoplasm and their method of exit from the host solely through other agencies. In case of bacteria, the disintegration of tissues helps them to ooze out in the form of slime on the host surface from where they can be dispersed through insects, wind and water. The fungi have the most elaborate system of exit and liberation of secondary inoculums. The spores of fungi are produced in vertical series on simple or branched spore-bearing hyphae or they are produced in aggregations such as sori of smut and rust fungi or spore masses in procumbent chains, special fruiting bodies, some fungi produces resting spores such chlymadospores and some fungi produces selerotia etc. the spores thus formed are dispersed and spread of the disease occurs during the same season.