Discipline Courses-I
Semester-II
Paper III: Mycology and Phytopathology
Unit-II
Lesson: Chytridiomycetes
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Introduction

Chytridiomycetes are considered as primitive members of Eumycota. They are also called as zoosporic fungi as they reproduce by motile uniflagellate reproductive cells (zoospore and planogamete) which have **single posterior flagellum of whiplash type (Opisthocont flagellum)**. However the zoospores of some members of the Neocallimastigales are multiflagellate. The flagellum is attached to blepharoplast within the cell. The Chytridiomycetes comprises of around 900 species in five orders. Fungi included here are called as 'chytrids'.

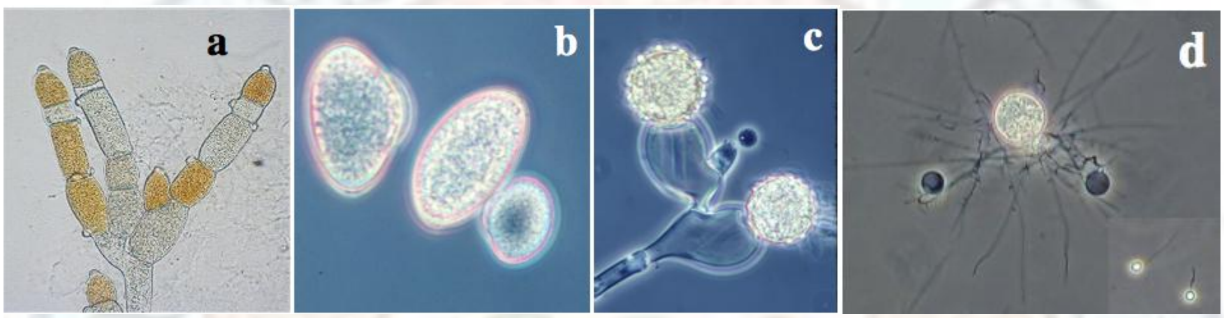

Figure: Chytridiomycetes: *Allomyces macrogynus* (a), *Coelomomyces stegomyiae* (b), *Monoblepharis sp.* (c), *Chytriomyces hyalinus* (d)

Source: Liu *et al. BMC Evolutionary Biology* 2006 **6**:74 doi:10.1186/1471-2148-6-74 (CC-BY-SA), http://www.biomedcentral.com/1471-2148/6/74

Ecology and significance

Chytridiomycetous fungi are mostly aquatic (water molds), however several species also grow aerobically in soil or mud. Species are found in ponds, sluggish, rivers, wet rice field, estuaries as well as in the sea. Many members are saprotrophs, utilize cellulose, chitin, keratin, etc., of decaying plant and animal debris in soil and mud. *Allomyces* occurs in soil and on dead animal matter in water, whereas *Monoblepharis* is found in clean water and growing on dead submerged twigs of various trees including needles of coniferous trees. Some chytrids are biotrophic parasites. They parasitize filamentous algae and diatoms which severely depletes the population of freshwater phytoplankton e.g. species of *Caulochytrium* are known as mycoparasites growing on the mycelium and conidia of some terrestrial fungi. Other chytrids such as *Synchytrium* and *Olpidium* spp. are biotrophic parasites of vascular plants and cause severe economic losses.

Figure: *Synchytrium endobioticum* causes black wart disease of potato.
Source: http://biomessixth10.wikispaces.com/Grassland+Facts (CC-BY-SA)

Olpidium brassicae is commonly present in the roots of many plants but it is relatively harmless, whereas its zoospores are vectors of plant virus that causes big vein disease of lettuce. *Coelomomyces* spp. is pathogenic to freshwater invertebrates including copepods and the larvae of mosquitoes and therefore can be used in bio control of mosquitoes.

Figure: Abdomen of Black fly-*Simulium piperi* with Coelomomyces
Source: http://empidid.com/NatEm/coelombf.html (Displayed with permission)

The most unusual group is the Neocallimastigales, which include anaerobic chytrids found in the rumen of cattle, sheep and caecum of horses and other herbivores, and play significant role in degradation of fibres entering the gut.

Chytridiomycetes are useful as experimental organisms in cellular and molecular biology. They are easy to manipulate in pure culture. The growth and appearance of chytrids in pure culture are different from those in their natural habitat. This has led to problems in classification based on thallus morphology. The availability of culture protocols has, however, helped in studying nutrition and physiology of chytrid.

Table: Importance of Chytridiomycetes

Fungus	Importance
***Chytridium conferve, Chytriomyces hyalinus, Rhizophlyctis rosea* and other saprotrophs**	**Primary invaders and decomposers of organic materials including cellulose, chitin, keratin and hemicelluloses thus helps in the cycling of nutrients**
Synchytrium endobioticum	**Causes serious black wart disease of potato tubers and thus significantly reduces the production of tuber formation and it turn severly effects our agriculture value in terms of economy.**
Physoderma maydis	**Causes brown spot of corn**
Urophlyctis alfalfae	**Causes crown wart of alfalfa**
Olpidium brassicae	**Its zoospores are important vectors for a number of plant viruses of economic importance**
Coelomomyces	**It act as good biological control agent of mosquitoes as it parasities mosquito larvae and adult copepods**
Blastocladiella emersonii* and *Allomyces macrogynus	**Both of them are used as an experimental organisms for fundamental research in cellular and molecular biology laboratories**

Characteristic features

- Most of the members are unicellular but advanced taxa form short chains of cells which are attached to the substratum with the help of rhizoids. They form a coenocytic dichotomously branched mycelium bearing chains of cells with tapering rhizoids which help in anchorage and absorption of nutrients. Extensively developed rhizoids form rhizomycelium. Some of the complex Chytridiomycetes bears more extensive mycelia thallus. Although the hyphae of these species are usually coenocytic, a septum is formed at the base of reproductive structures. Scattered septa can be seen in the older portions of the hyphae. Sometimes these complex species may also produce pseudosepta i.e. false septa or plugs which were found deposited at intervals in the hyphae.

- The mature thallus is surrounded by a cell wall, although it may be naked during early stages of development. The cell wall composition of majority of chytrids have chitin and β-glucan e.g. *Allomyces* and *Blastocladiella*, while some other sp. show presence of cellulose e.g. *Gonapodya*. Cellulose and chitin occur together in the walls of species of *Hyphochytrium* and *Rhizidiomyces*, members of the Hyphochytriomycota.

