= Hydnellum =

Hydnellum is a genus of tooth fungi of the family Bankeraceae in the order Thelephorales . Widely distributed in the Northern Hemisphere , the genus contains around 40 species . The fruitbodies of its members grow by slowly enveloping nearby bits of grass and vegetation . There is great variability in the form of Hydnellum fruitbodies , which are greatly influenced by environmental conditions such as rainfall and humidity , drying winds , and temperature . They are too tough and woody to eat comfortably . Several species have become the focus of increasing conservation concern following widespread declines in abundance .

Hydnellum species produce pigments that have been used to dye textiles . Several chemical compounds ? some with unique biological activity ? have been isolated and identified from the genus .

One of the better @-@ known species is the unusual pinkish @-@ white Hydnellum peckii , also known as " strawberries and cream " or as the " bleeding tooth fungus " due to the red droplets that appear on the pinkish or whitish fruitbodies . Another species , H. suaveolens , has a strong odor of anise or peppermint .

= = Taxonomy = =

Hydnellum was circumscribed by Finnish mycologist Petter Adolf Karsten in 1879 with what was then known as Hydnum suaveolens as the type species . Before then , fungi with spines (hydnoid fungi) had been grouped in Hydnum by Elias Fries in his 1821 work Systema mycologicum . Karsten defined Hydnellum as having fruitbodies with a corky or leathery , tough cap , and a centrally attached stipe . Synonyms of Hydnellum include Calodon (Karsten , 1881) , and Phaeodon (Joseph Schröter , 1888) .

Hydnellum is classified in the family Bankeraceae , which was circumscribed by Marinus Anton Donk in 1961 . The genus was not in Donk 's original family concept , which included only Bankera and Phellodon , genera whose species made hyaline (translucent) , and ornamented spores . Donk left Hydnellum in the tribe Hydnelleae of the family Thelephoraceae , along with Sarcodon and Hydnodon . In 1981 , however , Walter Jülich emended Donk 's concept of the Bankeraceae , adding hydnoid genera that produced brown , lobed spores ? Hydnellum and Sarcodon .

The name comes the Greek hydnum meaning spongy plant or fungus . The British Mycological Society , in their recommended list of common names for fungi in the United Kingdom , name Hydnellum fungi in the form " descriptor word " plus " tooth " , such as " gold tooth " (H. auratile) , " zoned tooth " (H. concrescens) , and " velvet tooth " (H. spongiosipes) .

= = Description = =

Hydnellum fruitbodies have caps and stipes , often with indeterminant growth forms , that may grow in spurts and decay over several weeks . Neighboring fruitbodies can coalesce , forming intricately intertwined caps and partially fused stipes . The flesh has a zoned appearance and is fibrous when fresh , but becomes hard and woody when dry . Zones in the flesh reflect differences in growth during periods of low daytime and high nighttime humidity , and give a fairly accurate record of daily growth . The spines are crowded closely together and typically decurrent (extending down the length of the stipe) . They may be a variety of colors , such as white to yellow , olive green , shades of orange , light brown , or dark brown in age .

Spores of Hydnellum are almost spherical to oblong and tuberculate , and are brown in mass . The basidia (spore @-@ bearing cells) are narrowly club @-@ shaped and usually four @-@ spored ; there are no cystidia in Hydnellum . Three types of hyphae are found in the flesh of Hydnellum : generative hyphae (thin @-@ walled , not inflated) ; skeletal hyphae (thick @-@ walled and narrow) ; and thin @-@ walled gloeoplerous @-@ like hyphae , which stain with methyl blue .

In conditions of high humidity , several species can form striking colored drops on the actively growing caps : red drops in H. peckii , H. diabolus , H. ferrugineum , and H. cruentum , yellow drops

in H. caeruleum , and coffee @-@ colored drops in H. mirabile . The common names of H. peckii reflect its appearance : " strawberries and cream " and " bleeding tooth fungus " . Some Hydnellum species have a mealy odor (e.g. H. mirabile and H. pineticola) similar to freshly ground flour . H. zonatum smells like melilot , while H. suaveolens has an sweet odor resembling anise or peppermint . All are too tough and woody to be edible , and many have an acrid taste anyway .

