FORESTRY COMMISSION
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PRINCIPAL BUTT ROTS OF CONIFERS

by
R. J. GLADMAN and B. J. W. GREIG
Forestry Commission

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This booklet is planned as a forester's guide to the recognition of the three most common and damaging decays of standing conifers in Great Britain. The fungi that cause these rots are the basidiomycetes *Fomes annosus* (Fr.) Cooke, *Armillaria mellea* (Vahl. ex Fr.) Kummer and *Polyporus schweinitzii* Fr. They are primary root rotting organisms, infection usually beginning in the root system and developing there before proceeding into the stem, where more extensive damage is caused. In addition, however, they may all sometimes enter the stem by other means, for example through stem wounds.

A relationship normally exists between the age of the crop attacked and the state and extent of the decay within it. Younger crops thus often show only incipient decay, whereas mature trees are often well rotted, and a large proportion of their timber may be lost. This booklet therefore includes illustrations and descriptions of both the early and the more characteristic advanced stages of rot caused by each of the fungi concerned. Brief notes on the occurrence and relative importance of each butt rot are also given.

The descriptions and illustrations that follow refer to the gross characteristics of the fungi and the rots they cause, and microscopic details are not included.

FOMES ANNOSUS

A White Pocket Rot

This is the most widespread and damaging of these butt-rot fungi. Infection is carried from plantation to plantation, and from forest to forest, by airborne spores of the fungus, which are generally available throughout the country for most of the year, and which readily germinate on freshly-cut conifer stumps. Colonisation of whole stumps and their roots then takes place, and the fungus then spreads from the infested stumps' roots to those of nearby living trees where they are in contact. The highest incidence of the disease is therefore found in second or subsequent-rotation conifer crops, in which infected stumps are most likely to occur, whereas the fungus is absent from first-rotation woods until thinning is commenced. Rhizomorphs like those of *Armillaria mellea* (described below) are not formed and the fungus does not exist freely in the soil.

Many of the conifer species in use today in this country are susceptible to butt-rot attack by *Fomes annosus*, and although the degree of attack varies according to sites and soils, species susceptibility can be broadly classified as follows: Western hemlock (*Tsuga heterophylla*) and Western red cedar (*Thuja plicata*) are probably the two worst-affected species when planted on an already-infected site, and often, when early thinnings are carried out, show as much as 50% crop infection. Sitka and Norway spruces (*Picea sitchensis* and *P. abies*) and the larches (*Larix* spp.) are also susceptible, and when they are growing on previously-infected sites, crops of these species will often contain 30% of diseased trees by the time pole stage has been reached.

Douglas fir (*Pseudotsuga taxifolia*) is more resistant, but is not comparable with the pines and Silver firs (*Abies* spp.), which show excellent resistance to heart-rot caused by this fungus. In the case of Douglas fir, severe root rot (as opposed to decay within the butt) is often caused by *Fomes* infection. When susceptible species are planted on alkaline sites, root and butt rot is particularly severe and in mature trees decay sometimes extends for fifteen or twenty feet up the stem.

It must be noted here, moreover, that *F. annosus* may cause death as well as heart rot in conifers, and although pines are resistant to heart rot, they are often killed by the fungus. On infested sites, killing may take place from about two years after plant-

ing, though on first-rotation areas deaths do not usually occur until after cultural operations such as thinning, rack cutting or brashing have been initiated. These operations give rise to infection centres, around which dead trees tend to appear in groups some five years later. Normally deaths are sufficiently numerous to be of economic importance only on alkaline sites with a pH higher than 6·0, and on ex-agricultural land that has been tilled and limed, elsewhere, they are infrequent.

Forestry Commission Leaflet No. 5, entitled: *Fomes annosus*, (In preparation), describes the fungus more fully.

