place through hydathodes as well as stomata to gain entry into the tissues. *Bacterium amylovorum*, which is responsible for fire blight of apples and pears, enters through stomata, hydathodes and nectaries. It can also enter through non-cutinized surfaces, such as those of stigma and anthers, and through wounds.

On the other hand, the process of infection of plant viruses is quite different from above mentioned mechanisms of infection. The plant viruses are very highly infectious and filterable in nature, and gain their entry into host tissues mainly through the help of sucking insects. The leaf-sucking insects feed by a long and delicate stylet apparatus which not only serves to suck up the leaf juices but also to inject saliva through a second channel along the passage forced through the tissues; this generally reaches the phloem of host plant. An *incubation* or *latent period* in the insect between the time of ingestion of the virus and its successful transmission to a new host is found in a group of virus diseases, usually transmitted by leaf hoppers and thrips.

PATH OF INFECTION

The path of infection is concerned with the entry of the parasite into the host. The most important modes of the entry of the parasite into the host are being discussed here.

Table : 7.1

PATH OF INFECTION

Direct		Indirect	
1. Entry through intact or cuticularized surface Epidermis	2. Entry through non-cutinized surface (*i.e.*, through special organs) such as : (a) flower infection (b) seedling infection (c) bud infection (d) needle leaves (e) root-hairs	3. Entry through natural openings such as : (a) stomata (b) lenticels (c) hydathodes	4. Entry through artificial openings (a) entry through injuries (b) entry through lesions (c) entry through wounds caused by insects.

1. Entry Through Intact Surface

This type of infection generally takes place by plant pathogenic fungi. For example *Botrytis cinerea* penetrates actively through the cuticle into the interior of the leaves. This fungus can also penetrate, by a similar process into organs which are covered by protective layers other than cuticle. In the case of *Erysiphe graminis*, it has been found

that a germ-tube from a spore sown on a leaf of plant, gives rise to a fine stylar process from it, which pierces the cuticle, and induces the formation of a local internal swelling of the underlying cellulose wall, so that a small papilla projects from the under-side of the wall into the cell. In successful infections, this papilla is being penetrated by the haustorial tube and latter enters the epidermal cell and forms a haustorium.

2. Entry Through Non-cutinized Surface

There are several plant tissues, which have no cuticle and make way for pathogens, which use these organs as passage for migration into deep-seated tissues. They grow through these organs towards other organs in which they give rise to the characteristic disease and in which they may reproduce. In particular, the flowers, seedling, buds, needles and root-hairs serve as entry points for infectious plant diseases.

(a) Flower infection. The flower infection can take place through *stigma*. Because of secretions and special structure, the stigma offers the parasite, the most favourable substrate for its germination. Such stigma infection is commonly found in *Sclerotinia cinerea*, causing blossom and twig blight of stone fruit trees. In other cases the germ-tube of the pathogen enters the ovary through the stigma-end and style and takes asylum therein, remains passive and transmits infection to its offspring in the next season, *e.g.*, *Ustilago tritici* and *Botrytis anthophila*.

In addition to the stigma, flower infection also takes places, through the nectaries, because of their non-cutinized tissues and sugary secretions. This path of infection is used by *Bacillus amylovorous*, causing fire blight of apples; *Sclerotinia fruticola*, causing brown rot of pears and *Taphrina deformans*, causing leaf-curl of peaches.

(b) Seedling infection. In the seedling infection the seedling is infected but it does not itself becomes diseased; it gives asylum to pathogen with showing any symptoms. The seedling grows into a plant and the parasite develops in its tissues. The symptoms of disease first appear some months later, generally at the time of flowering, *e.g.* smuts and bunts. Seedling infection of this type is very commonly met with in the grain smut and loose smut of sorghum caused by *Sphacelotheca sorghi* and *S. cruenta* respectively; bunt of wheat (*Tilletia caries*); flag smut of wheat (*Urocystis tritici*), etc. In other cases the symptoms of disease appear at the time of emergence of seedling, *e.g.* downy mildew of cereals (*Sclerospora graminicola*), onion smut (*Urocystis cepulea*) and foot rots caused by *Pythium*, *Fusarium* and *Rhizoctonia*.

(c) Bud infection. In this type of infection, disease ensues only when infection takes place sufficiently early, to ensure that the causal organism reaches the growing point. The fungus causing the scab of apples, *Venturia inaequalis* makes its way into blossoms through the young buds. Wart disease of potato (*Synchytrium endobioticum*) also results from bud infection. The myxamoebae can penetrate only through the buds (eyes) and the area immediately surrounding them and not through the hard skin of tuber.