Differences between Hydnellum species tend to be more distinguishable in younger specimens . Fruitbody development is greatly influenced by environmental factors such as levels of rainfall , drying winds , and temperature . The blue tooth (H. caeruleum) , for example , develops a deeper blue color when it grows during cooler autumn weather . Optimal growth occurs during periods of frequent light rains and high humidity ; if the habitat dries out , growth will stop , but may resume after further precipitation . This intermittent growth affects the fruitbodies of different species to variable extents , leading to large variations in form , surface texture , and color . The morphological variability of fruitbodies and the dependence of their appearance upon environmental conditions has made Hydnellum a difficult group to study . Canadian mycologist Kenneth A. Harrison , who described several new species from North America , noted " [t] he remarkable longevity of individual sporophores of many species and the changes in appearance that occur during the long period of their development have confused all workers studying this group . " For example , H. aurantiacum , initially white , becomes in turn shades of orange , rusty @-@ brown , and brownish @-@ black . Its fruitbody initially has a turbinate (cushion @-@ like) shape with a lumpy surface , later becoming flattened to funnel @-@ shaped with a smooth to corrugated surface texture .

The caps form from the top of the short stipe by the growth and expansion of a blunt margin and later as a thickening of the upper surface . Spines start to form when the cap hangs over the stipe slightly . They are white in many species , but become brown in maturity as the brown @-@ colored spores accumulate on the surface .

= = Habitat and distribution = =

Hydnellum fungi are mycorrhizal , and are usually found in coniferous and mixed woods . Favored tree hosts include members of the Fagaceae and the Pinaceae . The genus is widely distributed in the Northern Hemisphere , particularly Europe and North America , but some species are found in the tropical Asia . Harrison identified a dozen new species from North America in the 1960s . Rudolph Arnold Maas Geesteranus recognized European 16 species in his 1975 treatment of the genus .

Some Hydnellum species , including H. ferrugineum and H. scleropodium , form a tough mat of mycelia in the humus and upper soil of pine forests . This mycelial mat grows larger with old trees , and can cover an area of several square meters . These areas generally lack dwarf shrubs and promote the vigorous growth of mosses ; reindeer lichens often occur in the center of large mats . The presence of the fungus changes the nature of the soil , resulting in a thinner humus layer , decreased groundwater penetration , decreased soil pH , and increases in the level of root respiration as well as the quantity of roots . The fungus also decreases the organic carbon and nitrogen concentrations . Soil with the mycelium becomes more podzolized than the surrounding soil .

= = Conservation = =

Some Hydnellum species have been shown to be in decline in Europe , including the Czech Republic , the Netherlands , Norway , and Scotland . In the United Kingdom , several are listed in the biodiversity action plan for stiped hydnoid fungi : H. aurantiacum is classified as critically endangered ; H. caeruleum , H. ferrugineum are listed as endangered , while H. concrescens , H. spongiosipes , H. peckii , and H. scrobiculatum are considered vulnerable . H. ferrugineum and H. peckii are sensitive to the increased nitrogen deposition resulting from clear @-@ cutting , a forestry practice used in some areas of Europe .

Conservation efforts for Hydnellum are hindered by the fact that some species are difficult to

discriminate in the field , making it hard to determine an appropriate conservation status . Techniques based on species @-@ specific PCR primers and DNA extraction from soil have been developed to detect the mycelia of various Hydnellum species without having to rely on the presence of fruitbodies , which may help conservation efforts as well as improve understanding of below @-@ ground ecology . Similar techniques have been used to show that , in the case of H. aurantiacum and H. caeruleum , the fungus can persist below the ground for at least four years without producing fruitbodies .

= = Bioactive compounds = =

Several chemical compounds ? some with unique biological activity ? have been isolated and identified from Hydnellum species . For example , H. peckii contains atromentin , a pigment with anticoagulant properties similar to heparin . Atromentin also possesses antibacterial activity , inhibiting the enzyme enoyl @-@ acyl carrier protein reductase (essential for the biosynthesis of fatty acids) in the bacteria Streptococcus pneumoniae .

Some species are used as dyes . H. caeruleum , used in North America and Scandinavia to dye silk and wool , produces a range of colors including tan , blue , and forest @-@ green , depending on the mordant that is used . H. peckii produces gray , brown , and olive colors . Hydnuferrugin and hydnuferruginin are pigments responsible for the coloration of H. ferrugineum and H. zonatum . Geogenin is a yellow pigment found in H. geogenium .

