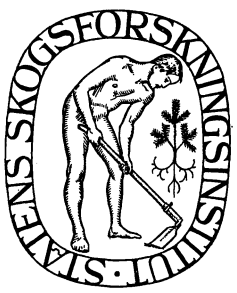

Investigations on the fungal flora of spruce and pine stumps

Undersökningar över svampfloran på gran- och tallstubbar

by

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Introduction

The stumps and roots remaining in the ground after felling a stand of trees represent a considerable part of the total volume of wood. According to estimates that agree rather well with each other (LUNDBERG 1916, WALDENSTRÖM 1946) the stump and the branches contain about 30 % of the volume of wood in a tree. The proportion of stump in the total volume of wood may however vary within wide limits depending on species, locality and other factors. This is shown in greater detail by the figures in table 1.

There is thus a very large quantity left behind after felling. In round figures this is about 15 million cubic metres of the annual Swedish felling of 50 million cubic metres. During the two world wars the stump wood was used to some extent for fuel and for the production of tar but in peace time it is not possible at least at the present to utilise this very large quantity of wood.

What happens to all this wood? The fresh stumps are rapidly attacked by both fungi and insects which initiate a process of decay. Very little is known of the course of this break-down or of the organisms which take part in it. The question has a number of aspects. It is not entirely without significance which particular organism infects stumps. Disease producing insects and fungi can find suitable conditions in stumps for growth. Thus it is well known that *Armillaria mellea,* an important cause of damage, can very easily infect fresh stumps which then serve as a centre of infection for further attacks. According to the investigations of RISHBETH, fresh stumps afford an entry for the root rot fungus *Fomes annosus* which in some parts of Sweden is responsible for considerable economic damage. The infection and growth of these two fungi and perhaps some other harmful agents in stumps is thus a question of great importance in practical forestry. Some harmful insects

such as the larger pine shoot beetle (*Blastophagus piniperda*) and the ambrosia beetle (*Xyloterus lineatus*) also attack stumps.

The stumps are infected as well by a large number of harmless insects and fungi which are very largely responsible for the break-down of the stumps. Amongst the fungi there are representatives of almost all groups. Of these the rot fungi undoubtedly play the greatest role in break-down. Systematically, a large number of fungi have been described which occur primarily or even exclusively on stumps. However as far as we could find there have been almost no investigations from the ecological point of view. The rapidity of the infection of a stump, the progress of the rot in the stump and the time taken before the development of fruiting bodies are problems of which little is known. The present work has attempted to answer some of these questions raised but it does not constitute any sort of exhaustive answer and should be regarded as a preliminary orientation in some of the many interesting problems in ecology, forest pathology and systematics which are connected with the stumps left in the ground. This investigation deals exclusively with the fungal flora of spruce and pine stumps of an age not greater than five years.

Part I. A systematic description of some stump fungi

A large number of fungi have been isolated from sporophores and from boring cores taken from stumps at various times. These fungi included representatives of all the larger groups and it appeared that an examination of many of them in greater detail would be of interest. Space does not permit this and it has been necessary to restrict this paper to an account of the rot fungi found in the stumps. A list of these rot fungi is given below.

Thelephoraceae

1. *Corticium alutaceum*
2. *Corticium laeve*
3. *Grandinia farinacea*
4. *Trechispora Brinkmanni*
5. *Coniophora spp.*
6. *Peniophora gigantea*
7. *Peniophora pithya*
8. *Stereum pini*
9. *Stereum sanguinolentum*

Polyporaceae

10. *Polyporus abietinus*
11. *Polyporus amorphus*
12. *Polyporus borealis*
13. *Polyporus caesius*

14. *Polyporus circinatus*
15. *Polyporus fuliginosus*
16. *Polyporus stipticus*
17. *Poria mollusca*
18. *Fomes pinicola*
19. *Trametes heteromorpha*
20. *Trametes pini*
21. *Trametes serialis*
22. *Lenzites sepiaria*

Armillaria mellea and *Fomes annosus* occur as primary rot fungi in the living trees. *Armillaria* very often grows into newly cut stumps through the root system (GARRETT, 1956) and it is possible that *Fomes annosus* can also infect the freshly cut stumps via root contacts (RENNERFELT, 1957) as well as by air borne spores (RISHBETH, 1950, 1951, MOLIN, 1957). These two fungi are regarded in this paper as *forest rot fungi* and not as stump fungi in the proper sense.

The other fungi in the list have probably infected the stumps after cutting by air borne spores falling on the top and the upper parts of the stump. These fungi can therefore be suitably gathered into an ecologically uniform group under the name of *stump fungi*. Systematically they belong in most cases to the *Thelephoraceae* and *Polyporaceae* while *Agaricaceae* have been found more occasionally. The following is a detailed description of some of the fungi listed above.

It is apparent from tables 2—8 that amongst these stump fungi there is a small group which occurs with very much greater frequency than all the others both in the number of sporophores found and in the number of mycelia isolated from the stumps. These fungi which belong to *Thelephoraceae* in the wider sense are: *Peniophora gigantea* (Fr.) Massee, *Trechispora Brinkmanni* (Bres.) Rogers and Jackson and *Stereum sanguinolentum* (A. and S.) Fr. After them there comes *Polyporus abietinus* (Dicks.) Fr., and then with considerably lower frequency a large number of other *Polyporus* species together with further *Thelephoraceae*. Some of the fungi which have been found are well known both systematically and in culture; if they are dealt with again here it is because they differed, especially in culture, in one or more characters from the descriptions hitherto given. In some cases other authors have been cited when our own measurements especially of basidia and spore sizes have been too few to give a reliable value; in such cases our own results fall within the limits given unless otherwise stated. Rate of growth is given in cms after 10 days at 22° C on 2.5 per cent malt agar; reactions on gallic acid agar and on tannic acid agar were carried out according to DAVIDSON, CAMPBELL and BLAISDELL (1938).

Thelephoraceae

1. *Corticium alutaceum* Bres.

Syn. *Corticium radiosum* Fr.
Corticium citrinum Pers.
Gloeocystidium alutaceum (Schrad.) Bourd. and Galz.

Corticium alutaceum was placed in the genus *Gloeocystidium* section *Ceracea*, by BOURDOT and GALZIN (1927) because of its gloeocystidia. It is not unusual on conifer wood. Developed identifiable sporophores of *C. alutaceum* were found only on 4 year old pine stumps at Högby mo. A fungus was also isolated from cultures of mycelium taken from samples from 1—3 year old spruce stumps which formed numerous fructifications typical for *C. alutaceum*.

Sporophore

The large waxy, creamy yellow to chamois yellow, sporophores have a wide, 1—5 mm white fibrillar margin and can be characterised by the presence of small or large gloeocystidia, 50—150 × 6—16—27 μ (Bourd. and Galz.), long oval to fusiform often constricted in the centre with hyaline contents. Basidia 35—60 × 5—9 μ: spores hyaline, subglobose 4—7 × 4—6 μ (Bourd. and Galz.).

The fungus which after culturing was identified as *C. alutaceum* was isolated several times from spruce stumps.

Cultural characters

Growth moderately rapid to rapid, 5—8 cm in 10 days. Advancing zone hyaline, even. Mat white, with sparse downy aerial mycelium. Mycelium somewhat radially arranged and reticulate. Reverse unchanged or slightly bleached. Diffusion zones on gallic acid agar absent, on tannic acid agar diffusion zones weak to moderately strong; growth on gallic acid agar 18—23 mm, on tannic acid agar 14—26 mm. After 3—4 weeks fructifications appear on malt agar, sometimes extending over the whole surface. The fruiting surface waxy, alutaceous, smooth, with occasional small tubercles.

Hyphae in the advancing zone hyaline, 2—6 μ in diameter with abundant conspicuous clamp connections. Irregular gloeocystidia appear on the aerial mycelium before fructifications appear, often fusiform, 60—80 × 10—20 μ. Basidia clavate, 30—50 × 5—10 μ, with four spores on long sterigmata 4—6 μ). Spores hyaline, subglobose to globose, 5—8 × 4—8 μ (fig. 1).

Corticium alutaceum with its sparse aerial mycelium and rather broad hyphae resembles at first *T. Brinkmanni* cultures but its growth is a little slower. Older cultures are readily characterised by the typical sporophores.

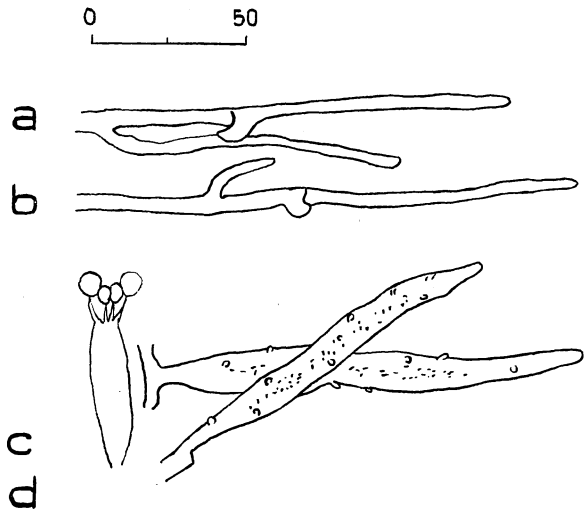

Fig. 1. *Corticium alutaceum:* a, b) substrate hyphae from the advancing zone, c) basidium and basidiospores, d) cystidia on aerial hyphae.

2. *Corticium laeve* Pers.

Syn. *Corticium evolvens* Fr.

Corticium laeve occurs very commonly on the wood of both conifers and broadleaved trees. Sporophores of this fungus were found on 3—5 year old spruce and on 4 year old pine stumps and the mycelium (Plate II: 3) was found on 1—4 year old spruce stumps but not nearly as often as *Peniophora gigantea, Trechispora* or a number of *Polyporus* species. In addition to *C. laeve* a number of other *Corticium* species were found although in most cases they could not be more closely defined. Since even the culture characteristics of these species are unknown and since they only occurred sporadically in our material no attempt has been made to determine the species or to describe them in culture and they have been grouped in the tables as *Corticium spp.* Only *Corticium alutaceum* could be identified in culture. It is very likely that several of the unidentified basidiomycete mycelia that were found belong to *Corticium* or to a closely related group.

Sporophore

The fruiting bodies of *C. laeve* are several cm across, roundish, later coalescing, soft and separable from the substrate. The colour is variable, brownish, light brownish-gray yellow to a gray brown with a whitish, somewhat hairy margin. Upper surface smooth often cracked. Basidia 25—40—90 × 4.5—9 μ; spores obovate, sometimes slightly bent at the base 7—9—12 × 4.5—7 μ (Bourd. and Galz.). In the hymenium there are also fusiform cystidiola, somewhat longer than the basidia.

Cultural characters

C. laeve has been described in culture by ROBAK (1942). Growth is moderately rapid to rapid, 5—9 cm in 10 days. Advancing zone even, hyaline. Mat at first thin, hyaline, downy, the aerial mycelium extending to the limit of growth. After a short time the mat is denser, raised, cottony, remaining appressed and nearly translucent in the central part of the colony. Colour at first white, then slightly leather coloured, darker on the edges of the dishes or on the top of the slant in test-tubes. Reverse unchanged to chamois. Odour none or slightly fungal. No diffusion zones on gallic acid and tannic acid agars; growth on gallic acid agar 7—12 mm, on tannic acid agar 10—15 mm.

Hyphae in the advancing zone hyaline, 1.5—4 μ in diameter with numerous clamp connections even on the aerial mycelium. Aerial mycelium of irregularly interwoven hyphal masses; narrow fibre hyphae 4—5 (6) μ in diameter, without clamp connections, branching occurs. No oidia or chlamydospores were found. No fructifications formed in culture.

Corticium laeve in culture macroscopically has a rather typical growth form and colour but microscopically it is difficult to characterise and is distinguished almost by the absence of any special microscopic feature.

3. *Grandinia farinacea* (Pers.) Bourd. and Galz.

Syn. *Odontia farinacea* Bres.
Odontia nivea Quel.

Grandinia farinacea is common on rotting conifer wood but fully developed sporophores were never observed on the stumps examined; the mycelium was occasionally isolated from 1—4 year old spruce and 3—4 year old pine stumps, somewhat more often from the older stumps. It does not appear to be especially active as a stump rot fungus.

Sporophore

Sporophore thin, farinaceous crust, sometimes soft membranous with an uneven often indefinite margin, sometimes thin crusty somewhat fibrillar or granular, white or yellowish white to a light leather colour. The spores are formed on short hemispherical to skittle shaped excrescences, 1—2 mm, often pointed or dentate, very soft and terminating in sterile hyphae. Numerous oxalate crystals in the sporophores; basidia 6—12—21 × 3—5 μ, spores ovoid to round, finely and densely spiny, 3—4.5 × 2.5—4 μ (Bourd. and Galz.).

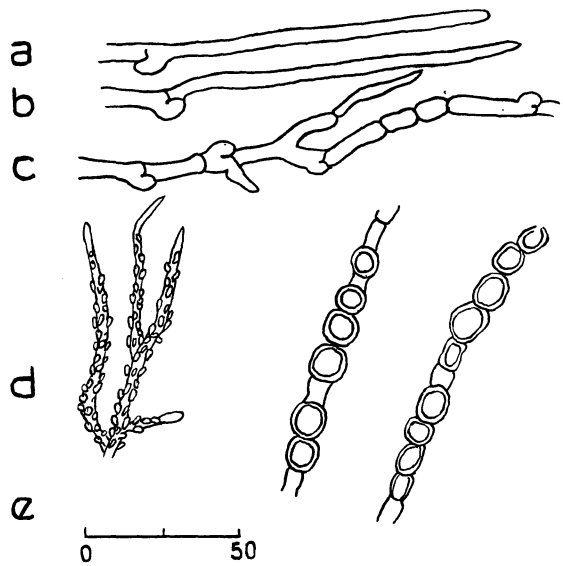

Fig. 2. *Grandinia farinacea:* a, b) submerged hyphae from the advancing zone, c) hyphae from older part of the submerged mycelium, d) branched incrusted hyphae form the aerial mycelium, e) chlamydospores from the aerial mycelium.

Cultural characters

Grandinia farinacea has not previously been described in culture.

Growth rapid, 7—10 cm in 10 days; slow growing (2.5 cm in 10 days) strains, were sometimes found. Advancing zone even, hyaline. Mat white, with very slight tinges of creamy to pinkish-yellow colour. Aerial mycelium usually lacking or as a narrow downy-floccose zone around the colony, 3—4 mm from the limit of growth. Surface of the colony is wrinkled and gelatinous. Some isolations may produce more aerial mycelium; the mat is then slightly raised, farinaceous-granulose and appressed and translucent in the older parts. Reverse somewhat darker, slight leathery to brownish yellow in colour. Odour strong, sweet, like that of *Clitocybe geotropa*. No diffusion zones on gallic acid agar or tannic acid agar; traces of growth on gallic acid agar, no growth on tannic acid agar.

Hyphae in advancing zone hyaline, rather broad, 2.5—6 (7) μ in diameter, sinuose, rather short-celled, with conspicuous clamp connections and ordinary branching (fig. 2). Submerged hyphae in the older parts often agglutinated and indistinct. On aerial mycelium in older parts there are numerous short upright unbranched incrusted hyphae, often united at the base in small bunches. Numerous intercalary oval to subglobose chlamydospores may sometimes occur on aerial mycelium in chains. No fructifications were observed in the cultures.

Cultures of *G. farinacea* although they may show appreciable variation in macroscopic appearance are easily recognisable by the characteristic odour, the very typical incrusted hyphae on the aerial mycelium and the broad short celled agglutinated substrate hyphae.

4. *Trechispora Brinkmanni* (Bres.) Rogers and Jackson.

Syn. ? *Corticium arachnoideum* Berk. Ann. Mag. Nat. Hist. 13: 345, 1844.
? *Hypochnus coronatus* Bon. Hedwigia 15: 76, 1876.
Odontia Brinkmanni Bres. Ann. Myc. 1: 88, 1903.
Corticium coronilla v. Höhn. and Litsch. Ann. Myc. 4: 291, 1906.
Corticium octosporum Schroet. ex Höhn. and Litsch. Ann. Myc. 4: 292, 1906.
Grandinia Brinkmanni (Bres.) Bourd. and Galz. Bull. Soc. Myc. Fr. 30: 252, 1914.
Corticium varians Kniep, Zeitschr. Bot. 7: 372, 1915.
Sistotrema coronilla (v. Höhn.) Donk ex Rogers, Univ. Iowa St. Nat. Hist., 17: 23, 1935.

Trechispora Brinkmanni was very often present on the stumps examined. Sporophores were found on 1—5 year old spruce stumps, most often on 2—3 year old stumps (on ca. 20 %). It was also found on 1—5 year old and most often on 3—5 year old pine stumps. The mycelium was found most often on 1—3 year old spruce, as often as 30 % on one year old spruce stumps.

Although a number of recent investigations on this and closely related species have been published neither the limits of the species nor their correct names are as yet completely clarified. ROGERS himself in his latest work has expressed doubts on the name used and has suggested that it is possible that the correct name should be *Corticium arachnoideum*. The species described earlier, *Corticium coronilla, C. octosporum* and *Grandinia* (*Odontia*) *Brinkmanni* must be regarded as one and the same species. The very closely related species *Corticium diademiferum* Bourd. and Galz., *Corticium coroniferum* v. Höhn. and Litsch. and *Corticium niveo-cremum* v. Höhn. and Litsch. could possibly also be included here although with somewhat less certainty.

A very detailed account of fungi belonging to this group has been published by BIGGS (1937) who has investigated extensive herbarium material and has grown numerous cultures of these fungi. Her work has covered the simple resupinate *Thelephoraceae* with undifferentiated sporophores which grow as

thin white or yellowish films on decaying wood and which produce characteristic basidia described as urniform and coronate. In these fungi a small ellipsoid probasidium is formed first and from the upper end of this a narrower neck grows out and produces at the apex a crown of five to eight sterigmata and spores. According to BIGGS this description corresponds to the previously described species *Corticium coronilla* v. Höhn. and Lit., *C. octosporum* Schroet., *C. diademiferum* Bourd. and Galz., *C. niveo-cremum* v. Höhn. and Lit. and *Grandinia Brinkmanni* (Bres.) Bourd. and Galz. From the results of her investigations BIGGS came to the conclusion that these species could not be differentiated either by the sporophores or by the cultural characteristics. ROGERS (1935) came to the same result earlier and from herbarium material showed that these species merged into each other and that in practice it was impossible to separate them. He therefore grouped these species under the name *Sistotrema coronilla* (v. Höhn. and Lit.) Rogers. BIGGS did not wish to use the name *Sistotrema* which she kept for fungi whose sporophores are organised in quite a different way to those of *Corticium*. She suggested instead the name *Corticium coronilla* v. Höhn. and Lit., Rogers. JACKSON (1943) later separated all the resupinate *Thelephoraceae* with *Urnigera* type basidia into the genus *Trechispora* Karst. as opposed to the reflexed and stipitiate forms which were left as the genus *Sistotrema*. ROGERS' earlier *Sistotrema coronilla* thus became *Trechispora Brinkmanni* (Bres.) Rogers and Jackson. Later (1944) ROGERS in an investigation of the genera *Trechispora* and *Galzinia*, describes *Trechispora Brinkmanni* as including the species *Corticium coronilla, C. octosporum* and *Grandinia Brinkmanni* and treats *Trechispora diademifera* (Bourd. and Galz.) Rogers, *T. coronifera* (v. Höhn. and Litsch.) Rogers and Jackson and *Corticium niveo-cremum* v. Höhn. and Litsch. as independent species although he considered them closely related to *T. Brinkmanni*.

Our own observations on the occurrence and appearance of forms belonging to this group approach most closely the descriptions of BIGGS. These fungi are rather common on rotting conifer stumps and are small insignificant filmy white, gray to yellowish *Thelephoraceae*, sometimes with more or less prominent parts with spines, with or without oxalate crystals in the subiculum, with an indefinite edge and urniform basidia with 5—8 spores, mostly oblong-ellipsoid, but sometimes approaching subglobose and also with basidia of variable size and shape on otherwise inseparable forms; these forms could not even be separated in cultures.

ROGERS (1944) gives the following description of *Trechispora Brinkmanni:*

Fructification thin, even or minutely papillose, when fresh waxy-pruinose, waxy-farinose, farinose-arachnoid, or delicately membranous, grayish (when very thin), glaucous or pure white; when dry, pruinose and barely visible, vernicose farinose, arachnoid or

rarely subpellicular or coarsely reticulate-fibrillose, white or rarely changing to yellowish; hyphae thin-walled, with large clamps throughout, the subicular 4—7 μ in diameter, straight- and long celled, sometimes inflated at the septa to 9 μ (ampullate), often rare or wanting, the subhymenium short-celled, contorted, abundantly branched, (1.5—2—) about 4 μ in diameter, occasionally firm, usually collapsed with contents often condensed into refractive resinoid masses, frequently interspersed with coarse crystalline material; basidia formed in clusters as the result of repeated proliferation from the subtending clamps, when immature subglobose to oblong, elongating by a cylindrical outgrowth, truncate and more or less expanded at the summit (to 5.5 μ), at maturity (7—) 10—24 × (4) 5—6 (8) μ, bearing about the periphery of the summit rarely 4 or 5, usually 6—8 recurved, capillary or subulate sterigmata 3—5 μ long; spores oblong-ellipsoid to subcylindric, straight or slightly depressed on the inside or very slightly curved, abruptly attenuate toward the apiculus, 3.5—7 × (1.5) 2—3 (—4.5) μ.

This description agrees well with most of our material: the spores are mostly subcylindric, very slightly curved and 3—7 × 2.4 μ and the basidia formed in clusters as described (fig. 3). However forms have been found with gloeocystidia but otherwise inseparable from *T. Brinkmanni* although according to ROGERS this should place them in *T. coronifera*. Such forms were not separated in our material but were referred to *T. Brinkmanni*. Forms with smaller basidia and roundish (subglobose) spores—*T. diademifera* according to ROGERS—were found occasionally in otherwise typical *T. Brinkmanni* cultures and these also were similarly referred to *T. Brinkmanni*. Basidia and spores of *Corticium niveo-cremum* type were not found on our material from wood but occurred in Petri dish cultures.

A detailed description of *Trechispora Brinkmanni* in culture has been given by BIGGS (1937), who distinguished four main types:

I. Growth rapid submerged, no microscopic distinguishing characters. Hyphae usually agglutinated and indistinct, of narrow diameter. Bipolar heterothallism. No fructifications.

II. Growth rapid and always with some aerial mycelium. Sometimes producing bulbil-like cells. Hyphae often agglutinated and indistinct, up to 5—6 μ. Homothallic. Fructifications both in monosporous and polysporous cultures.

III. Growth moderately rapid with or without conspicuous aerial rhizoidal strands. Bulbils and oidia produced. Hyphae distinct, 5—7 μ. Heterothallism tetrapolar, no fructifications.

IV. Growth very slow and almost entirely submerged, conspicuous separable cells produced apically or in chains. Hyphae distinct, 5—7 μ, heterothallic, no fructifications.

Specimens isolated during the present investigation were very uniform. Types III and IV did not occur and most cultures resembled an intermediate between BIGGS' types I and II.

Cultural characters

Growth rapid, 10—14 cm in 10 days. Advancing zone even, submerged, in most cultures mycelium entirely submerged but some sparse downy aerial mycelium may occur. Mat white, sometimes slightly yellowish, reverse bleached. Rich fruiting frequently occurs even in monosporous cultures after four to six weeks. Fruiting surface white, reticulate-fibrillose, powdery to minutely

papillose. Odour none or faintly sweetish, somewhat sticky. On gallic and tannic acid agars no diffusion zones; on gallic acid agar growth 18 (15—20) mm, on tannic acid agar no growth (fig. 4).

In advancing zones hyphae hyaline, 1.5—4 μ in diameter, with small clamp connections. The submerged mycelium in older parts agglutinated, hyphae often indistinct, wider and more short celled than in advancing zone, with larger clamp connections. In the central parts groups of bulbil-like cells of varying diameter are produced. In four to six week old cultures fruiting occurs almost always. Ellipsoid probasidia are formed in clusters on the hyphae after repeated proliferation from the subtending clamps as in the

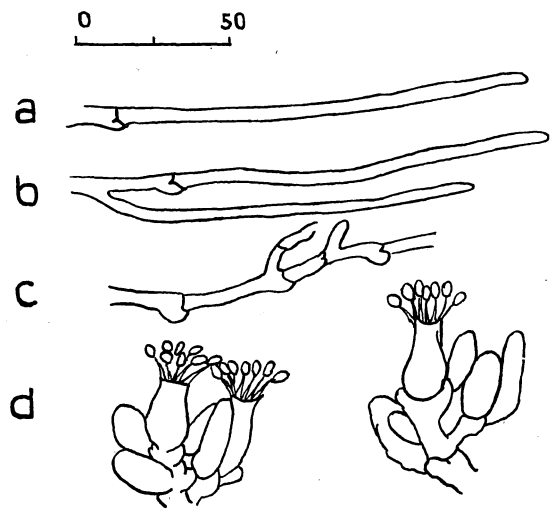

Fig. 3. *Trechispora Brinkmanni:* a, b) submerged hyphae from the advancing zone, c) older submerged hyphae, d) basidia with basidiospores in culture.

fructifications on wood. From the upper end of these a narrower neck grows out with 4—8, usually 6—8 recurved subulate sterigmata, 3—5 μ long. Spores often subcylindric to oblong-ellipsoid, slightly curved, 3—7 × 2—3 μ. Basidia varying 10—30 × 4—8 μ.