- The simplest forms of chytrids are **endobiotic** in which the entire thallus, including rhizoids and reproductive structures are formed inside the host cells e.g. *Diplophlyctis* and *Synchytrium*. The more advanced forms are **epibiotic** in which only the rhizomycellium is inside the host cell while the reproductive structure is present externally on the host surface or on a living host cell. It also grows on dead organic matter with their rhizomycellium embedded into the living or dead tissues on which they live, e.g. *Rhizophydium*. In *Physoderma*, both epibiotic and endobiotic sporangia are found.

- In unicellular forms, the thallus is **holocarpic**, whereas in filamentous forms it is **eucarpic**. Biotrophic species such as *Olpidium, Physoderma* and *Synchytrium* are endobiotic and holocarpic where the whole thallus is present within the host cell, and at maturity the entire structure, except for the wall which surrounds it, is converted into reproductive units, i.e. zoospores, gametes or resting sporangia. Advanced taxa e.g. *Allomyces, Monoblepharis* are eucarpic, where the reproductive structures (sporangia and resting sporangia) arise from a part of vegetative thallus. Eucarpic thalli may have one or several sporangia and hence called as **monocentric** (having only a single reproductive structure) or **polycentric** (having more than one reproductive structure). In some species e.g. *Rhizophlyctis rosea* both monocentric and polycentric thalli are present.

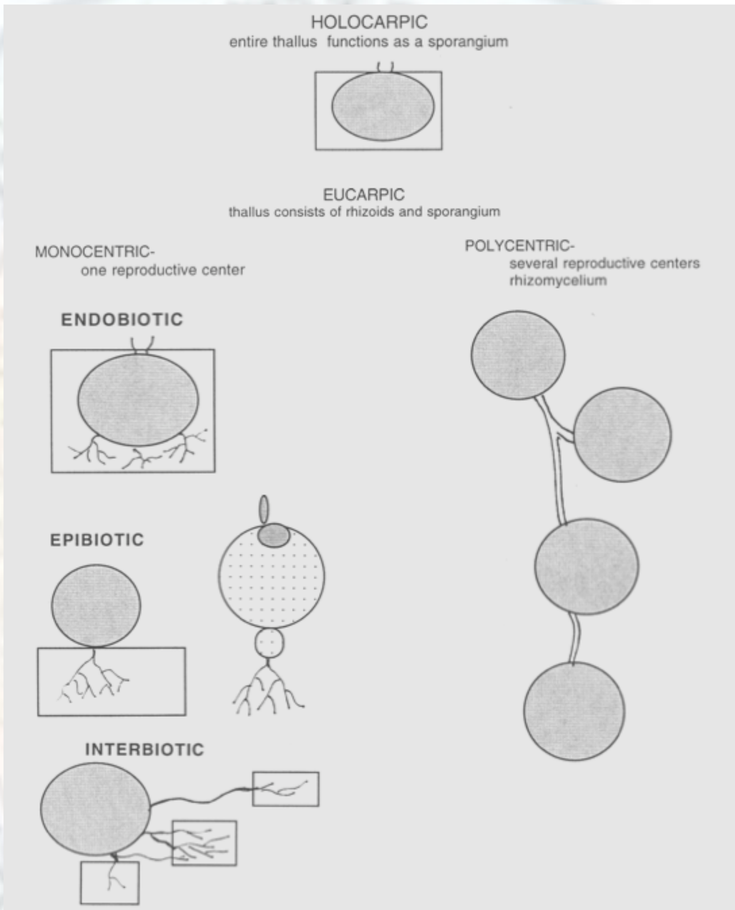

Figure: Diagrammatic representation of forms of thallus structure in Chytridiomycetes
Source: http://bama.ua.edu/~chytrid/morphological/thallus_types.htm

- In monocentric thalli, the zoospore on germination gives rise to a rhizoidal system bearing a single sporangium or a resting spore e.g. *Diplophylyctis, Entophlyctis* and *Rhizophlyctis,* but in polycentric forms like *Cladochytrium* and *Nowakowskiella* a more extensive, branched rhizoidal system called as rhizomycelium is formed on which numerous sporangia develop.

Table: Different forms of thallus structure in Chytridiomycota

Types of thallus/ substratum	Examples
Endobiotic	***Diplophlyctis*** **and** ***Synchytrium*** **(Chytridiales)**
Epibiontic	***Rhizophydium*** **(Chytridiales)**
Epibiontic and Endobiotic	***Physoderma*** **(Blastocladiales)**
Holocarpic	***Olpidium*** **(Spizellomycetales) and** ***Synchytrium*** **(Chytridiales)**
Eucarpic	***Allomyces*** **(Blastocladiales),** ***Gonapodya, Harpochytrium, Monoblepharella*** **and** ***Oedogoniomyces*** **(Monoblepharidales)**
Monocentric	***Diplophylyctis, Entophlyctis*** **and** ***Rhizophlyctis*** **(Spizellomycetales),** ***Piromyces*** **and** ***Neocallimastix*** **(Neocallimastigales)**
Polycentric	***Cladochytrium*****,** ***Nowakowskiella*** **(Chytridiales), and** ***Rhizophlyctis*** **(Spizellomycetales),** ***Anaeromyces*** **and** ***Orpinomyces*** **(Neocallimastigales)**

Reproduction

Chytrids usually reproduce both by asexual and sexual means. There are considerable variations within the group in the nature of these reproductive structures.

Asexual Reproduction

In general, asexual reproduction takes place by the formation of multinucleate zoosporangia which may be spherical, cylindrical, pear-shaped or irregularly lobed bearing one or more discharge tubes or exit papillae. Due to the cytoplasmic cleavage within zoosporangia several uninucleate zoospores or mitospores with a posterior whiplash flagellum are formed.

Depending on the method of zoospore discharge, chytrids can be **operculate** or **inoperculate**. In operculate chytrids such as *Chytridium, Chytriomyces* and *Nowakowskiella*, the tip of the discharge tube breaks up at the line of dehiscence and is seen as a special cap or operculum. Zoospores escape through an opening formed by the separation of the minute circular cap like lid or operculum at the end of the discharge tube.

