Kingdom Chromista

Members of Chromista are single-celled and multicellular eukaryotes. Flagella are present. They are tiny unicellular, flagellates to the large brown algae known as kelp. Molecular studies have confirmed the inclusion of certain organisms once considered fungi, as well as some heterotrophic flagellates. Despite their diversity of form and feeding modes, a few unique characters group these organisms.

Phylum :Oomycota

Oomycota is a phylum of filamentous chromists containing over 500 species. The majority of these organisms are in the groups commonly known as **water** molds or downy mildew. "Oomycota" means "egg fungi", referring to the oversize oogonia which house the female gametes (eggs).

Its Characteristics features

Vegetative thallus filamentous, coenocytic, in some groups unicellular. Cell wall lacking chitin (except for a few taxa), made of glucan and cellulose.Asxual reproduction by biflagellate zoospores.Sexual reproduction by oogonia (female) and antheridia (male)- no motile gametes. The sexual spore is oospore. They have diploid life cycle.

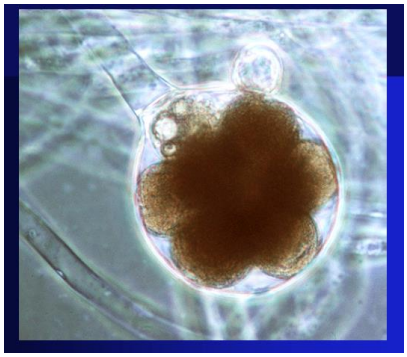
Sexual reproduction is oogamous

Female gamete (oosphere) produced by an oogonium

Depending on taxon, there may be one to many oospheres per oogonium

Male gamete is produced by antheridium and transferred to the oogonium by gametangial contact and migration of male nuclei.

Saprolegnia



Asexual reproduction is by zoospores

Zoospores have flagella

The anteriorly directed flagellum bears two rows of hairs.

The posteriorly directed flagellum is a whiplash (smooth) type. Phylogenetically unrelated to the fungi but similar in morphology & physiology

Orders

Saprolegniales

Leptomitales

Lagenidiales (Salilagenidiales)

Peronosporales

Saprolegniales

Saprolegniaceae

Saprolegnia

Asexual reproduction

The sporangia of Saprolegnia develop at the tips of the hyphae. The hyphal tip which is pointed in the vegetative condition, swells and becomes club-shaped, rounded at the tip and accumulates denser cytoplasm then a septum develops at the base of the sporangium. The hyphal tip contains uninucleate pieces, each of which differentiates into zoospore. As the sporangium ripens the basal septum of the sporangium becomes concave and the tip of the sporangium breaks down at the clear protuberant tip. The spores are released quickly one by one as they pushed under pressure. The zoospores (primary zoospores) are pear-shaped bear two apically attached flagella. They

swim for a time and then withdraw the flagella and encyst. Following the period of rest they germinated to produce kidney-shaped zoospores (secondary zoospores) bear two laterally attached flagella, they siwm for a time and withdraw the flagella and encyst. The cyst germinates to a germ tube and develop hypha.

Proliferation of zoosporangia

It is an interesting and characteristic feature in saprolegnia. The basal septum of the empty zoosporangium initiates the development of a secondary zoosporangium. It grows and bulges into the empty sporangium to form a new sporangium. The new sporangium matures within the primary one. This process may be repeated and several zoosporangia may thus be formed within the walls of the next older one

Sexual reproduction

Oogonia containing one or several eggs (oosphere) are fertilized by antheridia. A septum at the base of the oogonium and antheridia cut them off from the subtending hyphae. Fertilization is accomplished by the penetration of fertilization tubes into the oogonia. The male nucleus fuses with single egg nucleus. The fertilized egg (oospore) form a thick wall and after weeks or months oospore germinates by germ tube or give rise to a sporangium. The The majority of species are homothallic **(monoecious),** that is a culture derived from a single zoospore will give to a mycelium forming both oogonia and antheridia. Some species are heterothallic (dioecious).

