KEYS TO THE GENERA OF TRUFFLES (ASCOMYCETES)

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INTRODUCTION

Truffles are belowground (hypogeous) relatives of the cup fungi (Castellano et al., 1989; Trappe, 1979). They have evolved a spore dispersal strategy that depends on animals. As a truffle matures its spores, it begins to emit an odor, a chemical signal to animals that a feast awaits (Trappe and Maser, 1977). Nearly all mammals seem attracted to ripe truffles and will eat them whenever they detect them (Maser et al., 1978).

Humans are numbered among the animals that enjoy eating truffles, although only a few of the several hundred known species please the human palate. North America abounds in truffles, and new species are turning up regularly as new places are explored for them. The activities of the North American Truffling Society (Box 296, Corvallis, OR 97339-0296) have been particularly fruitful in this respect.

The growth of interest in the quest for truffles has generated increasing demand for up-to-date keys to identify them. At the request of the editorial committee of *McIlvainia,* we developed keys to Ascomycete truffle genera on a world-wide basis. Keys to the truffle genera base solely on spore characteristics were published by Castellano et al. (1989) with the special intent of identifying fungi eaten by animals as represented by spores in stomach contents or feces. The collector who has a truffle in hand but no microscope will want a key that permits identification at least to genus by macroscopic characteristics. Even when a microscope is available, use of characters in addition to spores can greatly simplify identification.

OCCURRENCE OF TRUFFLES

Although laymen have generally heard only of the true truffles (order Tuberales), truffle-like fungi are diverse. They occur in many families and genera of the Ascomycetes (true truffles), Basidiomycetes (false truffles), and some Zygomycetes, and the general principles of finding, describing, and preserving them apply to most species. For the purposes of this paper we will use the general term truffles for all truffle-like fungi, but we present keys only to the Ascomycete genera.

Though abundant in much of North America, truffles are seldom encountered by collectors who seek specimens only on or above the ground surface. Having learned the art of finding truffles the collector will find this bounty more often then not. Moreover, the likelihood of turning up new taxa offers an incentive, since little of the world has been well-explored for truffles .

Truffles are typically found near mycorrhizal roots of woody plants in or near forests, groves, and shrub areas. Some fungal species are relatively nonselective in terms of mycorrhizal host species that they associate with; for example, *Elaphomyces granulatus* associates with trees in several genera and families. Other truffles require hosts from a few or only one genus. An example of such narrow host specificity is *Tuber gibbosum* with Douglas-fir (*Pseudotsuga menziesii*).

In habitats that remain moist through the summer, truffles often grow in the litter layer or, occasionally, so close to the surface that they emerge at maturity. Some spring-fruiting species develop on the humus surface under snow banks, to be revealed as the snow melts. More typically, however, truffles reach maximum development near the interface between humus and mineral soil – it is here that mycorrhizae develop most profusely. A few, such as certain species of the genera *Tuber* and *Elaphomyces*, characteristically fruit more deeply in the soil; some, indeed, have been found at depths of several feet.

Certain microhabitats are particularly congenial for some truffle species. For example, *Hydnotrya variiformis* fruits profusely in buried rotten conifer wood.

Every kind of seasonal occurrence is represented among the truffles. In temperate regions there is usually a flush of fruiting in spring, summer, or autumn, depending on rainfall patterns. Maximum truffle production generally coincides with maximum fruiting of wild mushrooms. Many species normally fruit in one particular season, while others appear sporadically or more or less continuously throughout the growing season. The Basidiomycetes tend to be relatively ephemeral; the primordium forms, expands, and the sporocarp matures and decays in a relatively short time. Many Ascomycetes, by contrast, take several months to mature and then decay only slowly. Such fungi can be found throughout the growing season but sometimes cannot be identified for lack of spores until late in the season. *Elaphomyces* spp. are particularly durable and may even overwinter to mature in the year following initial expansion of the primordium.