The Fructification

This is normally bracket shaped, measuring between two and ten inches across, and appears particularly on the sides of infected stumps in sheltered positions. It is perennial, tough and leathery, with an upper surface that is often concentrically zoned. The colour of the upper surface varies from a rich, chestnut-brown in young specimens to dull slate-grey in old ones, and it has a white outer rim which may be either thick or thin, according to the vigour of growth of the fruit-body (Plate 1). The underside (Plate 2) which may be white or biscuit-coloured, is perforated by very numerous minute pores, from which spores are released at most times of the year. *Fomes* fructifications vary considerably in shape and size, and are often hidden beneath litter and vegetation. They are commonly produced on infected roots in the cavities formed by the root plates of wind-blown trees. In this case, they are not bracket-shaped, but flattened to the contour of the root, and form only a pore surface. During development of the fructifications, twigs, grass, and other small objects are often encircled and enclosed within them (Plate 1).

Pustules, or imperfectly-formed sporophores, are sometimes found on the surfaces of infected stumps under a covering of fallen needles. They are small flattish bodies, white and roughly circular, usually $\frac{1}{4}$–$\frac{1}{2}$ an inch in diameter, and of a rubbery consistency. Partially formed pores are sometimes seen on their exposed surfaces. The mycelium (spawn) of *Fomes* does not form strands, but is thin and tissue-like. It can be found only occasionally under the bark of killed roots and is of little value in identification.

The Decay

(1) *Stain Stage*

The very early stage of butt-rot infection shows only as stain in the stem cross-section when trees are felled, and is often positioned eccentrically to coincide with the original root infection. The appearance of the stain varies between species. In Western hemlock, Western red cedar, and Lawson cypress (*Chamaecyparis lawsoniana*) it shows as a dark brown area, contrasting with the light-coloured wood, especially in juvenile timber.

In the larches, a brownish-grey stain first appears, often in the sap wood, and becomes darker brown or reddish-brown as infection develops (Plate 4e). It is darker brown in colour than that produced by early heartwood formation in larch (Plate 4d), although both may appear as irregular areas.

In spruces, (especially Sitka) staining due to *Fomes* is also brown in colour (Plate 4b), but is commonly associated with a pink, lilac, or bluish discolouration. Unattacked wood of Sitka spruce has been found to develop a natural pinkish hue when growing in certain conditions, e.g. sometimes on peat, but in this case no brown stain is present. In Plate 4a, a cross-section of a stem of Sitka spruce shows natural brown staining, not associated with fungal infection.

(2) *Incipient Decay*

Incipient decay is a term that refers to the stage of rot infection which has advanced beyond the staining of tissues but which has not produced actual rot. It is illustrated in Plate 4b, in the centre of the Sitka spruce specimen.

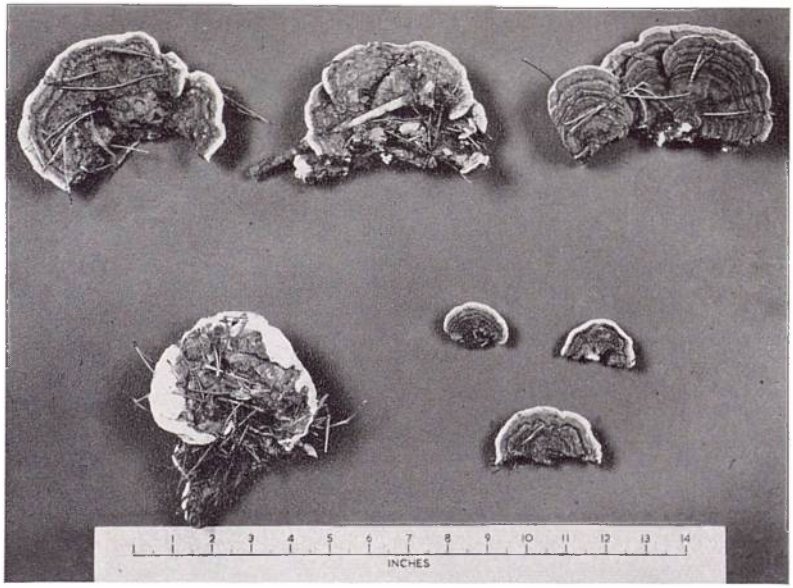

PLATE 1. FRUCTIFICATIONS OF FOMES ANNOSUS, UPPER SURFACES.
Note the wide variation in size and form. The concentric zoning is clearly visible in the top right-hand sporophore, and the characteristic habit of encircling small objects is seen in the centre (top) specimen (scale shown).

