ELEVEN

Phylum OOMYCOTA

water moulds, downy mildews

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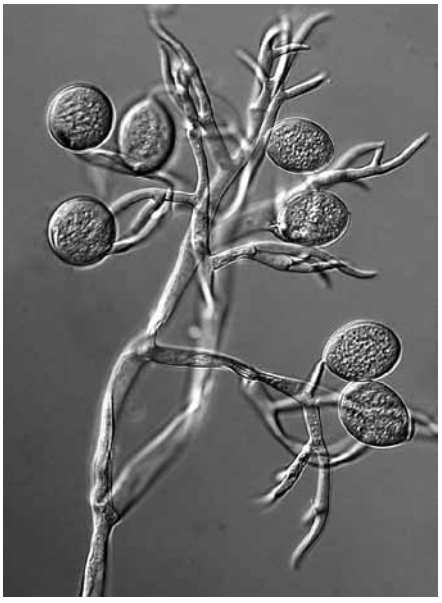


Peronospora conglomerata, with sporangia, from a leaf of *Geranium molle*.
Jerry A. Cooper, Landcare Research

Oomycota are mostly fungoid chromists, some of which have major ecological and economic significance. The majority are multicellular and used to be allied with fungi. Like fungi, they extend fungus-like threads (hyphae) into decaying matter or the cells and tissues of living hosts, including humans (Bulaji et al. 1999). Currently one of two non-photosynthetic heterokont phyla, the name Oomycota is used here following the Dictionary of Fungi. An alternative name is Pseudofungi, coined by Cavalier-Smith (1986). Three classes are recognised (Cavalier-Smith 2004) – Bigyromonadea (with the sole genus *Developayella*), the fungus-mimicking Hyphochytrea (*Pirsonia* and hyphochytrids), and Peronosporea (Oomycetes).

Chloroplasts appear to have been lost secondarily in the Oomycota. Inasmuch as the group is heterokont and lacks chitin and β-glucan in cell walls, it is well placed among the chromists. The most important exemplars in New Zealand are plant pathogens (oomycetes such as the downy mildews, collar rots, and damping-off species) and a few others, altogether about 150 presently recorded species but total diversity is likely to be much higher.

Members of class Oomycetes are characterised by biflagellate zoospores and walls composed of a cellulose-like material. They vary from unicellular to species with extensive, mostly nonseptate mycelia and are widespread in aquatic and terrestrial environments. Ecologically, they may be saprobes (feeding on decaying or non-living matter) or parasites, attacking fungi, other oomycetes, plants, fish and occasionally other animals.

Because they cause many economically important diseases, some pathogenic members are relatively well known. The genus *Phytophthora* (literally 'plant destroyer') contains many pathogens of importance to native and cultivated plants and to human history. The famine resulting from failure of the potato crop in Ireland in 1845–1847, and the subsequent death or migration of a million people, was caused by *Phytophthora infestans*, late blight of potato and a member of the Pythiales. In New Zealand, this species affects potato and tomato, and is one of several species of the cosmopolitan genus *Phytophthora* to occur in this country, many parasitic on aerial parts of plants and forming wind-dispersed sporangia while others are soil-borne.

Phytophthora cinnamomi is widespread and common in New Zealand soils under exotic and native forests and has been responsible for the death of a range of trees including shelterbelt species, avocado, *Pinus*, *Camellia*, and *Agathis* (Newhook 1959; Newhook 1970; Pennycook 1989). Damage by *P. cinnamomi* is typically localised when plants become highly stressed during summer droughts preceded by a warm wet winter. The species is thought to have been introduced

to New Zealand by Maori as it is known in the Pacific on *Colocasia esculenta* (taro), a crop plant brought by Maori for cultivation in this country (Johnston et al. 2003). Assessments of impacts on native forests suggest that this oomycete has had long-term effects on establishment, regeneration, and spread of dominant forest species such as kauri and beech. Establishment of kauri seedlings was found to improve by use of the fungicide Ridomil at *Phytophthora*-infested sites (Horner 1984). While mycorrhizal beech seedlings are less susceptible to this pathogen, the natural pattern of regeneration of beech may have been disrupted by mortality of non-mycorrhizal beech seedlings due to *P. cinnamomi* (Johnston et al. 2003). In avocado orchards, the serious disease caused by *P. cinnamomi* has been overcome by routine trunk injections and sprays of phosphorous acid (Giblin et al. 2005).