Peronosporales

Order Peronosporales, Aquatic or terrestrial; parasitic on algae or vascular plants, the latter mostly obligate parasites causing downy mildews; in advanced species, zoosporangia borne on well-differentiated sporangiophores, deciduous and behaving as conidia (asexually produced spores); example genera include Albugo, Peronospora, Bremia, and Plasmopara.

Habitat

They are aquatic, amphibious and terrestrial species. Forming a highly group of obligate parasites.

Somatic features

Mycelium well-developed. Consisting of coenocytic slender hyphae that branch freely. Hyphae may be intercellular or intracellular. Produce spherical/knob or elongated type of haustoria (Haustorium is a specialized hyphal extension that is formed by some obligate fungi which penetrates into the host cell and absorbs nutrients).

Asexual Reproduction

In most of the species asexual reproduction by means of only kidney or reniform shaped biflagellate zoospores.

Sporangia are borne on the sporangiophore. Example – Pythium gracile, Pythium debaryanum, Phytophthora infestans, etc. Within the sporangium zoospores are produced. Upon germination a membrane bounded vesicle is produced at the end of exit or discharge tube. The undifferentiated protoplasm from the zoosporangium passes into the vesicle. Within about 15 to 20 minutes, the protoplasm differentiates into zoospores. Finally, zoospores released when the vesicle ruptures. After releasing, the zoospores swim for some time, come to rest, encyst and germinate each by a germ tube that develops into the new mycelium.

In some of the species the sporangia borne on sporangiophores and are deciduous upon maturity. In this respect, the whole sporangium acts as a spore and germinates by a germ tube instead of producing zoospores. Example – Albugo candida.

Sexual Reproduction

Sexual reproduction is gametangial contact. Sexual reproduction is by means of well-differentiated oogonia and antheridia borne on the same or on different hyphae.

Meiosis takes place in the gametangia, resulting in the formation of haploid oospheres and antheridial nuclei. The oogonium is generally globose, contains a single uninucleate or multinucleate oosphere, surrounded by a layer of periplasm. The antheridium is uninucleate or multinucleate. When gametangial contact is occurred, fertilization tube is formed by the antheridium, pushes through the oogonial wall and the periplasm, and reaches the oosphere. If the oosphere is uninucleate, a single male nucleus fuses with the female nucleus and forms the zygote. If the oosphere is multinucleate, more male nuclei fuse with female nuclei and multiple fertilizations occur. After fertilization, the oosphere develops a thick wall and becomes an oospore. The periplasm serves as nourishment for the developing oospore. The mature oospore generally lies free within the oogonial wall. After overwintering, the oospores germinate in the spring, by putting out germ tubes, which develops into mycelium. Classification of Peronosporales order based on sporangia and sporangiophores characters There are three well-defined families of Peronosporales:-

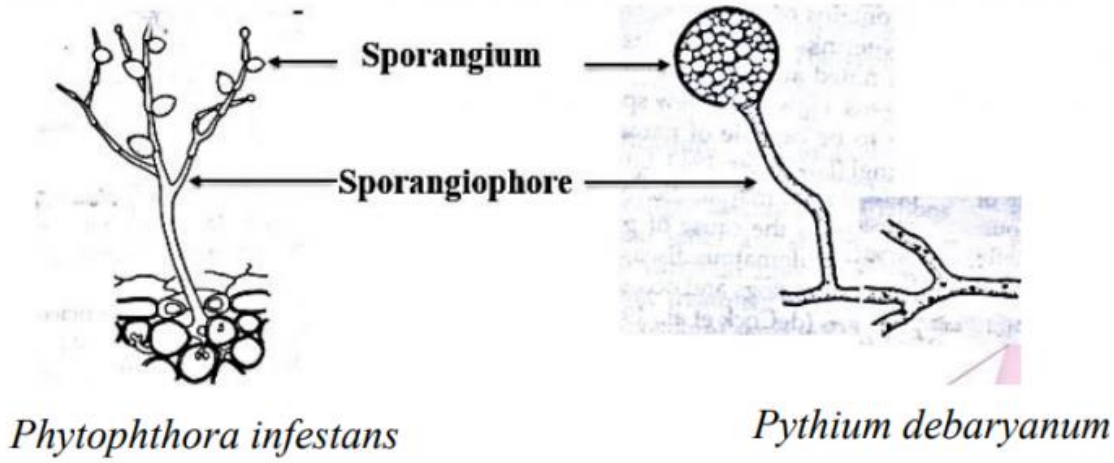
Pythiaceae
Peronosporaceae
Albuginaceae

1-Pythiaceae

Pythium aphanidermatum – damping off of tobacco (Nicotiana tabacum) and stem rot of papaya (Carica papaya).
P. myriotylum – rhizome rot of zinger (Zingiber officinale).
P. debaryanum – damping of crucifers.
Phytophthora infestans – late blight of potato (Solanum tuberosum).