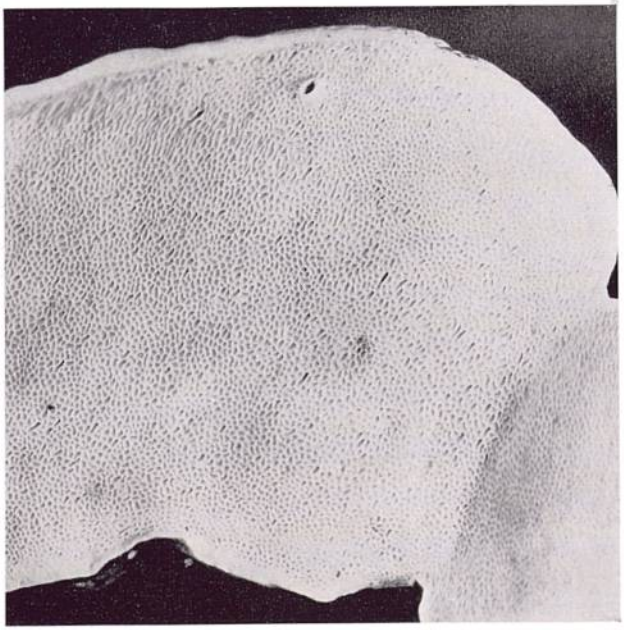

PLATE 2. UNDERSIDE OF FOMES ANNOSUS FRUCTIFICATION.
Showing the tube surfaces (x $1\frac{1}{2}$).

PLATE 3. DECAY CAUSED BY FOMES ANNOSUS.
European larch. Longitudinal, radial section. The dry fibrous nature of the advanced decay is seen at the bottom of the photograph in the central portion of the specimen. Above this the characteristic small white pockets are visible (x ⅓).

