

= *Gyromitra esculenta* =

Gyromitra esculenta / ʔdʔaʔroʔʔmaʔtrʔ ʔʔskjʔʔlʔntʔ , ʔdʔʔrʔ- / , is an ascomycete fungus from the genus *Gyromitra* , widely distributed across Europe and North America . It normally fruits in sandy soils under coniferous trees in spring and early summer . The fruiting body , or mushroom , is an irregular brain @-@ shaped cap dark brown in colour that can reach 10 cm (4 in) high and 15 cm (6 in) wide , perched on a stout white stipe up to 6 cm (2 @.@ 4 in) high .

Although potentially fatal if eaten raw , *Gyromitra esculenta* is a popular delicacy in Scandinavia , Eastern Europe , and the upper Great Lakes region of North America . Although popular in some districts of the eastern Pyrenees , it is prohibited from sale to the public in Spain . It may be sold fresh in Finland , but it must be accompanied by warnings and instructions on correct preparation .

Although it is still commonly parboiled before preparation , evidence suggests that even this procedure may not make *Gyromitra esculenta* entirely safe for consumption , thus raising concerns of risk even when prepared properly . When consumed , the principal active agent , gyromitrin , is hydrolyzed into the toxic compound monomethylhydrazine (MMH) . The toxin affects the liver , central nervous system , and sometimes the kidneys . Symptoms of poisoning involve vomiting and diarrhea several hours after consumption , followed by dizziness , lethargy and headache . Severe cases may lead to delirium , coma and death after 5 ? 7 days .

= = Taxonomy and naming = =

The fungus was first described in 1800 , by mycologist Christian Hendrik Persoon , as *Helvella esculenta* , and gained its current accepted binomial name when the Swedish mycologist Elias Magnus Fries placed it in the genus *Gyromitra* in 1849 . The genus name is derived from the Greek terms *gyros* / ʔʔʔʔʔ " round " and *mitra* / ʔʔʔʔʔ " headband " . Its specific epithet is derived from the Latin *esculentus* , " edible " .

It is known by a variety of common descriptive names such as " brain mushroom , " " turban fungus , " elephant ears , or " beefsteak mushroom / morel , " although beefsteak mushroom can also refer to the much less toxic *Fistulina hepatica* . Dating from the 19th century , the German term *lorchel* is a result of the older *lorche* , itself from the 18th century Low German *Lorken* , aligning with the similar sounding (and similar looking) *morchel* .

Gyromitra esculenta is a member of a group of fungi known as " false morels " , so named for their resemblance to the highly regarded true morels of the genus *Morchella* . The grouping includes other species of the genus *Gyromitra* , such as *G. infula* (elfin saddle) , *G. caroliniana* and *G. gigas* (snow morel) . While some of these species contain little to no gyromitrin , many guidebooks recommend treating them all as poisonous , since their similar appearance and significant intraspecific variation can make reliable identification difficult .

The more distantly related ascomycete mushrooms of the genus *Verpa* , such as *V. bohemica* and *V. conica* , are also known as false morels , early morels or thimble morels ; like the *Gyromitra* , they are eaten by some and considered poisonous by others .

The genus *Gyromitra* had been classically considered part of the family *Helvellaceae* , along with the similar @-@ looking elfin saddles of the genus *Helvella* . Analysis of the ribosomal DNA of many of the *Pezizales* showed *Gyromitra esculenta* and the other false morels to be only distantly related to the other members of the *Helvellaceae* and instead most closely related to the genus *Discina* , forming a clade which also contains *Pseudorhizina* and *Hydnотrya* . Thus the four genera are now included in the family *Discinaceae* .

= = Description = =

Resembling a brain , the irregularly shaped cap may be up to 10 centimetres (3 @.@ 9 in) high and 15 centimetres (5 @.@ 9 in) wide . Initially smooth , it becomes progressively more wrinkled as it grows and ages . The cap colour may be various shades of reddish- , chestnut- , purplish- , bay- , dark or sometimes golden @-@ brown . Specimens from California may have more reddish

@-@ brown caps . Attached to the cap at several points , the stipe is 3 ? 6 centimetres (1 @.@ 2 ? 2 @.@ 4 in) high and 2 ? 3 centimetres (0 @.@ 8 ? 1 @.@ 2 in) wide . *Gyromitra esculenta* has a solid stipe whereas those of true morels (*Morchella* spp .) are hollow . The smell can be pleasant and has been described as fruity , and the fungus is mild @-@ tasting . The spore print is whitish , with transparent spores that are elliptical and 17 ? 22 ?m in length .