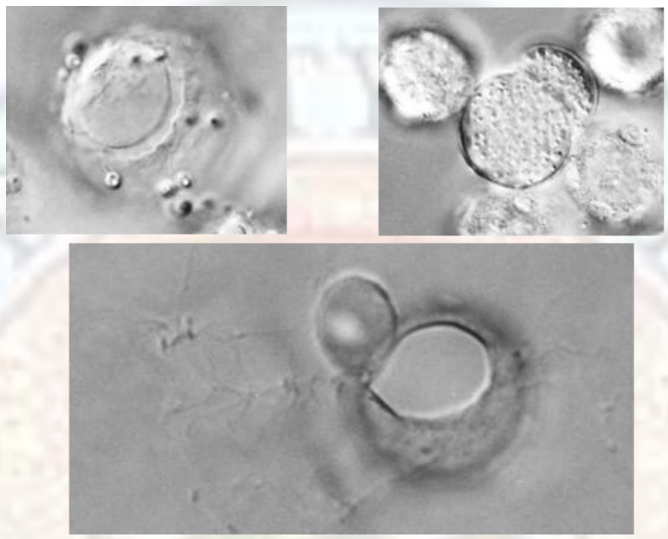

Figure: Operculate discharge of zoospores in chytridiomycetes
Source:http://bama.ua.edu/~chytrid/Powell/MSA09-Powell%20Reproduction_files/slide0025_image025.gif

In case of inoperculate chytrids such as *Olpidium, Diplophlyctis* and *Cladochytrium*, the sporangium forms a pore or a discharge tube which penetrates to the exterior of the host cell and its tip becomes gelatinous and dissolves away, allowing the zoospores to escape. Operculate species are considered as more advanced.

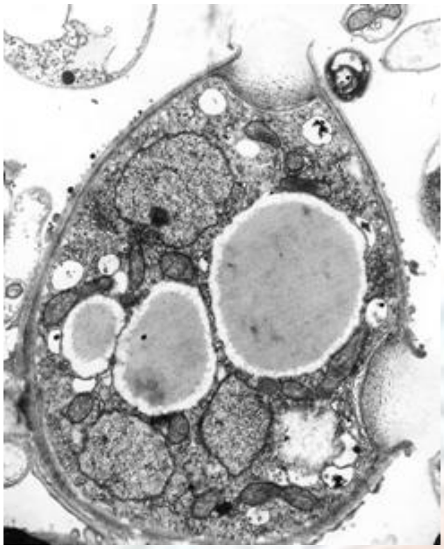

Figure: Inoperculate discharge of zoospores

Source:http://bama.ua.edu/~chytrid/Powell/MSA09-Powell%20Reproduction_files/slide0026_image018.gif

Zoospores

Zoospores are naked, uninucleate tiny mass of protoplast furnished with a single whiplash type of flagellum inserted at the posterior end. Within the plasma membrane, the cytoplasm contains a posteriorly located nucleus containing a distinct nucleolus. A single large basal mitochondrion is present towards the posterior region of the nucleus. The majority of the RNA and ribosomes are present on the anterior region of the nucleus forming a cap like structure called as nuclear cap. Numerous lipid bodies, mitochondria and membrane bound vesicles are present in the cytoplasm. Mitochondria mostly occur along the nuclear cap membrane.

Figure: Diagrammatic representation of zoospore.

Source: Author

The number of zoospores formed in a single zoosporangium varies with size of sporangium. For a given sp. the size of zoospore is roughly constant but the size of the sporangium varies, i.e. one to two zoospores in a tiny sporangium to many hundred in a large sporangium. It has been reported that *Rhizophlyctis rosea* when cultured in a media deficient in carbohydrate bears a tiny sporangia containing only one or two zoospores, whereas when cultured on cellulose-rich media it bears a large sporangia containing many hundred of spores.

Zoospore ultrastructure is regarded as a more satisfactory basis of classification due to the plasticity in morphology of thallus under different growth conditions. After maturation of zoospores, the matrix of sporangium absorbs water and swells rapidly due to which a pressure develops inside the sporangium which causes the exit papillae to burst opens at the final stages of sporangial maturation. As soon as the internal pressure is relieved by the ejection of some zoospores, those remaining inside the sporangium escape by swimming through the exit tube. The spores are discharged in masses in some species, which later on separates into single zoospores, but in others the zoospores make their escape individually.

Zoospore encystment and germination

The period of zoospore movement varies. Flagellated zoospores are capable of active swimming; while swimming they show characteristic jerky movements and abrupt changes in direction. However some zoospores are incapable of active swimming and thus instead they show amoeboid crawling. Swimming may last for only a few minutes or prolonged for several hours. Prior to germination, the zoospore comes to rest and encysts. The flagellum contracts, it may be completely withdrawn. This behavior also varies with different species. In holocarpic parasites the zoospore encysts on the host surface and the cytoplasmic contents of the zoospore are injected into the host cell.

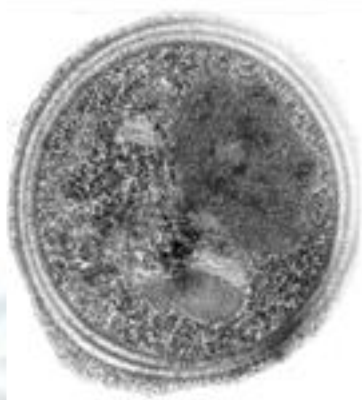

Figure: Longitudinal section of a fully encysted zoospore

Source: http://bama.ua.edu/~chytrid/Letcher/MSA09Letcher%20zoospore_files/frame.htm

In many **monocentric chytrids** rhizoids develop from one point on the zoospore cyst and the cyst itself enlarges to form the zoosporangium, but there is variation in the type of development in which the cyst enlarges into a prosporangium from which the zoosporangium later develops. In the **polycentric** types, the zoospore on germination forms a limited rhizomycelium on which a swollen cell arises, giving off further branches of rhizomycelium.

When cyst germinates from a single point on the wall of the zoospore it is called as **monopolar** germination or when its from two points i.e. growth takes place in two directions it is called as **bipolar** germination. The mode of germination is an important character in distinguishing, for example, the Chytridiales (monopolar) from the Blastocladiales (bipolar).

