

= Limnoperdon =

Limnoperdon is a fungal genus in the monotypic family Limnoperdaceae . The genus is also monotypic , as it contains a single species , the aquatic fungus Limnoperdon incarnatum . The species , described as new to science in 1976 , produces fruit bodies that lack specialized structures such as a stem , cap and gills common in mushrooms . Rather , the fruit bodies ? described as aquatic or floating puffballs ? are small balls (0 @. @ 5 ? 1 mm diameter) of loosely interwoven hyphae . The balls float on the surface of the water above submerged twigs . Experimental observations on the development of the fruit body , based on the growth on the fungus in pure culture , suggest that a thin strand of mycelium tethers the ball above water while it matures . Fruit bodies start out as a tuft of hyphae , then become cup @-@ shaped , and eventually enclose around a single chamber that contains reddish spores . Initially discovered in a marsh in the state of Washington , the fungus has since been collected in Japan , South Africa , and Canada .

= Taxonomy , classification and phylogeny =

The family , genus and species were first described in a 1976 publication by graduate students Gustavo Escobar and Dennis McCabe , and undergraduate Craig Harpel who , in the fall of 1974 , found the fungus as part of " a class project to find and isolate phycomycetes " . The holotype is located in the University of Washington Mycological Herbarium . An isotype (duplicate of the holotype specimen) is located in the Herbarium of the University of El Salvador in San Salvador .

Limnoperdon incarnatum was originally thought to be associated with the Gasteromycetes , an artificial assemblage of species united by the fact that their spores mature inside the fruit bodies and are not forcibly discharged from the basidia . Other morphologically similar genera include the Gasterella of the family Gasterellaceae , and the Protogaster of the family Protogastraceae ; however , it was excluded from these genera because of significant differences in spore color and structure , presence of clamp connections , and structure of the basidia . For these reasons the new family Limnoperdaceae was described to contain the new species , and it was classified along the Protogastraceae in the (now defunct) order Protogastrales . More recently , molecular phylogenetics has been used to clarify the relationship Limnoperdon with other fungi . In 2001 , David Hibbett and Manfred Binder established the membership of Limnoperdon incarnatum in the euagarics clade , a phylogenetically related group of species traditionally forming the order Agaricales . Additional molecular studies have placed Limnoperdaceae in the pluteoid clade of the Agaricales , a grouping that includes the families Pluteaceae , Amanitaceae , and Pleurotaceae ; other studies that used comparisons of ribosomal DNA sequences placed Limnoperdon near the gilled genera Melanoleuca or Resupinatus , of the Tricholomataceae family .

A 2007 field study that used molecular techniques to survey aquatic fungal taxa in a small springbrook in Valley Spring , Southern Ontario , Canada discovered many fungal taxa with high genetic affinity to Limnoperdon incarnatum , which suggests that a closely related species may also be common in streams .

= Description =

The genus description is similar to the family description , but further specifies that the fruit bodies float , are sometimes embedded in a loose subiculum (a woolly or net @-@ like growth of hyphae) , and that the spores are reddish . The fungus has been described as an " aquatic puffball " , although a later review considered " floating puffball " to be a more apt descriptor .

The fruit bodies of L. incarnatum are tiny , oval to roughly spherical , and measure 35 ? 1250 by 200 ? 450 ?m . The floating balls are sometimes enclosed in a loose subiculum , with a whitish surface that is byssoid (consisting of fine threads) . The peridium (the outer protective tissue layer) is 18 ? 30 ?m thick , byssoid , and made of clamped hyphae typically 2 @. @ 5 ? 4 ?m in diameter intertwined with dendrophyses (irregularly branched cystidia) 1 ?m in diameter . The surface of the peridium is hydrophobic , a feature that helps keep water off the growing hymenium during its

development , and gives the fruit body buoyancy .

The gleba is a single chamber , reddish in color , with a cavity that has an oblate spheroid shape . Initially empty , in maturity it is filled with spores that measure 330×1220 by 180×420 μm . The smooth inner surface of the chamber comprises the fertile spore @-@ bearing tissue (the hymenium) . The basidia (spore @-@ bearing cells) ? conspicuous when viewed under the microscope ? are hyaline (translucent) , more or less club @-@ shaped , and usually have basal and apical swellings separated by a narrow strip of variable length . The basidia are four @-@ spored , and have inflated sterigmata with a central constriction . The basidia measure 20×90 (typically 25×55) μm long by 8×10 μm thick . Reddish in mass , the spores are obovate (egg @-@ shaped , with the broad extremity located away from the base) , smooth , thick @-@ walled , and measure 11×16 (typically 12×15) by 7×10 μm . They have a beaked pedicel that is 2×4 by 2×5 μm , and a basal germ pore .

= = Habitat and distribution = =

The species was originally discovered floating in petri dishes that contained submerged hardwood twigs previously collected from a marsh next to a playground on the south shore of Lake Union in Seattle , Washington . After the initial 1976 publication , *L. incarnatum* was reported the following year when Keisuke Tubaki recovered it from wood blocks submerged in brackish water in Japan ; scientists Seiya Ito and T. Yokoyama later reported collecting it in Japanese rice paddy fields . Later surveys uncovered the fungus in several localities in South Africa and in freshwater ponds in Canada .

= = Development = =

Escobar grew cultures of the fungus by placing fresh fruit bodies on agar containing growth medium with an extract of horse dung . The tips of the hyphae were used to obtain axenic cultures ; the fungus can grow on a variety of media commonly used to grow fungi in the laboratory . Depending on the composition of the growth media , fruit bodies were formed as early as eight days after initiating , when grown at 20°C (68°F) and under dim light . When minute agar blocks containing mycelium were submerged in distilled water , mycelial strands grew towards the water surface and eventually gave rise to floating fruit bodies connected to the parent agar block by strands of hyphae .

Mycologist Dennis McCabe studied the development of the fruit body using specimens grown in pure culture . Starting out as a hyphal tuft , the fungus grows into a cup shape before eventually closing in completely to create the spherical structure of the mature fruit body . When the fungus is in the cup stage , the exposed hymenium is immature ; typically , spores develop after the fruit body is fully closed . In some cases , the fruit body stops developing at the cup stage while the hymenium continues to mature . This results in a cup @-@ shaped fungus with an exposed layer of basidia bearing normal and mature spores . *Limnoperdon incarnatum* is a structurally simple fungus , and relatively easy to grow in culture , suggesting it may have potential as a model organism for fruit body development in general . Under the experimental conditions used , fruit bodies matured to produce spores about 72 hours after the fungus started growing . The aborted cups resemble the sporocarps of the cyphelloid fungi , but can be distinguished by their orthotrophic spore attachment and the lack of ballistospory (forceful spore discharge) . McCabe and Escobar later suggested that the fungus may have evolved the loss of ballistospory by being compensated with the cup @-@ shaped fruit body closing at maturity . *Halocyphina villosa* is another small cup @-@ shaped Basidiomycete fungus that has adapted to a marine environment ; in contrast to *L. incarnatum* , however , it starts out with a closed fruit body that later opens up to become cup @-@ shaped .

Although it is not known with certainty how the spores are dispersed , they may disperse passively in the water , or a mature spore @-@ containing fruit body may float on the water surface for dispersal . *L. incarnatum* is homothallic , a mode of reproduction commonly employed by marine fungi that may confer a competitive advantage in marine environments .