COLLECTING TRUFFLES

The most important tool for unearthing truffles is a garden cultivator or rake. Preferences vary, but we find a four-tined garden cultivator with the handle cut to a comfortable length (about 30 inches) to be most efficient. Hand cultivators are also satisfactory but require more stooping and cover less area than the larger type. Once a likely spot is chosen for examination, the litter is gently raked aside and the exposed humus inspected for specimens. The humus is then raked away down to mineral soil. During and after each stroke of the fork, the material being worked should be carefully watched. Having reached mineral soil the collector will often find it worthwhile to rake several inches deeper especially if there is any suggestion (mycelial network) that something is growing underneath. After completing the search for specimens at a particular spot the duff and soil should be replaced as best as can be done.

Specimens growing in the site examined will either be uncovered or “pop out” from the raking. It pays to look especially for small, dark, inconspicuous specimens because then they will be seen along with the larger or more brightly colored ones. Once a specimen is found, note the depth and kind of material in which it was growing and look for evidence of associated mycelium. Truffles are often gregarious, and many additional specimens may well be nearby in the same substrate or mycelial network.

Having collected all specimens uncovered at the site, the collector should take notes on their fresh color and odor and whether latex is exuded from a cut surface or the specimens change color when either cut or bruised (press the surface firmly). If no immediate color change occurs, the specimens should be rechecked after 30 - 60 minutes and again after several hours. The date, location of a collection, and notes on associated vascular plants, including tree seedlings and shrubs as well as overstory trees, are useful in describing the ecology of these fungi. Specimens can be kept in waxed paper sandwich bags (avoid plastic bags) until final processing.

A good indicator of truffle activity is the presence of fresh small animal digs. Squirrels and mice usually unearth truffles one at a time, leaving a small pit; sometimes they will nibble the upper part of a specimen and leave the lower part. Usually they will dig only a few of the specimens present, leaving others to mature later. Once a pit is found, careful raking of several square feet of surrounding ground to about the same depth as the bottom of the pit is likely to yield specimens. Needles, leaf fragments, other debris, or spider webs in a small animal dig usually indicate it is so old that further exploration will be unprofitable. Tunnels usually are not closely related to occurrence of truffles; if the bottom of a hole cannot be felt with a finger, it should not be regarded as an indictor of truffles.

Other animals, too, are attracted to truffles. Wild pigs, deer and bear sometimes paw up sizeable tracts that harbor specimens. Such areas can be profitably searched, and sometimes specimens can be found lying on the surface.

Truffles are also found where the soil is somewhat compacted or where the humus layer is thin. Under such circumstances even relatively small specimens will hump up the humus enough to be detected by a perceptive searcher, while large species may emerge through the surface. Thus campgrounds, old tractor trails, abandoned roads, and road banks are particularly productive places to look.

With experience, a collector will recognize microhabitats likely to produce truffles. Generally, they are most numerous and diverse in places with relatively little ground vegetation. Often the soil adjacent to rotten logs is good, particularly the “microbenches” on the upper sides of long-fallen trees lying along the contour of moderate slopes.

Finally, random searching can provide fine collections. Seemingly unlikely sites can harbor some species that do not often occur elsewhere. In one instance, a splendid group of *Tuber* specimens were discovered during cultivation of a rose garden in a city residential area.

Each specimen should be cut in half. Many species resemble each other on the surface but differ in the interior; examining the interior minimizes the chance of including more then one species in a single collection.

For several reasons, well-dried specimens are more useful and easier to maintain than those preserved in liquid. Specimens are preferably described and dried as soon after collection as possible; once deterioration begins, much of their value for later study is lost. This applies particularly to Basidiomycetes, although specimens in very good condition can often be stored in a refrigerator for several days if absolutely necessary. Each specimen should be halved before drying; large ones can be cut in several vertical slabs.

Best preservation results from rapid drying at relatively low temperatures. A circulating oven or food dryer set at 30˚C works well. Without good air circulation, specimens will warm without drying rapidly and deteriorate rapidly. Silica gel provides a good way for drying specimens in the field (Hoseney, 1963). Small containers (half-pint and one-pint sizes) with lids and a tightly sealed container of oven-dried silica gel can be conveniently taken on collecting trips. When a collection is ready to be dried, the specimens are cut in two or more pieces, depending on size, and covered with silica gel granules. Pieces should not touch each other. No more than one collection should be put in a given container because, when dried, species can often be difficult to tell apart. One to two days will dry specimens thoroughly by this method if enough silica gel has been added in proportion to the volume or material to be dried.