Sexual Reproduction

Sexual reproduction involves nuclear fusion and meiosis, which are quite variable in different forms. Most chytrids have haploid zoospores and thalli i.e. they have **haplontic life cycle** but some show an alternation of haploid (gametothallic) and diploid (sporothallic) generations i.e. **haplo-diplontic life cycle**. In the order Blastocladiales, apart from differences in their reproductive organs, the morphology of the two types of thallus is very similar, such phenomenon is known as **isomorphic alternation of generations**.

Sexual reproduction, which includes nuclear fusion and meiosis, may occur in several ways.

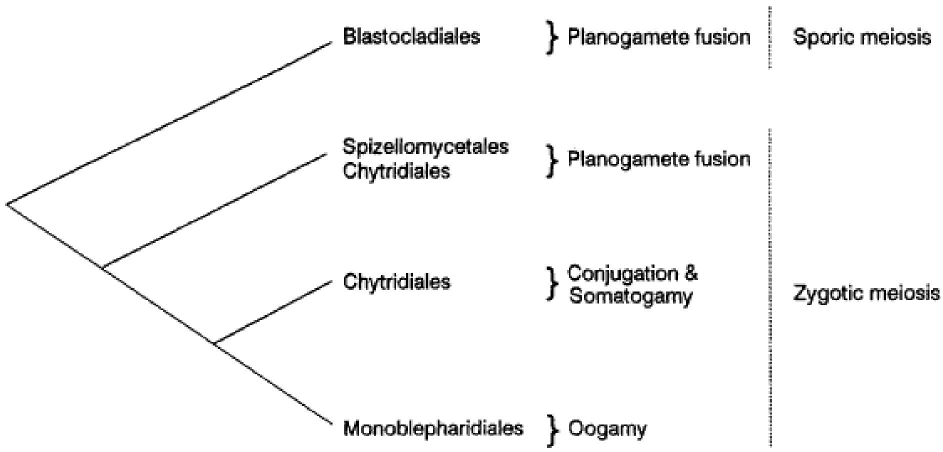

Figure: Classification of chytridiomycetes based on types of reproduction
Source: Webster and Weber,2007.

In some chytrids sexual reproduction is **isogamous** i.e fusion of gametes which are uninucleate and posteriorly uniflagellate and there is no morphological difference between the two fusing partners, but in some Blastocladiales (e.g. *Allomyces*) **anisogamy** takes place by fusion between a smaller, more actively motile male gamete with a larger, sluggish female gamete. In other chytrids, it may be **oogamy**, where fusion takes place between an actively motile male gamete and a much larger, non-flagellate, immobile globose egg, characteristic of Monoblepharidales.

Somatogamy, the fusion of undifferentiated hyphae or rhizoids, has been well studied in cultures of the freshwater fungus *Chytriomyces hyalinus*.

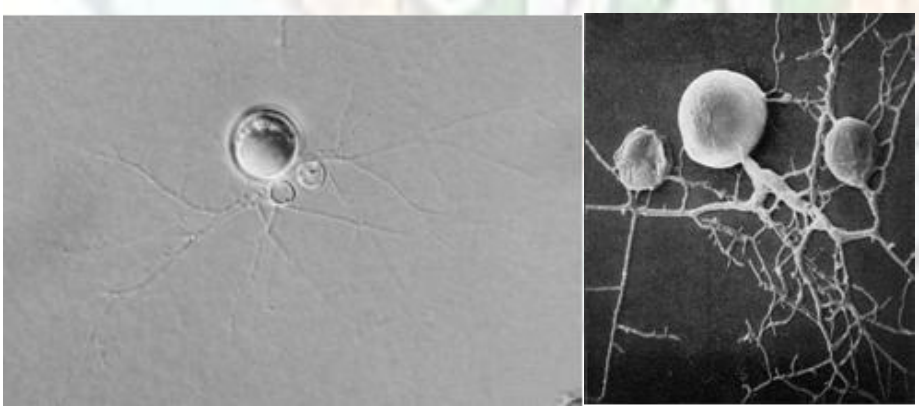

Figure: Somatogamy or rhizoidal fusion as seen in *Chytriomyces hyalinus*
Source:http://bama.ua.edu/~chytrid/Powell/MSA09-Powell%20Reproduction_files/frame.htm

Zoospores of *C. hyalinus* are released from the zoosporangium by the opening of a lid-like operculum. They germinate to form uninucleate rhizoidal thalli and the tips of the rhizoids from adjacent thalli, which are apparently not genetically distinct from each other, may fuse. At the point of fusion an incipient resting body develops and swells while cytoplasm and a nucleus migrate into it from each contributory thallus. Somatogamy is followed by karyogamy. Nuclear fusion occurs in the resting body to form a diploid zygote nucleus. The resting body continues to enlarge and develops a thick wall. This type of sexual reproduction by somatogamous conjugation probably occurs in several genera of inoperculate and operculate chytrids.

Fusion of gametangia (gametangio-gametangiogamy) has been reported for *Zygorhizidium planktonicum*, a parasite of the diatom *Synedra*. This species reproduces asexually by epibiotic zoosporangia. The zoospores released from zoosporangia germinate and form new zoosporangial thalli or gametangial thalli of two sizes with globose uninucleate gametangia. Conjugation occurs when a conjugation tube grows from the smaller donor to the larger recipient gametangium. After nuclear fusion, the larger gametangium develops a thick wall and functions as a diploid resting spore. After a period of maturation the resting spore acts as a **prosporangium** and give rise to a thin-walled **meiosporangium**. Meiosis occurs in these meiosporangia, followed by mitosis and cytoplasmic cleavage to form zoospores. A variant of this form of sexual differentiation (gametangio-gametogamy) has been reported in species of *Rhizophydium*; this involves copulation between the gametangium of a rhizoid-forming thallus and a motile gamete that encysts directly on the gametangium.