Amongst this rather homogeneous material of typical *T. Brinkmanni* there were some divergent forms that occurred more seldomly:

I. Cultures that in all respects, even in the oxidase reaction, resembled the fungus described above but which formed more compact white, smooth fructifications with smaller and rounder basidia 8—25 × 5—10 μ, and smaller oval to subglobose spores 3—5 × 2—4 μ. This form approaches the *T. diademifera* described by ROGERS (1944) but a determination of the species could not be made with certainty because of lack of material from sporophores

on stumps. The fungus was only found in culture and could not be related to fruiting bodies in a natural environment.

II. A second divergent form could be distinguished by its weak yellowish brown colour, and its numerous yellowish granular sporophores in culture. It gave no reactions on gallic acid and tannic acid agar and grew about as fast on both substrates: 12 mm on gallic acid agar and 15 mm on tannic acid agar.

The size of the basidia and spores agreed more or less with *T. Brinkmanni* but instead of the round vesicular bodies it formed long irregular drawn out and swollen hyphal points between the young basidia. This fungus could corre-

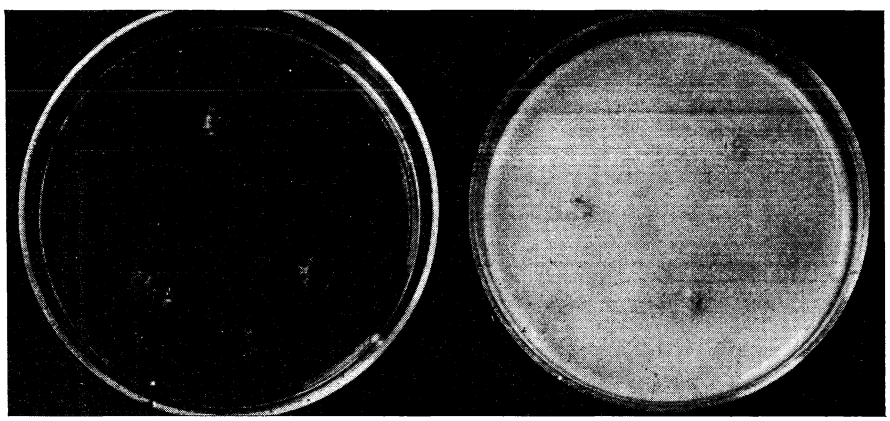

Fig. 4. *Trechispora Brinkmanni* on gallic acid agar (left) and tannic acid agar (right).

spond to *T. coronifera* but the basidia instead of being typically urniform were more clavate, nearer to *Corticium niveo-cremum* but not so broad as in this species. This form was also counted as *T. Brinkmanni* but it possibly may belong to some other closely related species.

5. *Coniophora spp.*

Coniophora arida (Fr.) Karst. and *Coniophora olivacea* (Fr.) Karst. were the only *Coniophora* species found on the stumps examined. Sporophores were found on 2—4 year old, most often on 3 year old spruce stumps, and on 2—4 year old, most often on 4 year old pine stumps. Mycelium was found on stumps of all ages but never with any frequency. Pure cultures of these species were obtained from spores but more material would be necessary to give a description of these species in culture since they resemble each other and also *C. puteana* (Fr.) Karst. in a number of characteristics (Plate IV: 4). Young mycelium of *C. olivaceum* grows in a similar way to *C. puteana*, but

more slowly, later it turns olive-brown and forms a stringy aerial mycelium. The hyphae in the advancing zone are broad with verticillate clamp connections.

6. *Peniophora gigantea* (Fr.) Massee.

Syn. *Corticium giganteum* Fr.

Occurs very frequently on pine and spruce stumps especially at 2—3 years old. Sporophores occur more often on pine than on spruce stumps (fig. 15). It is present on 90 per cent of 1 year old pine stumps. According to the results from boring chips, *P. gigantea* was dominant on 1—2 year old stumps and occurred more often on pine than on spruce.

Sporophore

The large, typical, sporophores, often 20—30 cm across or more, are formed under the bark on stumps and on exposed parts of the root system on both spruce and pine. In humid weather the sporophores are waxy or tallow like and rather thick, after drying they are thin, and separate from the substrate rather easily (Plate I: 1—4). At first the colour is a dirty or creamy white and somewhat transparent; older sporophores are darker, yellowish or almost brown or greyish. The margin of younger sporophores is fringed to rhizoid like. Hyphae thick, 5—7 μ, with occasional clamp connections. In the hymenium, there are numerous fusiform cystidia, entangled in the middle and often incrusted at the apex, 40—100 × 9—16 μ. Basidia 12—18—30 × 4—5 μ; spores subcylindrical, 6—8 × 2.75—4 μ (Bourd. and Galzin).

A *Peniophora* very similar in growth to *P. gigantea* but definitely grey in colour and with smaller thinner cystidia, larger basidia and somewhat larger elliptical spores is not infrequently encountered especially on spruce. It seems to agree with *Peniophora cornea* (Bourd. and Galzin). J. Eriksson (Fungi exiccati Suecici no 1854, 1950), found by J. Eriksson in Lapland on pine. Bourdot and Galzin give for this species: cystidia 60—75 × 9—11 μ; basidia 36—45 × 7—8 μ; spores 6—10.5 × 3—3.5 μ. Our own measurements give: cystidia 50—85 μ; basidia 20—35 × 5—7 μ and spores 6—8 × 3—4 μ. However since examples were collected which were very difficult to place either in *P. gigantea* or in *P. cornea* and since numerous cultures of spores gave mycelia that in all respects appeared to be typical *P. gigantea* mycelium, it was not possible during the course of this investigation to separate these two fungi as distinct species and the grey form of *Peniophora* has been regarded as a form of *P. gigantea*. Bourdot and Galzin (1927, p. 318) in their description of *P. cornea* also considered it rather likely that this fungus was not an independent species but only a form of *P. gigantea*.

Cultural characters

Peniophora gigantea grown in culture has been described in detail by BIGGS (1938), CARTWRIGHT and FINDLAY (1938, 1946) and NOBLES (1948). A short description of *P. gigantea*, as grown in our cultures, is given here since our strains which were isolated both from spores and from mycelium in the stumps had very constant and uniform characters but differed somewhat from the detailed description given by NOBLES and also from the shorter description of CARTWRIGHT and FINDLAY.

Growth moderate to rapid, 9—14 cm in 10 days. Advancing zone even, raised aerial mycelium extending to the limit of growth. Mat white, producing a loose, not very high, soft floccose-farinaceous, even aerial mat over the whole area, more appressed in the older parts (Plate III: 1). Reverse unchanged. Odour none or faintly fragrant. On gallic acid agar diffusion zones moderate, growth 11 (10—14) mm; on tannic acid agar no diffusion zones, no growth.

In advancing zone hyphae hyaline, 4—6 μ in diameter, large clamp connections occurring rather frequently, singly or rather often in pairs. Aerial hyphae and submerged hyphae in the older parts 2.5—5 μ in diam., septa usually simple. Numerous oidia in the higher parts of the aerial mycelium as laterally branched chains, extending almost to the limit of growth. Oidia 2.5—6 μ in diameter, mostly 5—10 μ in length. Numerous upright, long and sometimes branched, incrusted hyphal branches on the older parts of the aerial mycelium on hyphae nearest to the agar surface (fig. 5). After more than a month in culture the oidial chains tend to disappear and the incrusted hyphae dominate. In two month old cultures on part of the incrusted hyphae there are formed cystidia which in shape and size are like those found in the sporophores of *P. gigantea*. Scattered basidia with spores or sporophores a few mm in size may form in Petri dish cultures. In test tube cultures after 3—4 months sporophores, a few cm across, are nearly always formed at the edge of the agar, creamy white, brownish yellow or almost brown-violet in colour.

The rich floccose-farinaceous aerial mycelium, the prominent large double clamp connections at the growing margin of the mycelium and the occurrence of cystidia and basidia were typical of our cultures, which were confirmed by Dr NOBLES as *P. gigantea*.

The occurrence of double clamp connections in *P. gigantea* was noted earlier by BIGGS (1938) in both mono- and polysporous mycelia. According to her the formation of this type of clamp connection is abnormal and occurs in fungi with multinucleate cells. She found double clamp connections in *P. gigantea* only on very thin agar films for cytological investigations but not in normal cultures. However fully formed double clamp connections were very common on normal cultures of our material. Similar double clamp connections

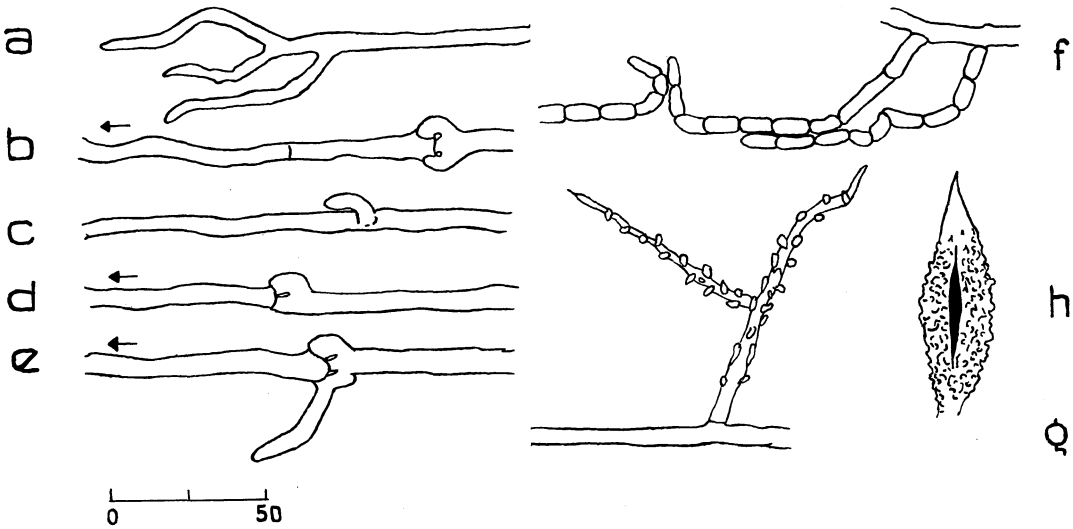

Fig. 5. *Peniophora gigantea:* a) hyphae from the advancing zone, b—e) clamp connections on hyphae from the advancing zone, f) oidia on the aerial mycelium, g) cystidium from the aerial mycelium in culture, h) incrusted hyphae from the aerial mycelium.

have also been found by BIGGS in herbarium material from other *Peniophora* species such as *P. carnea* Burt., *P. sanguinea* Fr. and *P. velutina* DC.

No definite differences were observed between the numerous strains isolated from pine and spruce stumps and as strains from *P. cornea* type sporophores. Freshly isolated mycelia from young pine stumps are usually faster growing and form the most abundant aerial mycelium but after some time in culture these mycelia cannot be distinguished from others.

In the bark and on wood *P. gigantea* forms a white wadded mycelium and small white somewhat yellowish strings which can be separated from other sterile mycelia since as well as the ordinary rather broad hyphae 3—6 μ in diameter with large clamp connections, they also form long incrusted hyphae similar to those formed in culture (Plate II: 1—2).

7. *Peniophora pithya* (Pers.) Erikss.

Syn. *Peniophora cinerea* (Fr.) Cke var. Piceae Karst.
Peniophora plumbea (Fr.) Karst.

Peniophora pithya has been described in detail by ERIKSSON (1950) and NOBLES (1956). *P. pithya* sporophores were not found on the stumps examined but mycelium was isolated on several occasions from 1—3 year old spruce stumps, especially from the top surfaces of one year old stumps.

Peniophora pithya according to ERIKSSON is a well defined species which differs from *P. nuda* and *P. violaceo-livida* by the absence of gloeocystidia and from *P. cinerea* by having larger cystidia and smaller spores. It is rather common on *Picea abies* in all parts of Sweden.

As described by ERIKSSON, the fructifications are thin, totally attached to the substratum, with no sterile margin; the colour in wet weather is dark greyish-blue to almost blue black; in dry weather the colour is light reddish-grey to more or less brown. Gloeocystidia are lacking; cystidia numerous, conical, up to 20 × 70 μ, strongly incrusted, basally brown, handle-like. Basidia clavate, 20—25 × 4—6 μ, spores 5.5—6.5 × 2—2.5 μ, cylindrical, somewhat curved, hyaline.

The cultural characters of the mycelium, determined after NOBLES' description of *P. pithya* were as follows:

Growth moderately rapid to rapid, 4.5—8 cm in 10 days. Advancing zone even, with downy mycelium to the limit of growth. Mat white, with small irregular buff to brown areas and brown mycelium on the edges of dishes. Mat at first unevenly raised, thin, cottony-floccose to woolly-floccose, somewhat reticulate. The older parts become appressed, downy-subfelty with translucent areas, remaining high and dense cottony on the dish edges. Reverse unchanged or slightly bleached. Odour slight to strong, medicinal (iodoform). Sporophores were not found in cultures. Diffusion zones on gallic and tannic acid agars moderately strong to strong; growth on gallic acid agar 25 (20—30) mm, on tannic acid agar 40 (33—50) mm.

Hyphae in the advancing zone hyaline, with numerous conspicuous clamp connections. Hyphae narrower than in *Stereum pini*, 1.5—4 μ in diam., frequently branched. On aerial hyphae swellings with short hyphal branches growing out from them. Short hyphae with dendritical branching are often found on aerial hyphae and sometimes on submerged mycelium. Gloeocystidia, irregular in form, are almost always found in older cultures. Cystidia, as described for sporophores, not infrequent in older cultures. Cystidia slender, sometimes branched at the base, with relatively thin walls and narrow brown lumina, more or less incrusted, 30—70 × 10—20 μ. Terminal and intercalary oval chlamydospores sometimes occur on both aerial and submerged mycelium.

The cultures described agreed with NOBLES' detailed description of *Peniophora pithya* cultures. The macroscopic appearance of our cultures was typical; gloeocystidia and cystidia were present together with dendritically branched lateral hyphae on the aerial mycelium and occasionally on the submerged mycelium.

8. *Stereum pini* Fr.

Stereum pini was found a few times in the mycelium stage on 1—2 year old pine stumps. This fungus is not so frequently found as for example *Peniophora*

gigantea, *Trechispora* or most of the *Thelephoraceae* which are discussed here and probably has little importance as a rot fungus on stumps.

Sporophore

Sporophore resupinate, with loose margins, small, under 1 cm, leathery, irregularly tuberculate, smooth with very short hairs. Hymenium grey, bluish or lilac to reddish brown. Basidia 20—30 × 4—5 μ; spores subcylindrical, 6—9 × 2.3 μ, slightly curved (Bourd. and Galz.). Gloeocystidia in the trama oval to spherical, cystidia in the hymenium claviform or fusiform, not much longer than the basidia, often incrusted.

Detailed descriptions of this fungus have been given by BURT (1920), OVERHOLTS (1939) and NOBLES (1956).

Cultural characters

Excellent descriptions of cultures of this fungus have been given by NOBLES (1956), and there is nothing to add to them. Cultures obtained during the present investigation had the following appearance, in good agreement with NOBLES' description:

Growth rapid, 7—9 cm in 10 days. Advancing zone even, with slightly raised aerial mycelium to the limit of growth. Mat white, with age forming small irregular patches of a buff brown colour, sometimes formed only on the edges of the dish. In test-tube cultures a brown colour is produced along the whole edge of the slant. Mat raised at first, cottony floccose to woolly floccose, becoming appressed on the older parts, then felty with radially reticulate small strands. Some larger tufts of cottony mycelium often spread over the surface or around the edges of the dishes. Reverse unchanged with small brown irregular areas. Odour slight to strong, characteristic somewhat sweetish fungal smell. On gallic and tannic acid agars, diffusion zones moderately strong to strong; no growth on gallic acid agar, on tannic acid agar growth 30—45 mm.

Hyphae in advancing zone hyaline, 2—6 μ in diameter, with numerous conspicuous clamp connections. Thick- and rough-walled hyphae on the older parts of the aerial mycelium. Irregularly hooked gloeocystidia and sometimes the broad, incrusted cystidia as usually found in sporophores, may appear. No sporophores were produced in our cultures.

The macroscopic appearance of the cultures, the typical thick walled hyphae in the aerial mycelium and the occurrence of gloeocystidia and cystidia are of considerable assistance in the identification of *Stereum pini* cultures.

9. *Stereum sanguinolentum* (A. and S.) Fr.

Syn. *Stereum crispum* Quel.
S. rigens Karst.

Stereum sanguinolentum is one of the commonest stump fungi on both spruce and pine although it occurs more frequently on spruce. The sporophores were found on 2—4 year old, most often on 2 and 3 year old (20 %) spruce stumps (fig. 6). The mycelium was isolated from 1—3 year old spruce stumps especially from one year old stumps (60 %).

Fig. 6. Young fruiting bodies of *Stereum sanguinolentum* on a 2 year old spruce stump.

Sporophore

The easily recognised sporophores of *S. sanguinolentum* were sometimes fully resupinate, sometimes with a margin that is curved over; they showed no great variation and agreed with the usual descriptions.

Cultural characters

Detailed descriptions of cultures of *S. sanguinolentum* have been given by FRITZ (1923), CARTWRIGHT and FINDLAY (1938, 1946), ROBAK (1942) and NOBLES (1948). This fungus shows little variation in the sporophores but may

vary appreciably in culture as has been stressed by ROBAK's careful investigations of the species.

Growth slow to moderately rapid, 4—8 cm in 10 days. Advancing zone in slowly growing forms lacunose and submerged, in rapidly growing forms even, with sparse downy aerial mycelium extending to the limit of growth. Mat white and moderately dense at first with a low silky to floccose aerial mycelium (Plate III: 3). Later variable in colour and density, yellow ochre to ochraceous orange to buckthorn brown or salmon red, the red colour deepening with age. The submerged mycelium is usually more reddish in colour and the substratum itself may become coloured in shades of red-orange to red-brown. Mat first downy to floccose, slightly raised, then soft and cottony to felty or rather skin like. The colour and texture of the mat often uneven, with concentric or irregular zones. Odour varying from none to slightly fungal to —in most cultures—a light to strong fragrant odour like that of *Polyporus benzoinus*. Oxidase reaction varying. In most of our samples there are no diffusion zones on gallic acid agar, on tannic acid agar the diffusion zones are moderate. No growth on gallic acid agar and 10—15 mm on tannic acid agar. In some samples however the diffusion zones on gallic acid agar are moderate, and on tannic acid agar moderate to strong; growth on gallic acid agar 5—10 mm, on tannic acid agar 10—15 mm. This last type agrees with NOBLES' description of the fungus.

Hyphae in the advancing zone hyaline, 2.5—7 μ in diameter, usually with simple septa but on some of the larger hyphae there are large clamp connections, singly, in pairs, or in whorls of 3—5. The branching of the aerial mycelium is very variable, sometimes the aerial mycelium consists of long, sparingly branched, septate hyphae, sometimes it is built up of rather short, upright, dendritically branched short-celled hyphae. On the ends of the hyphae there are cystidium like structures with thickened walls, sometimes encrusted. In submerged mycelium there may be large conducting hyphae with reddish contents, as described by CARTWRIGHT (1946) but they are lacking in most cultures. No kind of fructification ever occurred in our cultures.

As is apparent from the description *Stereum sanguinolentum* is very variable in culture, both in appearance and in oxidase reactions. ROBAK (1942) has described three growth types for this fungus; our material could not be divided into these three types but showed rather all combinations of the characters described and furthermore was liable to vary during culture. There was possibly a slowly growing almost stunted type which could be distinguished by having a deeply lacunose mycelium margin, sparse aerial mycelium, and an intense colour and odour. However variations in oxidase reactions did not correspond to different morphological types.

Polyporaceae

10. *Polyporus abietinus* (Dicks.) Fr.

Syn. *Polystictus abietinus* (Dicks.) Cke.
Coriolus abietinus (Dicks.) Quel.
Hirschioporus abietinus (Dicks.) Donk.
Trametes abietina (Dicks.) Pilat
Irpex fusco-violaceus (Schrad.) Fr.
Irpex violaceus (Pers.) Quel.

Polyporus abietinus was the commonest species of *Polyporus* in the stump material examined and both mycelium and sporophores were often found. Sporophores or conspicuous strands of mycelia were often present on 2—3 year

Fig. 7. Mycelium of *Polyporus abietinus* on a 3 year old pine stump.

old spruce stumps (30—40 %) and less often on 2—3 year old pine stumps (15 %) (fig. 7). Mycelium was isolated most often from 1—3 year old spruce stumps especially 3 year old stumps and less often from pine stumps.

Sporophore

The sporophore is small, 1—3 cm, bracket-shaped or resupinate, usually imbricate, with a grey hairy slightly zoned upper surface and a grey-violet to brown-violet pore surface. The tubes are short, 0.3—0.8 mm long, at first more or less round, then becoming angular and torn. The texture is tough, leathery and elastic even after drying, the trama whitish to light reddish brown. The spores are colourless, subcylindrical, 6—9 × 3.4 μ. In the hymenium numerous fusiform or oval cystidia bearing a crown of crystals.

Irpex fusco-violaceus (Schrad.) Fr. or *Irpex violaceus* (Pers.) Fr., which BOURDOT and GALZIN consider as a separate species has more recently been taken to be a form of *P. abietinus* (PILAT 1936), RAESTAD (1940), MACRAE (1941) and ROBAK (1942). ROBAK showed that poroid and irpicoid forms may form mycelial anostomoses more easily between intermediate and between intermediate and extreme forms and not so easily between two extreme forms. Another species closely related to *P. abietinus* is *Polyporus biformis* Fr. (*Polyporus pergamenus* Fr.), which occurs on broadleaf trees and may possibly be a biological form of *P. abietinus*.

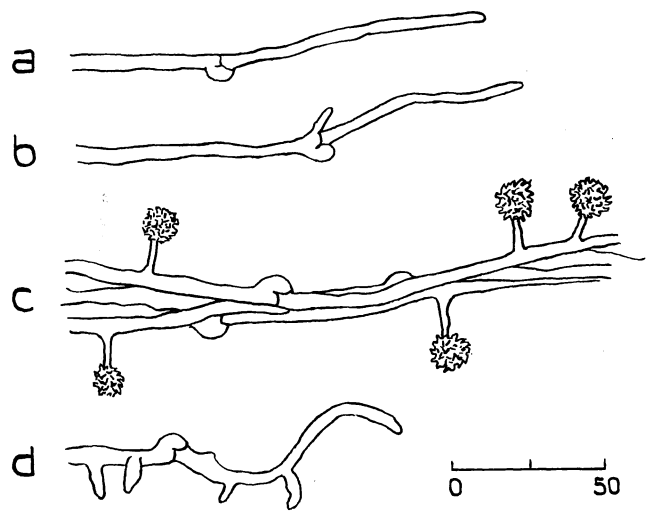

Fig. 8. *Polyporus abietinus:* a, b) hyphae from the submerged mycelium, c) mycelial strands with cystidia from the aerial mycelium, d) young aerial hyphae.

Cultural characters

Polyporus abietinus cultures have been described by FRITZ (1923), GARREN (1938), MACRAE (1941), ROBAK (1936, 1942), CARTWRIGHT and FINDLAY (1938, 1946) and NOBLES (1948, 1953). Growth slow to moderately rapid, 2—5 cm in 10 days. Advancing zone even, hyaline. Mat white, at first moderately dense, appressed, silky or sparse cottony-floccose, with radially arranged hyphae even in the aerial mycelium (Plate V: 1). With age the mat gets denser with almost felty aerial mycelium. Both on wood and in culture the fungus shows a tendency to form conspicuous radiating mycelial strands with fan-like branches at the tips. Odour none or faintly fungal. On gallic acid and tannic acid agars the diffusion zones are strong or very strong; no growth on gallic acid agar, trace of growth on tannic acid agar.

Hyphae in the advancing zone hyaline, septate, branched at acute angles, 1.5—5 μ in diameter. Clamp connections numerous and conspicuous. Fibre

hyphae may occur on the aerial hyphae. Oidia and chlamydospores are lacking. On the aerial mycelium numerous short branches are formed, with swollen globose to conical tips, bearing a cap of crystals resembling the cystidia found in the hymenium of this fungus (fig. 8).

Cultures of *P. abietinus* are very characteristic and easily recognisable; with the exception of the closely related *P. pergamenus* from broad leaved trees which is very similar in culture and of *Odontia bicolor* (NOBLES 1953), it cannot be confused with any other fungus. According to NOBLES the rather similar *Odontia bicolor* can be distinguished from *P. abietinus* by the cystidia which carry very much larger caps of crystals.

P. abietinus is often encountered on stumps, especially on younger stumps in the mycelium stage. It then forms snow-white branched mycelial strings up to 1 mm wide with fan like branchings at the tips similar to those found in culture. These strings gave typical *P. abietinus* mycelium when cultured and even on wood they were easily recognisable by the numerous crystal bearing cystidia, similar to those formed on the mycelium in cultures and growing out on short hyphal branches on the strands.

11. *Polyporus amorphus* Fr.

Syn. *Gloeoporus amorphus* (Fr.) Clem. and Shear
Polystictus amorphus (Fr.) Big. and Vuillemin
Leptoporus amorphus (Fr.) Quelet
Polyporus albo-roseus (Karst.) Sacc.

Polyporus amorphus is very common in some places (Högby mo) especially on 3—4 year old pine stumps. It is also found but less commonly on 3—5 year old spruce stumps (Plate II: 4). It was found more seldom in cultures, presumably due to the very slow growth of its mycelium on malt agar.

Cultural characters

Earlier descriptions of cultures of this fungus have been given by NOBLES (1948) and are in good agreement with our own observations.

Growth very slow, advancing zone even, appressed, mat white, appressed to slightly raised, felty to velvety, somewhat farinaceous (Plate V: 2). No fruiting bodies occurred on our material but according to NOBLES (1948) they may occur as irregular pores on the surface. Odour strong, sour. On gallic acid and tannic acid agars diffusion zones moderately strong; no growth.

Hyphae hyaline, with clamp connections, narrow. On aerial mycelium numerous fibre hyphae; in submerged mycelium irregular swollen cells may occur.