In special circumstances where it is not practical to take silica gel, e.g., in wilderness areas, light-weight frames covered with fine mesh screen are useful. The screens can be set up for drying in the breeze and sun or near a campfire.

THE KEYS

Truffles have a limited number of macroscopic characters for use in keys. Having evolved the belowground fruiting habit, they often lack distinctive features such as stems or brightly colored caps. Many resemble small potatoes or dirt clods more than a mushroom or cup fungus. Consequently, a key based solely on macroscopic characters has limitations. We present a first attempt at a macroscopic key and have tried to use common words in lieu of technical terms when possible. The first challenge is to determine whether a specimen is an Ascomycete or Basidiomycete. No single macroscopic character differentiates the two groups. Accordingly we present Key No. 1 for this first determination. If the specimen is an Ascomycete, one can turn to Key No. 2 if no microscope is available. Key No. 3 is an alternative for use with a microscope. In Key 2, that utilizes macroscopic characters, some choices depend on the specimen being mature, for example the application of a drop of iodine to see if the specimen gives a blue or black reaction. It often won't unless it is at least partially matured, but how does one know without a microscope to check whether asci are filled with spores? We have not determined a way around such a dilemma. Fortunately, most collections will include some mature specimens.

We also use geography in the macroscopic key, for example by specifying that a genus occurs only in the Northern Hemisphere or only in association with Southern Hemisphere trees such as eucalypts or only in deserts. Normally we prefer to avoid this approach, because a genus known today only from certain kinds of places may turn up in other places tomorrow as the search for truffles expands into new territory. Still, we needed all the options to make the macroscopic key workable.

In some cases a particular genus keys out in two or more places. The genus *Tuber,* for example, does so because it is diverse in form and color and yet difficult to describe in a readily understood way without recourse to microscopic characters.

In a second key we include microscopic as well as macroscopic characters, again with minimal use of technical terms. Those that have access to a microscope will generally find the second key to be more satisfying. Moreover, it enables one to check the characters of the specimen in hand with those given in descriptions in sources such as Trappe (1979) or Castellano et al. (1989).

After the keys we give references to the best available keys to species of each genus. In many cases, no reliable, updated keys are available. We are working towards correcting that deficiency, but it is a large task.

Key 1: Differentiating Between Ascomycetes and Basidiomycetes

1. Truffle surface ±evenly covered with round to angular warts (use hand lens) ..... **Ascomycetes**
1. Truffle surface not warty **2**
2. Truffle solid in cross-section (use hand lens) **3**
2. Truffle with one to many empty or spore-filled canals or chambers **4**
3. Truffle interior gelatinous or exuding a sticky fluid ..... **Basidiomycetes**
3. Truffle interior firm to crisp, not exuding a sticky fluid ..... **Ascomycetes**
4. Chambers single to many, >3 mm broad ..... **Ascomycetes**
4. Chambers or canals <3 mm broad **5**
5. Truffle with a stem or stem-like tissue in cross-section ..... **Basidiomycetes**
5. Truffle lacking a stem or stem-like tissue in cross-section **6**
6. Truffle with rootlet-like strands (rhizomorphs) at base or appressed on surface ..... **Basidiomycetes**
6. Truffle lacking rhizomorphs **7**
7. Truffle interior with long, meandering canals ..... **Ascomycetes**
7. Truffle interior with rounded to slightly elongate or irregular chambers **8**
8. Truffle flesh soft, white to yellow or brown ..... **Basidiomycetes**
8. Truffle flesh firm to crisp, gray to brown or purple ..... **Ascomycetes**