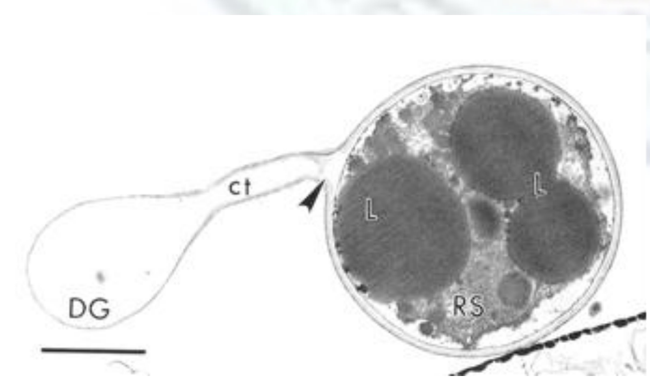

Figure: Gametangial copulation in *Zygorhizidium planktonicum* (Canter, 1967; Doggett and Porter 1996). DG: Donor gametangium, ct: Conjugation tube, L: Lipid bodies, RS: Resting spore.

Source:http://bama.ua.edu/~chytrid/Powell/MSA09-Powell%20Reproduction_files/slide0007_image063.gif

Generally the product of sexual reproduction is a resting spore or resting sporangium with thick cell wall, but it is known that thick-walled sporangia may also develop asexually and in many chytrids sexual reproduction has not been described and possibly does not occur. Resting sporangia of some chytrids may remain viable for many years.

Classification

Fossil chytrids have been reported from the 400 million-year-old Rhynie chert, a site known for the discovery of fossil remains of the earliest known vascular land plants. Clusters of holocarpic, endobiotic thalli resembling the present day *Olpidium* have been found inside cells of a coenobial alga preserved within the hollow axes of a vascular plant, and epibiotic sporangia with endobiotic rhizoids have been seen attached to meiospores of a vascular plant, much like those of extant chytrids like *Rhizophydium* which grow on pollen grains (Taylor et al., 1992).

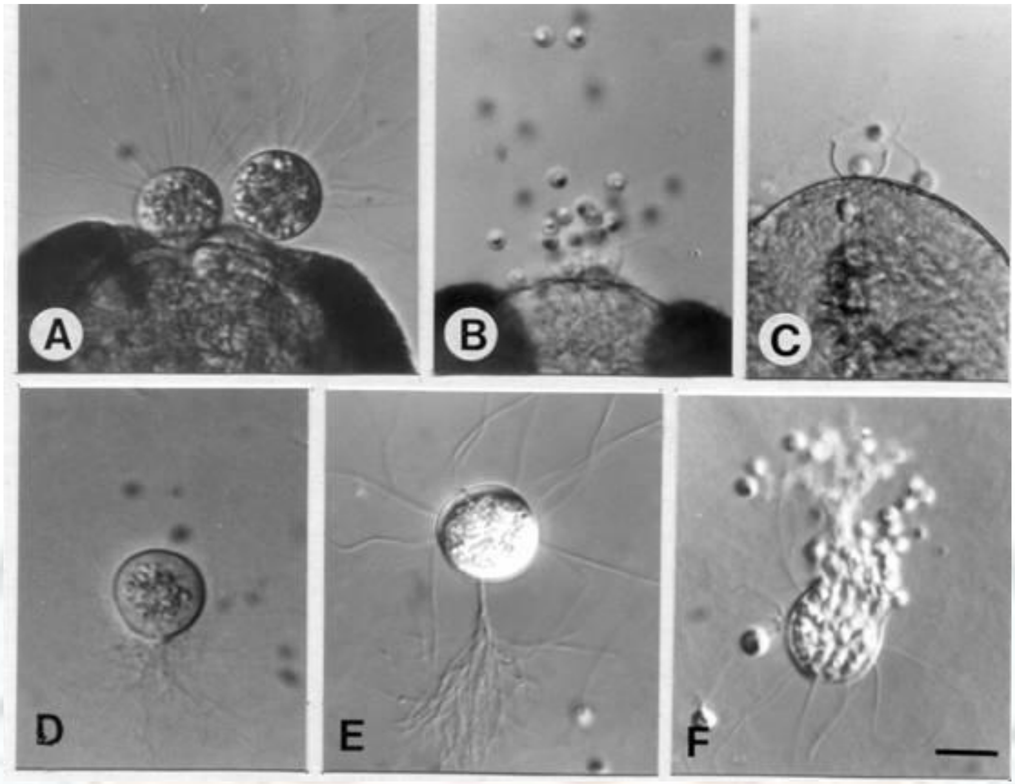

Figure: *Rhizophydium chaetiferum*. A, on pine pollen, sporangia with long hairs; B, on pine pollen, discharging sporangium; C, bowl-shaped empty sporangium; D, young sporangium; E, sporangium with hairs and thread-like rhizoids; F, discharging zoospores. (Bar = 10 μm)
Source: http://www.bcrc.firdi.org.tw/fungi/fungal_detail.jsp?id=FU200802080006

Chytrid-like fossils have also been found in strata of the 340 million-year-old Pennsylvanian (Carboniferous) era (Millay & Taylor, 1978) and from the more recent Eocene strata (Bradley, 1967). Formerly it has been thought to have an affinity for the Oomycota, Hyphochytriomycota or protists, the Chytridiomycota are now accepted as members of the true fungi, the Eumycota. They are probably ancestral to other groups of true fungi, especially the Zygomycota (Cavalier-Smith, 1987, 2001; D. J. S. Barr, 2001). The inclusion of the chytrids in the Eumycota is supported by several DNA-based phylogenetic analyses (e.g. Bowman et al., 1992; James et al., 2000), but the delimitation of orders within the Chytridiomycota is still problematic. Particularly puzzling is the grouping of the Blastocladiales with the Zygomycota on the basis of 18S ribosomal DNA sequences.

Chytridiomycota has been divided into five orders: **Blastocladiales, Chytridiales, Monoblephariales, Neocallimastigales** and **Spizellomycetales** based largely on ultrastructural features of the zoospores.

Table: Orders of Chytridiomycota are as following

Order	Number of described taxa	Examples
Chytridiales	**80 genera, 600 spp.**	***Cladochytrium,Nowakowskiella, Rhizophydium, Synchytrium***
Spizellomycetales	**13 genera, 86 spp.**	***Olpidium, Rhizophlyctis***
Neocallimastigales	**5 genera, 16 spp.**	***Anaeromyces,Caecomyces,Neocallimastix, Orpinomyces, Piromyces***
Blastocladiales	**14 genera, 179 spp.**	***Allomyces,Blastocladiella,Coelomomyces, Physoderma***
Monoblepharidales	**4 genera, 19 spp.**	***Gonapodya, Monoblepharella, Monoblepharis***

Chytridiales

This is by far the largest order, comprising more than 50% of the total number of chytrids described to date. It is difficult to characterize members of the Chytridiales because they lack any specific features by which species have been assigned to the other four orders. The classification of the Chytridiales has traditionally been based on thallus morphology (Sparrow, 1973) but, as pointed out by D. J. S. Barr (2001), this is unsatisfactory because of the great variability in thallus organization shown by the same fungus growing on its natural substratum and in culture. Future systems of classification will be based on zoospore ultrastructure and the comparison of several different types of DNA sequences, but too few examples have yet been studied to provide a definitive framework. Because of this we shall study genera which illustrate the range of morphology, life cycles and ecology of the Chytridiales without attempting to place them into families.