Molecular detection, assisted by morphological study, has led recently to increased recognition of new species of *Phytophthora* in New Zealand, even on introduced plant hosts. Dick et al. (2006) described *P. captiosa* and *P. fallax*, which cause a crown dieback of *Eucalyptus* in New Zealand, suspecting that these species originated from Australia where *Eucalyptus* is native; the first record of *P. fallax* in Australia was reported by Cunnington et al. (2010). *Phytophthora kernoviae*, on the other hand, was described from Cornwall, England, in 2005, causing serious disease of *Fagus sylvatica* (European beech) and the introduced *Rhododendron ponticum.* While suspected to have originated in Asia or South America, it was recorded in New Zealand soon after, first on *Annona cherimola* (cherimoya) and then in soils under native and exotic forests in several parts of the North Island including earlier records (as '*Phytophthora* sp.') from the 1950s (Ramsfield et al. 2009). In New Zealand, pathogenicity of this species is limited to the single record on cherimoya. To address quarantine concerns, exports of New Zealand logs to Australia must comply with Australian AQIS import requirements by providing a '*Phytophthora kernoviae* … Pest Area Freedom Declaration'.

Recent major epidemics by invasive pathogenic *Phytophthora* species have heightened global awareness of biosecurity threats arising from trade in contaminated plants and plant products. In most cases, invasive *Phytophthora* species cannot be eradicated owing to the time interval between initial invasion and eventual detection via host disease symptoms, as well as the difficulty to disrupt dispersal of propagules. *Phytophthora ramorum*, likely spread through the nursery trade (Brasier & Jung 2006), is responsible for the serious and widespread 'sudden oak death' in the western USA and Europe. In California, the aerially dispersed *P. ramorum* is pathogenic to more than 90 forest species, with high levels of mortality in susceptible oak species (Hüberli et al. 2008). These authors have also evaluated susceptibility of components of the New Zealand flora should *P. ramorum* arrive here, identifying five species, including *Fuschia excorticata* (tree fuchsia), *Leptospermum scoparium* (Manuka), and *Nothofagus fusca* (red beech), that are particularly susceptible.

Oogonia (female sex organs) of *Phytophthora fallax*, which causes crown die-back of *Eucalyptus* in Australasia.

Margaret A. Dick, Scion

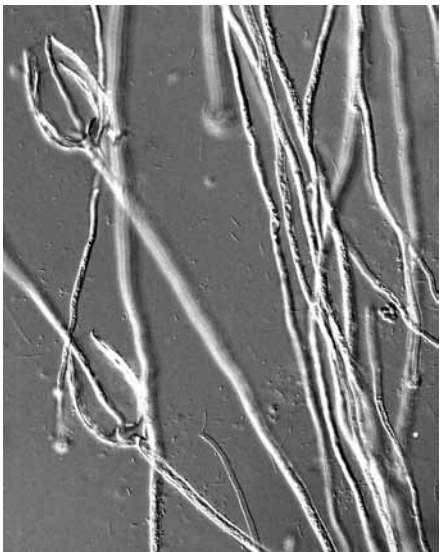
Summary of New Zealand Oomycota diversity

Taxon	Described species + infraspecific taxa	Known undescribed undetermined species	Estimated undiscovered species	Adventive species	Endemic species	Endemic genera
Bigyromonadea	0	0	0	0	0	0
Hyphochytrea	7	0	20	0	0	0
Peronosporea	144+1	10	50	106+1	1	0
Totals	**151+1**	**10**	**70**	**106+1**	**1**	**0**

Diversity by environment

Taxon	Marine/ brackish	Fresh-water	Terrestrial
Bigyromonadea	0	0	0
Hyphochytrea	0	0	7
Peronosporea	4	23	129+1
Totals	**4**	**23**	**136+1**

* Three species are found in wet terrestrial settings are are list in both the freshwater and terrestrial columns