Key 2: Ascomycete Genera Based on Macroscopic Characters

1. In dry to wet habitats under shrubs or trees **2**
1. In true deserts with herbs or shrubs **44**
2. Truffle with one to many empty or spore-filled chambers or canals **3**
2. Truffle solid, often marbled with veins **23**
3. Truffle sides and top with brown hairs (observe with hand lens) **4**
3. Truffle sides and top lacking brown hairs, but a tuft of hairs may be present at base **8**
4. Truffle surface warty **5**
4. Truffle surface not warty but may be ridged or convoluted **6**
5. Iodine on cross-section of mature truffle causing a blue to black reaction ..... ***Amylascus***
5. Iodine on cross-section of mature truffle causing a yellow to brown or no reaction ..... ***Genea***
6. Truffle with a single, brown-lined chamber ..... ***Hydnocystis***
6. Truffle chamber white-lined or chambers or canals more than one **7**
7. Truffle with broad chambers of various shapes; Northern Hemisphere ..... ***Geopora***
7. Truffle with narrow, labyrinthine canals; Australasia ..... ***Labyrinthomyces***
8.(3) Chambers one or a few, often broader than 3 mm **9**
8. Chambers or canals many, generally less than 3 mm broad **17**
9. Chamber single, in youth containing cottony hyphae, at maturity spore powder **10**
9. Chambers single to several, empty **11**
10. Peridium more than 3 mm thick, the surface yellow, brown, blue or black; world-wide ..... ***Elaphomyces***
10. Peridium less than 3 mm thick, bright orange to scarlet; New Zealand (and introduced to England) ..... ***Paurocotylis***
11.(9) Truffle surface minutely warty **12**
11. Truffle surface smooth to scabrous **14**
12. Truffle with a tuft of hairs at base ..... ***Genea***
12. Truffle lacking a basal tuft **13**
13. Truffle reddish brown to purple ..... ***Genea intermedia***
13. Truffle grayish yellow, brown or black ..... ***Genabea***
14.(11) Truffle with a large, single chamber and a basal stem ..... ***Sarcosphaera***
14. Truffle with one to several chambers, lacking a basal stem **15**
15. Iodine on cross-section of fresh, mature truffle causing a blue to black reaction ..... ***Peziza***
15. Iodine on cross-section of fresh, mature truffle causing a yellow, orange, red or no reaction ... **16**
16. Truffle lacking a basal tuft of hairs; Northern Hemisphere ..... ***Hydnotrya***
16. Truffle with a basal tuft of hairs; Southern Hemisphere ..... ***Gymnohydnotrya***

17.(8) Species of the Northern Hemisphere **18**
17. Species of the Southern Hemisphere **20**
18. Truffle surface warty ..... ***Balsamia***
18. Truffle surface smooth to minutely roughened **19**
19. Truffle with labyrinthine canals; Northern Hemisphere ..... ***Hydnotrya***
19. Truffle with small, irregular chambers; southern Europe & North Africa ..... ***Loculotuber***
20.(17) Truffle surface warty or cracked in a mosaic pattern ..... ***Dingleya***
20. Truffle surface smooth to minutely roughened **21**
21. Iodine on cross-section of truffle causing a blue to black reaction ..... ***Mycoclelandia***
21. Iodine on cross-section of truffle causing a yellow to orange or no reaction **22**
22. Truffle with a basal tuft of hairs ..... ***Gymnohydnotrya***
22. Truffle lacking a basal tuft of hairs ..... ***Reddellomyces***
23.(2) Truffle surface finely to coarsely warty **24**
23. Truffle surface smooth to scabrous or lobed and furrowed but not warty **28**
24. Truffle with a well-defined cavity on the side or top; interior veins usually converging at the cavity **25**
24. Truffle lacking a well-defined cavity, although irregular depressions or furrows may be present **27**
25. Truffle interior white or nearly white at maturity ..... ***Balsamia***
25. Truffle interior yellow to brown or nearly black or with veins of those colors **26**
26. Truffle surface black, the warts 1-4 mm broad; Europe ..... ***Tuber mesentericum***
26. Truffle green to brown or black, the warts 1 mm or less broad; Northern Hemisphere ..... ***Pachyphloeus***
27.(24) Truffle interior brown marbled with white meandering veins ..... ***Tuber***
27. Truffle interior with gray to olive pockets separated by white veins ..... ***Picoa***
28.(23) Truffle surface with brown or yellow hairs (observe with hand lens) **29**
28. Truffle surface smooth to roughened **30**
29. Truffle interior white to nearly white at maturity, with scattered white to light brown canals ..... ***Stephensia***
29. Truffle interior brown marbled with white veins at maturity ..... ***Tuber***
30.(28) Truffle with well-defined cavity on side or top **31**
30. Truffle lacking well-defined cavity, but depressions or furrows may be present **32**
31. Truffle interior white to near white at maturity; western North America and Japan ..... ***Barssia***
31. Truffle interior dark brown marbled with white veins at maturity; Europe ..... ***Tuber excavatum*** & allies
32.(30) Associated with trees or shrubs native to the Northern Hemisphere **33**