Mostly non-obligate parasites or saprobes. Sporangiophores usually undifferentiated from the mycelium, branched, indeterminate growth, resuming growth after the production of a sporangium. Periplasm thin layer or absent. Haustoria absent or branched. Under suitable conditions they can cause various destructive diseases in plants.
Examples –

Pythium spp. (cause seed rots, damping off diseases of seedlings of various plants).



Phytophthora infestans (cause late blight of potato- cause Irish famine in Ireland during 1845-1849, resulted in the death of about 1 million Irish people, emigration up to 1.5 million people to North America).

Late blight of potato

Symptom

The disease first appears as water soaked, light brown lesions on the edge or tips of the leaf blade.

Under favorable condition lesions spread fast over the entire leaflet and petiole. Due to the infection the leaves become rolled towards the center from the margin. The lesions turn dark brown, dry and brittle after the death of infected leaf tissues. On the underside of the infected leaves, whitish growth of the fungus can be seen under high humidity (heavy dew or rain). On stems, late blight causes brown lesions that look greasy. The pathogen causes purplish-brown lesions on the surface of tubers .

Life cycle of Phytophthora infestans

In most areas of the world where potatoes are, P. infestans appears to survive the winter in the form of mycelium in infected tubers.

But thick-walled oospores of this fungus are rarely produced in the most potato-growing regions of the world and do not appear to play significant role for the survival or propagation of the pathogen.
This appears to be related to the fact that most of the strains of P. infestans are heterothallic and require two compatibility groups, called as mating types, designated as A1 and A2, in order to produce oospores.
Now it is frequently occurring all over the world.
Effect of temperature and humidity on the life cycle of Phytophthora infestans
Temperature and humidity are the most important factors for the life cycle of P. infestans.
P. infestans is usually dispersed aerially one to several miles from the overwintering site to living potato or tomato foliage via sporangia which can survive exposure to dry, sunny conditions for up to an hour and even longer under cloudy conditions.
Sporangia can germinate within a few hours after landing on potato or tomato foliage if free moisture (e.g., dew, rainfall, sprinkler irrigation, fog) is present.

Germination takes place either indirectly via zoospores or directly via a germ tube that penetrates into foliage, stems, or fruit to initiate infections.

Infections are visible as small lesions after three to four days. Necrotic areas on some lesions are only 1 to 2 mm in diameter Lesions enlarge as the pathogen grows through the tissues, and the pathogen can sporulate from older lesions when the environment is favorable.

Temperature

Optimum temperature for growth of the mycelium is about 21^{o} C.
If temperatures remain at about 26^{o}C, hyphae of the pathogen usually die within a week.
Abundant sporangial formation takes in culture between 9 and 22^{o} C.
At this range abundant sporangia are produced within 14 weeks whereas at the lower temperatures (9-15^{o} C) 48 hours is required.