P. amorphus cultures are easily recognisable by the very slow growth, the typical aerial mycelium and swollen cells on the submerged mycelium.

12. *Polyporus borealis* Fr.

Syn. *Leptoporus borealis* (Fr.) Pilat.
Spongipellis borealis (Fr.) Patouillard
Polyporus mollis Pers.
Ceriomyces rubescens (Boudier.) Sacc.

Polyporus borealis is rather common on conifer stumps. On the material examined it was found quite often as the mycelium on spruce stumps of all ages, beginning with mycelium on 1—2 year old stumps and occurring as sporophores on older (4 year) stumps; it was not observed on pine. The sporophores were typical and showed little variation.

Fructification

The sporophore is a thick soft bracket, often kidney-shaped, sometimes growing imbricate, sessile or with a short stalk. The colour was whitish when young, later cream coloured light ochraceous yellow to pale yellowish brown, distinctly hairy or with appressed hairs. The margin is thin and the pores white to cream coloured, sinuate and torn. The flesh is spongy, tough, fibrous and often watery. The spores are ovoid to ellipsoid, hyaline, 4—6.5 × 3—5 μ. Cystidia fusiform or oblong with a cap of crystals.

Cultural characters

Good descriptions of this fungus in culture have been given by FRITZ (1923), ROBAK (1942), CARTWRIGHT and FINDLAY (1946) and NOBLES (1948).

Growth moderately rapid, 3—5 cm in 10 days. Advancing zone hyaline, even, with sparse, downy aerial mycelium. Mat white, at first farinaceous, then denser, appressed, velvety, with felty to leathery irregular zones, mycelium somewhat radially arranged (Plate V: 3). Irregular white, foliose to irregularly pored sporophores with large, angular or dentate pores often appear after 4—6 weeks. Reverse bleached. Odour slightly fungal. On gallic acid and tannic acid agars diffusion zones moderately strong to strong. No growth on gallic acid agar, traces of growth on tannic acid agar.

Hyphae in the advancing zone hyaline, with numerous conspicuous clamp connections, 2—5 μ in diameter. Aerial hyphae with clamp connections and numerous upright irregularly branched hyphal tips heavily incrusted with small crystals. More or less numerous oval terminal or intercalary chlamydospores may be present on both aerial and submerged mycelium. Typical basidia, cystidia and basidiospores are formed in the sporophores. Basidia sometimes occur in small groups on the aerial mycelium. Basidia 15—20 × 5—6 μ, basidiospores ellipsoidal, 4—6 × 3—5 μ.

Polyporus borealis cultures are readily characterised by the large sporophores with wide pores, the numerous typical incrusted hyphae on the aerial mycelium and by the macroscopic appearance of the mycelial mats.

13. *Polyporus caesius* (Schrad.) Fr.

P. caesius sporophores were occasionally found on pine stumps at Högby mo. The mycelium of this fungus was described by CARTWRIGHT and FINDLAY (1946). It was not found amongst the fungi isolated in cultures.

14. *Polyporus circinatus* Fr.

Syn. *Polyporus tomentosus* Fr. var. *circinatus* (Quel.) Jørst. and Juul
Polystictus tomentosus (Fr.) Karst. var. *circinatus* Pilàt

JØRSTAD and JUUL (1939) and PILÀT (1936) regarded *P. circinatus* as a variety of *P. tomentosus*. JØRSTAD and JUUL regarded the four species described by FRIES, *P. tomentosus, P. triqueter, P. circinatus* and *P. leporinus* as synonyms but suggested that forms with curved setae should be distinguished as *P. tomentosus* var. *circinatus*. *P. tomentosus* s. str. according to JØRSTAD and JUUL is very seldom found in Norway, although *P. circinatus* is rather common in spruce forests. No *P. circinatus* sporophores were found in the present material but the mycelium occurred sporadically on spruce stumps.

Sporophore

According to PILÀT (1936) the sporophore is rather variable depending on the growth site. On the ground it has a central foot, on wood it is almost sessile with a short thick lateral stipe. The pileus is 3—10 cm in diameter, flat or somewhat funnel shaped with an unzoned felty layer on the upper side, ochre yellow to rust coloured with coriaceous texture. The tubes are short, 2—5 mm, running downwards, cinnamon brown. The pores are narrow, pale to rust brown with whitish edge, at first regular and later irregular and torn. The spores are hyaline, variable ellipsoid to subglobose, 3.5—6 × 3—4.5 μ (PILÀT). Setae quite numerous, fusiform, pointed, curved, 30—80 × 7—10 μ.

Cultural characters

Cultures of *P. circinatus* have been described by FRITZ (1923), CARTWRIGHT and FINDLAY (1946) and NOBLES (1948). Growth very slow, 1.5—2.5 cm in 10 days. Advancing zone even or lacunose, hyaline and with an outer appressed zone. Mat varying in colour with irregular zones from honey yellow and yellowish brown to cinnamon or rust brown or dark brown patches. Texture more homogeneous, thin velvety to velvety felty with small tight cinnamon brown balls of aerial mycelium which sometimes grow out later to small sporophores with small round, regular pores. On gallic acid agar diffusion zones strong to very strong, on tannic acid agar moderately strong; growth on both media none or slight.

Hyphae in the advancing zone hyaline, 1.5—4 μ in diameter, with simple septa. Aerial mycelium a dense irregularly felted mass of hyaline and yellow

to brown hyphae, with irregular chlamydospore-like swellings on both aerial and submerged mycelium. Fusiform long setae, as in the sporophores, may occur on the aerial mycelium in cultures. In some cultures normal spores were formed on small round fructifications.

Cultures of *P. circinatus* might perhaps be confused with *Trametes pini* cultures but *P. circinatus* can be separated by its slower growth, much shorter and sparser aerial mycelium and by the more greyish rust brown shade. As pointed out by NOBLES (1948), *P. circinatus* often has characteristic chlamydospore-like bodies while *T. pini* has typical thick walled hyphae with peculiar thickenings.

15. *Polyporus fuliginosus* (Scop.) Fr.

Syn. *Polyporus resinosus* Fr.
Polyporus benzoinus (Wahl.) Fr.

Sporophores from *P. fuliginosus* were occasionally found on 1—4 year old spruce stumps, most often on 3-year old stumps. Pure cultures of *P. fuliginosus* mycelium were obtained from spores. A description in culture has not been given since more material would be necessary for this. This mycelium has not been isolated from stumps.

16. *Polyporus stipticus* (Pers.) Quel.

Syn. *Leptoporus stipticus* (Pers.) Quel.
Polyporus albidus (Schaeff.) Fr.
Tyromyces albidus (Schaeff.) Donk.
Leptoporus albidus (Schaeff.) Bourd. and Galz.
Polyporus chioneus Fr.
Polyporus trabeus Fr.
Tyromyces guttulatus (Peck) Murrill
Polyporus alutaceus Fr.

Sporophores and mycelium of this fungus were found occasionally on spruce stumps only.

Polyporus stipticus is a very variable species and a number of forms have been described by PILÀT (1936). According to PILÀT the American *P. palustris* Berk and Curt is a very closely related species.

Sporophore

Bracket shaped, sessile or with a very short stipe, effused-reflexed, individual or imbricate, 2—6 cm in diameter 0.5—2 cm thick. White, yellowish with age and after drying, upper side smooth or irregularly nodular, soft and fleshy, somewhat fibrous, after drying hard to very hard and brittle. Tubes up to 5—6 mm long, white, pores white to yellowish, small, at first regular, round or angular, then more deformed, sinuate and torn, labyrinthiform. Basidia 9—15 × 3—5 μ, spores ellipsoidal, hyaline, 3.5—4.5 × 2—2.8 μ.

Cultural characters

Polyporus stipticus cultures have not been described previously.

Growth rapid, 8—10 cm in 10 days. Advancing zone even, hyaline, downy aerial mycelium extending to the limit of growth. Mat white, producing brown colours in inhibition zones. Mat at first downy-floccose, but soon denser and raised and high cottony-woolly (Plate V: 4). Older parts felty-woolly with opaque patches and high cottony mycelium on transplant and around the dish edges. Reverse bleached with some yellowish patches. Odour distinctly fungal, somewhat sour. Diffusion zones on gallic and tannic agars weak to moderately strong; no growth or traces of growth on either medium.

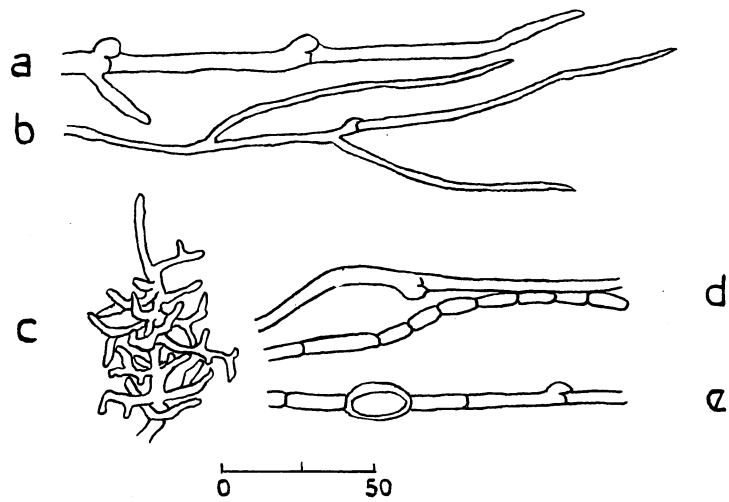

Fig. 9. *Polyporus stipticus:* a, b) hyphae from the advancing submerged mycelium, c) dendritically branched hyphae from the aerial mycelium, d) aerial hyphae with oidia, e) chlamydospores from the aerial mycelium.

Hyphae in advancing zone hyaline, 1.5—5 μ, with abundant clamp connections. Aerial hyphae as in advancing zone, with numerous fibre hyphae, 1.5—3.0 μ in diameter. Chlamydospores rare, oval, terminal or intercalary, 9—12 × 5—7 μ, some scattered short chains of oidia on the aerial mycelium, oidia cylindrical, 3—4 × 7—8 μ (fig. 9). Sometimes small soft white sporophores with small quite regular pores occur in the cultures. Typical spores were found in some of them. On younger aerial mycelium short upright bush-like repeatedly branched hyphae.

Polyporus stipticus has no obvious microscopic characteristics but the macroscopic appearance together with the rapid growth and the typical reaction on gallic acid and tannic acid agars are a good guide to the identification.

17. *Poria mollusca* (Pers.) Bres.

Sporophores of this fungus were found a few times on 3—5 year old spruce stumps.

18. *Fomes pinicola* (Sw.) Gillet.

Syn. *Fomes marginatus* (Fr.) Gillet.
Ungulina marginata (Fr.) Pat.
Polyporus marginatus Fr.
Fomes ungulatus (Schaeff.) Sacc.
Polyporus pinicola (Sw.) Fr.
Trametes pinicola (Sw.) Karsten
Fomes ponderosus Schrenck

Sporophores of this fungus were found rather rarely on 2—4 year old spruce stumps but not on pine. *F. pinicola* mycelium was isolated from 1—3 year old pine and spruce stumps.

Sporophore

The perennial sporophores are very typical in appearance, at first soft broad and thick, nodular, and later ungulate. Young sporophores have a reddish brown resinous coating on the upper surface. The old sporophores become corky-woody, greyish to blackish, with a reddish brown margin. The trama is pinkish buff to buff, the pores small, round, with quite thick edges, yellowish or pinkish buff. No cystidia, basidia 20—26 × 6—9 μ, spores obovate, 6—9 × 3—4.5 μ.

Cultural characters

Earlier detailed descriptions of *F. pinicola* cultures have been given by FRITZ (1923), MOUNCE (1929 a, b), CAMPBELL (1938), MOUNCE and MACRAE (1938), CARTWRIGHT and FINDLAY (1938, 1946) and NOBLES (1948).

Growth slow to moderately rapid, 2.5—5 cm in 10 days. Advancing zone hyaline, even, with downy aerial mycelium extending to the margin. Mat white, at first loose, arachnoid then slightly raised, cottony to cottony-woolly mostly very uniform in appearance, sometimes with scattered tufts of higher mycelium (Plate III: 4). Odour none or slightly fruity. Reverse unchanged or pinkish-yellowish (especially in tube cultures). On gallic acid and tannic acid agar no diffusion zones; growth on gallic acid agar 15—30 mm, on tannic acid agar traces to 25 mm. Typical fruiting surfaces, with thick somewhat corky edges and regular small round pores with thick pore walls, producing typical spores are often formed in test tube cultures and sometimes on plates.

Hyphae in the advancing zone hyaline, rather narrow, 1.5—4 μ in diameter, with numerous conspicuous clamp connections. On aerial mycelium in older cultures numerous fibre hyphae appear. Terminal and intercalary chlamydospores sometimes found on aerial and submerged mycelium. Basidiospores on fructifications obovales, 6—8 × 3—4 μ.

Fomes pinicola cultures have no special easily recognisable microscopical characteristics but they often form typical sporophores in older cultures and even in the sterile stage they are very similar although difficult to describe.

On stumps *F. pinicola* can form large extended sheets of sterile mycelium between the wood and the bark. These membranes have an indefinite edge and shape and are very much thicker and tougher than in *Armillaria*.

19. *Trametes heteromorpha* (Fr.) Bres.

Syn. *Daedalea heteromorpha* Fr.
Lenzites heteromorpha Fr.
Trametes subsinuosa var. *heteromorpha* (Fr.) Pilat
Trametes irpicoides (A. Bond.) Pilat
Polystictus heteromorpha (Fr.) Lloyd

Trametes heteromorpha sporophores were found only occasionally on 4 year old spruce stumps and sporadically as mycelium on one year old spruce stumps.

Fructifications

Sporophore resupinate, effused-reflexed, or bracket-like often coalescing at the sides, imbricate, leathery to corky, large, 0.5—4 cm thick, white to greyish or yellowish, somewhat zoned, with appressed hairs. Margin rounded, tubes 20—30 mm long, white or greyish, pores quite large, angular to daedaloid. Most of the sporophore is built up of tubes; the trama is relatively thin. Basidia 15—20 × 6—8 μ, spores hyalines, oblong-ellipsoid, 8—10 × 3—4.5 μ. No cystidia.

Cultural characters

Earlier descriptions have been given by MOUNCE (1935) and by NOBLES (1948).

Growth moderately slow to slow, 1.5—4 cm in 10 days. Advancing zone even, hyaline, sometimes appressed, aerial mycelium often extending to the limit of growth. Mat white but inhibition zones against other fungi may produce a narrow brown zone. Mat at first downy, then quite compact, appressed, woolly, usually homogeneous but with irregular higher ridges and tufts of aerial mycelium. Poroid fruiting areas with broad irregularly tagged pores and thick pore walls are produced in the middle parts of the colonies after 4—6 weeks. Reverse unchanged to light pinkish. Odour slightly fruity or peppermint. No diffusion zones on gallic and tannic acid agars; growth on gallic acid agar 10—20 mm, on tannic acid agar no growth or only traces.

Hyphae in the advancing zone hyaline, with conspicuous large clamp connections, sinuose, frequently branched and quite broad, 2.5—6 μ in diameter. They proliferate characteristically, branches often growing out from the clamp connections and from the sides opposite and soon producing new

clamp connections and new hyphal branches. Aerial hyphae up to 6 μ in diameter, with clamp connections. Fibre hyphae numerous, irregularly interwoven. Irregularly swollen cells may appear on the aerial hyphae. Typical oblong-oval spores, 8—10 × 3—4.5 μ are produced in the fruiting areas (fig. 10). No oidia or chlamydospores were found.

According to NOBLES it can be very difficult to separate cultures of *Trametes serialis* and *T. heteromorpha,* the only certain method being pairing experiments with monosporous mycelia of the unknown fungus and known monosporous cultures of *T. serialis* and *T. heteromorpha.* There are however

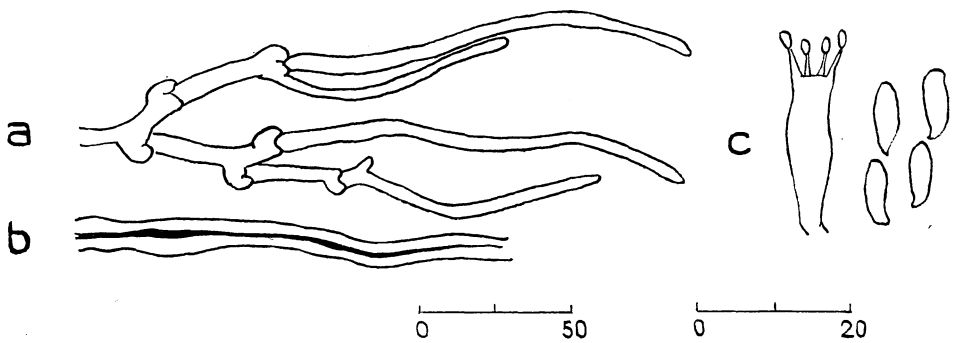

Fig. 10. *Trametes heteromorpha:* a) submerged hyphae from the advancing zone, b) fibre hyphae from the aerial mycelium, c) basidium and basidiospores.

definitive differences between cultures of the two fungi, even macroscopically the mycelium of *T. heteromorpha* is much more uneven than the mycelium of *T. serialis;* microscopically there are small conical, light refracting outgrowths on the mycelium of *T. serialis* which are not present on *T. heteromorpha;* the hyphae on *T. heteromorpha* are broader and characteristically branched. If sporophores form in the culture, *T. heteromorpha* can be easily recognised by the large long-elliptical spores.

20. *Trametes pini* (Th.) Fr.

Syn. *Polyporus pini* (Th.) Pers.
Fomes pini (Th.) Lloyd
Xanthochrous pini (Th.) Pat.
Phellinus pini (Th.) Pilat
Fomes abietis Karst.
Trametes abietis (Karst.) Sacc.
Xanthochrous abietis (Karst.) Bourd. and Galz.
Polyporus piceinus Peck.

Trametes pini sporophores were not found on the stumps examined but the mycelium was isolated from 1—3 year old pine and spruce stumps; it was isolated more often from stumps with root rot.

Sporophore

Trametes pini sporophores are rather variable in appearance and the fungus has often been divided into several species and sub-species: These, however, are based mostly on the colour of the sporophores and the size and shape of the pores and give no firm basis for division into species. The smaller, often annual form on spruce has been described as a special species, *Trametes abietis*, but the differences between this and the typical *T. pini* are very small.

The sporophores are usually more than one year old, 5—12 cm, 3—8 cm thick, very variable in shape from small buttons to ungulate caps. The upper surface is rough, hairless, becoming rimose and incrusted with age. The colour is dark, rusty brown, with a bright yellow margin in young specimens. Older sporophores darken almost to black. The texture is hard corky to woody, the colour of the trama is ferrugineous, concolorous with the tubes which are often stratified. The pores are irregular, round to angular to daedaloid. Their diameter varies greatly. The spores are at first hyaline, ovoid or ellipsoid to subglobose, 5—6 (9) × 4.5—5.5 (7) μ (PILÀT), then become pale ochraceous brown. Setae frequent, fusiform-conical, dark brown, 40—60 × 6—10 μ (PILÀT).

Cultural characters

Earlier descriptions have been given by FRITZ (1923), PERCIVAL (1933), OWENS (1936), CAMPBELL (1938), CARTWRIGHT and FINDLAY (1938, 1946) and NOBLES (1948).

Cultures from spruce and pine vary somewhat in appearance. The following is a description of material from pine.

Growth very slow, 1.5—3 cm in 10 days. Advancing zone hyaline, even, with aerial mycelium extending to the limit of growth. Mat from the beginning coloured honey yellow or chamois to ochraceous, tawny, antique brown or buff. The margin is always more yellowish in colour. Mat raised, dense cottony-woolly, mostly woolly with a nodose somewhat zoned surface. Reverse deeper coloured than the aerial mycelium, in deep brown hues. Odour none. Diffusion zones on gallic and tannic acid agars strong to very strong, usually stronger on the former agar. Growth on both media, traces to 10 mm.

Hyphae in the advancing zone hyaline, narrow, 2—4 μ in diameter, with simple septa. Aerial mycelium with hyaline hyphae or hyphae with yellow to brown contents, with simple septa, and often with scattered dark brown cells in hyaline hyphae. Irregular terminal or intercalary swellings on the hyphae which are otherwise like fibre hyphae, with thick brown cell walls and very narrow lumina. The older parts of the aerial mycelium may have setae slender, pointed, with brown contents and with the same dimensions as the

sporophores. They are never very numerous. No fructifications were found in the cultures.

Strains isolated from spruce differ in their even slower growth, the sparser, shorter and more appressed aerial mycelium and in the colour which more rapidly than in the material from pine turns to brown, mostly a warm yellow brown, sienna brown or rust brown tone, and always with zones in different shades of brown. Setae and irregularly swollen cells occur in this material also. The older test tube cultures from pine and from spruce may be very similar.

Several authors (NOBLES, OWENS, CARTWRIGHT) have pointed out that different strains of *T. pini* are rather variable and according to NOBLES the identification of strains of this fungus can sometimes be rather difficult. She gives the peculiar swollen fibre hyphae of *T. pini* as the only certain characteristic for this species. However none of the Northern European conifer rot fungi can be confused with *T. pini* in culture except for *P. circinatus* which can sometimes be rather similar.

21. *Trametes serialis* Fr.

Syn. *Polyporus serialis* Fr.
Polyporus callosus Fr.
Poria callosa (Fr.) Cooke

This fungus was found overall on the stumps examined, the sporophores most often on older stumps. On spruce the sporophores were found on 3—5 year old stumps, most often on 4—5 year old where it occurs on 15 per cent of all stumps. The sporophores were present about as often on pine stumps. The mycelium of *T. serialis* was found rather often and was present even in 1 year old pine and spruce stumps.

Sporophore

White, on the upper side brown, somewhat hairy, corky sporophore. Pileate, coriaceous, often growing downwards with a small part of the sporophore pileate and grown together in large resupinate surfaces. Pileus often 2—5 cm, 1—2 cm thick, with round, snub, white margin. Pores 1.5—5 mm long, white, round or angular, at first thick walled, later thinner and dentate. Old sporophores can be almost black. Basidia claviform, hyaline, 18—25 × 5—6 μ. In the sterile part of the hymenium there are swollen hyphae which carry an incrusted cap on the top and are broader than the basidia. Spores oblong-elliptic, hyaline, narrowing at the base, 6—10 × 3—4 μ.

Cultural characters

This fungus has been described in detail in culture by ROBAK (1936, 1942), DAVIDSON and CAMPBELL (1943), CARTWRIGHT and FINDLAY (1938, 1946) and NOBLES (1943, 1948).

Growth slow, 2.5—4.5 cm in 10 days. Advancing zone hyaline, even, broad. Mat white, appressed, floccose to felty, sometimes forming irregular patches with veins radiating from the centre. Large irregular pored surfaces are often formed after 2—6 weeks (Plate IV: 1). Reverse unchanged. Odour slight to pronounced fungus smell. No diffusion zones on gallic and tannic acid agars, but on gallic acid agar after a longer time a distinct brown zone may appear. Growth on gallic acid agar 15—30 mm, on tannic acid agar traces of growth to 15 mm.

Hyphae hyaline, rather narrow, 1.5—4 μ, somewhat sinuous, much branched, with numerous conspicuous clamp connections. In aerial mycelium fibre hyphae very numerous, with thick, refractive walls, aseptate. Small pointed projections on the outside of many aerial hyphae where the walls are thickened and refractive. Typical basidia and spores are formed on the fruiting surfaces.

NOBLES (1943) discovered that *Poria microspora* Overholts (*Poria monticola* Murr.) was often confused with *T. serialis*. This fungus in culture can be distinguished by its weak rose colour and foliose sporophores. It may sometimes also be difficult to separate *T. serialis* from other white rot fungi such as *T. heteromorpha* and *Lenzites albida* Fr.; the latter occurs on broad leaved trees while *T. heteromorpha* and *T. serialis* can be separated by the characteristic microscopic features (cf. under *T. heteromorpha*).

22. *Lenzites sepiaria* (Wulf.) Fr.

Syn. *Gloeophyllum sepiarium* (Wulf.) Karst.
Daedalea sepiaria (Wulf.) Fr.

Lenzites sepiaria sporophores were found sporadically on 2—4 year old spruce stumps but never on pine stumps. The mycelium was isolated from 1—4 year old spruce stumps, especially from 4 year old stumps but was never found on pine stumps.

Sporophore

The sporophores can vary considerably in size and shape but are always easily recognisable. They are pileate and corky, 1—5 cm broad and up to 10 cm long with winding daedaloid lamellae (fig. 11). Fully resupinate forms also occur. The pileus is hairy and at first ochre yellow, but later chestnut brown to dark brown with a yellow edge, partly zoned with rough haired and almost bald zones. Lamellae anostomosing, with large irregular pores at the margins, often dentate, lighter than the sporophore and powdered with white, trame rust brown to brown. Spores cylindrical, hyaline and bent, 7—12 × 3—4.5 μ (PILÀT).

Several forms of *L. sepiaria* have been described, especially from mines.

Cultural characters

Earlier descriptions of *L. sepiaria* cultures have been given by FRITZ (1923), CARTWRIGHT (1929), MOUNCE and MACRAE (1936), ROBAK (1942), CARTWRIGHT and FINDLAY (1938, 1946), DAVIDSON, LOMBARD and HIRT (1947) and NOBLES (1948).