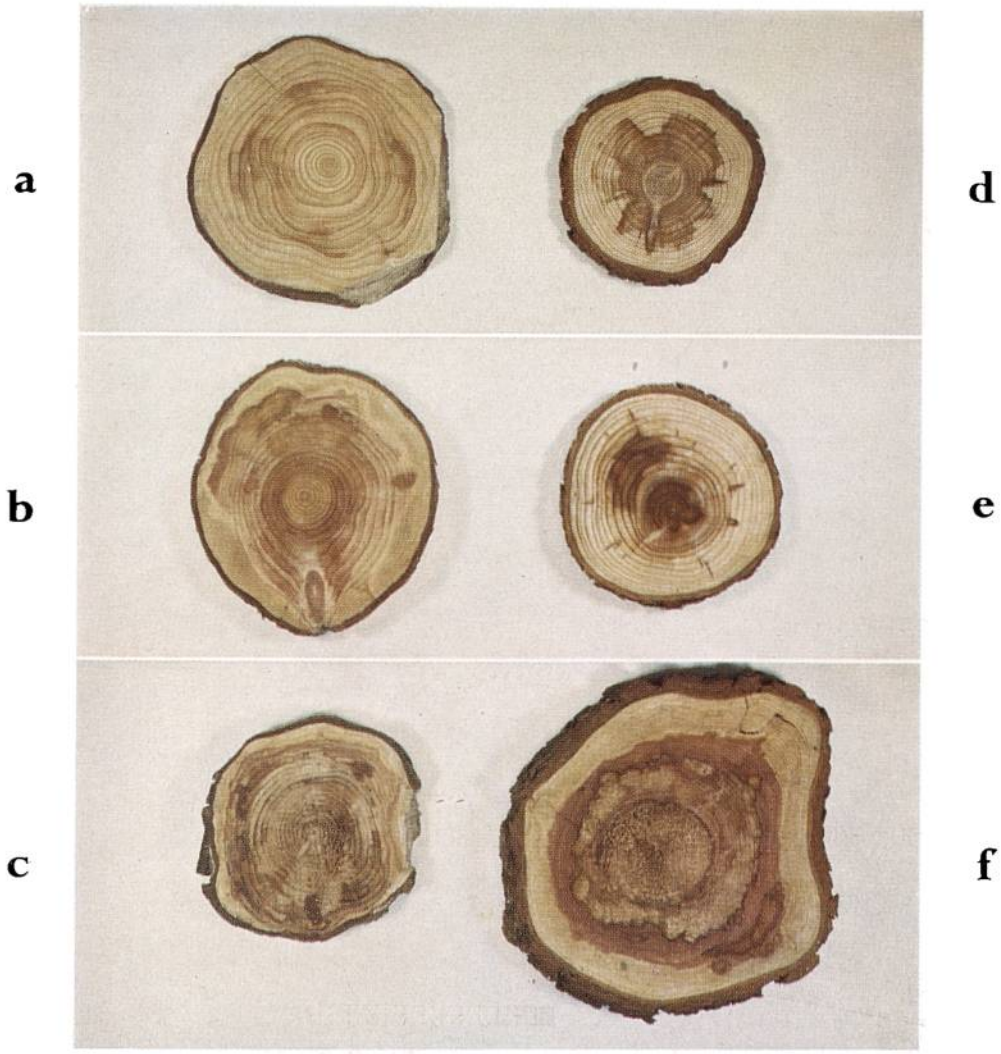

PLATE 4. STAIN AND DECAY CAUSED BY FOMES ANNOSUS (WITH EXAMPLES OF NATURAL STAINING).

Transverse sections from butts of newly-felled trees (x 1/10).

(a) Sitka spruce.
Natural staining.

(b) Sitka spruce.
Staining and incipient decay (the light yellow central region) caused by *Fomes annosus*.

(c) Sitka spruce.
Advanced decay.

(d) European larch.
Natural staining which is due to the formation of early (false) heartwood.

(e) European larch.
Staining due to infection by *Fomes annosus*.

(f) European larch.
Advanced decay.