Humidity

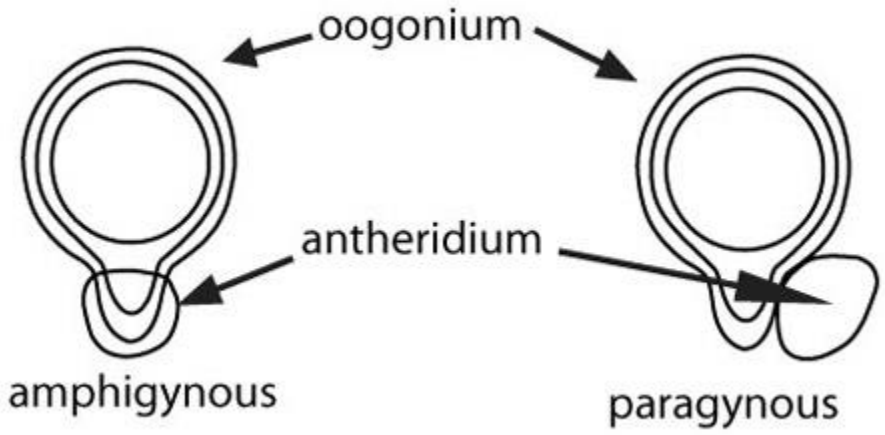
Optimum relative humidity for sporangium production is 100% and minimum relative humidity is 91%.
When relative humidity drops much below 100%, the sporangia die in a few hours.

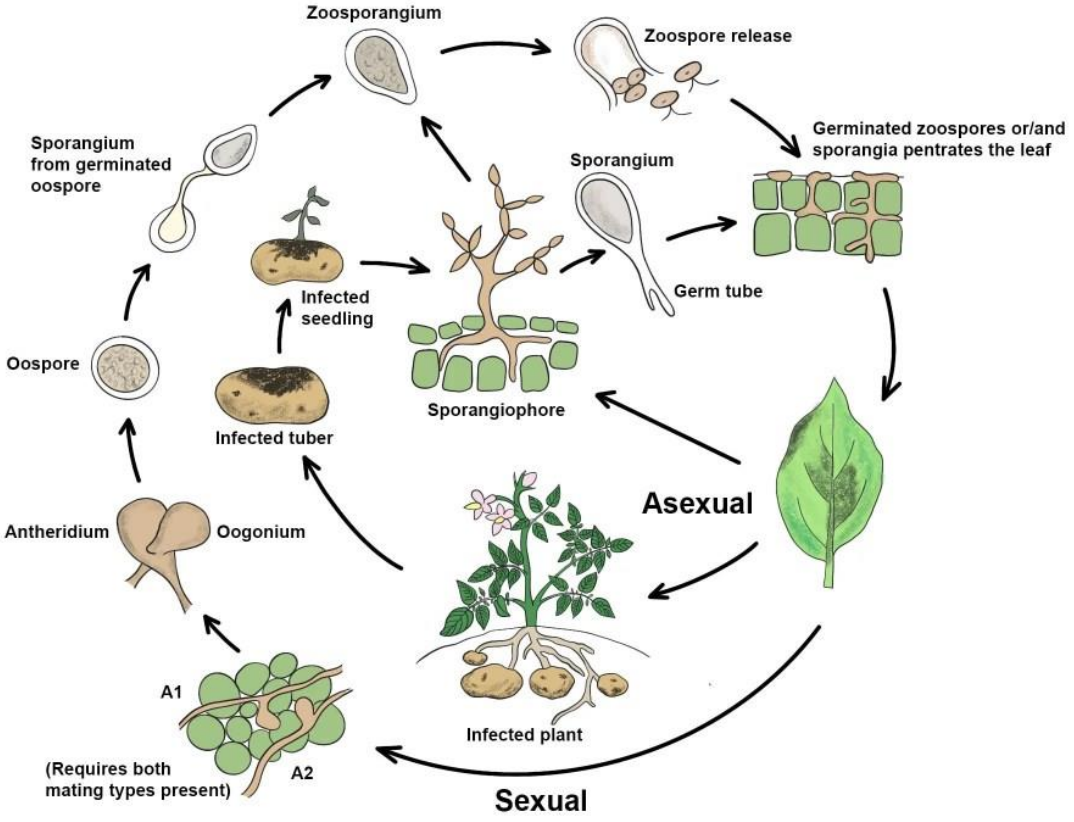
In the presence of water the sporangium germinates either directly by a germ tube that enters through a stoma and infects the leaf or by means of zoospores.

Antheridium
Antheridia in Phytophthora can be either amphigynous or paragynous.

Amphigynous antheridium
An amphigynous antheridium completely surrounds the oogonial stalk, an oogonium with an amphigynous antheridium forms when the oogonial hyphae grows through the antheridium.
Heterothallic species will always have amphigynous antheridia. Example – Phytophthora infestans.