32. Associated with trees or shrubs native to the Southern Hemisphere.....**42**
33. Drop of iodine on cross-section of fresh, mature truffle causing a blue to black reaction.....
.....***Hydnotryopsis***
33. Drop of iodine on cross-section of fresh, mature truffle causing a yellow to orange or no reaction.....**34**
34. Truffle interior with rounded, colored, spore-bearing pockets, pockets separated by white to near-white veins.....**35**
34. Truffle interior with meandering, colored, spore-bearing veins intermingled with darker veins**37**
35. Pockets of truffle interior rose colored .....***Delastria***
35. Pockets yellow to gray, olive or brown.....**36**
36. Pockets of truffle interior yellow to brown; truffle surface brown; spores spiny or reticulate ....
..... ***Terfezia***
36. Pockets gray to olive or rarely brown; truffle surface brown to black; spores smooth ...***Picoa***
37.(34) Truffle surface nearly white, the interior pale violaceus gray marbled with white veins; known only from Oregon ..... ***Cazia***
37. Truffle surface gray to yellow, pink or various shades of brown; interior with brownish yellow to dark brown veins; of wide distribution.....**38**
38. Truffle interior with white to pale yellow flesh marbled with narrow, brownish yellow to brown veins.....***Choiromyces***
38. Truffle interior with dark gray to brown flesh marbled with narrow, white or near-white veins**39**
39. Truffle with a short stem or stem lacking; white veins of interior lined with a palisade of .....
elongate cells; known only from Oregon and Italy.....***Fischerula***
39. Truffle lacking a stem; white veins of interior of globose or interwoven cells, lacking a .....
palisade.....**40**
40. White veins of interior lined with globose cells; spores globose ..... ***Hydnobolites***
40. White veins of interior of interwoven hyphae; spores globose to ellipsoid.....**41**
41. Asci in truffle tissue containing one huge spore; Italy .....***Paradoxa***
41. Asci in truffle tissue mostly with 2 or more spores; cosmopolitan ..... ***Tuber***
42.(32) Drop of iodine on surface of fresh, mature truffle causing a blue to black reaction; asci borne on truffle surface .....***Sphaerozone***
42. Drop of iodine on surface of fresh, mature truffle causing a yellow to brown or no reaction...
.....**43**
43. Truffles brain-like, with folds and ridges; surface gelatinous to slimy when fresh.....
.....***Ruhlandiella***
43. Truffles subglobose, not brain-like; surface dry to moist, not gelatinous or slimy .....
.....***Sphaerosoma***

44.(1) Truffle surface with brown hairs (observe with hand lens).....**45**
44. Truffle surface lacking brown hairs, a tuft of hairs may be present at base.....**46**
45. Truffle interior with meandering canals; Australia..... ***Stephensia***
45. Truffle interior solid with pockets of tissue separated by slightly paler veins; Arabian Peninsula to North Africa..... ***Phaeangium***
46. (44) North American species.....**47**
46. European, Asian, African, or Australian species.....**48**
47. Truffle interior brown, powdery when dry ..... ***Carbomyces***
47. Truffle interior white to light yellow, firm..... ***Terfezia***
48.(45) Truffle interior with meandering veins; Australia or South Africa..... ***Choiromyces***
48. Truffle interior with light yellow to light brown pockets separated by paler veins **49**
49. Drop of iodine on cross-section of fresh, mature truffle causing a green to blue or black reaction .....***Tirmania***
49. Drop of iodine on cross-section of fresh, mature truffle causing a yellow to orange or no reaction ..... ***Terfezia***