Growth slow, 2.5—6 cm in 10 days. Advancing zone curved, with a narrow hyaline zone. Mat white at first, but after ca. 10 days yellowish, chamois to snuff brown colours appear in patches. The colour in most cultures is always uneven. Aerial mycelium uneven, patchy, with slightly raised, velvety-woolly

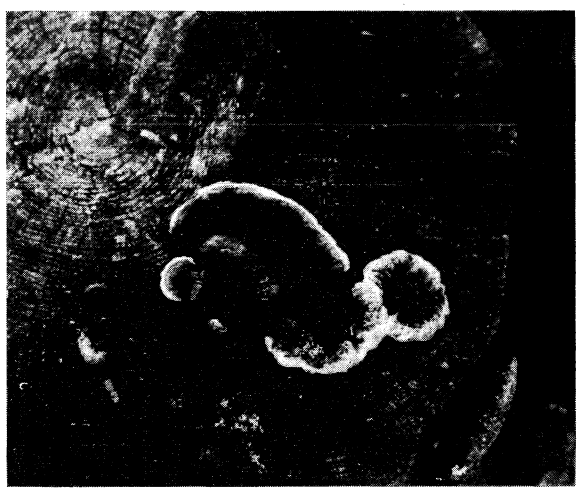

Fig. 11. *Lenzites sepiaria* on a 5 year old spruce stump (about half nat. size).

to small cottony patches, or appressed farinaceous. Reverse patchy, unchanged with dark brown zones under the coloured mycelium. Odour, none or slightly aromatic. No diffusion zones on gallic and tannic acid agars; sometimes a weak to moderately strong diffusion zone may appear later on gallic acid. Growth on gallic acid agar, traces to 2.0 mm; on tannic acid agar no growth. Abnormal fruiting bodies may occur in culture.

Hyphae in advancing zone hyaline, sinuose, frequently branched, 1.5—4 μ in diameter, with numerous conspicuous clamp connections. In the aerial mycelium as well as the hyaline hyphae there are brown fibre hyphae and hyphae, called "conducting hyphae", with thick walls and broad lumina. Part of the mycelium with clamp connections soon breaks up in numerous oidia. The oidia are often cylindric or somewhat irregular to ovoid. Terminal or intercalary chlamydospores may occur, especially in the submerged mycelium.

According to ROBAK (1942) cultures of *L. sepiaria* can easily be confused with cultures of *Trametes odoratus* (Wulf.) Fr., which can be distinguished almost only by the intensive odour. Our own cultures of *T. odorata* were readily separated from cultures of *L. sepiaria* partly by the strong smell and also by the sparse formation of oidia in *T. odoratus* and by the macroscopic appearance of the cultures since *T. odorata* always formed large quantities of white cottony-woolly aerial mycelium mixed with brown flecks, while *L. sepiaria* in older cultures always kept a yellow brown colour. NOBLES (1948) gives as a good distinguishing characteristic the formation in *L. sepiaria*, in contrast to other fungi, of oidia on the diploid mycelium with clamp connections.

Agaricaceæ

The most important of the Agaricaceae found on the stumps was *Armillaria mellea* which has a special position among stump fungi. Because of the damage it causes in forests it has often been investigated in culture. Detailed descriptions of the very typical mycelium of *A. mellea* have been given by REITSMA (1933), BENTON and EHRLICH (1941), DAVIDSON, CAMPBELL and VAUGHAN (1942), CARTWRIGHT and FINDLAY (1938, 1946) and NOBLES (1948). *Armillaria* was found on the younger stumps as the mycelium, present on younger stumps mostly as characteristic sheets (fig. 12) and on older stumps as sheets and rhizomorphs. It was much more frequent on spruce than on pine and attacked spruce at an earlier stage, since it was present already on 25 per cent of one year old stumps, while it occurred on only 8 per cent of one year old pine stumps (fig. 15, tables 2 and 3). In culture, *Armillaria* grows very slowly and cannot compete with other fungi present. It is therefore, compared with other stump fungi difficult to detect in culture, and cultures from boring cores will obviously show values for the frequency of occurrence of the fungus which will be too low.

Of the other *Agaricaceae*, occasional sporophores were found of *Collybia platyphylla*, *Hypholoma fasciculare*, *Paxillus atrotomentosus*, *Pholiota squarrosa*, *Pleurotus mitis* and *Tricholoma rutilans*. Since the sporophores of these species are very easily perishable in comparison with sporophores belonging to *Thelephoraceae* and *Polyporaceae* it is more by chance that these fungi are found and they certainly occur much more often than would appear from the material presented here. With the exception of descriptions of a few of the *Agaricaceae* by NOBLES (1948) and a few other scattered notes, these fungi have not yet been described in culture. Mycelia of *Hypholoma fasciculare* (Plate IV: 2), *Pholiota squarrosa* and *Tricholoma rutilans* have been grown from spores and described; they

have been found to be readily characterised morphologically but of these fungi *Hypholoma* and *Pholiota* were only seldom isolated from boring cores and *Tricholoma* not at all. The group "not identified" (tables 5—8) probably contains a number of *Agaricaceae*.

Fig. 12. Mycelium sheets of *Armillaria mellea* on one year old spruce stump.

Other fungi

Of the remaining fungi found on the stumps the commonest was *Trichoderma viride* Pers. ex Fr. which can impede the isolation of other fungi especially in the autumn when it forms numerous spore-masses under the bark (fig. 13). It grows very fast in culture and especially inhibits growth of the slow growing rot fungi from the boring cores. This prevented isolation of rot fungi from a large number of stumps where they were almost certainly present. Fast growing blue stain fungi were very often present on the stumps but they did not usually inhibit rot fungi from growing out. Very common among the blue stain fungi were: *Ophiostoma penicillatum* (Gross.) Siem. strains on both pine and spruce while on spruce there were *O. piceae* (Münch) Syd. and *O. olivaceum* Math. and on pine there was *O. pini* (Münch) Syd. The omnipresent *Pullularia pullulans* (de Bary and Low) Berkh. and *Cladosporium herbarum* Link. were also very common on both pine and spruce. There also occurred

on a rather large number of stumps *Phialophora spp. Haplographium penicilloides* Fautr., *Rhinocladiella atrovirens* Nannf., *Torula ligniperda, Rhinotrichum, Coniosporium, Phoma* and *Cytospora* species. More occasionally *Scopularia phycomyces* (Auersw.) G. Goid. and *Cordana pauciseptata* Preuss. were found. The commonest of the *Hyphomycetes Mucedinaceae* apart from *Penicillium* were *Cephalosporium* and *Cylindrocephalum* and *Verticillium* species. The very fast growing *Gliocladium viride* Matruch. could sometimes be as difficult as *Trichoderma. Geotrichum candidum* and *Dipodascus* species

Fig. 13. Spore-masses of *Trichoderma lignorum* on a 2 year old spruce stump.

were often isolated from younger stumps. On 4 year old and older stumps it was difficult to isolate the rot fungi; there were large numbers of *Hyphomycetes* present as well as those already named, such as *Acremonium, Botrytis, Cephalothecium, Fusarium* (very often), *Oidiodendron* and *Spicaria* species. *Chaetomium globosum* and *Pestalozzia* species also occurred in a number of tests. *Mucor Ramannianus* Möller and other small *Mucor* species were often present especially on older stumps. A great number of sterile *Phycomycetes* mycelia were isolated from the older stumps.

Although many of these fungi are certainly interesting both from systematic and ecological point of view, we did not have time to carry out any detailed investigations into these fungi at this occasion.

Part II. The occurrence of sporophores on stumps

During the autumn months the weather is very favourable for the formation of sporophores and mycelia and an inventory has been made of the fungi present at this time on stumps of different ages. These observations have been made mainly at the Tönnersjöheden research forest and at the State forest at Bogesund (fig. 14). For the investigation part of the bark was removed down to the roots and the fungi present and their location were noted. In many cases only the mycelium was found and these fungi were also recorded when the mycelium was so characteristic that it could be identified by macroscopic inspection.

The fungi found on spruce have been listed in table 2. The commonest was *Armillaria mellea*, easily recognisable by the white mycelial sheets which grew up from the roots between the bark and the wood (fig. 12). On older stumps the rhizomorphs were also common. The sporophores were not formed nearly as often as the mycelium under the bark and seemed to occur more often on 2—3 year old stumps than on one year old stumps. As well as the age of the stumps, the temperature and the humidity of the air all affect the formation of the sporophores.

Armillaria mycelium was found most often on 3—5 year old stumps (fig. 15) but considerable differences were observed in different areas. In one place in a single area more than half of the stumps were attacked while in another place in that area the mycelial sheets of *Armillaria* were completely absent. No investigation was made of whether this was due to the composition of the forest, to the soil conditions or to similar factors. It was obvious however that spruce stumps were very easily infected by *Armillaria*, especially the roots. From these primary centres of infection it can then easily spread to surrounding healthy trees (GARRETT 1956). *Armillaria* is thus of considerable importance as a stump fungus.

Peniophora gigantea was also found on a large number of spruce stumps. It often forms large sheets hundreds of square cms in area largely composed of young and older sporophores which have coalesced (Plate I). Usually the fungus was best developed under the bark on the upper and middle parts of the stump.

The following fungi were found on more than 20 per cent of the stumps: *Trechispora Brinkmanni, Polyporus abietinus, Stereum sanguinolentum* and *Coniophora spp.* Other species were found only occasionally.

Very few sporophores were found on one year old stumps since even if most of these are already infected the mycelium has not yet reached the sporophore forming stage (table 11). Between 10 and 15 different species were

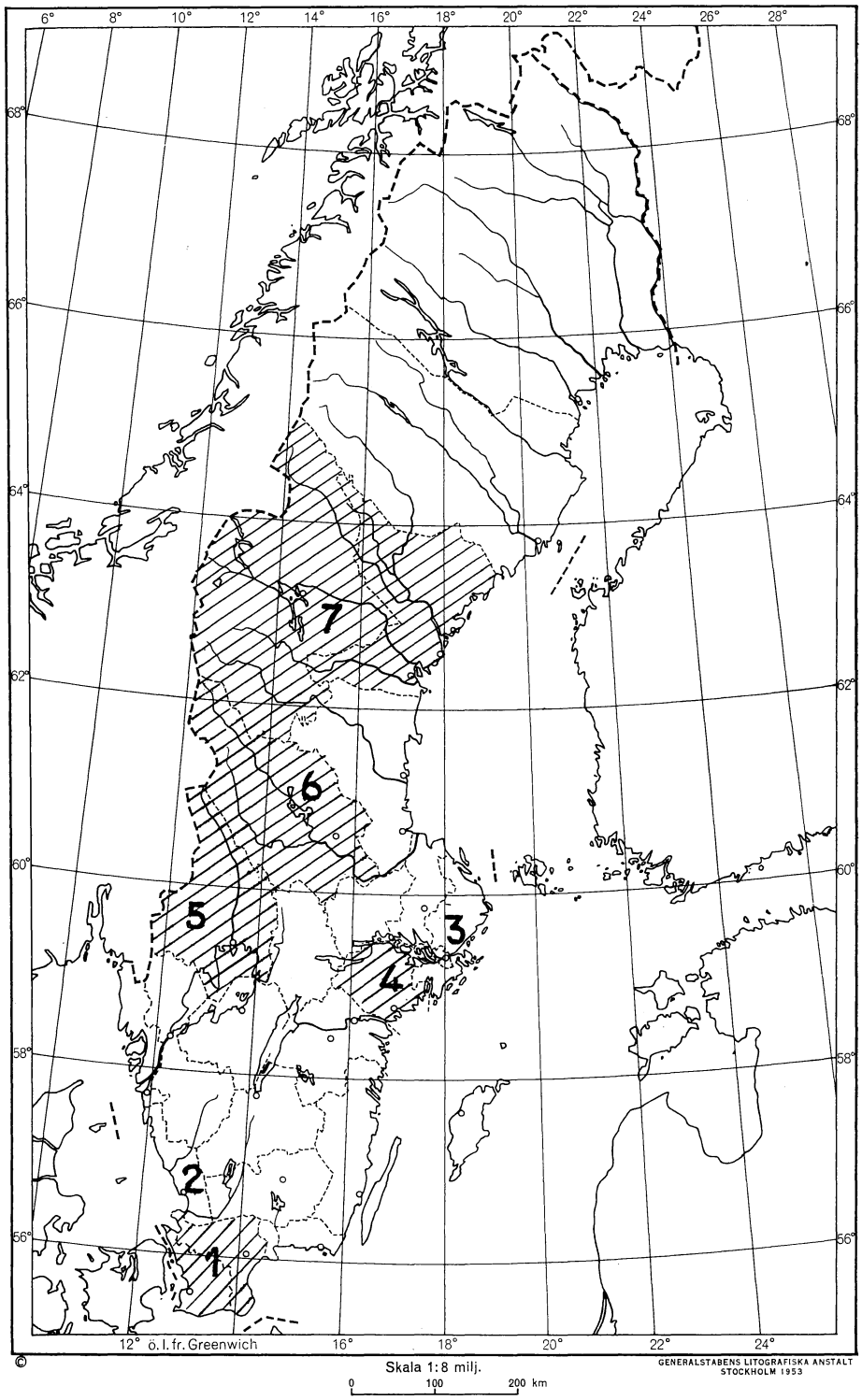

Fig. 14. Map showing localities where stump samples were collected (cf. table 5).

found on 2—5 year old stumps, usually better and more richly developed on the upper part of the stumps than on the lower.

Table 3 shows the corresponding results for pine. It is apparent that *Armillaria* has been seen only to a very small extent on pine stumps (fig. 15). It is possible that it is present more often than was indicated by macroscopic inspection, but neither mycelial sheets nor rhizomorphs were observed to the same extent on pine as on spruce stumps.

The fungus which largely dominated on the pine stumps was *Peniophora*

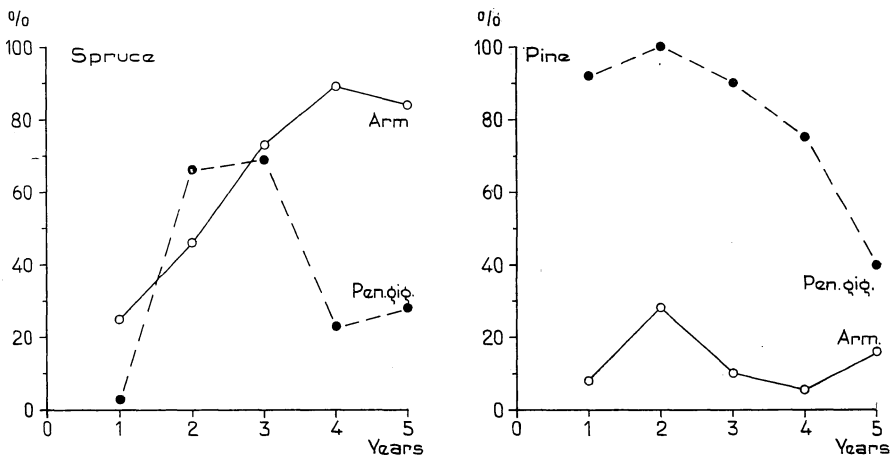

Fig. 15. Occurrence of mycelium and fruiting bodies of *Armillaria mellea* and *Peniophora gigantea* on spruce and pine stumps, 1—5 years old.

gigantea. The mycelial sheets and sporophores of this fungus could be readily observed during the first year and after two years every stump examined was infected with *Peniophora* (fig. 15). After 2—3 years the sporophores were still very common (Plate I). The mycelium occurred very frequently also on the thick crusty bark which was often partly interwoven by a mass of mycelial threads (Plate II: 1—2).

The other fungi which occurred relatively often were the same as were found on spruce stumps that is, *Trechispora Brinkmanni, Polyporus abietinus, Stereum sanguinolentum* and *Coniophora spp. Polyporus abietinus* was identified in a number of cases only by the occurrence of the mycelium which had a characteristic growth form (fig. 7).

Other fungi were encountered only occasionally. Sporophore formation was most developed on the 3—5 year old stumps (table 11).

A special investigation was carried out at Högby mo where an experiment was set up in an attempt to confirm RISHBETH's stump infection theory for root rots. On this area which is now covered with 20 year old pine, different

lots have been worked over at different times of the year using different thinning systems, with and without chemical treatment of the stumps (table 4). As is shown in the table, on many stumps no sporophores developed which may partly be due to the small size of the stumps, many being not more than 4—6 cm in diameter. Where sporophores had been formed *Peniophora*, *Polyporus amorphus* and *Polyporus abietinus* predominated. The last named fungus was very prevalent on one of the lots with high stumps but possibly the ecological conditions were especially favourable in this lot for its development.

Part III. Fungi cultured from stump boring cores

The Swedish forest research institute has over a long period carried out investigations into rot fungi in Swedish forest trees by taking boring cores from standing trees. These cores have been taken under conditions as sterile as possible when working in the forest. The tools and the bark and wood of the tree are sterilised with 90 % alcohol and the cores placed immediately in tubes containing sterile agar. These cores are transferred to malt agar plates on arrival at the institute and the fungi which grow on the agar are noted down.

The same procedure has been used for examination of the fungus flora in stumps. Usually two cores have been taken from opposite sides into the middle of the stump at about 5 cm below the top of the stump (fig. 16). Sometimes three cores have been taken. Samples were taken both from spruce stumps from healthy trees and from those attacked by forest rot. The pine stumps were all healthy when the trees were felled. Samples have been taken from a total of 1,483 stumps, 1,273 of them spruce and 210 pine. Of the spruce stumps 717 appeared to be healthy at cutting while 556 had a forest rot of one sort or another. The stumps were between 1 and 4 years old. The annual rings were not counted to determine the age of the trees, but they had been between about 60 and 120 years old. The material was collected at several different places in Sweden as shown in the list in table 5 and on the map in fig. 14.

In the examination of the cores, interest has been directed primarily towards the identification and isolation of the rot fungi which grew out. As is apparent from tables 6—9 rot fungi were not isolated from all the boring cores taken. Some cores were sterile; these were mostly from first year stumps. Probably during the first year the mycelium had not penetrated throughout the wood

to such an extent that it could be certain that the boring cores went through infected wood.

No rot fungi were isolated from a relatively large number of cores. These instead gave bacteria, yeasts, moulds and blue stain fungi. If rot mycelia were present in the wood, they must have been suppressed by the rapidly growing moulds. *Gliocladium spp.* and *Trichoderma viride* were especially troublesome in this way. No attempts have been made to find special mould inhibiting substrates. By using selective agar media containing compounds

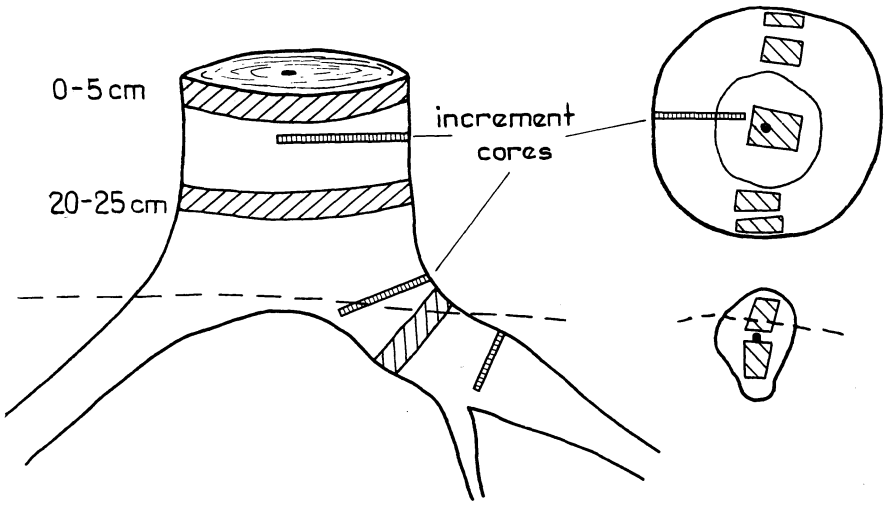

Fig. 16. Sampling method for investigation of mycelia in the stumps and for the determination of moisture content and density of stump wood.

toxic to bacteria, moulds etc. it might be possible to obtain more *Basidiomycetes* in the Petri-dishes. Such selective media are described, *e.g.* by MELIN and NANNFELDT (1934) using activine (sodium p-toluene-sulphochloramide) and RUSSELL (1956) using o-phenyl phenol.

The time of year appears to have some influence on the occurrence of these moulds and similar organisms and with samples taken during late summer and autumn there is a greater risk of moulds suppressing the rot fungi. During this time of year the number of such spores in the air is of course greatest (MATHIESEN-KÄÄRIK 1955) and there are often large masses of mould spores under the bark (fig. 13).

The care with which the samples are taken is important and most of the samples have been taken by members of the mycological section of this institute. A few samples have been taken by other people following the same instructions.

1. *Rot fungi in spruce stumps*

The rot fungi which were found have been separated into four different groups in tables 6—9. The first group comprises *Armillaria mellea* and *Fomes annosus* which are both important causes of damage to growing trees. The second group includes rot fungi which have been identified and must almost without exception have infected the stumps after felling. The third group includes mycelia which occurred fairly frequently in the cultures but which have not yet been identified with known mycelia (type I—X). The last group includes those rot mycelia which could hitherto not be classified in any way. Continued work on the identification should make it possible to distinguish several different rot fungi in this group.

a. The occurrence of Armillaria mellea and Fomes annosus

These two fungi are of considerable importance in Swedish forests. It has long been known that *Armillaria* is frequently present in the soil and can rapidly invade stumps after a tree has been felled. From these stumps the fungus can send out rhizomorphs and infect neighbouring trees or a new generation of forest (GARRETT 1956).

In the case of *Fomes annosus*, RISHBETH (1950) has shown that in England infection of pine can take place through newly cut stumps. Thus for eight East Anglian pine plantations thinned during 1955, the incidence of *Fomes annosus* in stumps one year later ranged from 30 to 100 per cent, averaging about 60 per cent (RISHBETH 1957). In the south of Sweden MOLIN (1957) has found that aerial infection occurs in about 10 % of the stumps and has shown that root rot increases considerably with increasing severity of cutting.

The occurrence of these two fungi in fresh stumps may thus have considerable practical significance in Swedish forestry.

As shown in tables 6—9 *Armillaria* was isolated from only a few of the stumps which were healthy when cut. The maximum was 3.8 %. As already shown in part II the presence of *Armillaria* on stumps was usually indicated by the occurrence of mycelial sheets and of rhizomorphs. The low frequency of the fungus on agar cultures is almost certainly connected in the main with the easy suppression of the slowly growing mycelium by other faster growing mycelia.

The difficulty of culturing *Armillaria* is apparent from the test samples taken from stumps which when cut appeared to be attacked by *Armillaria;* even in these *Armillaria* was found in a maximum of 14.2 % of the samples (table 6). According to our experience a central *Armillaria* rot with holes in it is nearly always strongly contaminated by bacteria, moulds and blue stain fungi. The fungus is most easily cultured from a tree which is dying from

an acute attack, with *Armillaria* growing up between the bark and the wood. There is usually pure mycelium here and growing some distance into the wood.

Fomes annosus was found in a maximum of 7.6 % of the cores taken from the stumps of healthy trees. This figure agrees rather well with the figures obtained previously by MOLIN (1957) and RENNERFELT (1957). It is however not entirely certain that these cases are due only to aerial infection. Even if the stump surface itself is healthy there may be a root rot spreading from below to the level at which the samples are taken.

A large number of samples have been taken from stumps which were already damaged by rot when cut. Table 10 lists the fungi responsible for the rot as far as could be decided from the superficial appearance. It can be seen that according to this appraisal *F. annosus* was the commonest rot fungus, occurring in about 76 % of the rot damaged stumps. *Armillaria* appeared to occur in 5 % of the stumps but this figure is probably too low. Other rots which could not be attributed to any definite fungus were present in 19 % of the stumps.

Many different fungi have grown out of these forest rot samples. *F. annosus* was isolated from a maximum of 55.7 % of those samples that were presumed to contain it. This was in one year old stumps. After this the percentage of *F. annosus* cultures sank continuously and it could not be demonstrated in four year old stumps. It was probably present as living mycelium in at least some of these but was suppressed by moulds and other organisms. On other occasions we have isolated *Fomes annosus* mycelium from spruce stumps 6 years old (RENNERFELT 1946) and 10 years old (MOLIN 1957) respectively. *F. annosus* was also obtained from cores that were presumed to contain *Armillaria* sometimes in even greater numbers than *Armillaria* itself (table 6). It was sometimes also found together with *Armillaria* in rotted stumps.

It was found throughout that the forest rot fungi were most easily cultured from stumps which were at the most one year old. In a number of cases the fungus causing a rot has been cultured from a very high percentage of such material. Thus on one occasion 50 newly cut rot damaged stumps gave *F. annosus* from 100 % of the samples taken. If the stumps are more than one year old the increasing amount of secondary fungi makes it more difficult to culture the original rot fungus.

The results obtained from the cultures show that it is rather difficult to decide from the superficial appearance alone the identity of the fungus causing a rot.

b. Other rot fungi (stump fungi)

Stumps which were initially healthy gave a large number of rot fungi, in most cases due certainly to aerial infection after cutting. The same fungi

predominated that were found by visual examination of the stumps, that is *Peniophora gigantea, Trechispora Brinkmanni, Stereum sanguinolentum* and *Polyporus abietinus* (tables 6—9), but as shown in table 2 they were not isolated from the boring cores in the same frequency. No fungus was isolated from more than 36 % of the samples (table 8, *T. Brinkmanni*), but they must have been present in considerably greater frequency in the stumps.

A number of rot fungi occurred more or less sporadically in the Petri-dishes. At least two of them, *Polyporus borealis* and *Trametes pini* may have been present in the tree before felling (JØRSTAD and JUUL 1939). In the material now investigated by us the probability of this would, however, be very small. *Fomes pinicola* may also occur in the tree but probably is more often present due to direct stump infection.

Of the non-identified fungi, type VI was isolated rather often but the others occurred only sporadically. There may be several different rot fungi amongst the "not identified" especially *Agaricaceae.* It is possible that they play a more important role in the decomposition of the stump than the quantitatively low figures would indicate.