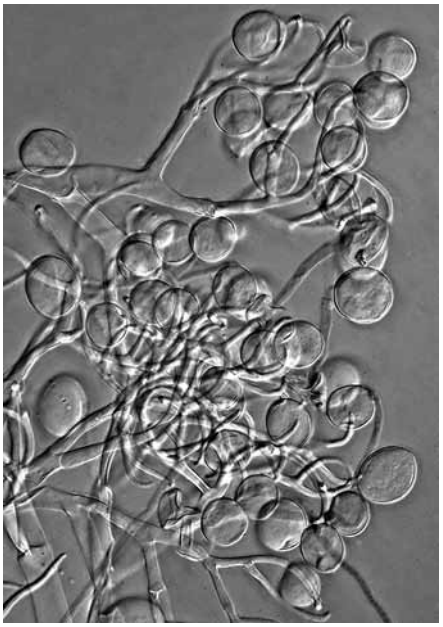
Phytophthora inundata, with nested empty sporangia and proliferation of the hypha beyond the sporangium.
Margaret A. Dick, Scion

Kauri dieback disease has been recognised as a significant threat to *Agathis australis* (kauri). The causal agent *Phytophthora* taxon 'Agathis' (PTA) has been recorded in several parts of Northland and Auckland including in forests containing the iconic giant trees. Previously described as *P. heveae* (Gadgil 1974), the pathogen causes a collar rot characterised by bleeding trunk lesions near the ground, yellowing foliage, and tree death. Trees of a broad age range are susceptible (Beever et al. 2009). As part of the current response, extensive public education led by Auckland Council and MAF seeks to minimise transfer of the soil-borne pathogen on boots and equipment, with boot-wash stations established at the entrance to the more popular tracks in kauri forests. Soil sampling in forests for molecular detection of PTA is in progress to determine distribution of the pathogen.

Other damaging pathogenic species of *Phytophthora* in New Zealand include *P. cactorum* on apples and *Pinus radiata* seedlings, *P. fragariae* on strawberries, and *P. citrophthora* on citrus (Dingley 1969; Beever et al. 2006; Reglinski et al. 2009).

Pythium, another cosmopolitan oomycete genus in soils and fresh water, causes damping-off diseases of zoospore-infected seedlings and sometimes older plants. Some aquatic species parasitise algae; others are saprobes growing on insect cadavers or decaying vegetation. The genus is relatively well known in New Zealand, with a guide to methods of isolation and preservation, a taxonomic key, and illustrated microscopic features of 27 species (Robertson 1970). *Pythium* is typically more frequent in cultivated than in forest soils (Domsch et al. 1980), and populations of pathogenic species on pasture have been reported to increase following spray irrigation of pasture with dairy-shed effluent (Waipara & Hawkins 2000). *Pythium oligandrum* is both plant pathogen and mycoparasite, causing a 'black compost' disease and significantly reduced yields of *Agaricus bisporus*, the commercially cultivated button mushroom (Godfrey et al. 2003). It is also parasitic on other *Pythium* species and on several mould fungi including *Trichoderma* species.

The causal agent of 'swamp disease' of horses was first recognised as *Pythium* by Austwick and Copland (1974) and later described by others as *Pythium insidiosum*. Known mainly from the tropics and subtropics, this species causes pythiosis, a skin disease of dogs, horses, cattle, and occasionally humans (Fraco & Parr 1997). These authors reported the first New Zealand record of *P. insidiosum*, causing keratitis, a severe inflammation of the eye's cornea. The affected patient, a fit 28 year-old male, sustained the infection following a day 'playing ball' in a hot pool. The pathogen was totally resistant to all antifungal agents and treatment involved surgical excision. Subsequently, *P. insidiosum* has been recorded in New Zealand from a horse (White 2006).