Key 3: Ascomycete Genera Based on Microscopic Characters

1. Spores in a powdery mass at maturity; asci, when present, borne among cottony hyphae, autolysing at maturity **2**
1. Spores not in a powdery mass at maturity; asci, when present, borne in a hymenium or embedded in glebal tissue, persistent **5**
2. Asci present, at least near peridium, and light to dark brown in KOH; deserts of southwestern North America ..... ***Carbomyces***
2. Asci absent (ephemeral) or, if present, hyaline to green in KOH **3**
3. Spores smooth; peridium orange to scarlet when fresh ..... ***Paurocotylis***
3. Spores with spines, ridges, or a reticulum; peridium white to yellow brown or black **4**
4. Truffles hollow, becoming stuffed with cottony hyphae and spore powder, never dehiscent, never with a basal tuft of hyphae ..... ***Elaphomyces***
4. Truffles with chambered gleba, the chambers becoming thin-walled and stuffed with spores and hyphae; sporocarps with basal tuft of hyphae, dehiscent at maturity ..... ***Scleroderma*** (Basidiomycotina)

5.(1) Asci green to blue (sometimes faintly) in Melzer's reagent **6**
5. Asci hyaline to yellow or brown in Melzer's regent **13**
6. Truffles hollow or occasionally with 2 large chambers; base with rudimentary stipe ..... ***Sarcosphaera***
6. Truffles multichambered or solid **7**

7. Spores smooth or minutely roughened **8**
7. Spores spinose, papillose, reticulate, etc. **9**
8. Asci cylindric; Australia ..... ***Mycoclelandia***
8. Asci ellipsoid to globose; North Africa & West Asia ..... ***Tirmania***

9.(7) Spores globose **10**
9. Spores ellipsoid **11**
10. Truffles smooth; glebal veins containing narrow hyphae; Northern Hemisphere ..... ***Pachyphloeus conglomeratus***
10. Truffles verrucose; glebal veins lined with broadly ellipsoid to isodiametric cells Australia ..... ***Amylascus***

11.(9) Hymenium on truffle surface ..... ***Sphaerosoma***
11. Hymenium inside truffle **12**
12. Asci narrowly cylindric, operculate, with uniseriate spores; truffles with at least some hollow chambers ..... ***Peziza***

12. Asci clavate to broadly cylindric, with no apical operculum apparatus; truffles solid ..... ***Hydnotryopsis***

13.(5) Truffles hollow or chambered from infolding, the interior surface lined with peridium-like tissue that completely encloses the asci..... **14**

13. Truffles solid or, if chambered, the interior surfaces not lined with peridium-like tissue..... **16**

14. Spores smooth ..... ***Hydnocystis***

14. Spores ornamented..... **15**

15. Spore ornaments rounded to conical..... ***Genea***

15. Spore ornaments of narrow spines..... ***Genabea***

16.(13) Asci in an even to disorderly hymenial palisade (sometimes also embedded in tissue) **17**

16. Asci never in a distinct hymenial palisade, instead mostly randomly embedded in glebal tissue..... **31**

17. Spores smooth at maturity..... **18**

17. Spores ornamented at maturity **21**

18. Truffle surface smooth..... **19**

18. Truffle surface tomentose **20**

19. Spores globose; truffle surface bright orange to scarlet..... ***Paurocotylis***

19. Spores oblong to globose; truffle surface yellowish pink to brown..... ***Barssia***

20.(18) Truffle with one to many open chambers >3 mm broad..... ***Geopora***

20. Truffle chambers mostly stuffed with cottony hyphae or asci, < 3 mm broad..... ***Stephensia***

21.(17) Hymenium on truffle surface..... **22**

21. Hymenium lining chambers or canals within truffle..... **23**

22. Spores reticulate; paraphyses with gelatinous sheath..... ***Ruhlandiella***

22. Spores warty; paraphyses lacking gelatinous sheath..... ***Sphaerozone***

23.(21) Truffle surface tomentose; asci much longer than paraphyses..... ***Labyrinthomyces***