The stump fungi were also found in stumps with a primary forest rot though not so often. The proportions of the different fungi appeared to be about the same as in the stumps from healthy trees. This is probably because these stump fungi have more difficulty in establishing themselves in stumps which are already largely occupied by rots than in a stump from a healthy tree. In addition it may be more difficult to isolate some of these fungi if a rather fast growing species such as *Fomes annosus* is present in the wood.

A summary of the number of species of rot fungi found in stumps from healthy trees is given in table 11 and was made partly from external observations of sporophores and mycelia on the outside of the stumps and partly from the mycelia isolated from the boring cores. The table shows clearly that maximum infection of the stumps occurs in the first year. However with increasing age it becomes more and more difficult to isolate the different mycelia because of the increasing number of organisms such as bacteria and moulds. It is quite difficult to isolate pure cultures of rot fungi from stumps that are more than four years old but observation of the sporophores shows that the stump flora in this respect is richest during the third to the fifth years. This is of course connected with the time required by the fungus in the vegetative stage before the formation of sporophores.

2. *Rot fungi in pine stumps*

Only pine stumps from healthy trees were investigated. Pine stumps with forest rot were almost never found in the areas from which the material

described here was collected. Table 12 shows the fungi isolated. *Armillaria mellea* was found in a few scattered cases; *Fomes annosus* was never found.

Of the other fungi, *Peniophora gigantea* very largely predominated both in the cultures and in the number of sporophores. *Trechispora Brinkmanni* and *Stereum sanguinolentum* were also rather common but other fungi occurred only occasionally.

There were much fewer species present on the pine stumps than on the spruce (table 11). The number of sporophores observed increased to a maximum after 3—5 years while the number of species isolated from the boring cores decreased after the first year.

3. *Rot fungi in chemically treated stumps*

Freshly cut stumps were treated with different chemicals at various times partly with the intention of testing RISHBETH's stump infection theory. The stumps were treated either with creosote oil or with copper naphthenate painted on with a brush. Boring cores from these stumps were taken for examination 1—3 years after treatment.

As shown in tables 13—14 none of the cores were sterile. *Armillaria mellea* was not isolated in any case and *Fomes annosus* in only one or two spruce stumps. The stump fungi were not very numerous either in frequency or in number of species and this was especially noticeable in the case of the usually dominant *Peniophora gigantea* and *Trechispora Brinkmanni*. It would thus appear that this treatment to some extent hinders aerial infection and the growth of these fungi.

Part IV. The occurrence of rot mycelia in different parts of the stump

In part II it was shown that sporophores and other parts of the fungi were more richly developed on the upper parts of the stumps than on the lower. A series of samples were taken from stumps of different ages in order to show whether the same relationship would be found in the isolation of the fungus mycelium from boring cores. These cores were taken approximately as shown in fig. 16. Double samples were taken from opposite sides at the top and at the bottom.

The fungus flora had very largely the same composition as that shown previously. The fungi grown from spruce cores are listed in table 15. There were only a few sterile samples.

The forest rot fungi *Armillaria mellea* and *Fomes annosus* were found only in a few samples and in slightly greater numbers in the lower parts than from the top of the stumps.

The stump fungi were found almost throughout in larger numbers in the samples taken from the top of the stumps than in the samples taken from the bottom of the stumps. This could be interpreted as indicating that the main part of the infection was due to air-borne spores falling on the upper surface of the stumps. This is also apparent from the summary shown in table 16.

Similar observations were made with pine although the material available was small (table 17).

Part V. Decomposition and infection of the stumps

1. *Rotting experiments in the laboratory*

Rotting experiments have been carried out with fungi isolated from the stumps in order to get some idea of their activity in the break down of wood under standard conditions.

The sap and heart wood of Scots pine (*Pinus silvestris*) and Norway spruce (*Picea abies*) were subjected to rotting by the soil-block method (HUNT and GARRATT 1953) using ordinary garden soil. Five samples were used for each test on sap wood and four for each test on heart wood. Each sample was $2 \times 2 \times 2$ cm.

The water content of the wood probably plays an important role in the ability of a fungus to attack the wood. Since it is difficult to carry out experiments in which the water content of the wood is controlled exactly, two completely different moisture ranges were used. In one set the specimens were placed above the soil on small thin sheets of wood. In the other the specimens were buried in the earth so that only one or two mm were visible above the soil; in this case the bottles were inoculated after sterilisation, with a mycelium suspension (the contents of a Petri-dish were finally ground and dispersed in 100 ml of sterile water and 5 ml was spread with a pipette over the surface of the soil).

The rotting experiments were run for four months. The water content of the samples was determined and the loss of weight of the specimens was taken as a measure of the extent of attack by the fungus. The results obtained are given in tables 18 and 19 and in fig. 17. It is clear that the fungus has attacked the specimens buried in the soil more than the specimens lying

above and probably the moisture content of the samples which were buried was more favourable for the fungus. According to the detailed investigations made by BJÖRKMAN (1946) most rot fungi require a relatively high water content in the substrate although the range is rather wide. The tables show that pine sapwood was more strongly attacked than heart, but no definite differences were observed between spruce sapwood and heartwood. The pine heartwood is protected by the pinosylvin phenols but there are no corresponding fungicidal substances in spruce (RENNERFELT and NACHT 1955).

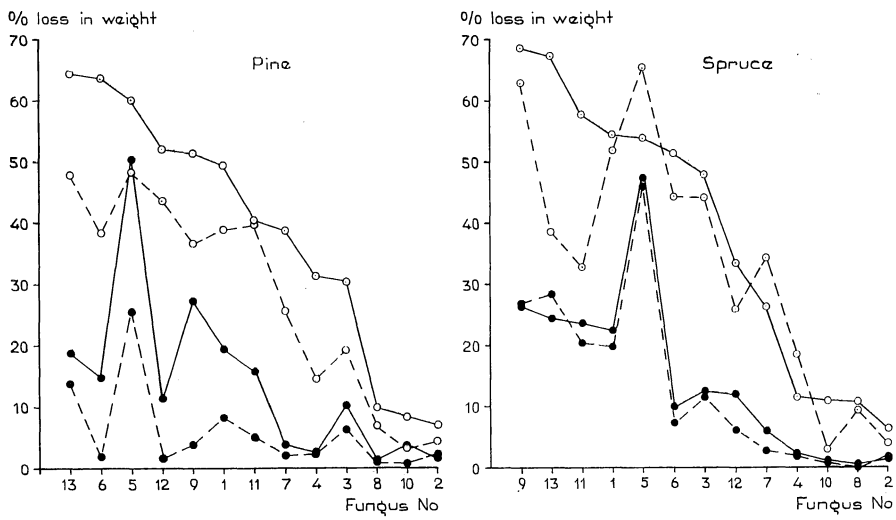

Fig. 17. Per cent loss in weight caused by stump fungi attack on wood from Scots pine and Norway spruce. Fungi (tables 18, 19) arranged in order of decreasing attack on sapwood in soil.

○——○ sapwood } in ●——● sapwood } above
○- - -○ heartwood } soil ●- - -● heartwood } soil

There are considerable differences in the strength of attack by the different fungi. High weight losses (greater than 30 %) were caused by *Peniophora gigantea, Fomes pinicola, Polyporus borealis, Lenzites sepiaria, Fomes annosus* and the two hitherto unknown rot fungi, type I and type X. On the other hand *Trechispora Brinkmanni, Stereum sanguinolentum, Polyporus abietinus* and *Armillaria mellea* caused only low weight losses. It is difficult to say whether these results will apply directly to stumps. The very common and very active *Peniophora gigantea* should play an important role in the break-down of stumps but a weakly rotting fungus like *Trechispora Brinkmanni* can hardly have any great significance in break-down in spite of its common occurrence.

2. *Stump decay under natural conditions*

The break-down of stumps depends on a number of factors such as the climate, the type and the severity of the infection and the species of the stump. Detailed studies of the course of the decay of a stump have not been made but a number of investigations have been carried out which may be of interest. The material for these investigations was collected from the State forest Bogesund near Stockholm where an area with 0—5 year old stumps was placed at our disposal.

a. Moisture content of the stump wood

The water content of the wood is of very considerable significance in the development of the fungi and a number of investigations have been undertaken on this point using discs sawn out of the stumps partly from the upper part, partly at a level about 20—25 cm from the top of the stump and also from the roots. Test pieces were taken from these discs as shown in fig. 16 and were weighed immediately after cutting on a portable balance and then again after drying to constant weight at 105° C. Sets of samples were taken from 7—8 stumps. The values obtained for moisture content are given in tables 20—22. In freshly felled stumps the moisture content was about the same as in the standing tree (NYLINDER 1950) and was highest in the outer sapwood, somewhat lower in the inner sap and only slightly above the fibre saturation point in the heartwood.

After cutting the moisture content undergoes considerable changes. The values obtained are naturally very dependent on the time of year and on the weather at the time of sampling. The condition of the stump also has an effect. An old rot damaged stump takes up water more readily than a comparatively fresh stump which has not yet been converted to rot wood to any extent. The samples that were collected at different times of the year and under different weather conditions show very clearly this strong increase (or decrease) in water content. It is of particular interest that the moisture content of heartwood, especially in spruce, after only a year is above the levels where a fungal attack might be hindered by lack of water, though on the average the heartwood in both spruce and pine takes up water with considerably more difficulty than the sap.

In root wood the moisture content is high all through (table 22). The low values obtained in a couple of cases are from samples from the outer layers of the wood.

b. Density of the stump wood

The stump is gradually broken down and disappears due to the combined activity of fungi, bacteria and insects. In a very long country like Sweden

the climate will of course have a considerable influence on the time taken for complete break-down. In the south of Sweden spruce stumps for example were strongly decayed after 5—6 years but in the northern parts of the country a stump can last in good condition considerably longer, often more than twenty years. The effect of climate on the course of stump decay has not been systematically studied but some investigations have been carried out at the State forest Bogesund near Stockholm on the infection and break-down of 0—5 year old spruce and pine stumps.

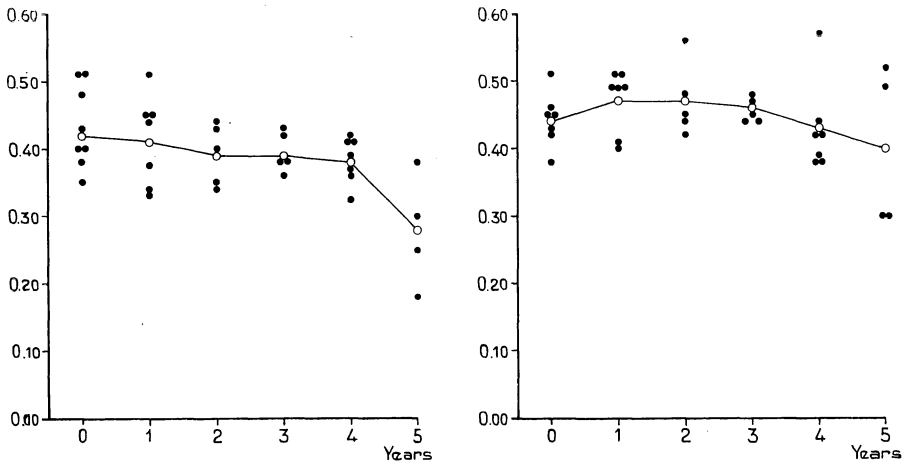

Fig. 18. Densities of stump wood samples, 0—5 years old, left, spruce sapwood; right spruce heartwood (curves connect mean values for each year).

Determinations of the density of stump wood have been used in an attempt to get some idea of how soon the break-down begins. The densities of the stump wood samples investigated are shown in table 23. In spruce sapwood the density falls slowly during the first four years but during the fifth year there is a sharp reduction in the density (fig. 18). According to calculations carried out by the Institute statistical section there is a significant difference between the densities of stumps of 0—4 years old and those of 5 years old ($p < 0.001$). On the other hand no significant difference could be detected in spruce heartwood over the five year period. Because of the greater difficulty of water absorption, rotting does not begin nearly as rapidly in heartwood as in the sapwood and the rotting process is probably also slower even when it has begun.

Conditions in the break-down of a pine stump are rather complicated. During the first five years there was no marked reduction in the density of the stump (table 23). On the contrary in a number of cases the density

rose. Closer examination showed that this was connected with an enrichment of resin in the stumps. As shown in fig. 19 and table 24 the sapwood in fresh stumps and those that are one or two years old usually has little resin. In some stumps however (in the present material in a four and a five year old stump) the resin content of the sapwood was surprisingly high. The maximum was found in the sapwood of a 5 year old pine stump which had no less than 35.2 % of resin, corresponding to 232 g/dm³. This high resin content gives a high density. Thus the sapwood of a resinous 4 year old pine stump had a

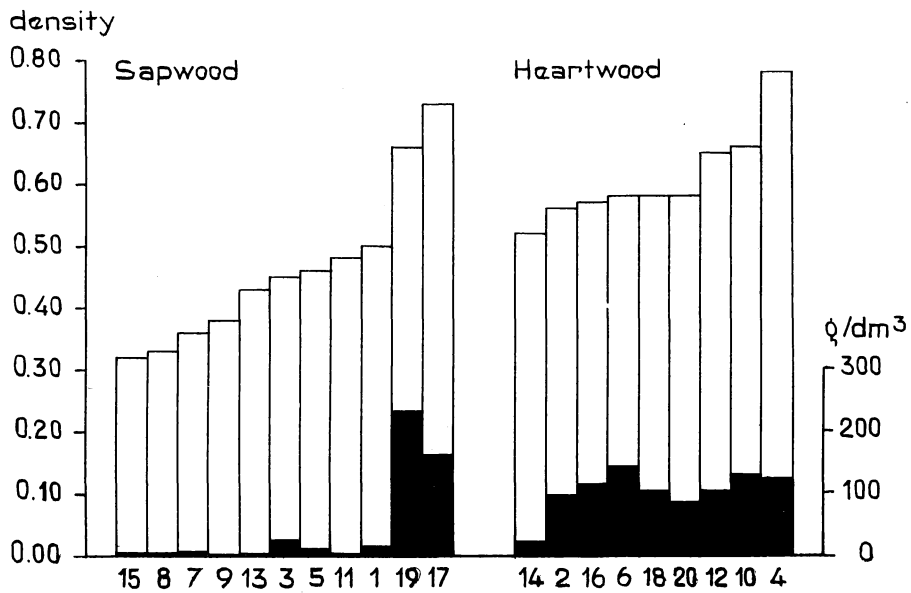

Fig. 19. Density (full column) and resin content (shaded column) of pine stump sapwood and heartwood (cf. table 24).

density of 0.73 while a low-resin pine stump of the same age had a density no higher than 0.32. This high resin content has also impeded the decay of the stump wood.

Plate XV: 2 shows a highly resinous five year old stump (table 24, T: E 2). The wood was little attacked by fungi although there were extensive passages made by larvae of certain longicorn beetles in both sapwood and heartwood. In stumps with low resin content the sapwood is at least in part strongly attacked after five years (Plate XV: 1).

The heartwood of the stumps examined had, even at the beginning, a considerably higher average figure for resin content (table 24, fig. 19). Only one of the samples had little resin but none of the samples analysed had a resin

content as high as the maximum found in some of the sapwood samples. Probably however the resin content of the heartwood also can increase after felling. The heartwood of one very resinous 3 year old stump had a density as high as 1.04.

The heartwood of pine stumps is surprisingly resistant to the attack of fungi. This is apparent from *e.g.* Plate XIV which shows more or less strong attack on the sapwood while the heartwood is almost free from fungal attack. However in a number of cases the insect attack in the heartwood is very conspicuous. The greater resistance of pine heartwood to the attack of rot fungi is partly due to its resistance to water absorption (table 21) and partly also to the high average resin content and especially to the occurrence of the fungicidal pinosylvin phenols (RENNERFELT and NACHT 1955).

c. Infection and break-down

With the exception of *Armillaria mellea* which apparently always grows up from the roots towards the top of the stump and possibly of *Fomes annosus* which in a number of cases perhaps also infects stumps in the same way, the infection of the stumps should be due to airborne spores which settle on the stumps and find more or less good conditions for germination there.

The stumps are presumably uniformly infected over the whole of the surface but it appears as though the infection, at least on spruce, can flourish most easily in an area around the inner part of the sapwood bordering the heartwood. Probably the moisture conditions are most favourable in this part of the stump. The moisture content of the heart is too low and in the outer sap perhaps too high at the beginning. In addition the resin flow in the outer part of the sap is often so high that it should be able to hinder germination effectively (Plate VI). During the whole of the first year after felling or at least a large part of it the cambium layer of a spruce stump is still living and the wood has a fresh yellowish white colour. An infection would thus have considerable difficulty in penetrating down between the bark and the wood. On the other hand *Armillaria* can grow from below almost to the rim of the stump during the first year (fig. 12). The development of the infection on spruce stumps can be followed in Plate VII: 1. During the first year, point infection develops in several places in the bordering region between the sapwood and the heartwood. The fungus mycelium will already have penetrated to a considerable depth down into the wood. The stump in Plate VII: 2 has been exposed to heavier infection but even in this case the infection is most clearly developed in the inner sapwood.

The further development of the infection can be studied in Plates VIII—XI. The sapwood gradually breaks up but the heartwood is more resistant.

The root wood seems to rot more slowly (Plate X: 2). This is probably due to the high moisture content of the root wood which allows the rot fungi to grow only slowly.

In pine stumps the bark loosens more rapidly and in thick-barked stumps a crack may develop even in the first year between the wood and the bark so that infection can penetrate and further hasten the loosening of the bark. *Peniophora gigantea* for instance is very frequently found in this type of situation during the first year (table 3, Plate II: 1) but usually there is no apparent rot in the sapwood (Plate XII: 1).

During the second year the infection of the stump is more extensive and visible break-down has already begun in localised patches (Plate XII: 2). This process then progresses steadily as in Plates XIII—XV. The sharp boundary between the attack of the fungus on the sapwood and on the heartwood is very conspicuous.

In roots the decay begins in the upper parts but here also the heartwood remains intact for a long time (Plate XVI).

Summary

Stump wood which is on the average about 30 % of the volume of the tree (table 1) is rapidly infected by a large number of fungi. The most important of these in the break-down of the stump are the rot fungi. About 25 different rot fungi have been isolated from 1—5 year old spruce and pine stumps. The mycelia and fruiting bodies of these fungi are described in detail in part I. A large number of blue stain fungi, moulds, *fungi imperfecti* etc. have also been isolated and are briefly mentioned.

The frequencies of occurrence of sporophores on stumps are given in part II (tables 2—4). *Armillaria mellea* appears rapidly on spruce stumps and a high percentage of stumps already show attack after one year. The stump fungi are dominated by *Peniophora gigantea, Trechispora Brinkmanni, Polyporus abietinus* and *Stereum sanguinolentum* which were all found on more than 20 % of the stumps examined. There was a somewhat greater number of species of fungi on spruce than on pine stumps. *Peniophora gigantea* was very common on pine.

The fungal flora was also investigated by culturing the mycelia from boring cores taken under sterile conditions from the stumps (part III—IV, tables 6—17). The slow growing *Armillaria* mycelium was found only in a few cases. *Fomes annosus* was isolated from a large number of boring cores from stumps with forest rots but only from a small number of stumps from healthy trees. The most common fungi found in the boring cores were *Peniophora gigantea, Trechispora Brinkmanni* and *Stereum sanguinolentum*. A larger number of fungi were isolated from the upper part of the stumps than from the lower part.

The ability of different stump fungi to attack spruce and pine wood has been investigated in the laboratory (part V: 1, tables 18—19). A high weight loss was caused by *Peniophora gigantea, Fomes pinicola, Polyporus borealis, Lenzites sepiaria* and *Fomes annosus* while *Trechispora Brinkmanni* and *Stereum sanguinolentum* caused only slight loss in weight. Attack was more rapid in specimens kept under moist conditions. Pine heartwood was attacked less than the sap but in spruce there was little difference in resistance between heart and sap.

The natural breakdown of the stumps is discussed in part V: 2. The moisture content of the wood is very important here and it can be seen from table 20—22 that it may vary within very wide limits, much greater than those in the standing tree. The moisture content is of course very dependent on variations in the weather and the condition of the stump.

The course of the breakdown of the stump has been investigated by determination of the density of the dry wood (table 23). After five years a more general degradation of the sapwood of the spruce stumps has set in. In pine stumps the breakdown is complicated in some cases by the formation of resin in large amounts (table 24). In these very resinous stumps there may be an increase in the density of the dry wood and the rot fungi may have difficulty in breaking down the wood though on the other hand, this resinous wood is no hindrance to some insects.

It might be supposed that the surface of the stumps is uniformly infected by the spores floating in the air. It appears however as if the spores have difficulty germinating in the outer parts of the sapwood and in the central heartwood. This may be due to the copious flow of resin in the sapwood, to the low moisture content of the heartwood and in the case of pine to poisonous substances in the heartwood. The first appearance of the infection and the progressive breakdown of 1—5 year old spruce and pine stumps can be studied more closely in Plates VI—XVI.

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We should like to thank Forest officer M. MALMGÅRD, Stockholm, Forest District Commissioner and Forest ranger G. LINDH, Bogesund, for indicating the areas where material from stumps of different ages could be collected.

Dr. MILDRED K. NOBLES, Ottawa, has very generously identified some of the mycelia isolated from stumps and *Trechispora Brinkmanni* was identified by Dr. J. ERIKSSON, Uppsala. Some determinations of the resin content in stump wood were carried out by fil. lic. NILS STJERNSTRÖM, Kungl. Tekniska Högskolan, Stockholm. For this valuable help we wish to express our sincere thanks.

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In this investigation Part I is written by KÄÄRIK , Part II—IV by KÄÄRIK and RENNERFELT and Part V by RENNERFELT.

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Sammanfattning

Undersökningar över svampfloran i gran- och tallstubbar

Stubbveden, som i medeltal utgör omkring 30 % av ett träds fastmassevolym (tab. 1) blir snabbt infekterad med ett stort antal svampar. Av dessa spelar för stubbens nedbrytning rötsvamparna den viktigaste rollen. Omkring 25 olika

rötsvampar ha isolerats i gran- och tallstubbar i en ålder mellan ett och fem år. I kap. I lämnas en närmare beskrivning av dessa rötsvampars mycel och fruktkroppar m. m.

I kap. II (tab. 2—4) redogöres för frekvensen av fruktkroppar på stubbarna. *Armillaria mellea* uppträder snabbt på granstubbar. Redan efter ett år kunna stubbarna förete en hög angreppsprocent. Av egentliga stubbsvampar dominera *Peniophora gigantea, Trechispora Brinkmanni, Polyporus abietinus* och *Stereum sanguinolentum,* som alla påträffats på mer än 20 % av de undersökta stubbarna. Antalet svamparter synes vara något större på gran- än på tallstubbar. På sistnämnda trädslag är *Peniophora gigantea* mycket vanlig.

Svampfloran undersöktes även genom framodling av mycel ur borrkärnor, som uttagits sterilt ur de olika stubbarna (kap. III—IV, tab. 6—17). Det långsamt växande *Armillaria*-mycelet erhölls blott i ett mindre antal fall. *Fomes annosus* växte ut i stort antal ur borrkärnor tagna ur stubbar med skogsröta, däremot blott i mindre antal ur borrkärnor från vid avverkningen friska stubbar. De vanligaste svamparna i borrproven voro *Peniophora gigantea, Trechispora Brinkmanni* och *Stereum sanguinolentum.* Från stubbarnas övre del isolerades ett större antal kulturer än från stubbarnas nedre delar.

I laboratorieförsök har stubbsvamparnas förmåga att angripa gran- och tallved undersökts (kap. V: 1, tab. 18—19). Hög viktförlust förorsakade bl. a. *Peniophora gigantea, Fomes pinicola, Polyporus borealis, Lenzites sepiaria* och *Fomes annosus,* medan t. ex. *Trechispora Brinkmanni* och *Stereum sanguinolentum* endast förorsakade en ringa viktförlust. Angreppet försiggick snabbare i fuktigt förvarade vedprov. Kärnved av tall angreps i mindre omfattning än splintved. Hos gran funnos inga större skillnader mellan resistensen hos splint- och kärnved.

I kap. V: 2 har den naturliga nedbrytningen av stubbarna studerats. En mycket viktig faktor härvidlag är fuktkvoten i stubbveden. Av tab. 20—22 framgår, att denna i stubben varierar inom mycket vida gränser, större än de som finnas i det rotstående trädet. Fuktkvoten är givetvis starkt beroende av variationer i väderleken och av stubbens beskaffenhet.

Nedbrytningens förlopp har undersökts genom bestämning av torrvolymvikten (tab. 23). Efter fem år synes en mera allmän nedbrytning av granstubbarnas splintved ha kommit igång. Hos tallstubbarna kompliceras nedbrytningen genom en i vissa fall mycket riklig produktion av harts (tab. 24). Hos dylika hartsrika stubbar kan i stället en kraftig ökning av torrvolymvikten konstateras och rötsvamparna synas ha stora svårigheter att bryta ned veden. För vissa insekter däremot utgör den hartsrika veden intet hinder.

Man torde få antaga, att stubbarnas hela yta blir likformigt infekterad av de i luften kringflygande sporerna. Det förefaller emellertid, som om sporerna hade vissa svårigheter att gro ut i splintens yttre delar och i den centrala kärnveden. Detta kan dels bero på rikligt kådflöde i splintveden och på låg fuktkvot i kärnveden jämte hos tallen även förekomst av giftiga kärnvedssubstanser. Infektionens första uppträdande och den alltmer fortskridande nedbrytningen hos 1—5-åriga gran- och tallstubbar kan närmare studeras på fotografierna på planscherna VI—XVI.

TABLES
and
PLATES

Tab. 1. Stump wood as a percentage of the trunk with bark, normal stump height.
(From Praktisk Skogshandbok 1938)

Soil type	Spruce	Pine
Fresh sandy moraine	24	21
Humus-rich fresh moraine	37	24
Somewhat swampy moraine	42	27
Swampy clay	41	35
Drained peat	61	36
Pure Sphagnum bog	—	53
Average	31	31

Table. 2. Fruiting bodies on 1—5 years old spruce stumps.