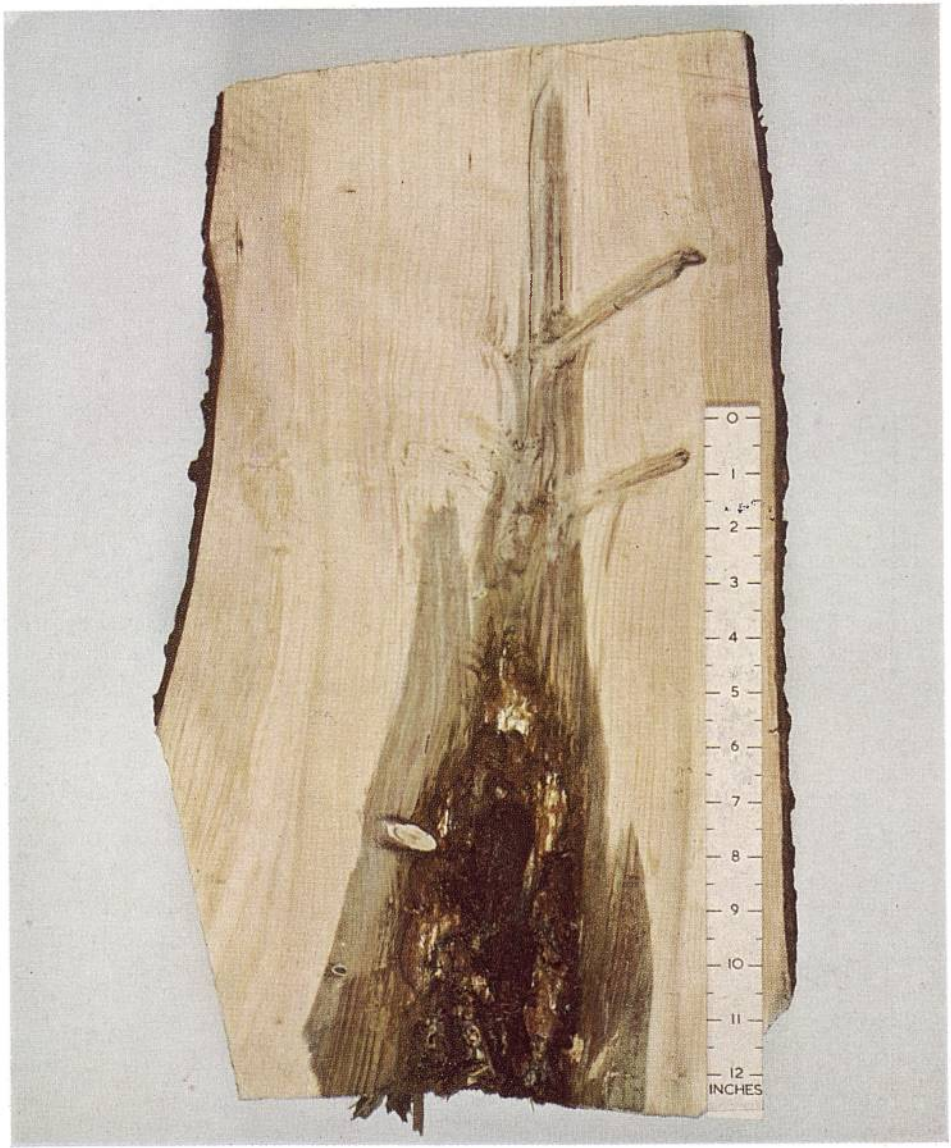

PLATE 5. DECAY CAUSED BY ARMILLARIA MELLEA.
Norway spruce. Longitudinal radial section. This photograph shows the very limited extent of the decay up the stem when compared with that caused by *Fomes annosus* and *Polyporus schweinitzii* (Plates 3 and 8). The central well-rotted portion contains many black skins of *Armillaria* tissue and has been invaded by other fungi and bacteria. Advanced decay caused by *Armillaria* alone can be seen surrounding this as areas of soft orange-brown rot in which whitish regions occur. Incipient *Armillaria* decay is clearly visible at the bottom-right of the infected area, and contains irregular cream coloured flecks (scale shown).

PLATE 6. STAIN AND DECAY CAUSED BY ARMILLARIA MELLEA.
Norway spruce. Transverse sections. The top specimen shows the early stage of infection indicated by the outer, pale, inky stain, and the central watery-brown stain. The lower specimen shows advanced decay. The very dark brown stain immediately surrounding the area of rot is characteristic (scale shown).

PLATE 7. DECAY CAUSED BY POLYPORUS SCHWEINITZII.
Douglas fir (top) and Sitka spruce (bottom). Transverse sections. Incipient decay is shown in the top specimen, where the radial cracks and flaking of tissue in the affected area are apparent, as is the red-brown staining surrounding it. The crack on the right of the specimen, extending to the bark, resulted from felling. Advanced decay is shown in the lower specimen. Characteristic features are the dry, crumbly nature of the rot; the radial fissures, and the creamy-white mycelium within them. The very dark ring of tissue which appears towards the outside of the decay is filled with resin and is not always present (scale shown).

PLATE 8. DECAY CAUSED BY POLYPORUS SCHWEINITZII.
Sitka spruce. Longitudinal, radial section. The radial cracking which tends to produce cubes of decay is illustrated. The narrow darker column to the right of the specimen is filled with resin (x ⅓).