Paragynous antheridium
A paragynous antheridium does not surround the oogonial stalk, and can be attached anywhere on the oogonium, in most species however, attachment will be close to the oogonial stalk. Some species exclusively produce one type of antheridia, but many species produce both types.





Biological control

1-Direct inhibition on Phytophthora infestans

Pseudomonas putida and Bacillus subtilis were used in susceptible potato. Both biological preparations suppressed development of zoospores in vitro.

2- Induced resistance to Phytophthora infestans

Induced resistance in a variety of host-pathogen systems is a well-documented phenomenon.

3-Resistance induced chemicals

There are five kinds of unsaturated fatty acids to induce systemic resistance against P. infestans. Linoleic acid, linolenic acid and oleic acid provided 82%,39% and 42% protection respectively.

02. Peronosporaceae

Obligate parasites of plants with branched tree-like sporangiophores of determinate growth, differentiated from the mycelium. Producing sporangia at the tips of branch of sporangiophore. Periplasm persistent and conspicuous. Haustoria varied and usually branched.

Examples –

Peronospora destructor (cause downy mildew of onion)
Plasmopara viticola (cause downy mildew of grape)

A number of common genera of Peronosporaceae has been differentiated by the branching of their sporangiophores.

Basidiophora
Sclerospora
Plasmopara
Peronospora
Bremia

Sclerospora graminicola – green ear disease or downy mildew disease of bajra (Pennisetum glaucum).
S. sorghi – downy mildew disease of jower (Sorghum vulgare).
Plasmopara viticola – downy mildew disease of grape (Vitis vinifera).
Peronospora pisi – downy mildew disease of peas (Pisum sativum).
P. destructor – downy mildew disease of onion (Allium cepa).
Pseudoperonospora cubensis – downy mildew of cucurbits.

Downy mildew disease symptom

Initial symptoms include large, angular or blocky, yellow areas visible on the upper surface. The spots may appear angular and they are often delimited by veins. As lesions mature, they expand rapidly and turn brown. The under surface of infected leaves appears water soaked. Upon closer inspection, a purple-brown mold becomes apparent. In disease-favorable conditions (cool nights with long dew periods), downy mildew will spread rapidly, destroying leaf tissue without affecting stems or petioles.

Plasmopara viticola – downy mildew disease of grape (Vitis vinifera).

Bremia lactucae
Downy mildew on lettuce
Peronospora parastica
on cabbage
Downy Mildews Fruiting from Stomata on Underside of Leave

Downy mildew disease symptom
Initial symptoms include large, angular or blocky, yellow areas visible on the upper surface. The spots may appear angular and they are often delimited by veins. As lesions mature, they expand rapidly and turn brown. The under surface of infected leaves appears water soaked. Upon closer inspection, a purple-brown mold becomes apparent. In disease-favorable conditions (cool nights
with long dew periods), downy mildew will spread rapidly, destroying leaf tissue without affecting stems or petioles.

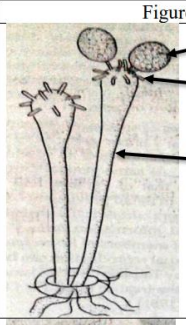
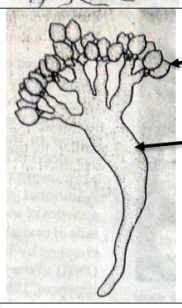
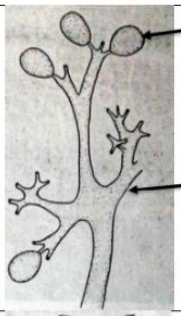
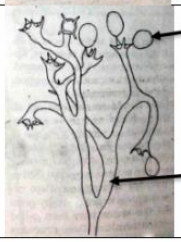
Downy Mildew of grape
Causal organism
Plasmopara viticola
Symptoms
Leaves Roughly circular yellowish discolourations .
White fluffy growth primarily on the lower leaf surface.
As lesions age, they turn brown from the centre outward.
Severely infected leaves may drop.