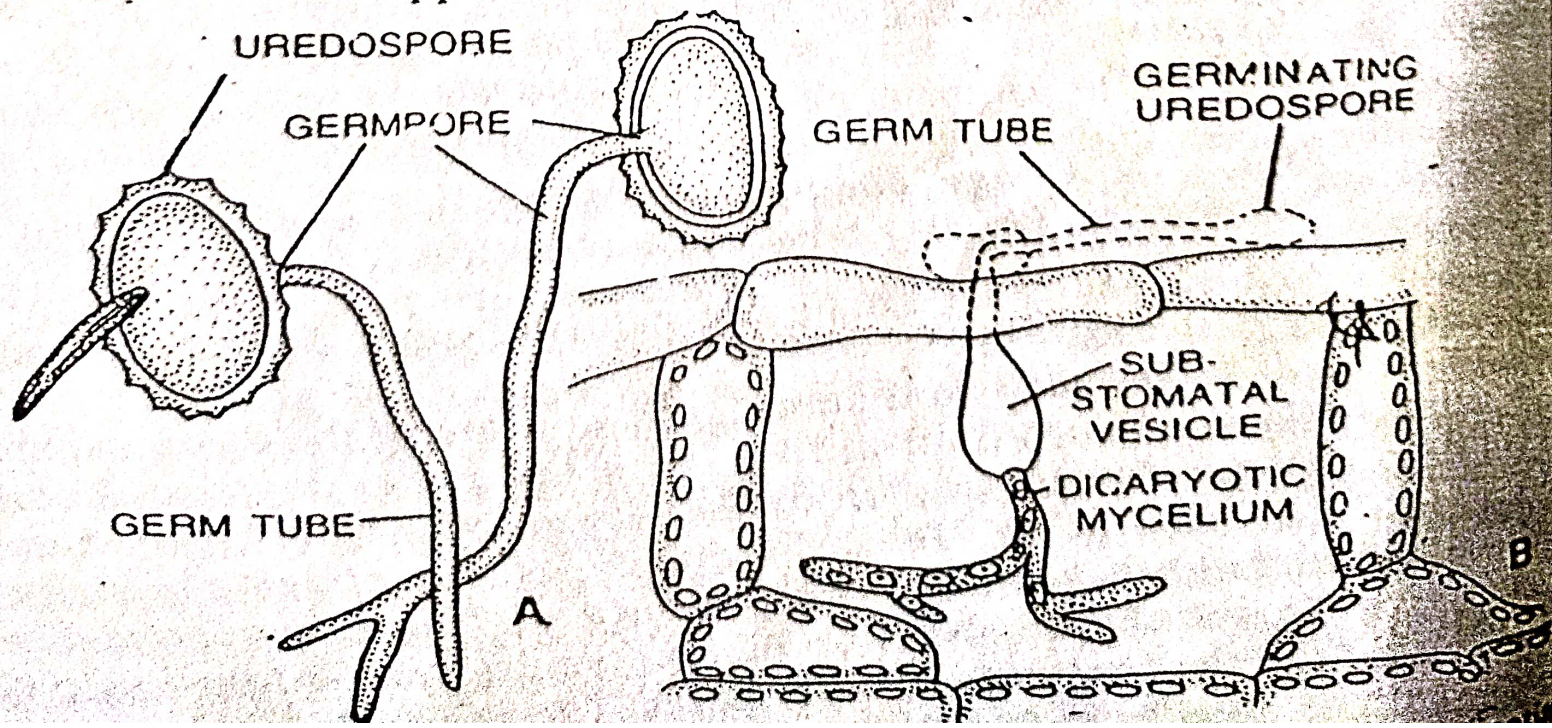
(d) **Needle leaves.** The hyphae of the pathogens which infect th needle leaves at their apices, grow downward in them. The infectio through needle points is of special significance in the dreaded blist rust of pine, which uses the needle points as avenues of entry of th sporidia (*basidiospores*) of *Cronartium ribicola*.