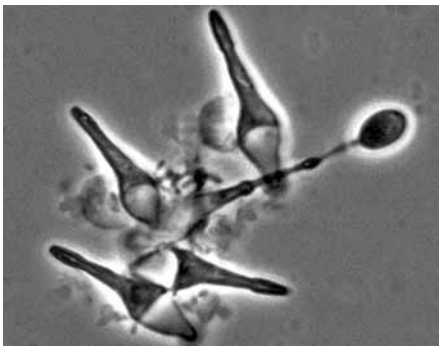
Sporangiate *Hyaloperonospora parasitica* from a seedling leaf of *Brassica oleracea* var. *botrytis*.
Jerry A. Cooper, Landcare Research

Peronospora and *Plasmopara* species (causing downy mildews) and *Albugo* species (the white rusts) include many other obligate plant pathogens. Downy mildews of economic importance in New Zealand include *Peronospora viciae* on peas, *P. antirrhini* on snapdragons, *P. sparsa* on boysenberries, *P. destructor* on onions, and *Plasmopara viticola* on grape. These oomycetes form wind-dispersed mitosporangia that germinate to produce hyphae or zoospores. *Albugo candida*, the white-rust pathogen of crucifers, also attacks the native *Lepidium ruderale* (Cook's scurvy grass) and is likely to be one of the factors leading to the decline of this species in the wild and its present threatened status (Baker 1955; Armstrong 2007).

Other oomycetes are parasites of filamentous fungi, algae, amoebae, and pollen grains. Several species of *Olpidiopsis* and *Rozella*, parasites of *Pythium*, *Achlya*, and other oomycetes, were isolated by Karling (1966, 1968b) from New Zealand soils. Water moulds (e.g. *Achlya* and *Saprolegnia*) include pathogens of algae, fish and their eggs, and invertebrates, as well as saprobes. Several saprobic species have been isolated from New Zealand pond water and soil samples (e.g. Karling 1968c; Elliott 1968).

Haptoglossa elegans, described from New Zealand (Barron 1990), is an especially curious aquatic oomycete that parasitises rotifers. Sunken spores of this fungus germinate to produce a so-called 'gun cell', which, when triggered by a passing rotifer, explodes and launches a harpoon-like missile, with protoplasm attached, into the animal.

Species belonging to class Hyphochytrea (hyphochytrids or Hyphochytridiomycetes) resemble the fungal chytrids (Chytridiomycetes) in having uniflagellate zoospores and living in fresh water and soil. However, they differ in the nature of the locomotory cilium (flagellum) and associated ultrastructure, being of the tinsel type in the former and whiplash in chytrids. They are common in New Zealand soils where a small number of saprobes and two parasites of oomycete fungi have been reported (Karling 1968a).



Gun cells of *Haptoglossa mirabilis*.
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Checklist of New Zealand Oomycota

Major environments are denoted by: F, freshwater; M, marine; T, terrestrial; F/T denotes a species that lives in a moist or wet terrestrial setting. Life habits and hosts are denoted by P, parasite; Pl, plant; V, vertebrate. E endemic species; A, adventive (naturalized alien); species not indicated by either notation are native (naturally indigenous but not endemic).

KINGDOM CHROMISTA
PHYLUM OOMYCOTA
Class HYPHOCHYTREA
Order HYPHOCHYTRIALES
HYPHOCHYTRIACEAE
Hyphochytrium catenoides Karling T
Hyphochytrium oceanicum Karling T
RHIZIDIOMYCETACEAE
Rhizidiomyces apophysatus Zopf T
Rhizidiomyces bivellatus Nabel T
Rhizidiomyces hansonii Karling T
Rhizidiomyces hirsutus Karling T
Rhizidiomyes saprophyticus (Karling) Karling T

Class PERONOSPOREA
Order LEPTOMITALES
LEPTOLEGNIELLACEAE
Aphanomycopsis punctata Karling T
Leptolegniella exoospora W.D.Kane T
Leptolegniella keratinophila Huneycutt T
INCERTAE SEDIS
Cornumyces pygmaeus (Zopf) M.W.Dick T

Order MYZOCYTIOPSIDALES
ECTROGELLACEAE
Haptoglossa elegans G.L.Barron T E
Haptoglossa heterospora Drechsler T
MYZOCYTIOPSIDACEAE
Myzocytiopsis microspora (Karling) M.W.Dick T
Myzocytium proliferum Schenk M
Myzocytium rabenhorstii (Zopf) M.W.Dick F
Syzygangia sp. sensu M.W.Dick 2001 F/T
SIROLPIDIACEAE
Sirolpidium bryopsidis (de Bruyne) H.E.Petersen M