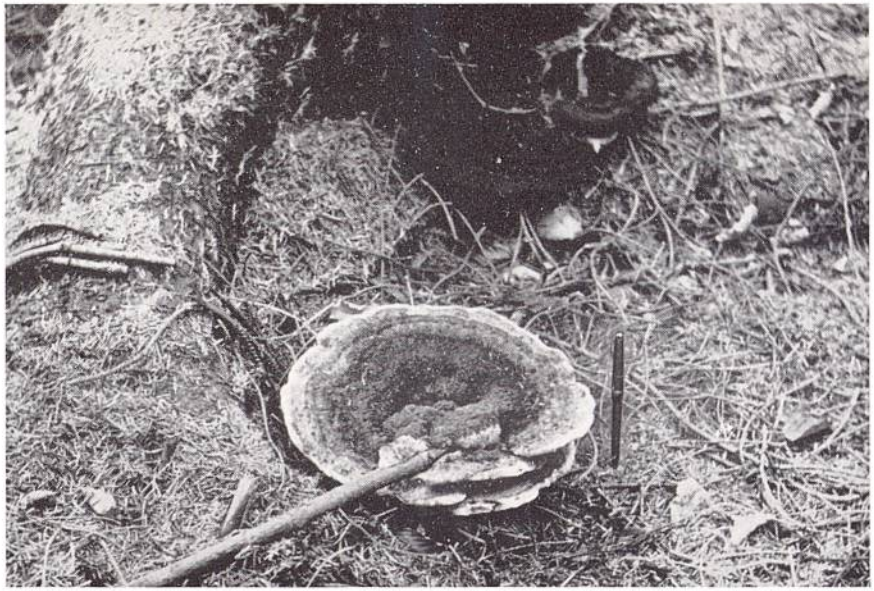

PLATE 9. FRUCTIFICATIONS OF POLYPORUS SCHWEINITZII.
The specimen in the foreground is a current active fructification, while in the background is an older dead one. The fructification is also often of the bracket form growing out from the tree stem (x$\frac{1}{6}$).

PLATE 10. FRUCTIFICATIONS OF ARMILLARIA MELLEA.
Group of young fructifications growing on the stem of an attacked trees. The photograph shows several characteristic features of the fungus including the gills, the annulus or ring, and the scales on the caps (x$\frac{1}{3}$).

At this stage the wood shows loss of weight, but it remains relatively firm and sound in structure. It is usually lighter in colour than the surrounding wood, from pale yellow to cork-coloured, and in a longitudinal section of an infected butt occasional black flecks can be seen. The area of incipient decay is almost always surrounded by an irregularly-shaped band of darker stained wood.

The small, narrow, white pockets that are the most characteristic feature of *Fomes annosus* heart rot begin to appear at this stage. They are regularly shaped and clearly defined, and are filled with a soft, white material which gives the decay the name "White Pocket Rot". These pockets are readily seen in a longitudinal section of a decaying stem (Plate 3), and are believed to be formed by the intensified activity of the fungus around the black specks, which later disappear.

(3) *Advanced Decay*

Wood in an advanced state of decay in the standing tree varies little between different conifer species. The tissues are well broken down, and the wood is dry, very light in weight, of a soft fibrous nature, and can readily be pulled out from the butts of infected felled trees in long strands. It is illustrated in the centre of the specimen shown in Plate 3, and in Plates 4c and 4f. In the final stages the individual pockets often coalesce and their white contents disappear, so that empty spaces then occur in the rotten wood.

ARMILLARIA MELLEA

A Wet Stringy Rot

Armillaria mellea, the Honey fungus, is probably best known to British foresters as a common cause of deaths of trees in young plantations. However, it also acts as a conifer root and butt rot, although this type of damage is not nearly as frequent as that caused by *Fomes annosus*, nor does it cause such severe losses in the stems and stands attacked.

As a butt-rot organism in conifer crops, it is virtually limited to ex-hardwood sites, or to mixtures of hardwoods and conifers, where attacks to the growing conifers develop from infection sources contained in the hardwood stumps. Movement of the fungus from stump to tree is largely by means of rhizomorphs. These are black, bootlace-like strands which spread out from infected stumps, etc., move freely through the soil, and infect roots of live trees which they encounter. These black rhizomorphs vary considerably in size and form. In the soil they are cord-like and may be from 1/16 to $\frac{1}{8}$ of an inch in diameter, but when they grow under the bark of killed roots or stems, they are flattened and forked and often anastomose to form extensive networks. When young and active they are not black, but light tan to reddish-brown, and have conical growing tips.

In young conifers, root attack by *Armillaria* often results in death of the whole tree. In older trees, however, only one or two roots may be killed, and in butt-rot-susceptible species this allows entry of the fungus to the heartwood in the butt, where decay develops slowly. Affected roots (often tap roots or secondary sinkers) may exude copious resin, and under their bark characteristic sheets of white or cream-coloured mycelium are found. These mycelial sheets are often fan-shaped, with much-branched tongues extending radially outwards from the source. Occasionally they are quite thick, and then closely resemble the inner peel of an orange.

Although the abundant airborne spores of the fungus are likely to play a part in its general dissemination and spread, there is no evidence that they readily colonise *conifer* stumps. This fact is supported by the repeated scarcity of the fungus in thinned conifer plantations growing on ground that was previously treeless.