Synchytrium

In this genus the thallus is **endobiotic** and **holocarpic**, and during reproduction it may be converted directly into a group (sorus) of sporangia, or to a prosorus which later on gives rise to a sorus of sporangia. Alternatively the thallus may turn into a resting spore which can function either directly as a **sporangium** and give rise to zoospores, or as a **prosorus**. The zoospores are of the characteristic chytrid type. Sexual reproduction is by copulation of **isogametes**, which results in the formation of thalli which develop into thick walled resting spores.

Figure: Synchytrium a holocarpic chytrid that infects potato
Source: http://comenius.susqu.edu/biol/202/fungi/chytridiomycota/default.ht (Displayed with permission)

Black wart disease of potato

Black wart disease of potato tubers is a serious disease caused by the biotrophic pathogen ***Synchytrium endobioticum***, an obligate endoparasite. The disease is prevalent in the areas with moist cool climate. In india, this disease is found only in Darjeeling (WB) and its surroundings. *Synchytrium* includes about 120 species which are **biotrophic parasites** of flowering plants. Some species parasitize only a narrow range of hosts, e.g. *S. endobioticum* on Solanaceae, but others, e.g. *S. macrosporum*, have a wide host range. Most species are not very destructive to the host plant but stimulate the formation of galls on leaves, stems and fruits.

Symptoms: The disease affects the underground part i.e. the potato tubers, which on infection show black or brown cauliflower like outgrowth.

Figure: *Synchytrium endobioticum*: newly harvested, warted potato tubers; note that some warts are already starting to rot.

Source: http://www.forestryimages.org/browse/detail.cfm?imgnum=0454023

Figure: *Synchytrium endobioticum* causes black wart disease of potato.
Source: http://biomessixth10.wikispaces.com/Grassland+Facts (CC-BY-SA)

Due to presence of fungus, host cells are stimulated to rapid cell division and cell enlargement leading to increase in number and size of cells showing **hyperplaria** and

hypotrophy. Galls or tumours may also be formed on aerial parts like shoots, which then appear as green twisted leafy structures. The tissue of heavily infected tubes gets converted into warts.

Thallus: *S. endobioticum* grows as naked, unicellular, uninucleate, amoeboid, holocarpic endoparasite in host epidermal cell. Soon a double layer chitnous wall develops around thallus. The fungus absorbs its food from the cell contents of the host.

Reproduction: *S. endobioticum* reproduces both asexually and sexually. At the time of reproduction, whole vegetative structure transforms into a reproductive unit, i.e. it is holocarpic monocentric.

Asexual reproduction: The casual organism (*S. endobioticum*) is present in the wart tissue of the infected tubers in the form of resting sporangium. Some mycologists call them as resting or winter spores that can remain viable for a long period.

Infection: Under favorable condition (moist soil, suitable temperature and presence of potato seedlings in the field), the resting spores, from infected potato tissue germinate and release uninucleate, posteriorly uniflagellate, naked haploid zoospores by rupturing of the enclosing memberane. The zoospores swim in film of water in the contaminated soil and they may reach healthy tuber or stolons, and come to rest on host surface. The zoospore withdraws its flagellum; the protoplast enters the host epidermal cells by forming a minute pore in cuticle and epidermis.

Prosorus stage: Once within the epidermal cell of the host, it sinks to the lower parts, absorb food form host cell and increases considerably in size. The nucleus also increases in size. It forms a thick double layered cell wall, outer cell wall is thick golden brown which is called as **exospore**, and inner thin hyaline layer called **endospore**.

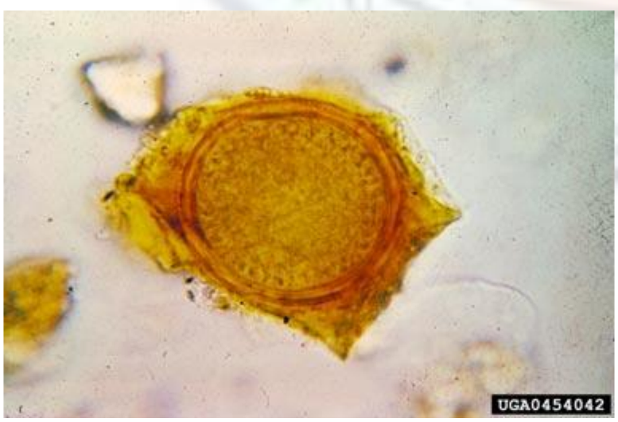

Figure: *Synchytrium endobioticum:* Prosorus

Source: http://www.forestryimages.org/browse/detail.cfm?imgnum=0454042

The mature thallus with a heavy golden wall is called **prosorus**. The structure is also called **summer spore**. The adjacent epidermal and cortical cells are stimulated to divide rapidly and repeatedly to form a minute gall or tumour or a wart like tissue. The infected hypertrophied cell containing prosorus becomes dead. Due to rapid division a rosette of host cells are developed around the infected cell. The rosette cells are some what corky and hard in nature.

Germination of prosorus: Prosorus (summer spore) germinates within the dead host cells by producing a tube like structure. The prosorus migrate into the vesicle in the upper part of the host cell. The nucleus of the prosorus undergoes repeated mitotic divisions forming 32 nuclei, followed by segmentation of prosorus. About 4-9 multinucleate polygonal segments are formed, each segment function as a **zoosporangium**. The nuclei of each chamber further divides repeatedly and ultimately 200-300 nuclei are formed in each of the segment. Multinucleate protoplast gets organized into uninucleate daughter protoplast. Each portion gets metamorphosed in to posteriorly uniflagellate zoospores.These zoospores are formed in favorable condition of water supply and appropriate temperature. They are released in film of water and again happen to infect healthy tubers.