Thelephoric acid is present in several Hydnellum species . This compound , derived metabolically from the shikimic acid pathway , inhibits the enzyme prolyl endopeptidase , which is involved in deteriorating certain neuropeptides that are believed to contribute to memory and learning . Hydnellum caeruleum and H. concrescens have several para @-@ terphenyl derivatives named thelephantins , some of which can inhibit the enzyme alpha @-@ glucosidase . The compounds hydnellins A and B are terphenyls found in H. suaveolens and H. geogerirum . The chemicals responsible for the fragrant anise @-@ like aroma of H. suaveolens have been identified as coumarin and para @-@ anisaldehyde .

= = Species = =

Karsten 's original 1879 circumscription of Hydnellum contained 19 species . Joost Stalpers included 34 Hydnellum species in his 1993 monograph on the Thelephorales . The tenth edition of the Dictionary of the Fungi (2008) indicated 38 species in the genus . As of January 2015 , Index Fungorum lists 39 species of Hydnellum .

Hydnellum aurantiacum (Batsch) P.Karst. (1879) ? Asia , Europe , North America
Hydnellum auratile (Britzelm .) Maas Geest . (1959) ? Europe , North America
Hydnellum caeruleum (Hornem .) P.Karst. (1879) ? Asia , Europe , North America
Hydnellum chrysinum K.A.Harrison (1964) ? North America
Hydnellum coalitum Maas Geest . (1975) ? Europe
Hydnellum compactum (Pers .) P.Karst. (1879) ? Europe
Hydnellum complicatum Banker (1906) ? North America
Hydnellum concrescens (Pers .) Banker (1906) ? Asia , Europe , North America
Hydnellum conigenum (Peck) Banker (1906) ? North America
Hydnellum cristatum (Bres .) Stalpers (1993) ? Europe , North America
Hydnellum cruentum K.A.Harrison (1961) ? Nova Scotia , Canada
Hydnellum crustulinum Maas Geest . (1971) ? Punjab , India
Hydnellum cumulatum K.A.Harrison (1964) ? Europe , North America
Hydnellum cyanodon K.A.Harrison (1964) ? North America
Hydnellum cyanopodium K.A.Harrison (1964) ? North America
Hydnellum earlianum Banker (1906) ? North America
Hydnellum ferrugineum (Fr .) P.Karst. (1879) ? North Africa , Asia , Europe , North America
Hydnellum floriforme (Schaeff .) Banker (1906) ? North America

Hydnellum fraudulentum Maas Geest . (1971) ? Australia
Hydnellum frondosum K.A.Harrison (1961) ? Nova Scotia , Canada
Hydnellum geogenium (Fr .) Banker (1913) ? Europe , North America
Hydnellum gracilipes (P.Karst.) P.Karst. (1879) ? Europe
Hydnellum longidentatum Coker (1939) ? United States
Hydnellum mirabile (Fr .) P.Karst. (1879) ? Europe , North America
Hydnellum multiceps K.A.Harrison (1961) ? Nova Scotia , Canada
Hydnellum nigellum K.A.Harrison (1964) ? North America
Hydnellum papuanum Maas Geest . (1971) ? Papua New Guinea
Hydnellum peckii Banker (1912) ? Europe , North America
Hydnellum regium K.A.Harrison (1964) ? North America
Hydnellum rickeri Banker (1913) ? North America
Hydnellum scleropodium K.A.Harrison (1964) ? North America
Hydnellum scrobiculatum (Fr .) P.Karst. (1879) ? Asia , Europe , North America
Hydnellum septentrionale K.A.Harrison (1964) ? North America
Hydnellum singeri Maas Geest . (1969) ? Colombia
Hydnellum spongiosipes (Peck) Pouzar (1960) ? Europe , North America
Hydnellum staurastrum Maas Geest . (1971) ? Malaysia
Hydnellum suaveolens (Scop .) P.Karst. (1879) ? Asia , Europe , North America
Hydnellum subzonatum K.A.Harrison (1961) ? Nova Scotia , Canada
Hydnellum tardum Maas Geest . (1975) ? Europe

= = = Cited works = = =

Harrison KA . (1961) . The Stipitate Hydnums of Nova Scotia . Publications of the Department of Agriculture Canada (Report) 1099 (Ottawa , Canada : Research Branch , Canada Department of Agriculture) . pp. 1 ? 60 .
Stalpers JA . (1993) . " The Aphyllophoraceous fungi I. Keys to the species of the Thelephorales " . Studies in Mycology 35 : 1 ? 168 .