Gyromitra esculenta resembles the various species of true morel , although the latter are more symmetric and look more like pitted gray , tan , or brown sponges . Its cap is generally darker and larger .

= = Distribution and habitat = =

Gyromitra esculenta grows on sandy soil in Temperate coniferous forest and occasionally in deciduous woodlands . Among conifers it is mostly found under pines (*Pinus* spp .) , but also sometimes under aspen (*Populus* spp .) . The hunting period is from April to July , earlier than for other species , and the fungus may even sprout up with the melting snow . It can be abundant in some years and rare in others . The mushroom is more commonly found in places where ground has been disturbed , such as openings , rivulets , washes , timber clearings , plowed openings , forest fire clearings , and roadsides . Enthusiasts in Finland have been reported burying newspaper inoculated with the fungus in the ground in autumn and returning the following spring to collect mushrooms .

Although more abundant in montane and northern coniferous woodlands such as the Sierra Nevada and the Cascade Range in northwestern North America , *Gyromitra esculenta* is found widely across the continent , as far south as Mexico . It is also common in Central Europe , less abundant in the east , and more in montane areas than lowlands . It has been recorded from Northern Ireland , from U?ak Province in Western Turkey , and from the vicinity of Ka? in the Antalya Province of Turkey 's southern coast .

= = Toxicity = =

Toxic reactions have been known for at least a hundred years . Experts speculated the reaction was more of an allergic one specific to the consumer , or a misidentification , rather than innate toxicity of the fungus , due to the wide range in effects seen . Some would suffer severely or perish while others exhibited no symptoms after eating similar amounts of mushrooms from the same dish . Yet others would be poisoned after eating *Gyromitra esculenta* for many years without ill @-@ effects . However , the fungus is now widely recognized as potentially deadly .

Gyromitra esculenta contains levels of the poison gyromitrin that vary locally among populations ; although these mushrooms are only rarely involved in poisonings in either North America or western Europe , intoxications are seen frequently in eastern Europe and Scandinavia . A 1971 Polish study reported at the time that the species accounted for up to 23 % of mushroom fatalities each year . Death rates have dropped since the mid @-@ twentieth century ; in Sweden poisoning is common , though life @-@ threatening poisonings have not been detected and there was no fatality reported over the 50 years from 1952 to 2002 . *Gyromitra* poisonings are rare in Spain , due to the widespread practice of drying the mushrooms before preparation and consumption , but has a mortality rate of about 25 % .

A lethal dose of gyromitrin has been estimated to be 10 ? 30 mg / kg for children and 20 ? 50 mg / kg in adults . These doses correspond to around 0 @.@ 2 ? 0 @.@ 6 kilograms (0 @.@ 4 ? 1 @.@ 3 lb) and 0 @.@ 4 ? 1 kilogram (0 @.@ 9 ? 2 @.@ 2 lb) of fresh mushroom respectively . However , individual responses may vary and people who have ingested similar amounts may develop anything from minimal to severe toxicity . Evidence suggests that children are more severely affected ; it is unclear whether this is due to a larger weight consumed per body mass ratio or to differences in enzyme and metabolic activity . Although the amount of gyromitrin present can be significantly reduced through parboiling , there is evidence that repeated consumption can increase risk of toxicity .

== Geographical variation ==

Populations of *Gyromitra esculenta* appear to vary geographically in their toxicity . A French study has shown that mushrooms collected at higher altitudes have lower concentrations of toxin than those from lower elevations , and there is some evidence that fungi west of the Rocky Mountains in North America contain less toxin than those to the east . However , poisonings in the west have been reported , although less frequently than in Europe .

== Biochemistry ==

The identity of the toxic constituents eluded researchers until 1968 , when acetaldehyde N-methyl-N-formylhydrazone , better known as gyromitrin , was isolated . Gyromitrin is a volatile water-soluble hydrazine compound hydrolyzed in the body into monomethylhydrazine (MMH) . Other N-methyl-N-formylhydrazone derivatives have been isolated in subsequent research , although they are present in smaller amounts . These other compounds would also produce monomethylhydrazine when hydrolyzed , although it remains unclear how much each contributes to the false morel's toxicity .