Life cycle of Plasmopara viticola

Plasmopara viticola is an obligate parasite, and it absorbs its nutrients from the living host tissue via globose haustoria. The hyphae are largely internal in the host. Sexual reproduction occurs through the fusion of antheridia and oogonia within the host tissue. *Plasmopara viticola* has only recently been shown to be

heterothallic. The resulting sexual spore is an oospore, which is the survival and resting stage of the pathogen.
Oospores represent the primary inoculum, and may overwinter in leaf litter or may be released into the soil as leaves decay or are buried by detritivores. They generally begin to germinate in significant numbers shortly after bud break of grape, and populations of oospores may continue to germinate for the entire growing season in some growing regions. Oospores form a single germ tube terminating in a sporangium. Zoospores form within the sporangia and are then released. Zoospores germinate and penetrate the plant only through functioning stomata, i.e., only on green host tissue. Sporangia and zoospores are easily desiccated.
Sporangia also serve as a means of secondary spread of the pathogen. Treelike sporangiophores, bearing white, lemon-shaped sporangia, are produced from a mycelial mat within the host tissue and emerge through stomata. Sporangia are disseminated by wind and rain splash. Zoospores released from the sporangia swim in free water (on the grapevine surface, and encyst near a stoma. Zoospores then germinate and penetrate through a stoma by the means of a germ tube. Sexual reproduction occurs towards the end of the season. The resulting oospores are thick-walled and serve as survival spores.

Disease Management
Cultural practices
Because moisture favors the development of downy mildew, grapevines should be established in well-drained sites with good air movement.
Genetic resistance
Using resistance varities of grape (Vitis vinifera) by using active programs to genitically modify V. vinifera cultivars to include disease resistance.
Chemical control
Both pre-infection (protective) and post-infection (systemic or penetrant) fungicides are widely used for the control of downy mildew. Pre-infection fungicides include the copper-based fungicides, such as Bordeaux mixture post-infection fungicides include phosphonate

Genera	Figure	Characteristics
01. *Basidiophora*		Sporangiophore is club- shaped with a swollen head over which the sporangia are born on minute sterigmata.
02. *Sclerospora*		Sporangiophore is a long, stout hypha with many upright branches near the end, bearing sporangia at the tips.
03. *Plasmopara*		Branches and subdivisions occur typically at right angles and are irregularly spaced.
04. *Peronospora*		Sporangiophores are dichotomously branched at acute angles and taper to gracefully curved pointed tips on which sporangia are borne.
05. *Bremia*		Sporangiophores are dichotomously branched and the tips of the branches are expanded into cup-shaped apophyses with four sterigmata each, bearing the sporangia along their margin