23. Truffle surface smooth to roughened; paraphyses at least as long as asci..... **24**

24. Truffles surface verrucose or cracked in a mosaic pattern..... **25**

24. Truffles surface smooth to convoluted or roughened, not verrucose..... **26**

25. Truffles with an apical cavity to which the interior canals converge; spores warty to spiny ..... ***Pachyphloeus***

25. Truffles lacking a cavity; interior canals not converging; spores warty ..... ***Dingleya***

26.(24) Truffle with a basal tuft of hairs ..... ***Gymnohydnotrya***

26. Truffle lacking a basal tuft of hairs..... **27**

27. Truffle solid, with meandering veins filled with even to disorderly palisades of asci **28**

27. Truffles with chambers lined with even to disorderly palisades of asci.....**29**
28. Asci straight; spores ornamented with rods or spines ..... ***Choiromyces***
28. Asci mostly crooked; spores ornamented with a low, warty reticulum.....***Cazia***
29.(27) Spores reticulate; hymenial palisade disorderly..... ***Loculotuber***
29. Spores spiny, warty, or covered with amorphous material; hymenial palisade even **30**
30. Spores spiny or covered with amorphous material, strong yellowish to reddish brown ..... ***Hydnotrya***
30. Spores warty, hyaline or pale colored.....***Reddellomyces***
31.(16) Asci light brown to brown; deserts of southwestern U.S. and Mexico .....***Carbomyces***
31 Asci hyaline to yellow or, if brown, the species associated with ectomycorrhizal trees; widely distributed.....**32**
32. Spores smooth or with circumferential lines barely detectable by light microscopy.....**33**
32. Spores prominently ornamented by maturity **34**
33. Gleba marbled by meandering veins lined by paraphyses and either empty or stuffed with cottony hyphae. .....***Balsamia***
33. Gleba with isodiametric to irregular pockets of asci separated by sterile tissue..... ***Picoa***
34.(32) Asci nearly filled with a single, large, reticulate spore .....***Paradoxa***
34. Asci multispored.....**35**
35. Spores ellipsoid **36**
35. Spores globose.....**37**
36. Spores ornamented with dark brown, rounded to conic warts or agglutinated spines .....***Fischerula***
36. Spores ornamented with discreet spines or a reticulum. .....***Tuber***
37.(35) Gleba marbled with meandering veins **38**
37. Gleba with isodiametric to irregular pockets of asci separated by sterile tissue.....**39**
38. Sterile veins of peridium-like globose to ellipsoid cells.....***Hydnobolites***
38. Sterile veins of loosely organized hyphae .....***Tuber***
39.(37) Asci 1-4 spored, the ornamentation of spores within a single ascocarp varying from long, flexuous spines to a reticulum..... ***Delastria***
39. Asci 5-8 spored or, if 1-4 spored, then spores consistently ornamented with stubby rods or low warts.....**40**
40. Truffle surface smooth; spores reticulate, spiny or warty ..... ***Terfezia***
40. Truffle surface brown-hairy; spores with low warts .....***Phaeangium***

SOME SOURCES FOR IDENTIFICATION OF TRUFFLES

Amylascus The two species are described and illustrated by Trappe (1975a).

Balsamia Trappe (1979) described the genus as a whole. Gilkey (1954) monographed the American species (as two genera, *Balsamia* and *Pseudobalsamia*), and Hawker (1954) covered the European species.

Barssia *Barssia oregonensis* is described by Gilkey (1925, 1954) and *B. yezo–montana* by Kobayasi (1938, as *Phymatomyces yezo–montanus*).