Fungus	Situation on the stump	Percentage of stumps with fruiting bodies				
		Age of stumps, years				
		1	2	3	4	5
Armillaria mellea	top	11	5	10	3.3	8
	base	25	46	73	89	84
Peniophora gigantea	t	3	66	69	23	28
	b	7	14	12	26	24
Trechispora Brinkmanni	t	1.5	19	22	6.5	20
	b	2	5	—	3.3	12
Polyporus abietinus	t	—	41	36	9.6	20
	b	—	28	20	—	56
Stereum sanguinolentum	t	4	22	20	9.6	—
	b	1.5	3	—	3.3	—
Coniophora spp.	t	—	10	27	16	—
	b	1	1.3	1.7	9.6	12
Trametes serialis	t	—	—	1.7	9.6	16
	b	—	—	—	—	8
Poria mollusca	t	—	—	3.4	—	—
	b	—	—	1.7	3.3	4
Lenzites sepiaria	t	—	4	—	3.3	—
	b	—	1.3	—	—	—
Fomes pinicola	t	—	3	—	6.5	—
	b	—	—	—	—	—
Polyporus fuliginosus	t	—	1.3	8.4	3.3	—
	b	—	—	1.7	—	—
» *amorphus*	t	—	—	14	3.3	4
	b	—	—	3.4	—	—
Merulius molluscus	t	—	—	5.0	—	—
	b	—	—	—	—	—
Corticium læve	t	—	—	6.7	9.6	12
	b	—	—	—	3.3	—
Poria sanguinolenta	t	—	—	1.7	—	—
	b	—	—	—	—	—
Pleurotus mitis	t	—	5	—	—	—
	b	—	—	—	—	—
Tremellaceæ spp.	t	—	—	17	3.3	—
	b	—	—	—	3.3	—
Trametes heteromorpha	t	—	—	—	6.5	—
	b	—	—	—	—	—
Polyporus borealis	t	—	—	—	—	12
	b	—	—	—	—	4
Hypholoma fasciculare	t	—	—	—	—	4
	b	—	—	—	—	—
Paxillus atrotomentosus	t	—	—	—	—	—
	b	—	—	—	—	4
Unidentified	t	—	—	3.4	—	12
	b	—	3	3.4	—	8

Table 3. Fruiting bodies on 1—5 years old pine stumps.

Fungus	Situation on the stump	Percentage of stumps with fruiting bodies				
		Age of stumps, years				
		1	2	3	4	5
Armillaria mellea	top	—	—	—	2.7	—
	base	8	28	9.5	5.5	16
Peniophora gigantea	t	92	100	90	75	40
	b	40	48	55	22	36
Trechispora Brinkmanni	t	8	12	17	22	20
	b	—	—	2.4	2.7	12
Polyporus abietinus	t	4	16	12	8	16
	b	4	4	19	—	48
Stereum sanguinolentum	t	—	—	—	16	—
	b	—	—	—	14	—
Coniophora spp	t	—	4	14	22	—
	b	—	—	—	5.5	—
Polyporus amorphus	t	—	—	2.4	2.7	8
	b	—	—	2.4	—	4
Trametes serialis	t	—	—	—	14	4
	b	—	—	—	—	8
Poria mollusca	t	4	—	14	—	—
	b	—	—	—	—	—
Merulius molluscus	t	—	—	—	5.5	4
	b	—	—	—	—	4
Corticium spp	t	—	—	4.8	5.5	4
	b	—	—	—	—	—
Protohydnum	t	—	—	—	—	4
	b	—	—	—	—	—
Hypholoma fasciculare	t	—	—	2.4	2.7	4
	b	—	—	—	—	—
Unidentified	t	—	4	4.8	—	4
	b	—	—	19	2.7	32

Table 4. No. of fruiting bodies on 4 year old pine stumps at Högby Mo.

Fungus	Experimental Plot No.						
	III	V	IX	VII	II	VIII	VI
No. of stumps investigated	53	73	118	36	83	54	52
Stumps without fr. bodies	29	27	12	18	61	29	30
Peniophora gigantea	1	8	20	14	5	11	11
Polyporus amorphus	19	32	1	8	6	8	2
» *abietinus*	2	6	79	4	2	2	3
Corticium læve	2	—	3	3	7	8	5
Trechispora Brinkmanni	—	—	—	6	—	1	—
Polyporus cæsius	—	1	—	2	—	—	—
Pholiota squamosa	—	—	—	1	—	—	—
Corticium	—	—	—	—	—	2	2
Collybia	—	—	—	—	—	1	1
Trametes heteromorpha	—	—	2	—	—	—	—
Peniophora sp	1	—	2	—	—	—	—
Tricholoma	—	5	1	—	2	—	—
Coniophora	2	2	—	—	—	—	—
Not identified	—	2	1	4	—	2	1

Plot III	Moderate	thinning,	low stumps,	Sept. '51
V	»	»	high »	» '51
IX	»	»	» »	March '52
VII	Heavy	»	low »	May '52
II	Moderate	»	wood tar	Sept. '52
VIII	»	»	» »	March '52
VI	»	»	Cuprinol	Sept. '52

Table 5. Number of spruce stumps from different areas.

Area	Stumps sound when cut Age, years				Stumps with root rot Age, years			
	1	2	3	4	1	2	3	4
1. Skåne	57	—	1	—	33	—	9	—
2. Tönnersjöheden	47	64	10	12	46	87	23	3
3. Bogesund	36	15	14	17	9	4	2	—
4. Central Sweden	36	13	—	—	25	—	—	—
5. Värmland	201	26	53	9	191	6	8	5
6. Dalarna	25	7	—	—	35	12	—	—
7. North Sweden	66	8	—	—	49	9	—	—
Total	468	133	78	38	388	118	42	8

Table 6. Frequency of decay fungi in increment cores taken from 1 year old spruce stumps.

	Sound stumps		Stumps with root rot					
			Fomes annosus		*Armillaria mellea*		other root rots	
Number of stumps investigated	468		294		21		73	
Fungus isolated	No.	%	No.	%	No.	%	No.	%
Sterile samples	31	6.6	11	3.7	1	4.7	1	1.3
No decay fungi	120	25,6	61	20,7	8	38,0	36	49,3
Armillaria mellea	10	2.1	10	3.4	3	14.2	7	9.5
Fomes annosus	21	4.4	164	55.7	6	28.5	—	—
Peniophora gigantea	68	14,5	14	4.7	4	19.0	1	1.3
Trechispora Brinkmanni	29	6.1	16	5.4	1	4.7	2	2.7
Stereum sanguinolentum	63	13,4	23	7.8	3	14.2	6	8.2
Polyporus abietinus	9	1.9	4	1.3	—	—	1	1.3
Fomes pinicola	16	3.4	7	2.3	—	—	2	2.7
Trametes serialis	10	2.1	5	1.7	—	—	3	4.1
Peniophora pithya	15	3.2	2	0.7	—	—	—	—
Lenzites sepiaria	4	0.8	7	2.3	—	—	—	—
Polyporus borealis	4	0.8	2	0.7	—	—	5	6.8
Trametes pini	2	0.4	—	—	1	4.7	7	9.5
Corticium læve	6	1.2	2	0.7	—	—	—	—
Coniophora spp.	4	0.8	3	1.0	—	—	—	—
Polyporus stipticus	5	1.0	—	—	—	—	—	—
Corticium spp.	3	0.6	1	0.3	—	—	—	—
Polyporus circinatus	2	0.4	1	0.3	—	—	—	—
Grandinia farinacea	3	0.6	—	—	—	—	—	—
Trametes heteromorpha	2	0.4	—	—	—	—	—	—
Type VI	32	6.8	—	—	—	—	6	8.2
VII	10	2.1	2	0.7	—	—	—	—
X	10	2.1	—	—	—	—	1	1.3
I	5	1.0	—	—	—	—	1	1.3
VIII	1	0.2	—	—	1	4.7	—	—
Not identified	20	4.2	3	1.0	3	14.2	3	4.1

Table. 7 Frequency of decay fungi in increment cores taken from 2 year old spruce stumps.

	Sound stumps		Stumps with root rot					
			Fomes annosus		*Armillaria mellea*		other root rots	
Number of stumps investigated	133		94		4		20	
Fungus isolated	No.	%	No.	%	No.	%	No.	%
Sterile samples	5	3.7	2	2.1	—	—	1	5
No decay fungi	48	36,0	23	24,4	1	—	2	10
Armillaria mellea	1	0.8	1	1.0	1	—	1	5
Fomes annosus	2	1.5	25	26.5	2	—	—	—
Peniophora gigantea	28	21.0	8	8.5	—	—	1	5
Trechispora Brinkmanni	30	22.5	26	27.6	—	—	2	10
Stereum sanguinolentum	15	11.2	8	8.5	—	—	—	—
Polyporus abietinus	8	6.0	6	6.3	—	—	—	—
Fomes pinicola	4	3.0	—	—	—	—	—	—
Trametes serialis	2	1.5	—	—	—	—	1	5
Peniophora pithya	2	1.5	1	1.0	—	—	—	—
Lenzites sepiaria	3	2.2	6	6.3	—	—	—	—
Polyporus borealis	—	—	6	6.3	—	—	—	—
Trametes pini	1	0.8	—	—	—	—	—	—
Corticium læve	3	2.2	1	1.0	—	—	—	—
Coniophora spp	1	0.8	—	—	—	—	—	—
Polyporus amorphus	1	0.8	—	—	—	—	—	—
» *circinatus*	1	0.8	—	—	—	—	—	—
Poria mollusca	1	0.8	—	—	—	—	—	—
Corticium spp	1	0.8	—	—	—	—	—	—
Grandinia farinacea	1	0.8	—	—	—	—	—	—
Type VI	2	1.5	—	—	—	—	—	—
VIII	2	1.5	1	1.0	—	—	—	—
IX	2	1.5	—	—	—	—	—	—
X	1	0.8	—	—	—	—	—	—
Not identified	19	14.2	5	5.3	—	—	5	25

Table. 8. Frequency of decay fungi in increment cores taken from 3 year old spruce stumps.

	Sound stumps		Stumps with root rot					
			Fomes annosus		*Armillaria mellea*		other root rots	
Number of stumps investigated	78		33		4		5	
Fungus isolated	No.	%	No.	%	No.	%	No.	%
Sterile samples	—	—	3	9	—	—	—	—
No decay fungi	25	32.0	13	39	1	—	2	—
Armillaria mellea	3	3.8	—	—	1	—	—	—
Fomes annosus	6	7.6	5	15	—	—	—	—
Peniophora gigantea	7	8.9	2	6	—	—	—	—
Trechispora Brinkmanni	28	36.0	13	39	—	—	—	—
Stereum sanguinolentum	5	6.4	1	3	—	—	1	—
Polyporus abietinus	11	14.1	2	6	1	—	—	—
Fomes pinicola	1	1.3	2	6	—	—	—	—
Trametes serialis	1	1.3	—	—	1	—	—	—
» *pini*	1	1.3	1	3	—	—	—	—
Peniophora pithya	1	1.3	—	—	—	—	—	—
Polyporus borealis	1	1.3	—	—	—	—	—	—
» *circinatus*	1	1.3	—	—	—	—	—	—
Poria mollusca	1	1.3	—	—	—	—	—	—
Corticium læve	2	2.6	—	—	1	—	1	—
» *spp.*	1	1.3	1	3	—	—	—	—
Coniophora spp.	1	1.3	—	—	—	—	—	—
Grandinia farinacea	5	6.4	—	—	—	—	—	—
Type I	1	1.3	—	—	1	—	—	—
X	1	1.3	—	—	—	—	1	—
Not identified	1	1.3	7	21	—	—	1	—

Table 9. Frequency of decay fungi in increment cores taken from 4 year old spruce stumps.

	Sound stumps	Stumps with root rot		
		Fomes annosus	*Arm. mellea*	other root rots
Number of stumps investigated	29	5	—	1
Fungus isolated	No.	No.		No.
Sterile samples	1	—	—	—
No decay fungi	22	5	—	1
Armillaria mellea	—	—	—	—
Fomes annosus	—	—	—	—
Corticium læve	1	—	—	—
Grandinia farinacea	1	—	—	—
Lenzites sepiaria	1	—	—	—
Polyporus borealis	1	—	—	—
Not identified	1	—	—	—

Table 10. Percentage of stumps with root rot divided according to rot species as judged by eye.

Stump age years	No.	*Fomes annosus*		*Armillaria mellea*		Other root rots	
		No.	%	No.	%	No.	%
1	388	294	76	21	5	73	19
2	118	94	80	4	3	20	17
3	42	33	78	4	9	5	13
4	8	7	87	—	—	1	13
Total	556	428	77	29	5	99	18

Table 11. Number of decay fungi on spruce stumps determined in different ways

Stump species	Method of determination	Stump age in years and number of species present				
		1	2	3	4	5
Spruce	Fruiting bodies	5	10	14	15	12
	Mycelia in increment cores	24	22	19	4	—
Pine	Fruiting bodies	5	5	9	11	10
	Mycelia	8	7	3	3	—

Table 12. Frequency of decay fungi in increment cores taken from pine stumps sound when cut.

	Age of stumps, years							
	1		2		3		4	
Number of stumps investigated	101		61		29		19	
Fungus isolated	No.	%	No.	%	No.	%	No.	%
Sterile samples	12	12	1	1.6	—	—	—	—
No decay fungi	17	17	21	34	14	48	13	68
Armillaria mellea	1	1	1	1.6	—	—	—	—
Fomes annosus	—	—	—	—	—	—	—	—
Peniophora gigantea	56	56	36	59	11	38	3	16
Trechispora Brinkmanni	7	7	4	7	4	14	—	—
Stereum sanguinolentum	7	7	—	—	—	—	1	5
Trametes serialis	3	3	—	—	—	—	—	—
Fomes pinicola	1	1	1	1.6	—	—	—	—
Corticium læve	2	2	—	—	—	—	—	—
Coniophora spp	1	1	—	—	—	—	—	—
Polyporus abietinus	—	—	—	—	1	3	—	—
» *stipticus*	—	—	1	1.6	—	—	—	—
Trametes pini	—	—	1	1.6	—	—	—	—
Stereum pini	—	—	1	1.6	—	—	—	—
Grandinia farinacea	—	—	—	—	—	—	1	5
Not identified	6	6	3	5	1	3	1	5

Table 13. Frequency of decay fungi in increment cores taken from spruce stumps treated with chemicals.

	Age of stumps, years		
	1	2	3
Number of stumps investigated	14	42	42
Fungus isolated	No.	No.	No.
Sterile samples	—	—	—
No decay fungi	4	18	5
Armillaria mellea	—	—	—
Fomes annosus	2	1	—
Peniophora gigantea	—	8	—
Trechispora Brinkmanni	—	2	16
Stereum sanguinolentum	3	8	1
Polyporus abietinus	1	2	12
Trametes serialis	—	—	2
Fomes pinicola	1	2	1
Lentinus lepideus	—	—	3
Lenzites sepiaria	1	1	2
Polyporus borealis	—	—	1
» *stipticus*	—	—	1
Trametes pini	1	—	—
Corticium sp.	—	—	1
Poria sp.	1	—	—
Type III	—	—	1
Not identified	3	4	6

Table 14. Frequency of decay fungi in increment cores taken from pine stumps treated with chemicals.

	Age of stumps, years		
	1	2	3
Number of stumps investigated	20	39	15
Fungus isolated	No.	No.	No.
Sterile samples	—	—	—
No decay fungi	10	7	7
Armillaria mellea	—	—	—
Fomes annosus	—	—	—
Peniophora gigantea	4	9	1
Trechispora Brinkmanni	—	—	4
Stereum sanguinolentum	—	4	1
Polyporus abietinus	—	6	1
Fomes pinicola	—	2	—
Lenzites sepiaria	—	4	—
Coniophora spp.	5	2	—

Table 15. Decay fungi grown on malt extract agar from increment cores taken at the top and at the base of spruce stumps which were sound when cut.

Number of samples	1-year stumps 114				2-year stumps 25				3-year stumps 50				4-year stumps 13			
Fungi isolated	top		base		top		base		top		base		top		base	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Sterile samples	—	—	2	1.8	3	12	—	—	—	—	—	—	—	—	—	—
No decay fungi	21	18.4	64	56.1	3	12	9	36	12	24	24	48	8	62	5	38
Armillaria mellea	2	1.8	8	7.0	—	—	1	4	3	6	4	8	—	—	—	—
Fomes annosus	7	6.1	9	7.8	—	—	—	—	5	10	6	12	—	—	1	8
Peniophora gigantea	18	15.7	14	12.2	3	12	8	32	4	8	1	2	—	—	2	15
Trechispora Brinkmanni	7	6.1	2	1.8	8	32	5	20	24	48	11	22	—	—	2	15
Stereum sanguinolentum	26	22.8	6	5.3	4	16	2	8	4	8	3	6	3	23	3	23
Polyporus abietinus	4	3.5	2	1.8	5	20	4	16	7	14	2	4	—	—	1	8
Fomes pinicola	3	2.6	1	0.9	1	4	1	4	—	—	—	—	—	—	—	—
Polyporus borealis	1	0.9	1	0.9	—	—	—	—	1	2	—	—	1	8	—	—
» *stipticus*	5	4.4	1	0.9	—	—	—	—	—	—	—	—	—	—	—	—
Corticium alutaceum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
» *læve*	1	0.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—
» *spp.*	2	1.8	1	0.9	—	—	—	—	5	10	2	4	—	—	—	—
Lenzites sepiaria	—	—	1	0.9	—	—	—	—	—	—	—	—	1	8	—	—
Trametes serialis	6	5.3	1	0.9	1	4	—	—	—	—	—	—	2	15	—	—
» *heteromorpha*	2	1.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
» *pini*	—	—	—	—	—	—	—	—	2	4	—	—	—	—	—	—
Coniophora spp.	2	1.8	—	—	—	—	—	—	—	—	1	2	—	—	1	8
Grandinia farinacea	3	2.6	—	—	1	4	1	4	—	—	1	2	1	8	—	—
Peniophora pithya	9	7.8	2	1.8	—	—	—	—	—	—	—	—	—	—	—	—
Polyporus amorphus	—	—	—	—	1	4	—	—	—	—	—	—	—	—	—	—
» *circinatus*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poria mollusca	1	0.9	—	—	—	—	—	—	1	2	—	—	—	—	—	—
Type I	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	—
III	—	—	1	0.9	—	—	—	—	—	—	—	—	—	—	—	—
VI	16	14.0	4	3.5	—	—	—	—	—	—	—	—	—	—	—	—
VII	2	1.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
VIII	—	—	1	0.9	2	8	—	—	—	—	—	—	—	—	—	—
IX	—	—	—	—	1	4	—	—	—	—	—	—	—	—	—	—
X	5	4.4	1	0.9	—	—	—	—	—	—	—	—	—	—	—	—
Not identified	5	4.4	—	—	2	8	1	4	—	—	2	4	1	8	—	—

Table 16. Number of decay fungi in increment cores taken at the top and at the base of spruce stumps.

Situation	Age of stumps, years							
	1		2		3		4	
	Total No.[1]	per core	Total No.[1]	per core	Total No.[1]	per core	Total No.[1]	per core
Top	127	1.1	29	1.2	57	1.1	9	0.7
Base	56	0.5	23	0.9	33	0.7	10	0.8

[1] The total number of species growing from each core was counted and all these totals were added to give this figure (cf. Table 15).

Table 17. Decay fungi grown on malt extract agar from increment cores taken at the top and at the base of pine stumps from healthy trees.

	1-year stumps		2-year stumps		3-year stumps		4-year stumps	
Number of samples	31		16		19		14	
Fungus isolated	top	base	top	base	top	base	top	base
Sterile samples	—	—	—	—	—	—	—	—
No decay fungi	7	9	1	2	12	7	10	11
Armillaria mellea	—	—	—	—	—	—	—	—
Fomes annosus	—	1	—	1	—	—	—	—
Peniophora gigantea	18	17	14	13	5	6	2	2
Trechispora Brinkmanni	4	—	2	—	2	2	—	1
Stereum sanguinolentum	—	—	—	—	1	—	—	—
Polyporus abietinus	—	—	—	—	—	2	—	—
Trametes serialis	2	—	—	—	—	—	—	—
Corticium læve	2	2	—	—	—	—	—	—
Polyporus stipticus	—	—	1	—	—	—	—	—
Grandinia farinacea	—	—	—	—	—	1	1	—

Table 18. Loss in weight and moisture content of wood blocks attacked by different stump decay fungi. Wood blocks above the soil.

No.	Fungus	Loss in weight, %				Moisture content, %			
		Scots pine		Norway spruce		Scots pine		Norway spruce	
		sap-wood	heart-wood	sap-wood	heart-wood	sap-wood	heart-wood	sap-wood	heart-wood
1	*Peniophora gigantea*	19.3	8.1	22.4	19.8	39	37	44	42
2	*Trechispora Brinkmanni*	1.5	2.1	1.3	1.5	41	32	66	42
3	*Stereum sanguinolentum*	10.1	6.2	12.4	11.5	51	36	55	54
4	*Polyporus abietinus*	2.5	2.3	2.2	1.7	32	32	30	30
5	*Fomes pinicola*	50.2	25.4	47.3	45.9	91	58	79	86
6	*Polyporus borealis*	14.9	1.7	9.9	7.1	46	31	42	38
7	*Polyporus stipticus*	3.6	2.0	5.7	2.6	33	30	42	33
8	*Corticium alutaceum*	1.2	0.9	0.2	0	31	30	33	32
9	*Lenzites sepiaria*	27.1	3.8	26.3	26.7	65	34	60	59
10	*Armillaria mellea*	3.5	0.7	0.9	0.5	55	38	40	43
11	*Fomes annosus*	15.8	5.0	23.5	20.4	63	40	62	59
12	St 47, type I	11.4	1.5	11.9	6.0	42	32	45	37
13	St 256, type X	18.7	13.7	24.4	28.2	39	36	48	48
	Average	13.8	5.6	14.5	13.2	48	36	50	46

Table 19. Loss in weight and moisture content of wood blocks attacked by different stump decay fungi. Wood blocks in the soil.

No.	Fungus	Loss in weight, %				Moisture content, %			
		Scots pine		Norway spruce		Scots pine		Norway spruce	
		sap-wood	heart-wood	sap-wood	heart-wood	sap-wood	heart-wood	sap-wood	heart-wood
1	*Peniophora gigantea* ...	49.2	38.8	54.2	51.8	76	72	70	85
2	*Trechispora Brinkmanni*	6.9	4.1	6.1	3.9	106	92	109	101
3	*Stereum sanguinolentum*	30.1	19.1	47.9	44.0	87	92	78	95
4	*Polyporus abietinus*	31.3	14.5	11.5	18.5	183	156	126	153
5	*Fomes pinicola*	60.0	48.1	53.7	65.2	191	155	187	181
6	*Polyporus borealis*	63.5	38.1	51.3	44.2	193	192	197	232
7	*Polyporus stipticus*	38.6	25.5	26.1	34.1	145	151	130	144
8	*Corticium alutaceum* ...	9.8	6.7	10.6	9.2	106	92	108	75
9	*Lenzites sepiaria*	51.2	36.5	68.5	62.9	174	76	211	239
10	*Armillaria mellea*	8.4	3.1	10.9	2.9	62	49	58	69
11	*Fomes annosus*	40.2	39.6	57.6	32.7	124	106	190	184
12	St 47, type I.....	52.0	43.5	33.3	25.7	123	156	92	145
13	St. 256, type X.....	64.4	47.6	67.1	38.5	135	125	111	79
	Average	39.0	28.1	38.5	33.6	131	116	128	137

Table 20. Moisture content in spruce stumps of different age.

Age, years	Per cent moisture content		
	outer sapwood	inner sapwood	heartwood
	min. av. max.	min. av. max.	min. av. max.
0	103...148...195	80...122...160	31...34...37
1	30...160...215	42...170...235	29...48...115
2	16... 67...168	25... 78...171	19...40... 72
3	28... 78...178	38... 75...130	33...56... 95
4	24... 53...130	27... 48... 96	25...34... 52
5	29... 75...180	46...137...206	27...42... 64

Table 21. Moisture content in pine stumps of different age.

Age, years	Per cent moisture content		
	outer sapwood	inner sapwood	heartwood
	min. av. max.	min. av. max.	min. av. max.
0	125...132...140	51... 99...137	27...28... 30
1	42... 68...104	56... 78...122	24...26 .. 29
2	29... 64...120	23... 72...106	29...35... 44
3	47...112...147	83...150...201	20...30... 40
4	15... 71...184	231...255...278	17...50...106
5	42... 88...187	35...100...181	37...46... 83

Table 22. Moisture content in stump roots of different age.

Age, years	Per cent moisture content					
	Spruce			Pine		
	min.	av.	max.	min.	av.	max.
0	33	79	132	42	129	170
1	79	138	241	98	129	154
2	53	128	187	42	103	148
3	41	101	157	97	128	146
4	27	77	180	99	140	201
5	42	103	144	86	160	237

Table 23. Density of wood from spruce and pine stumps.