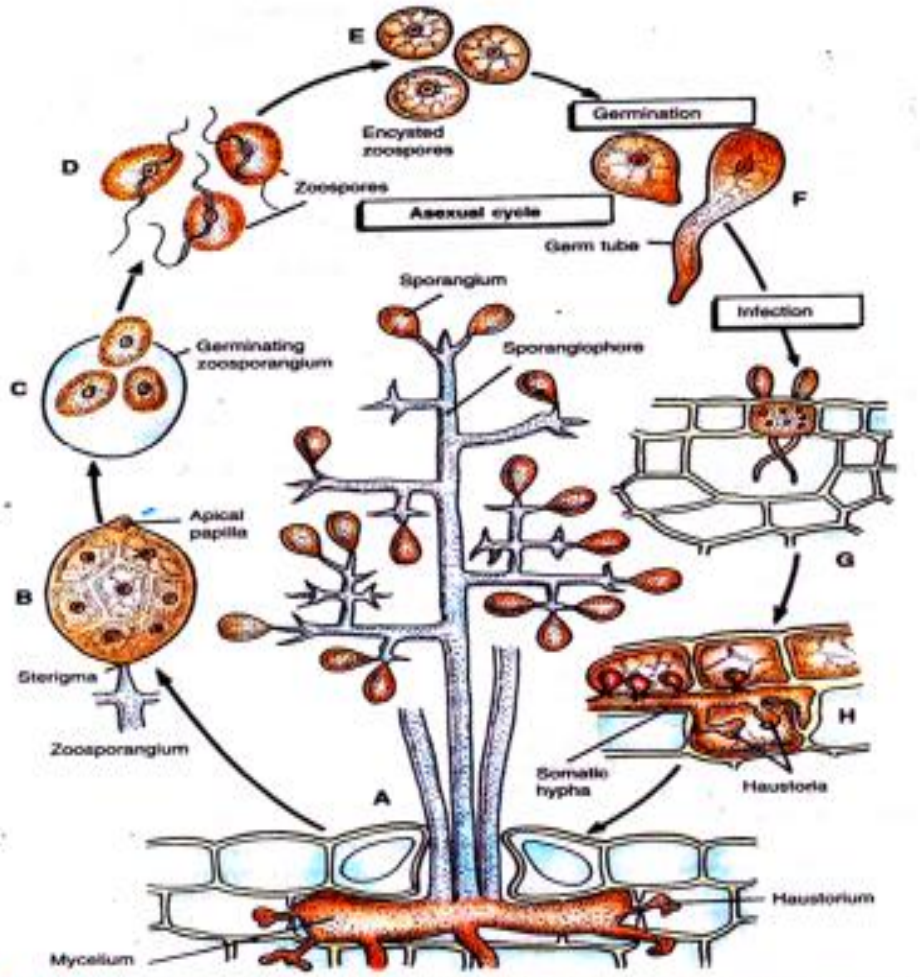


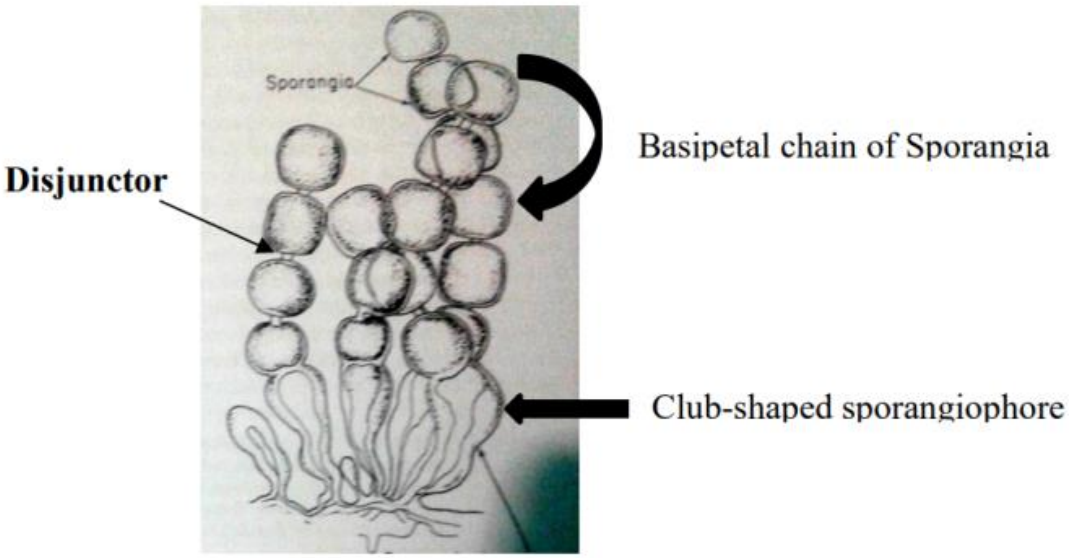
Fig. 6.36 (A-H). Illustrated asexual cycle of *Plasmopara viticola*. A, Sporangiophore with zoosporangia; B, Differentiation of zoospores; C, Germination of zoosporangium; D, Zoospores; E, Encysted zoospores; F, Germination of encysted zoospores; G, Stomatal penetration by the germ tube; H, Intercellular mycelium and the haustoria.

03.Albuginaceae

Albugo candida – white rust of mustard (Brassica juncea).
A. platensis – white rust of Boerhavia plant (Boerhavia repens)
A. bliti – white rust of amaranthus plant (Amaranthus sp.).

Obligate parasites of plants with unbranched, clavate or club shaped sporangiophores that bear, a basipetal chain of deciduous sporangia at their tips.

Oogonial periplasm persistent and conspicuous. Haustoria knob-like. Example- Albugo candida (cause white rust of crucifers).



Albugo candida