Order OLPIDIOPSIDALES
OLPIDIOPSIDACEAE
Olpidiopsis achlyae McLarty F
Olpidiopsis aphanomycis Cornu F
Olpidiopsis brevispinosa Whiffen F
Olpidiopsis pythii (E.J.Butler) Karling F
Olpidiopsis saprolegniae (A.Braun) Cornu var. *saprolegniae* F
INCERTAE SEDIS
Gracea gracilis (E.J.Butler) M.W.Dick T

Order PERONOSPORALES
ALBUGINACEAE
Albugo bliti (Biv.) Kuntze T A
Albugo candida (J.F.Gmel.:Pers.) Kuntze T A
Albugo centaurii (Hansf.) Cif. & Biga T A
Albugo portulacae (DC.) Kuntze T A
Albugo tragopogonis (Pers.:Pers.) Gray T A
Albugo trianthemae G.W.Wilson T A
PERONOSPORACEAE
Basidiophora entospora Roze & Cornu T A
Bremia lactucae Regel T A
Peronospora alsinearum Casp. T A
Peronospora alta Fuckel T A
Peronospora anemones Tramier T A
Peronospora antirrhini J.Schröt. T A
Peronospora calotheca de Bary T A
Peronospora candida Fuckel T A
Peronospora conglomerata Fuckel T A
Peronospora destructor (Berk.) Fr. T A
Peronospora dianthi de Bary T A
Peronospora digitalis Gäum. T A
Peronospora farinosa (Fr.:Fr.) Fr. T A
— f.sp. *betae* Byford T A
Peronospora ficariae Tul. ex de Bary T A
Peronospora grisea (Unger) Unger T
Peronospora jaapiana Magnus T A
Peronospora knautiae Fuckel ex J.Schröt. T A
Peronospora lamii A. Braun T A
Peronospora lepidii (McAlpine) G.W.Wilson T A
Peronospora manshurica (Naumov) Syd. ex Gäum. T A
Peronospora mesembryanthemi Verwoerd T A
Peronospora myosotidis de Bary T
Peronospora obovata Bonord. T A
Peronospora ornithopi Gäum. T A
Peronospora parasitica (Pers.:Fr.) Fr. T A
Peronospora rumicis Corda T A
Peronospora sparsa Berk. T A
Peronospora trifoliorum de Bary T A
Peronospora viciae (Berk.) Casp. T A
Plasmopara geranii (Peck) Berl. & De Toni T A
Plasmopara halstedii (Farl.) Berl. & De Toni T A
Plasmopara viticola (Berk. & M.A.Curtis) Berl. & De Toni T A
Pseudoperonospora cubensis (Berk. & M.A.Curtis) Rostovzev T A

Order PYTHIALES
PYTHIACEAE
Halophytophthora sp. M
Phytophthora cactorum (Lebert & Cohn) J.Schröt. T A
Phytophthora captiosa M.A. Dick & Dobbie T A
Phytophthora cinnamomi Rands T A
Phytophthora citricola Sawada T A
Phytophthora citrophthora (R.E.Sm. & E.H.Sm.) Leonian T A
Phytophthora cryptogea Pethybr. & Laff. T A
Phytophthora europaea E.M. Hansen & T. Jung T A
Phytophthora erythroseptica Pethybr. T A
Phytophthora fallax Dobbie & M.A. Dick T A
Phytophthora fragariae Hickman T A
Phytophthora gonapodyides (H.E.Petersen) Buisman T A
Phytophthora hibernalis Carne T A
Phytophthora infestans (Mont.) de Bary T A
Phytophthora inflata Caroselli & Tucker T A
Phytophthora inundata Brasier, Sánch. Hern. & S.A. Kirk T A
Phytophthora kernoviae Brasier Beales and S.M. Kirk T
Phytophthora medicaginis E.M. Hansen & D.P. Maxwell T A
Phytophthora meadii McRae T A
Phytophthora megasperma Drechsler T A
Phytophthora multivesiculata Ilieva, Man in 't Veld, W. Veenb.-Rijks & R. Pieters T A
Phytophthora multivora P.M. Scott & T. Jung T A
Phytophthora nicotianae Breda de Haan T A
Phytophthora palmivora E.J. Butler T A
Phytophthora primulae J.A.Toml. T A
Phytophthora plurivora T. Jung & T.I. Burgess T A
Phytophthora syringae (Kleb.) Kleb. T A
Phytophthora sp. Apple-Cherry T A
Phytophthora sp. Asparagus T A
Phytophthora taxon Agathis T A
Phytophthora taxon PgChlamydo T A
Phytophthora taxon Raspberry T A
Phytophthora taxon Salixsoil T A
Phytophthora taxon Walnut T A
Pythium acanthicum Drechsler T A
Pythium afertile Kanouse & T.Humphrey T A