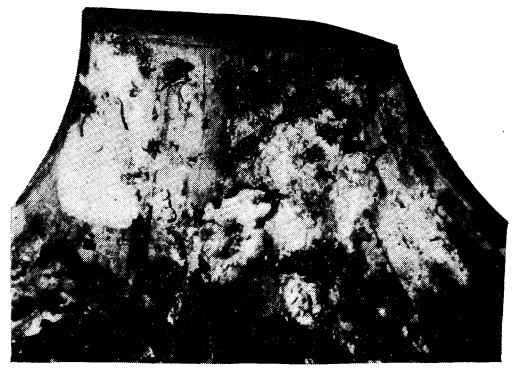
Age, years	Density						Number of samples							
	Spruce			Pine			Spruce				Pine			
	sap-wood	heart-wood	roots	sap-wood	heart-wood	roots	stumps	sap-wood	heart-wood	roots	stumps	sap-wood	heart-wood	roots
0	0.42	0.47	0.45	0.49	0.54	0.50	7	30	11	16	6	26	7	16
1	0.41	0.47	0.43	0.53	0.58	0.43	7	22	14	10	7	31	13	8
2	0.39	0.47	0.39	0.55	0.53	0.49	5	42	11	4	5	32	16	6
3	0.39	0.46	0.45	0.45	0.67	0.45	5	24	7	6	7	39	16	6
4	0.38	0.43	0.42	0.54	0.61	0.44	7	34	14	10	6	26	14	7
5	0.28	0.40	0.34	0.54	0.55	0.51	4	13	6	4	6	20	6	4

Table 24. Density and resin content of some pine stump samples.

Sample No.	Stump	Stump age, years	Type of wood	Density	Extract	
					%	g/dm³
1	T: F 1	0	sap	0.50	3.0	15
2			heart	0.56	17.6	99
3	T: F 2		s	0.45	5.7	26
4			h	0.78	16.2	126
5	T: D 1	1	s	0.46	2.3	11
6			h	0.58	24.4	142
7	T: A 1	2	s	0.36	2.6	8.3
8			s	0.33	1.7	5.6
9	T: C 3	3	s	0.38	0.7	2.7
10			h	0.66	19.7	130
11	T: C 4		s	0.48	0.5	2.4
12			h	0.65	16.2	105
13	T: C 10		s	0.43	0.8	3.4
14			h	0.52	4.2	22
15	T: B 1	4	s	0.32	1.9	6.1
16			h	0.57	20.2	117
17	T: B 3		s	0.73	22.1	161
18			h	0.58	17.9	104
19	T: E 2	5	s	0.66	35.2	232
20			h	0.58	14.6	85

Plate I.

1



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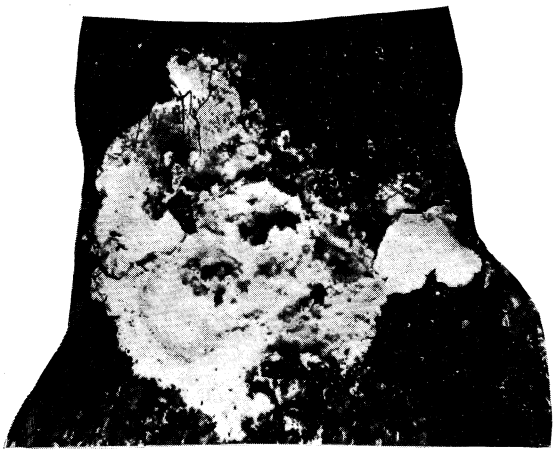

3

4

Plate I. Mycelium and sporophores of *Peniophora gigantea:* 1) on a 2 year old pine stump, 2) on a 4 year old pine stump, 3) on the bark of a 2 year old pine stump, 4) on a 4 year old spruce stump.

Plate II.

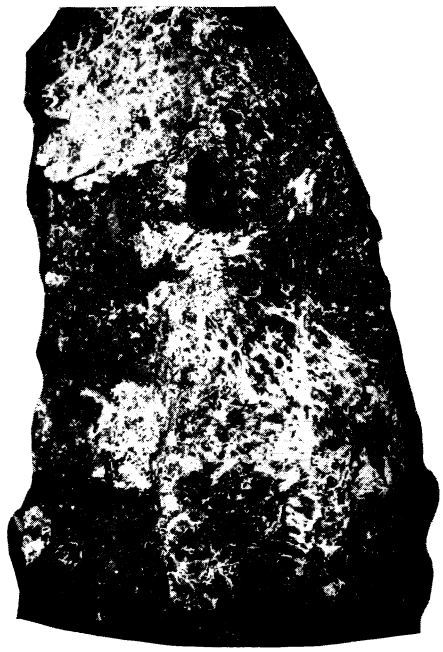

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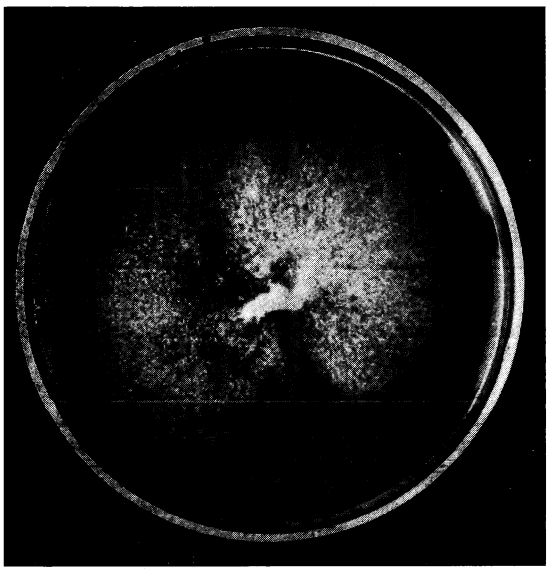
Plate II. 1—2: Mycelium of *Peniophora gigantea* on pine stump bark, 1) one year, 2) two year old bark.
3) Mycelium of *Corticium laeve* on a 4 year old spruce stump, 4) sporophore of *Polyporus amorphus* on a 4 year old spruce stump.

Plate III.



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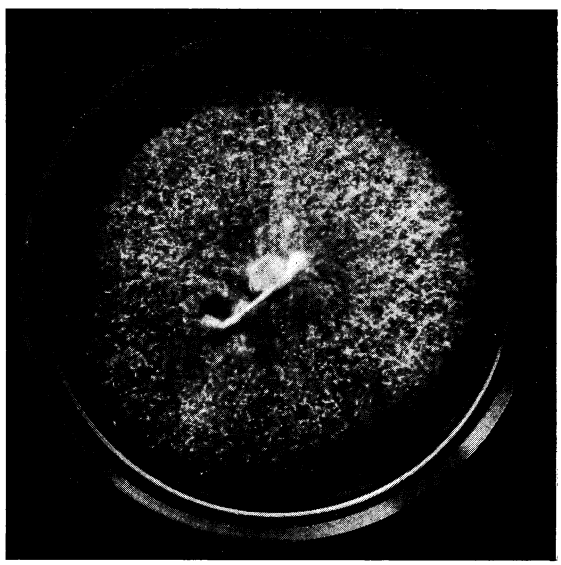
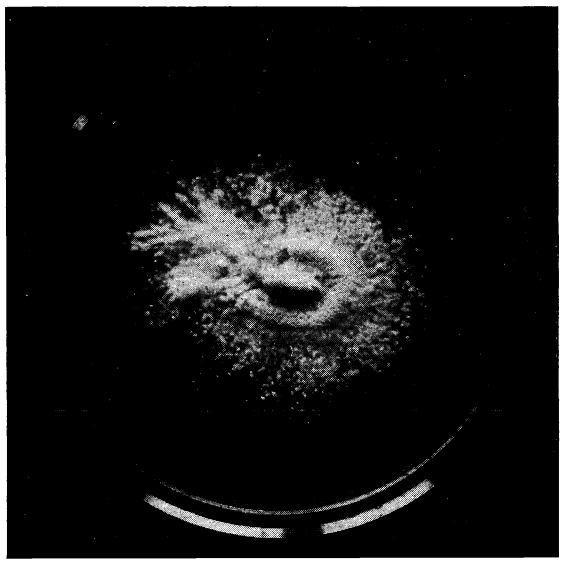


4

Plate III. Mycelium cultures about 10 days old on malt agar at 22° C; 1) *Peniophora gigantea*, 2) *Trechispora Brinkmanni*, 3) *Stereum sanguinolentum*, 4) *Fomes pinicola*.

Plate IV.



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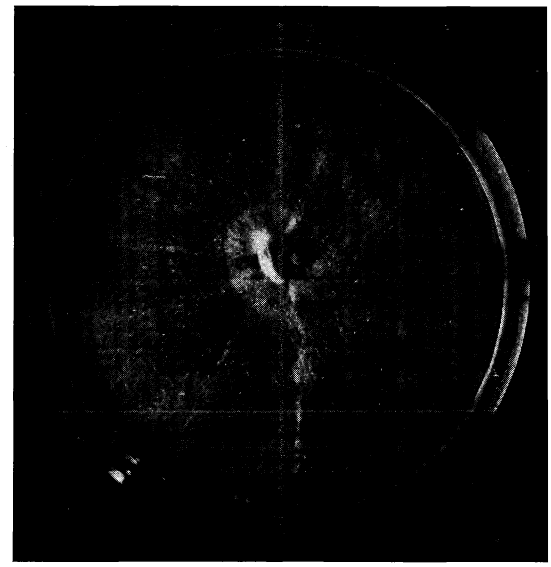

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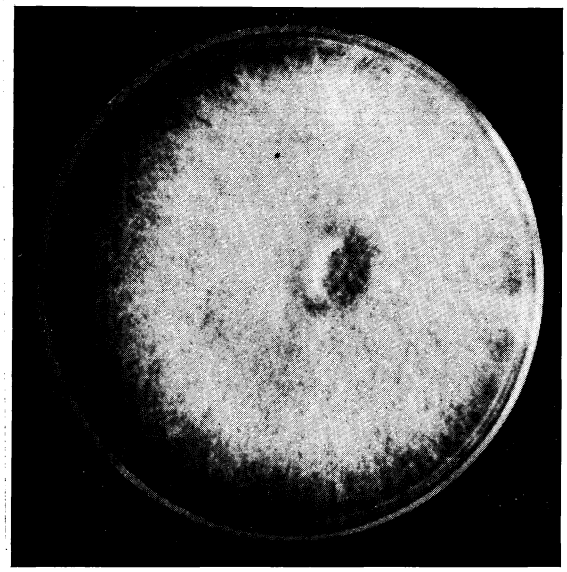

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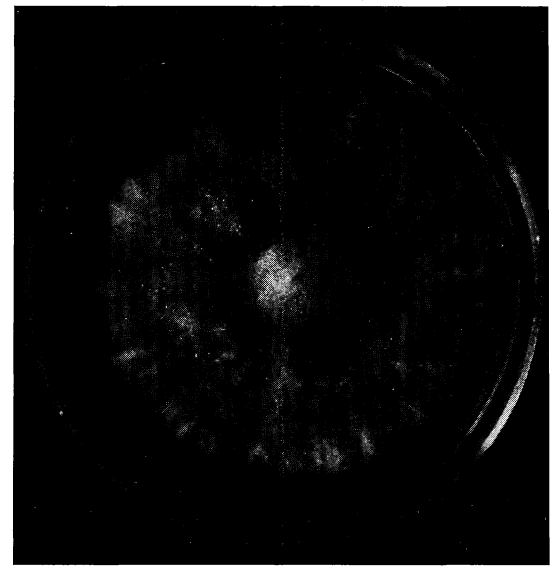
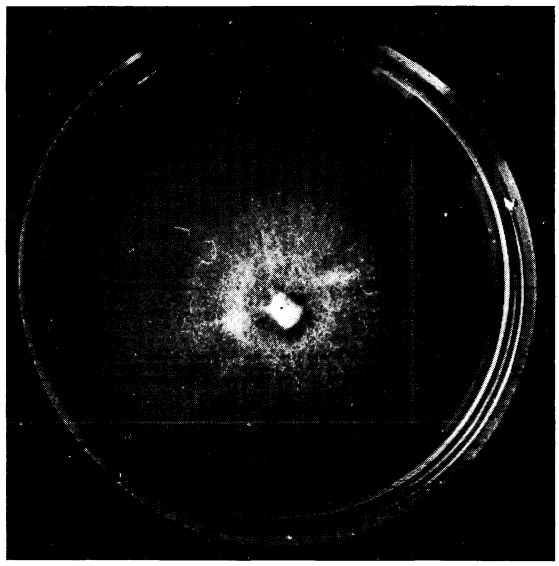


4

Plate IV. Mycelium cultures about 10 days old on malt agar at 22° C: 1) *Trametes serialis*, 2) *Hypholoma fasciculare*, 3) *Grandinia farinacea*, 4) *Coniophora sp.*

Plate V.

1



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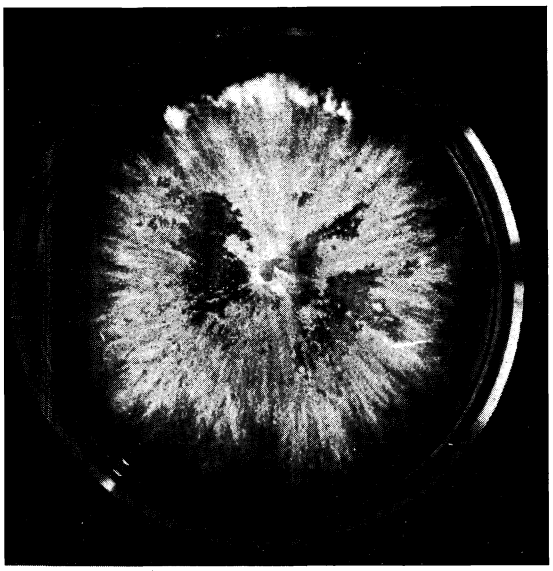

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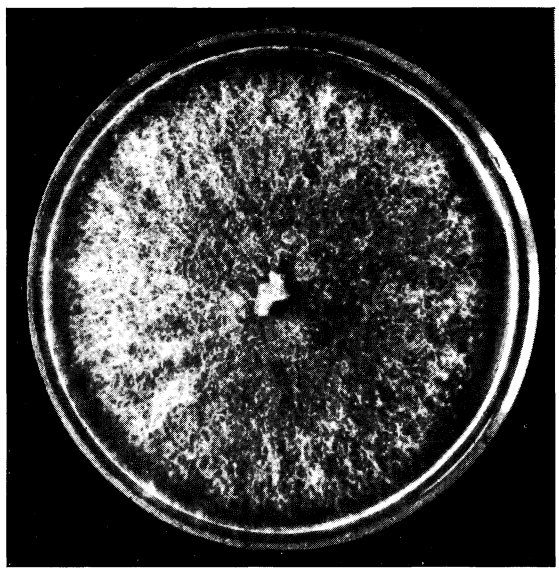

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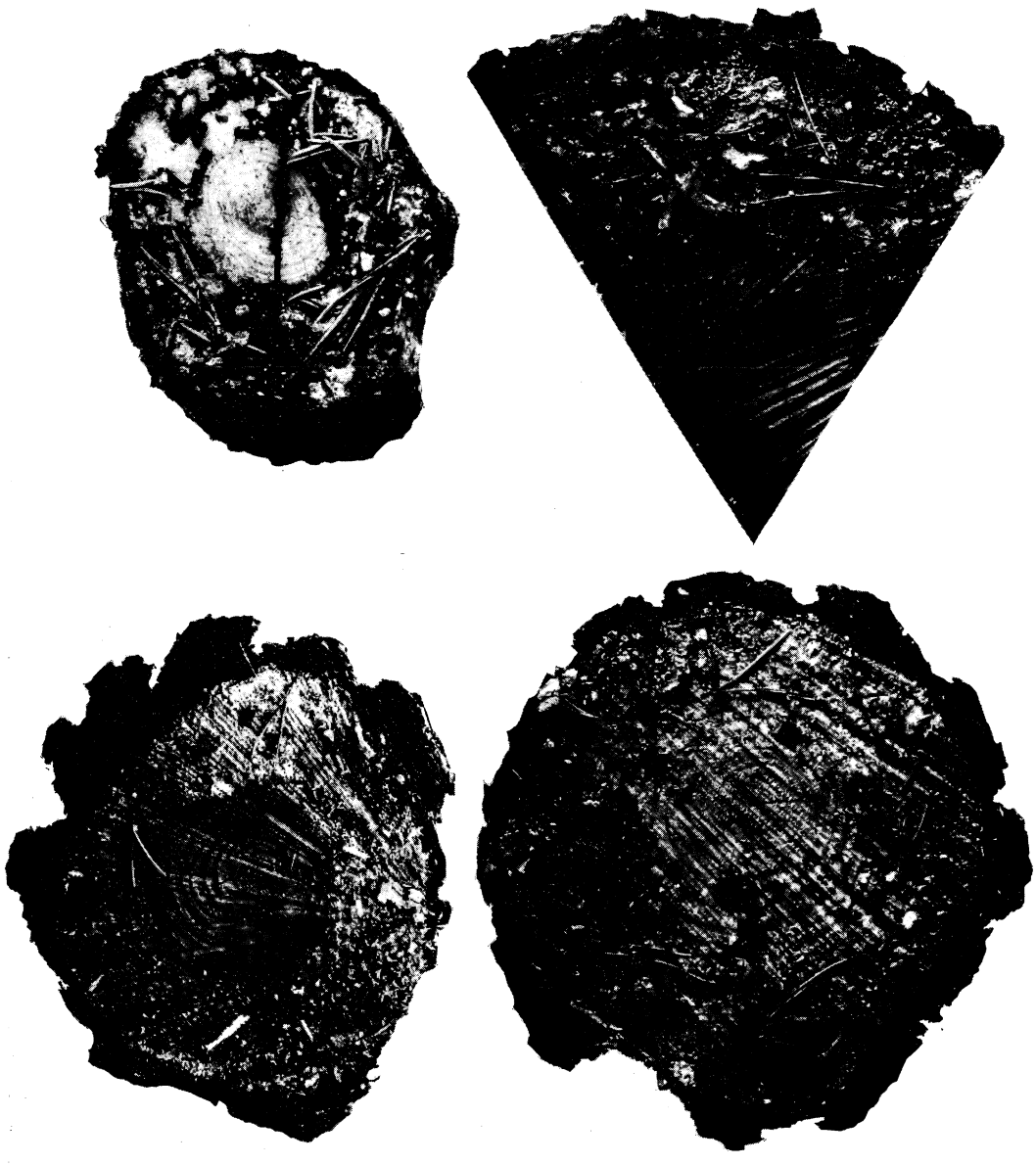
Plate V. Mycelium cultures about 10 days old on malt agar at 22° C: 1) *Polyporus abietinus*, 2) *P. amorphus* 3) *P. borealis*, 4) *P. stipticus*.

Plate VI.

1 2



3 4

Plate VI. Heavy resin-flow in sapwood of 3 month old stumps cut March 1957: 1) and 2) spruce, 3) and 4) pine.

Plate VII.

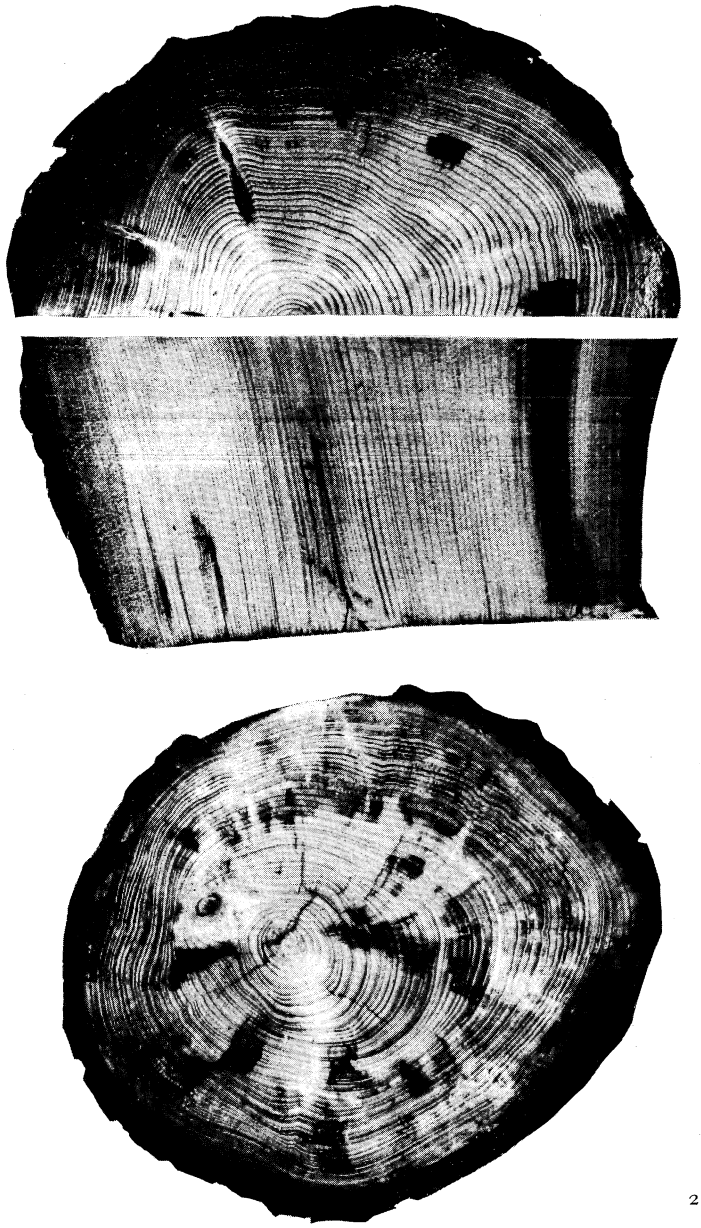
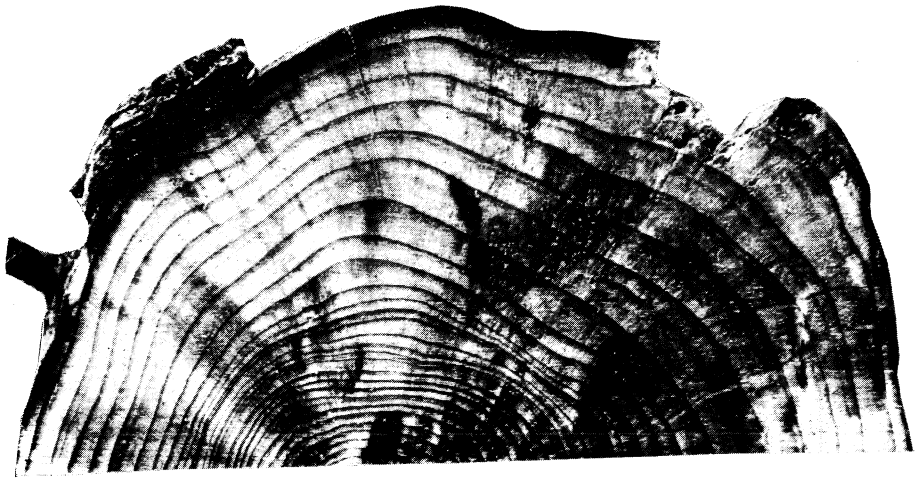


Plate VII. Infection in spruce stumps cut during winter 1955/56 and examined autumn 1956: 1) transverse and longitudinal section of a stump showing slight infection with *Peniophora gigantea;* 2) stump with many points of infection by *P. gigantea* and *Stereum sanguinolentum.*

Plate VIII.



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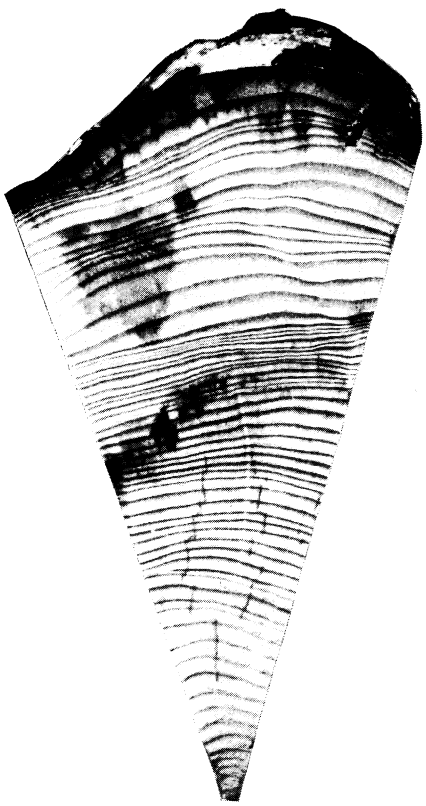

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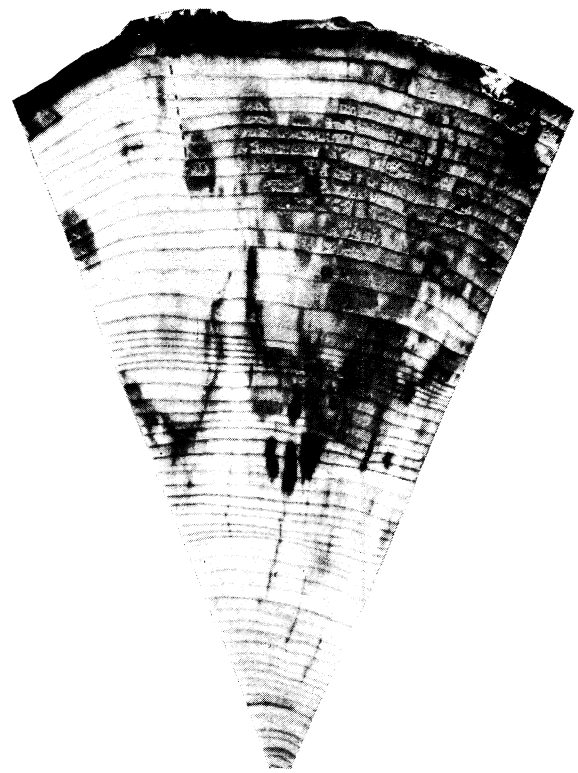


3

Plate VIII. The development of decay in two year old spruce: 1) rather heavy decay in part of the stump, 2) stump with *Armillaria* at the edge and *Polyporus abietinus* in the sapwood: 3) stump from which *Peniophora gigantea* and *Trechispora Brinkmanni* were isolated.

Plate IX.