The toxins react with pyridoxal 5-phosphate ? the activated form of pyridoxine ? and form a hydrazone . This reduces production of the neurotransmitter GABA via decreased activity of glutamic acid decarboxylase , producing the neurological symptoms . MMH also causes oxidative stress leading to methemoglobinemia . Additionally during the metabolism of MMH , N-methyl-N-formylhydrazine is produced ; this then undergoes cytochrome P450 regulated oxidative metabolism which via reactive nitrosamide intermediates leads to formation of methyl radicals which lead to liver necrosis . Inhibition of diamine oxidase (histaminase) elevates histamine levels resulting in headaches , nausea , vomiting , and abdominal pain .

== Symptoms ==

The symptoms of poisoning are typically gastrointestinal and neurological . Symptoms occur within 6 ? 12 hours of consumption , although cases of more severe poisoning may present sooner ? as little as 2 hours after ingestion . Initial symptoms are gastrointestinal , with sudden onset of nausea , vomiting , and watery diarrhea which may be bloodstained . Dehydration may develop if the vomiting or diarrhea is severe . Dizziness , lethargy , vertigo , tremor , ataxia , nystagmus , and headaches develop soon after ; fever often occurs , a distinctive feature which does not develop after poisoning by other types of mushrooms . In most cases of poisoning , symptoms do not progress from these initial symptoms , and patients recover after 2 ? 6 days of illness .

In some cases there may be an asymptomatic phase following the initial symptoms which is then followed by more significant toxicity including kidney damage , liver damage , and neurological dysfunction including seizures and coma . These signs usually develop within 1 ? 3 days in serious cases . The patient develops jaundice and the liver and spleen become enlarged , in some cases blood sugar levels will rise (hyperglycemia) and then fall (hypoglycemia) and liver toxicity is seen . Additionally intravascular hemolysis causes destruction of red blood cells resulting in increase in free hemoglobin and hemoglobinuria which can lead to renal toxicity or renal failure . Methemoglobinemia may also occur in some cases . This is where higher than normal levels of methemoglobin , which is a form of hemoglobin that can not carry oxygen , are found in the blood . It causes the patient to become short of breath and cyanotic . Cases of severe poisoning may progress to a terminal neurological phase , with delirium , muscle fasciculations and seizures , and mydriasis progressing to coma , circulatory collapse , and respiratory arrest . Death may occur from five to seven days after consumption .

== Treatment ==

Treatment is mainly supportive ; gastric decontamination with activated charcoal may be beneficial if medical attention is sought within a few hours of consumption . However , symptoms often take longer than this to develop , and patients do not usually present for treatment until many hours after ingestion , thus limiting its effectiveness . Patients with severe vomiting or diarrhea can be rehydrated with intravenous fluids . Monitoring of biochemical parameters such as methemoglobin levels , electrolytes , liver and kidney function , urinalysis , and complete blood count is undertaken and any abnormalities are corrected . Dialysis can be used if kidney function is impaired or the kidneys are failing . Hemolysis may require a blood transfusion to replace the lost red blood cells , while methemoglobinemia is treated with intravenous methylene blue .

Pyridoxine , also known as vitamin B6 , can be used to counteract the inhibition by MMH on the pyridoxine @-@ dependent step in the synthesis of the neurotransmitter GABA . Thus GABA synthesis can continue and symptoms are relieved . Pyridoxine , which is only useful for the neurological symptoms and does not decrease hepatic toxicity , is given at a dose of 25 mg / kg ; this can be repeated up to a maximum total of 15 to 30 g daily if symptoms do not improve . Benzodiazepines are given to control seizures ; as they also modulate GABA receptors they may potentially increase the effect of pyridoxine . Additionally MMH inhibits the chemical transformation of folic acid into its active form , folinic acid , this can be treated by folinic acid given at 20 ? 200 mg daily .