Pythium anandrum Drechsler T A
Pyhtium aphanodermatum (Edson) Fitz. T A
Pythium aquatile Höhnk T A
Pythium arrhenomanes Drechsler T A
Pythium butleri Subram. T A
Pythium chamaityphon Sideris T A
Pythium coloratum Vaartaja T A
Pythium debaryanum auct. non R.Hesse T A
Pythium echinulatum V.D.Matthews T A
Pythium erinaceum G.I.Robertson T A
Pythium gracile Schenk T A
Pythium graminicola Subraman. T A
Pythium inflatum V.D.Matthews T A
Pythium insidiosum De Cock, L.Mend., A.A.Padhye, Ajello & Kaufman T A
Pythium intermedium de Bary T A
Pythium irregulare Buisman T A
Pythium mastophorum Drechsler T A
Pythium megalacanthum de Bary T A
Pythium middletonii Sparrow T A
Pythium monospermum Pringsh. T A
Pythium myriotylum Drechsler T A
Pythium oligandrum Drechsler T A
Pythium paroecandrum Drechsler T A
Pythium rostratum E.J.Butler T A
Pythium spinosum Sawada T A
Pythium splendens Hans Braun T A
Pythium tenue Gobi T A
Pythium torulosum Coker & P.Patt. T A
Pythium ultimum Trow T A
Pythium undulatum H.E.Petersen T A
Pythium vanterpoolii V.Kouyeas & H.Kouyeas T A
Pythium vexans de Bary T A

Order SALILAGENIDIALES
HALIPHTHORACEAE
Haliphthoros sp. M

Order SAPROLEGNIALES
LEPTOLEGNIACEAE
Aphanomyces cochlioides Drechsler T A
Aphanomyces euteiches Drechsler T
Aphanomyces laevis de Bary F/T
Aphanomyces ovidestruens Gicklh. T
Aphanomyces phycophilus de Bary F
Aphanomyces raphani J.B.Kendr. T A
Aphanomyces stellatus de Bary F
Leptolegnia caudata de Bary T
SAPROLEGNIACEAE
Achlya caroliniana Coker F
Achlya flagellata Coker F
Achlya hypogyna Coker & Pemberton F
Achlya klebsiana Pieters T
Achlya prolifera Nees T
Achlya treleaseana (Humphrey) Kauffman F
Brevilegnia longicaulis T.W.Johnson T
Dictyuchus monosporus Leitg. T
Isoachlya unispora Coker & Couch F
Pythiopsis cymosa de Bary F/T
Saprolegnia australis R.F.Elliott F
Saprolegnia diclina Humphrey F
Saprolegnia ferax (Gruith.) Kütz. T
Saprolegnia litoralis Coker F
Saprolegnia terrestris Cookson ex R.L.Seym. T
Sommerstorffia spinosa Arnautov F
Thraustotheca clavata (de Bary) Humphrey F

Order SCLEROSPORALES
VERRUCALVACEAE
Sclerophthora macrospora (Sacc.) Thirum., C.G.Shaw & Naras. T A

Subclass INCERTAE SEDIS
Order ROZELLOPSIDALES
PSEUDOSPHAERITACEAE
Sphaerita dangeardii Chatton & Brodsky F
Sphaerita endogena P.A.Dang. F
ROZELLOPSIDACEAE
Rozellopsis inflata (E.J.Butler) Karling ex Cejp T