Carbomyces The two species are described and illustrated by Gilkey (1954).

Cazia The one species is described and illustrated by Trappe (1989).

Choiromyces No good keys to the species exist. Hawker (1954) and Ceruti (1960) describe *C. venosus* (= *C. meandriformis*) that occurs in both Europe and North America. *Choiromyces magnusii* is described by Ceruti (1960) and *C. alveolatus* by Gilkey (1939) (as *Piersonia alveolata* Harkness).

Delastria The one species is described and illustrated by Fischer (1938).

Dingleya Trappe et al. (1992) describes all species in detail.

Elaphomyces The most complete monograph of the genus is that by Dodge (1929), although a number of regional treatments have appeared since. Many new species await description.

Fischerula Trappe (1975b) describes both species in detail.

Genabea Gilkey (1954) describes American species; Fischer (1938) and Ceruti (1960) covers European species.

Genea Gilkey (1939, 1954) covers the North American species described so far; European taxa are keyed by Fischer (1938) and described by Hawker (1954), Lange (1956), and Ceruti (1960).

Geopora Burdsall (1968) monographed the genus on a world–wide basis.

Gymnohydnotrya The three species are described and illustrated by Zhang and Minter (1989).

Hydnobolites Gilkey (1939, 1954) described *H. californicus* Fischer, known only from California and Oregon, and Hawker (1954) described *H. cerebriformis* Tul. and Tul., which occurs in Europe and eastern North America.

Hydnocystis Burdsall (1968) describes the European species, *H. piligera* Tulasne and Tulasne, and Kobayasi (1963) describes the Japanese *H. japonica* (Kobayasi) Trappe (as *Protogenea japonica* Kobayasi).

Hydnotrya Gilkey's (1954) treatment is the best available, but the genus needs much revision and updating.

Hydnotryopsis	Trappe (1975c) discusses the two species keyed and described by Gilkey (1954) as *Choiromyces setchellii* Gilkey and *C. compactus* Gilkey.
Labyrinthomyces	The one species is described and illustrated by Trappe et al. (1992).
Loculotuber	The one species is described and illustrated by Alvarez et al. (1992).
Mycoclelandia	The two species are described and illustrated by Beaton and Weste as *Clelandia* species (1982).
Pachyphloeus	Gilkey (1954) describes North American species, Hawker (1954) and Lange (1956) cover European and Japanese species.
Paradoxa	The one species is described and illustrated by Mattirolo (1935).
Paurocotylis	The one species is described and illustrated by Dennis (1974).
Peziza	Korf (1973) presents a key to species, with additions and comments by Trappe (1979).
Phaeangium	The one species is described and illustrated by Alsheikh and Trappe (1983a).
Picoa	No inclusive keys exist. Gilkey (1954) covers the described American taxa.
Reddellomyces	Trappe et al. (1992) describes all species in detail.
Ruhlandiella	Dissing and Korf describe all species (1980).
Sarcosphaera	Trappe describes all species (1975c, 1979).
Sphaerosoma	Dissing and Korf (1980) describe the single known species and the taxonomic confusion that surrounded it in the past.
Sphaerozone	Dissing and Korf describe all species (1980).
Stephensia	Hawker (1954) describes and illustrates the most common species, *Stephensia bombycina* (Vittadini) Tulasne and Tulasne. The other described species, *S. peyronelii* Mattirolo (known only from Italy) and *S. shanori* (Gilkey) Gilkey (known only from Illinois) are described by Ceruti (1960) and Gilkey (1961), respectively.
Terfezia	See Gilkey (1954) and Trappe and Sundberg (1977) for North American species, Fischer (1938) for European, Asian, and African species, and Trappe and Sundberg (1977) for the one species known from Japan.
Tirmania	Both species are described and illustrated by Alsheikh and Trappe (1983b).
Tuber	Gilkey (1939, 1954) treated what was then known of the NA species. European species are variously keyed and described by Malençon (1938), Fischer (1938), Hawker (1954), Lange (1956), & Ceruti (1960).

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