Sexual reproduction

In scarcity of water or dry conditions, segments of prosorus function as gametangia which produce gametes by cytoplasmic cleavage into uninucleate protoplasts. These cells are called **planogametes**. The planogametes are similar to zoospores except that they are smaller in size. The planogametes of two different gametangia may be of the same sorus, fuse in pairs. Plasmogamy followed by karyogamy and biflagellate zygotes are formed. The biflagellate diploid zygotes swim for some time and finally come to rest on the surface of host tubers, and withdraw their flagella and penetrate the host epidermal cell like haploid zoospore.

Resting sporangia: Following infection, epidermal cells of the host enlarges in size (becomes hypertrophied) and divide rapidly (hyperplasia), and as such the infected cells are buried deeply within the host tissue. The diploid zygote enlarges and forms 2-3 layered thick cell wall and this is known as **resting sporangium**, also known as winter sporangium as it remains dormant throughout the winter season. It has a large centrally placed nucleus and the cytoplasm contains many membrane bound lipid bodies.

Germination of resting sporangia: Resting sporangia are released by the decay of host tissue. During spring season, nucleus of resting sporangium becomes active and divides repeatedly. First division is meiotic followed by several mitotic divisions. The multinucleate protoplast undergoes cleavage for many haploid uninucleate daughter protoplasts. Each daughter protoplast metamorphoses into a posteriorly uniflagellate zoospore, which get released on bursting open the wall of the sporangium.

Control of wart disease

Control of wart disease caused by *S. endobioticum* is based largely on the breeding of resistant varieties of potato. It was discovered that certain varieties such as Snowdrop were immune from the disease and could be planted on land heavily infected with *Synchytrium* without developing warts. Following this discovery, plant breeders have developed a number of immune varieties such as Maris Piper. However, some potato varieties that are susceptible to the disease are still widely grown, including the popular King Edward. In most countries where wart disease occurs, legislation has been introduced requiring that only approved immune varieties be planted on land where wart disease has been known to occur, and prohibiting the movement and sale of diseased material. Quarantine regulations are practiced to reduce spread of pathogens. In India entry of potato from Darjeeling hills where wart disease occurs is prohibited.

Other methods of control are less satisfactory. Attempts to kill the resting spores of the fungus in the soil have been made, but this is a costly and difficult process, requiring large scale fungicide applications to the soil. Copper sulphate or ammonium thiocyanate have been applied in the past at amounts of up to 1 ton acre^{-1}, and local treatment with mercuric chloride or with formaldehyde and steam has been used to eradicate foci of infection. Control measures based on the use of resistant varieties seem more satisfactory.

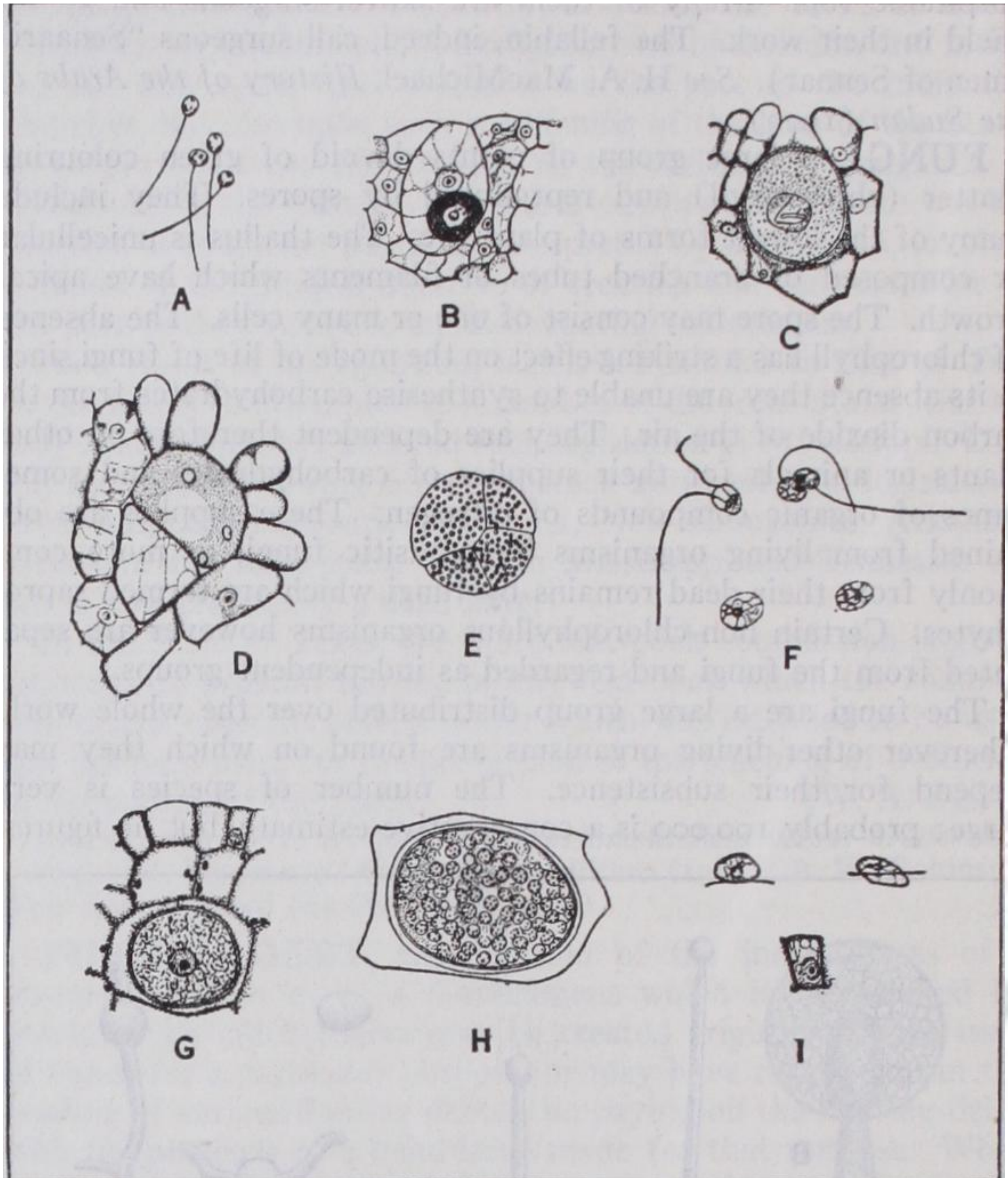

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FIG. 2.—LIFE HISTORY OF SYNCHYTRIUM ENDOBIOTICUM

A. Zoospores, B. Young protoplast within a hypertrophied epidermal cell, C. Mature summer spore, D. Germination of summer spore, E. Young sorus, future walls indicated by lines, F. Copulation of two planogametes, G. Young hypnospore, H. Hypnospore during maturation of zoospore primordium, I. Penetration of the zygote