(e) **Root-hairs.** The root-hairs are not cutinized, and therefore allo the parasites to enter which cannot perforate the cuticle. The myxamoeb of the club root of cabbage (*Plasmodiophora brassicae*) enter its ho through the root-hair and youngest epidermal cells. The mode of ent is also characteristic of *Fusarium* wilt, the Texas root rot fung (*Phymatotrichum omnivorum*), the fungus causing hollow stem sorghum (*Rhizoctonia bataticola*), etc. Entrance of the pathogens throu root hairs is of common occurrence in several root rotting fungi a soil-borne bacterial pathogens, *e.g.*, nodule bacteria (*Rhizobiu radicicola*) of Leguminous plants.

3. Entry Through Natural Openings

The natural openings such as stomata and lenticels serve as avenu of entry for plant pathogens. They are as follows :

(a) **Stomatal infection.** Entry through stomata is a passive proces In the uredospores of *Puccinia*, the actual entry is usually preceded b the formation of an appressorium over the mouth of the stoma. This m be a swelling or a thickening of a short length of the tip of the ger tube. It is being fixed to the surface of the guard cells of stoma by so kind of sticky secretion, and the actual entry through the stoma effected by a slender infection hypha which arises as a branch on t underside of the appressorium.



drop ; when they come near to a stoma, the flagella are retracted, they become rounded and encysted, and after only 12 minutes, under favourable conditions, a germ tube is driven down into the stomatal chamber.

On the other hand, the penetration of bacterial pathogens, takes place through the action of absorption. This action is in the nature of suction and is found in *Xanthomonas campestris, X. malvacearum, X. phaseoli* and several other aerial bacterial parasites.

(b) Lenticular infection. The entry of plant pathogens through the lenticels is also important. For instance, *Spongospora subterranea* (powdery scab of potato) and *Actinomyces scabies* (common potato scab), use the lenticels as avenues because they cannot break through the periderm. The germ tubes of the zoospores of *Phytophthora infestans* (late blight of potato) attack the tubers through the lenticels and through