= = = Carcinogenicity = = =

Monomethylhydrazine , as well as its precursors methylformylhydrazine and gyromitrin and raw *Gyromitra esculenta* , have been shown to be carcinogenic in experimental animals . Although *Gyromitra esculenta* has not been observed to cause cancer in humans , it is possible there is a carcinogenic risk for people who ingest these types of mushrooms . The toxins may be cumulative and even small amounts may have a carcinogenic effect . At least 11 different hydrazines have been isolated from *Gyromitra esculenta* , and it is not known if the potential carcinogens can be completely removed by parboiling .

= = Consumption = =

Despite its recognized toxicity , *Gyromitra esculenta* is marketed and consumed in several countries or states in Europe and North America . It was previously consumed in Germany , with fungi picked in and exported from Poland ; more recently , however , Germany and Switzerland discouraged consumption by prohibiting its sale . Similarly in Sweden , the Swedish National Food Administration warns it is not fit for human consumption , and restricts purchase of fresh mushrooms to restaurants alone . The mushroom is still highly regarded and consumed in Bulgaria , being sold in markets and picked for export there . In some countries such as Spain , especially in the eastern Pyrenees , they are traditionally considered a delicacy , and many people report consuming them for many years with no ill effects . Despite this , the false morel is listed as hazardous in official mushroom lists published by the Catalan Government and sale to the public is prohibited throughout Spain . Outside of Europe , *Gyromitra esculenta* is consumed in the Great Lakes region and some western states in the United States .

Selling and purchasing fresh false morels is legal in Finland , where it is highly regarded . However , the mushrooms are required by law to be accompanied with a warning that they are poisonous and legally prescribed preparation instructions . False morels are also sold prepared and canned , in which case they are ready to be used . Official figures from the Finnish Ministry of Agriculture and Forestry report a total amount of false morels sold in Finland of 21 @. @ 9 tonnes in 2006 and 32 @. @ 7 tonnes , noted as being above average , in 2007 . In 2002 , the Finnish Food Safety Authority estimated annual consumption of false morels to be hundreds of tonnes in plentiful years . In Finnish cuisine , false morels may be cooked in an omelette , or gently sautéed in butter in a saucepan , flour and milk added to make a bechamel sauce , or pie filling . Alternatively , more fluid can be added for a false morel soup . Typical condiments added for flavour include parsley , chives ,

dill and black pepper .

= = = Controversies = = =

In 2015 , Swedish chef Paul Svensson caused a controversy when he prepared a dish with *Gyromitra esculenta* in a TV show . Mushroom expert Monica Svensson criticized him for including it , because of the mushroom 's carcinogenic substances and the risk that inexperienced people might misinterpret the recipe and omit the steps that reduce the toxicity level . She also expressed criticism to Per Morberg for similar reasons . Paul Svensson said that he wasn 't aware of the carcinogenic effects and apologized afterwards , and he promised to remove the mushroom from his dishes .

= = = Preparation = = =

Most of the gyromitrin must be removed to render false morels edible . The recommended procedure involves either first drying and then boiling the mushrooms , or boiling the fresh mushrooms directly . To prepare fresh mushroom it is recommended that they are cut into small pieces and parboiled twice in copious amounts of water , at least three parts water to one part chopped mushrooms , for at least five minutes , after each boiling the mushroom should be rinsed thoroughly in clean water . Each round of parboiling reduces the gyromitrin contents to a tenth . The gyromitrin is leached into the water where it will remain , therefore the parboiling water must be discarded and replaced with fresh water after each round of boiling . Drying the mushrooms can also reduce the concentration of gyromitrin ; ten days of open air desiccation leads to the loss of 90 % of gyromitrin . However it is still recommended that the mushroom be boiled after drying .

MMH boils at 87 @. @ 5 ° C (190 ° F) and thus readily vaporizes into the air when water containing fresh false morels is boiled . Poorly ventilated spaces allow vapor to accumulate , resulting in gyromitrin poisoning . If boiling the mushrooms indoors , care should be taken to ensure adequate ventilation , and , if symptoms of gyromitrin poisoning appear , immediately seek fresh air . Even after boiling , small amounts of gyromitrin remain in the mushrooms . Given the possibility of accumulation of toxins , repeated consumption is not recommended .

= = = Prospects for cultivation = = =

Strains with much lower concentrations of gyromitrin have been discovered , and the fungus has been successfully grown to fruiting in culture . Thus there is scope for future research into cultivation of safer strains .