Source:http://gluedideas.com/Encyclopedia-Britannica-Volume-9-Part-2-Extraction-Gambrinus/Fungi.html

Probable life cycle of *Synchytrium endobioticum*

Haploid and diploid nuclei are represented by small empty and larger split circles, respectively. Key events in the life cycle are plasmogamy, karyogamy and meiosis. Resting spores within a warted potato contain a single nucleus which undergoes meiosis upon germination. Haploid zoospores are released from a single sporangium. If two zoospores pair up, a zygote is formed and penetration of a potato cell gives rise to a diploid thallus and, ultimately, a resting spore. Diploid infections cause host hyperplasia visible as the potato wart symptoms. If a zoospore infects in the haploid state, a haploid prosorus (summer spore) is formed, and hypertrophy of the infected and adjacent host cells ensues. A sorus of several sporangia is ultimately produced, with each sporangium releasing a fresh crop of haploid zoospores. *Synchytrium endobioticum* appears to be homothallic.

Summary

Chytridiomycetous fungi are considered to be as the most primitive members of Eumycota. The most characteristic feature of this class is production of motile uniflagellate reproductive cells (**zoospores** and **planogametes**), each with a single whiplash flagellum which is inserted posteriorly (opisthocont flagellation).

Major species of Chytridiomycetes grow as aquatic parasites or saprophytes; however many species occur in soil or mud also. Some species parasitize and destroy algae. A few genera such as ***Synchytrium***, ***Olpidium***, some members of ***Physoderma*** grow as parasites on economic plants and cause severe economic losses. A few anaerobic species reported to exist in the gut of herbivores. ***Coelomyces*** spp. Parasitize mosquito larvae can be used for biological control of mosquitoes. Chytrids can degrade chitin, Keratin, cellulose and hemicelluloses.

The plant body may be unicellular, elongated simple hyphae or well developed coenocytic mycelium. Some forms short chain of cells which can attach to substratum with rhizoids for intake of nutrients and anchorage. In complex members like ***Chytridium*** much branched rhizomycelium is formed. Hyphae are aseptate but pseudosepta in the form of thickened rings are present in some members of Blastocladiales. Septa are formed during formation of sex organs in coenocytic thalli. **Chitin** and **β glucan** are main constituent of cell wall. The parasitic forms may be endobiotic or epibotic.

In unicellular forms the thallus is **holocarpic**, whereas in filamentous forms it is **eucarpic**. It may bear **monocentric** or **polycentric** sporangium. They show **haplontic** life cycle however many members of order Blastocladiales bear two types of thalli **gametothalli** (haploid) and **sporothalli** (diploid), thus show alteration of generation or **haplo-diplontic** life cycle.

Asexual reproduction takes place with the help of zoospores which are posteriorly **uniflagellate**, the flagellum is of whiplash type. A nuclear cap consisting of RNA, wholly or partially covers the nucleus at the anterior end of the cell. Refractive lipid globules are spherical or pear shaped, and **operculate** or **inoperculate**.

Sexual reproduction takes by fusion of posteriorly uniflagellate planogametes may be **isogamous** or **anisogamous** depending on the species. In species belonging to order Monoblepharidales sexual reproduction is Oogamous. The zygote thus formed secretes a thick wall and is transformed into a resting spore or resting sporangium which produces zoospores on germination. Germination of zoospores may be **monopolar** or **bipolar**.

Sparrow (1973) divided the class Chytridiomycetes on the basis of vegetative characters, zoospores, mode of plasmogamy and resting spore into 5 orders: **Blastocladiales, Chytridiales, Monoblephariales, Neocallimastigales** and **Spizellomycetales.**

Exercises

1. Describe the general characteristic of chytridiomycetes.
2. How chytrids are significant to human beings?
3. Why chytrids are considered primitive fungi?
4. What characters of chytrids make us consider them as part of kingdom mycota?
5. How chytrids are different from other fungi?
6. What characters of chytrids show similarities with protozoa?
7. Give broad outline classification of chytridiomycetes.
8. Describe the casual organism, symptoms and control of black wart disease of potato.

9. Describe the structure and reproduction of any holocarpic fungus.
10. Describe / distinguish the following terms:
    a) Holocarpic and eucarpic fungi
    b) Epibiotic and endobiotic fungi
    c) Monocentric and polycentric
    d) Summer spore and winter sporangium
    e) Sorus and prosorus of *Synchytrium*
    f) Zoospores and gametes
    g) Isogamy, anisogamy and oogamy
    h) Rhizoids and rhizomycelium
    i) Hypertrophy and hyperplasia
    j) Operculate and inoperculate sporangia

11. Write short notes on the following:
    a) Opisthocant flagellatium
    b) Sex hormone in fungi
    c) Aquatic fungi
    d) Rumen fungi

Glossary

Anisogamy: Union of planogametes that are morphologically similar but differ in size.

Endobiotic: An organism that lives within its substrate, usually the cells of its host.

Epibiotic: An organism whose reproductive organs are on the surface of the substrate, but with part or all of the soma within the substrate.

Inoperculate chytrids: Used in reference to a discharge tube of a sporangium in a chytrid that lacks an operculum and zoospores are discharged through a pore.

Monocentric: A thallus that produces a single reproductive organ.

Operculate chytrids: Used in reference to a discharge tube of a sporangium in a chytrid that forms a wee-defined circular cap or an operculum to discharge zoospores.

Polycentric: A thallus with many centers at which reproductive organs are formed.

Rhizomycelium: A rhizoidal system extensive enough to resemble mycelium but without any nucleus.

Somatogamy: Fusion of somatic cells during plasmogamy.

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