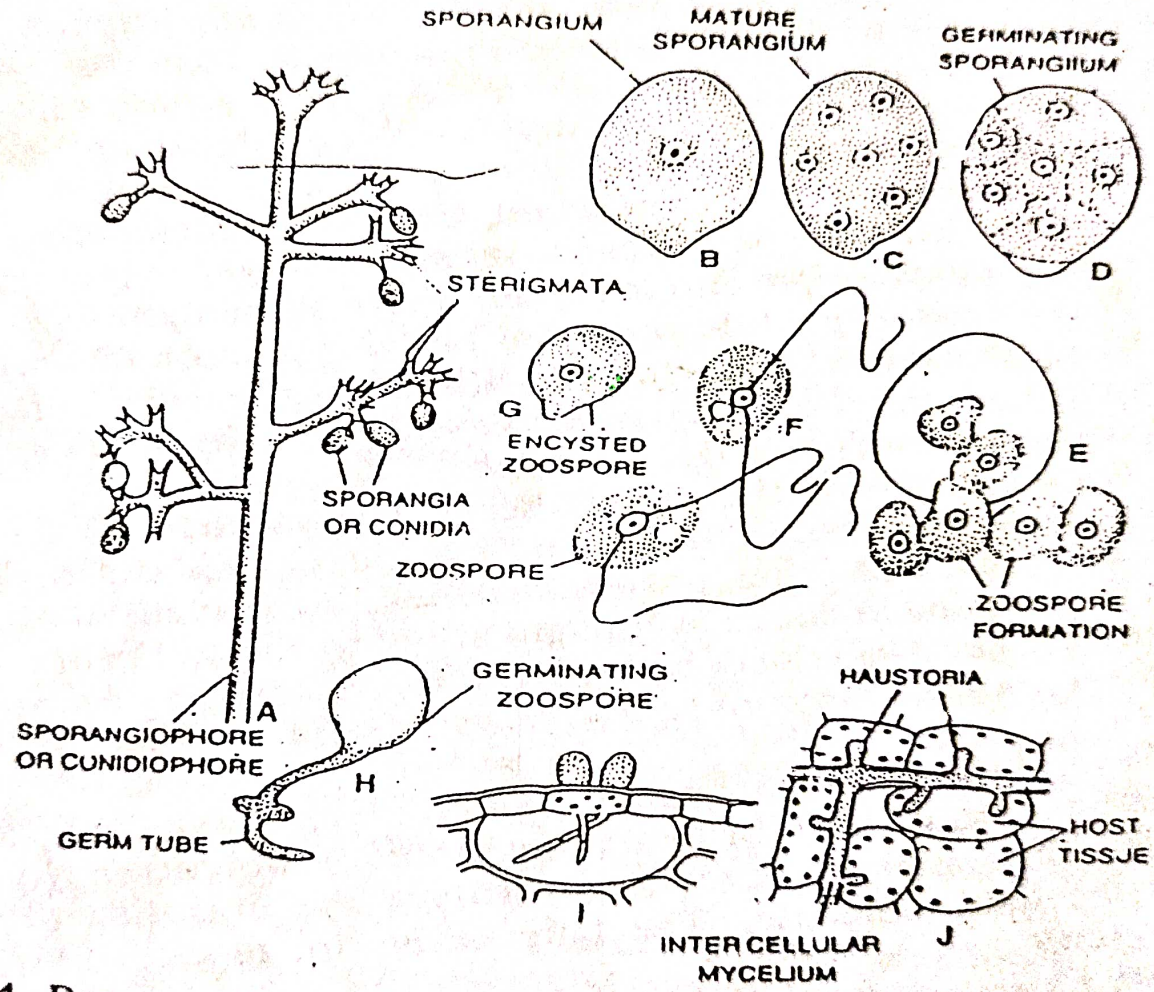


Fig. 7.4. Downy mildew of grapes (*Plasmopara viticola*). A , conidiophore possessing sporangia or conidia; B-D, germination of sporangium and production of zoospores; E, liberation of zoospores from sporangium; F, single biflagellate zoospore; G, encysted zoospore; H, germinating zoospore; I, infection on host; J, intercellular mycelium and haustoria in host tissue (A, after Farlow; B-J, after Gregory).

the wounds. *Botrytis cinerea* and *Nectria cinnabarina* also infect the hosts through the lenticels or through the wounds.

(c) Infection through hydathodes. *Xanthomonas campestris*, causing black rot of cabbage gains entry into host tissues through

hydathodes (water stomata) by the process of suction absorption.

4. Entry Through Artificial Openings

(a) Entry through injuries. The infections which take place through injuries are known as *wounds* or *traumatic* infections. For instance, the aerobic plant parasite of crown gall (*Bacterium tumefaciens*) has been regarded as a wound parasite since it produces a gall round the wound.

The wounds or injuries may be caused by various agencies such as farm operations, digging, hail storms, sun burn and several others. The organisms causing ripe rots and storage diseases such as *Rhizopus*, *Aspergillus*, *Colletotrichum*, *Fusarium* and several species of bacteria enter through the wounds or injuries.

Sometimes *Phytophthora infestans* (late blight of potato), *Alternaria solani* (early blight of potato) and *Plasmopara viticola* (downy mildew of grapes), penetrate into the interior of the leaf from the upper side by means of crevices and cracks in the cuticle. *Phytophthora palmivora*, causing gummosis of citrus trees in India gain entry into the bark through cracks at bud joint.

(b) Entry through lesions. A primary parasite gives rise to a lesion on the surface of the leaf ; later on this lesion can be used as a point of entry by a secondary parasite. For example, *Fusarium caeruleum*, causing dry rot of potato, cannot penetrate the uninjured skin of the tuber. But, if the tubers are already attacked by blight caused by *Phytophthora infestans*, then *F. caeruleum* enters the tuber through the necrotic tissue formed by the potato blight.

(c) Entry through wounds caused by insects. Injuries and wounds caused by insects are easily penetrated by various plant pathogens. This is a special type of wound infection, where the insect making the wound, also acts as the vector, which makes the transmission of the parasite to the new host. The brown rot fungus, *Sclerotinia fructicola*, is not carried by wasps and bees but these insects deposit the conidia in wounds formed by their stylets, which facilitates their entry into the fruits. The brown rot fungus, *Phomopsis versoniana*, enters the fruit of pomegranate through the path made by fruit borer. In the case of red rot of sugarcane caused by *Colletotrichum falcatum*, the secondary infection takes place through the borer injury of stem and leaves.

HOW PATHOGENS ATTACK PLANTS

The activities of pathogens in plants are mostly chemical in nature, and therefore, the diseases caused by pathogens on plants are the result of biochemical reactions that take place between substances secreted by the causal agents and those present within the plant. The substances secreted by pathogen in plants responsible for causing disease either directly or indirectly, include enzymes, toxins, growth regulators, polysaccharides and antibiotics. These groups of chemical substances vary in pathogenicity and their relative importance may differ from one disease to another. For example, in soft rots enzymes are most important,