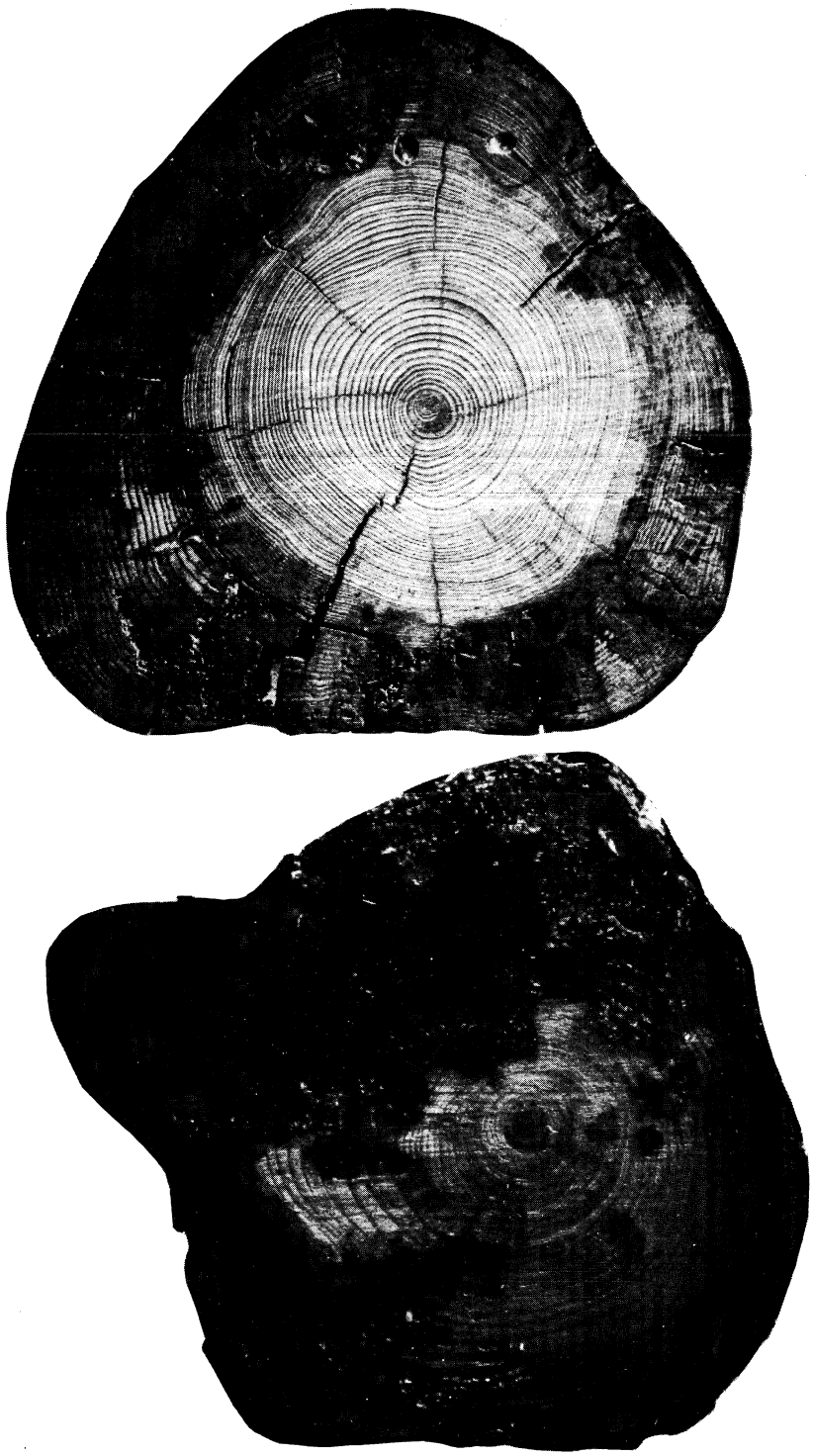
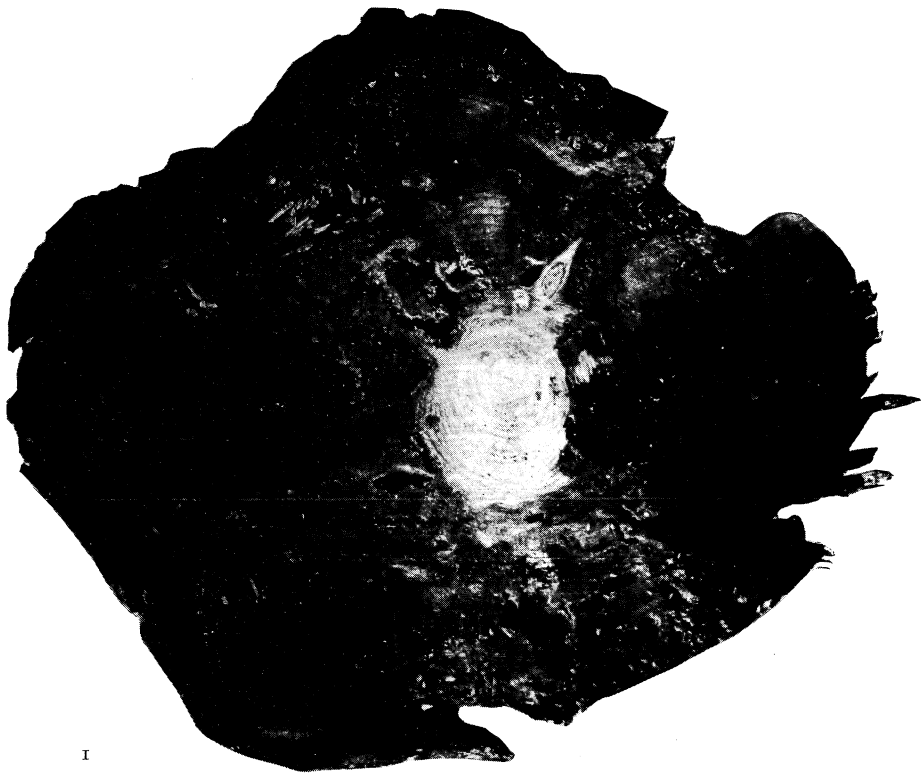


Plate IX. Three year old spruce stumps with partly heavy decay in parts of the sapwood. The heartwood almost intact. *Stereum sanguinolentum* was isolated from the upper stump.

Plate X.



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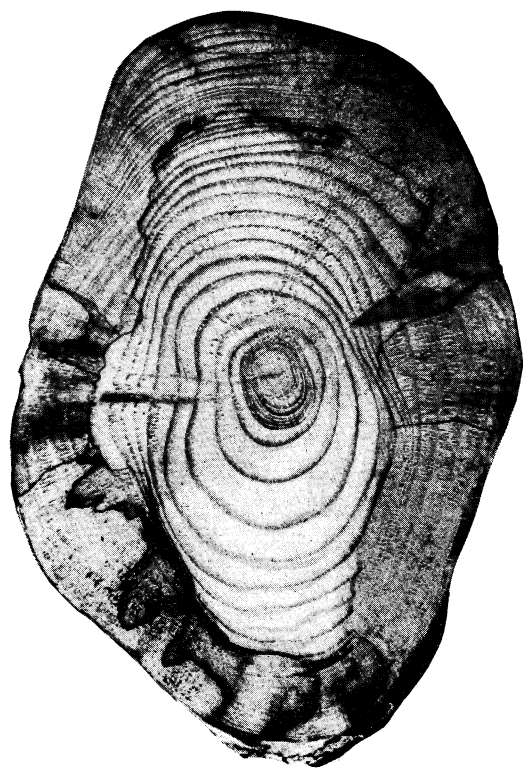

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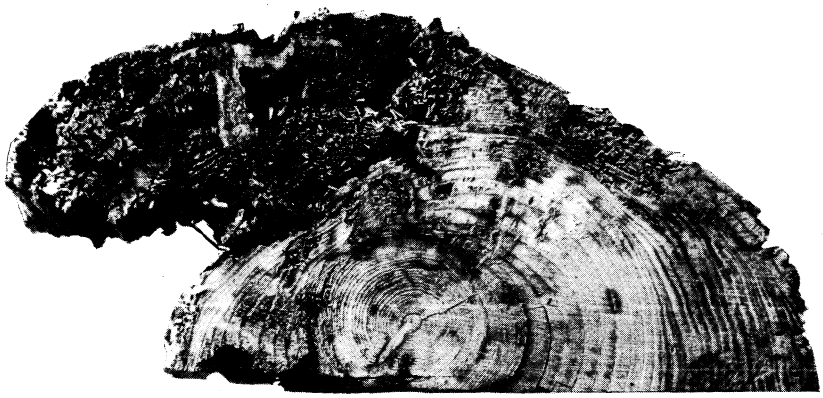
Plate X. Four year old spruce stump: 1) heavy decay of the sapwood in the upper part of the stump, 2) *Armillaria* rot in one of the bigger roots.

Plate XI.



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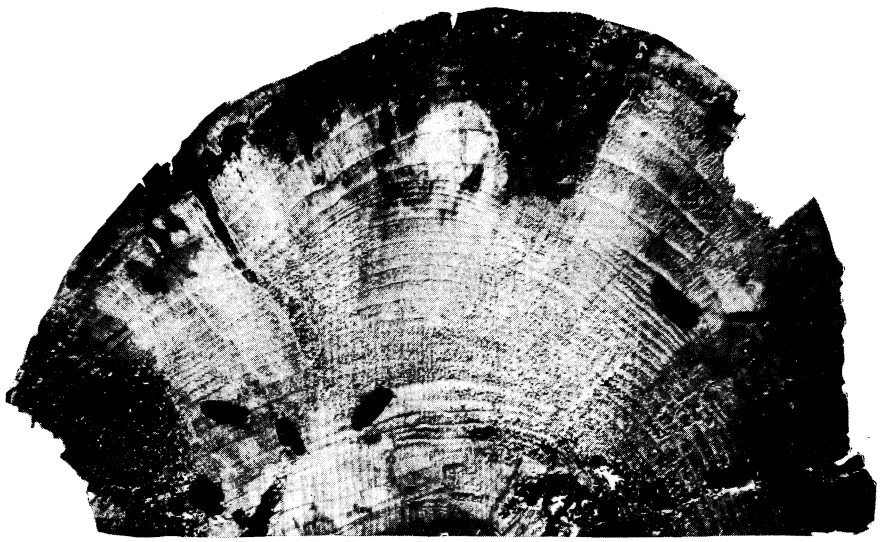

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Plate XI. Five year old spruce stumps: 1) part of the stump heavily rotted, 2) stump with severe attack of beetles and decay.

Plate XII.

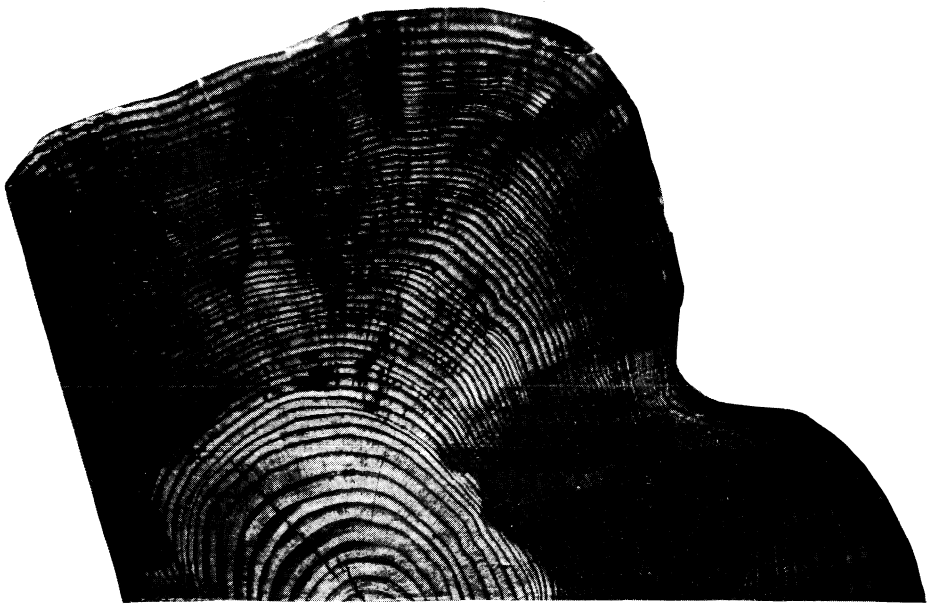

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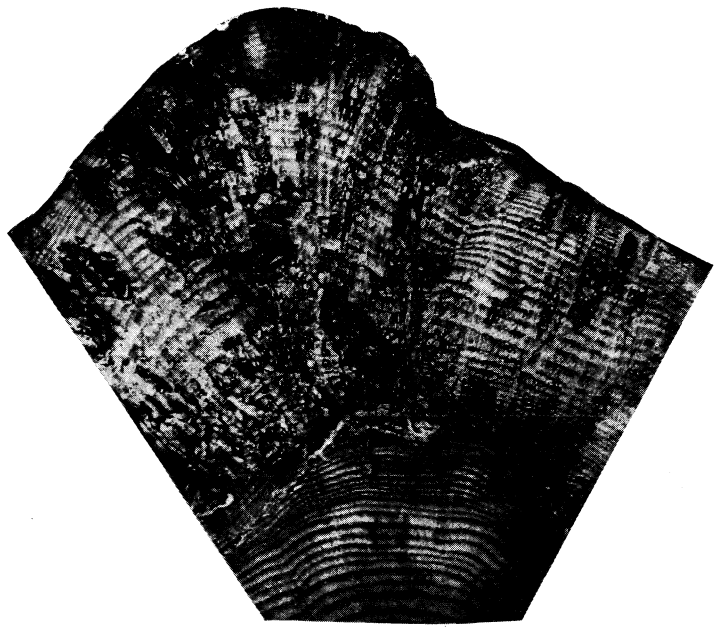
Plate XII. 1) one year old pine stump with very slight attack of *Peniophora gigantea*, 2) two year old pine stump, decay starting. *Peniophora gigantea, Polyporus abietinus, Stereum sanguinolentum* and *Trechispora Brinkmanni* were isolated.

Plate XIII.



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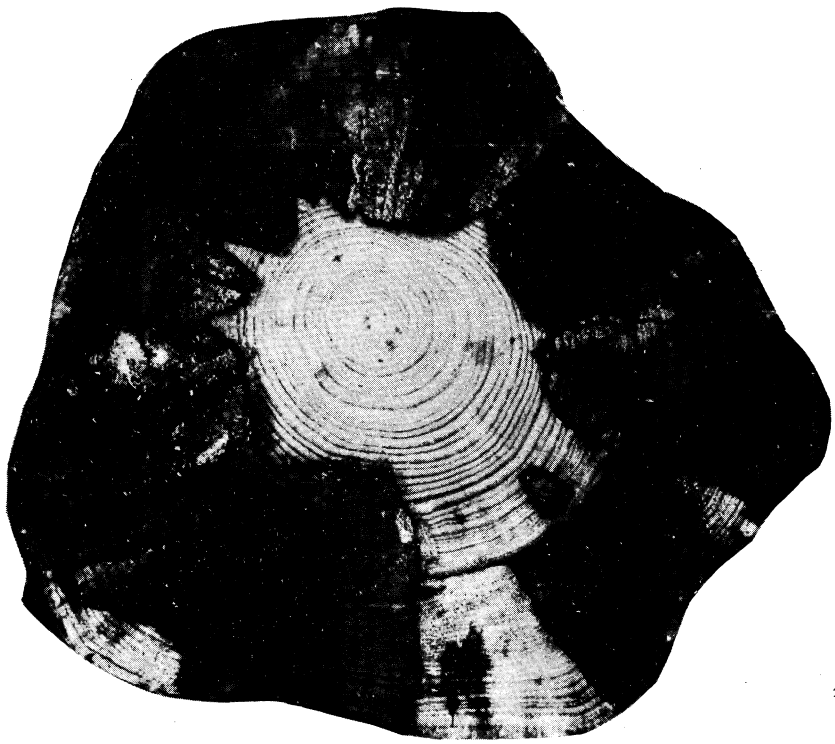

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Plate XIII. Three year old pine stumps: 1) attacked by *Polyporus abietinus*, 2) attacked by *Peniophora gigantea* and by blue stain fungi.

Plate XIV.

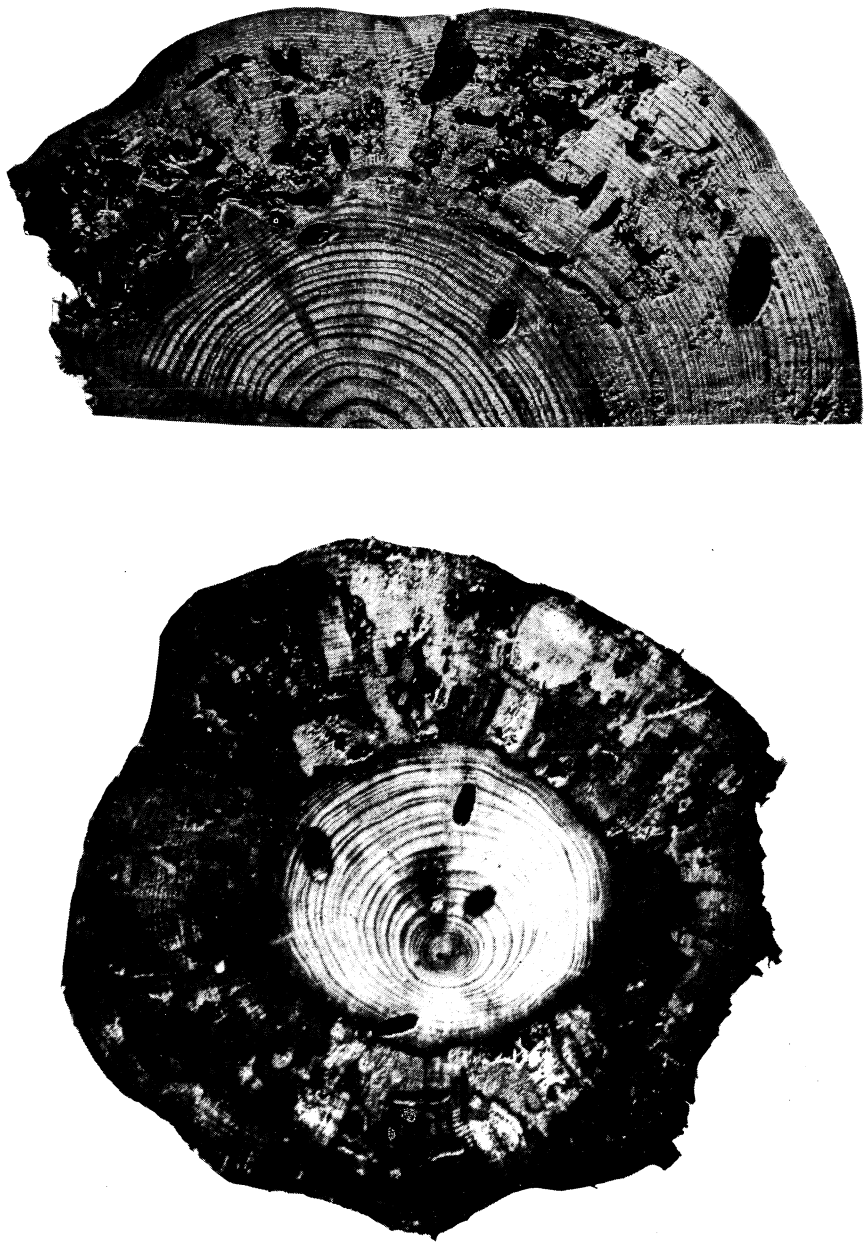
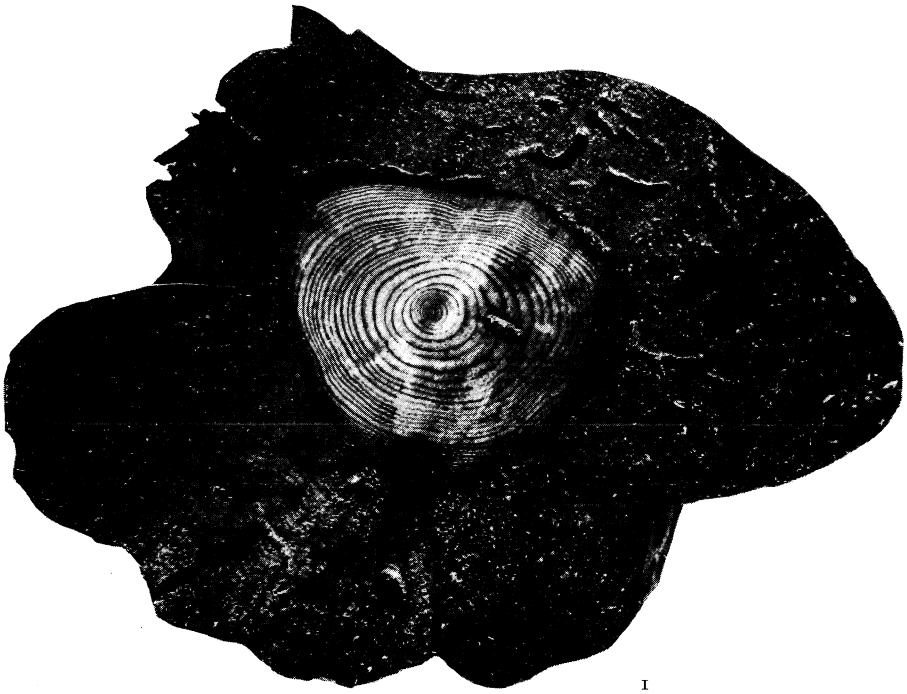


Plate XIV. Four year old pine stumps with severe decay. *Peniophora gigantea* was isolated from the upper stump. Both sap- and heartwood have been attacked by beetles.

Plate XV.



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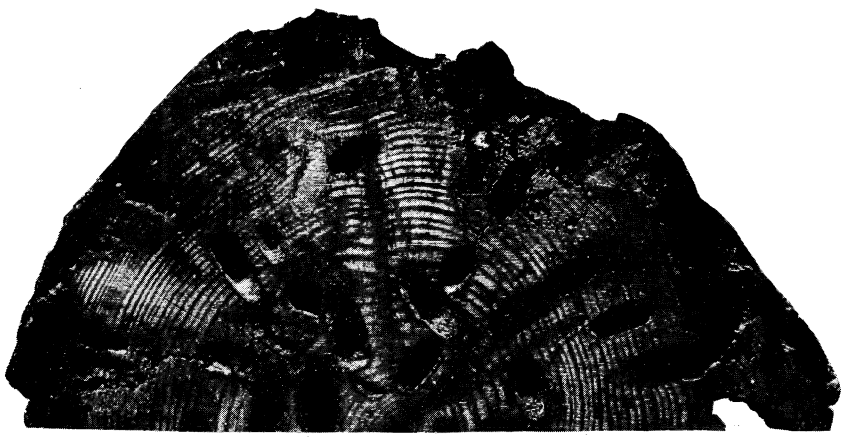

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Plate XV. Five year old pine stump: 1) with severe decay and beetles in the sapwood, 2) stump with high resin content (table 24, T: E 2) slight decay and heavy attack by longicorn beetles.

Plate XVI.

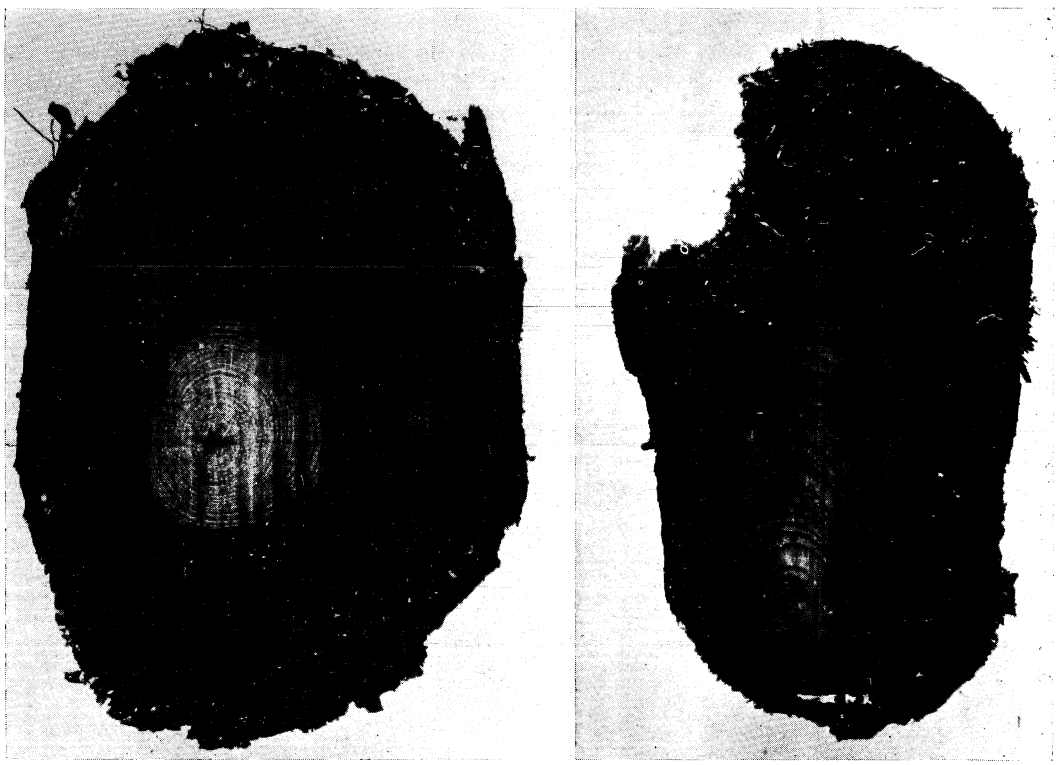

Plate XVI. Pine stump roots: 1) two year old stump root with decay starting in the upper part, 2) four year old stump root with severe decay in the sapwood.