As distinct from tree killing, root and butt-rot attacks by *Armillaria mellea* are found more frequently on Norway and Sitka spruce

than on any other conifer species planted in this country. Lawson cypress, Western red cedar and Western hemlock are also susceptible to this form of attack. In addition, Western red cedar seems especially susceptible to this decay entering through wounds on roots and stem bases. The larches and Silver firs are more resistant than any of these species, while Douglas fir and the pines are very resistant to heart rot by *Armillaria*. In all of these species, even in mature trees, heart rot caused by Honey fungus is confined to the lower trunk, seldom extending up the tree more than two feet (Plate 5). In pole-stage crops it is common to find that only small pockets of decay occur in the butt cross-section, i.e. considerably less than that shown in Plate 6, lower specimen.

Little association has been found between general site factors and degree of attack, except that the frequency of the disease increases if the crop, or any part of it, is unsuited silviculturally to the site, e.g. spruce on dry knolls.

Forestry Commission Leaflet No. 6, entitled *Honey Fungus* (H.M.S.O. 6d.) gives a description of the fungus, its characteristics, incidence and importance in this country.

The Fructification

This is of the toadstool type, and appears from September to late autumn, usually growing in clusters from the sides of infested stumps. They are pale honey-coloured at first, and have numerous brown scales on their rounded caps, but soon acquire a deeper, tawny-brown colour, and the scales then gradually disappear. They are usually three to six inches in height, with caps two to four inches across. A white ring, or annulus, is situated on the stem just below the pale coloured gills, which are slightly decurrent, i.e. they extend a little way down the stem (Plate 10). Spores are produced in very large quantities on the surfaces of these gills. It is unusual to find these fructifications growing on standing trees that have *Armillaria* butt rot: characteristically they occur on *stumps* or on the surface of the soil immediately above stump roots.

The Decay

(1) *Stain Stage*

In the susceptible species mentioned, cross sections of infected stems first show a pale stain. Initially this is pale brown, grey or bluish, and it later darkens to a deep brown or blue-black (Plate 6, upper specimen). It often has a water-soaked appearance.

(2) *Incipient Decay*

This varies little. It is mid-brown to orange-brown in colour, and again has a water-soaked appearance, thus contrasting with the dry, incipient decay caused by *Fomes annosus*. In longitudinal sections, early *Armillaria* decay contains scattered white or cream-coloured flecks (Plate 5, lower right-hand side). These are irregularly-shaped and are therefore unlike the *Fomes* pockets, although some of them may be of the same size. Black zone lines may sometimes be found on the butt-end of an infected felled tree within, or at the margin of, the incipient decay. These lines are very fine, as though drawn with a pen, and often form apices in outline, pointing in the direction of fungal extension, i.e. generally towards the outside of the stem.

(3) *Advanced Decay*

In the field, it has been found that *Armillaria* decay in the advanced stages is seldom "pure", and that commonly there are other organisms present, e.g. bacteria, so that the appearance of the gross rot is not characteristic of *Armillaria* alone. In Plate 5, the darker central portion of the rot is a good example of this complex condition. Advanced decay due to Honey fungus alone can be seen surrounding this as areas of soft, orange-brown decay, in which whitish regions occur. These white regions consist of remnants of wood tissue mixed with *Armillaria* mycelium. Two further features, typical of the rot at this stage, help in identification. These are the occurrence of irregular black skins of fungal tissue which often border areas of

soft white rot; and the wet, mushy nature of the orange-brown stringy decay which precedes it. Both can be seen in Plate 5.

POLYPORUS SCHWEINITZII
A Dry Crumbly Rot

This fungus has a widespread but sporadic distribution in the British Isles, and overall decay losses from it are small. This is due to its limited incidence and not to the degree of damage in individual trees, which is commonly severe.

In Britain, heart rot damage by *P. schweinitzii* in conifer plantations is most prevalent on sites which have carried previous crops of either pines or hardwoods, but even on these sites it is not commonly found. In these plantations infection develops first in the tree roots. The relationship between this fungus and the previous crop history is not clearly understood, because of a general lack of knowledge of the infection biology of *P. schweinitzii*. It appears that spores are capable of infecting woody tissues on conifers, e.g. stem wounds, but observations and experimental evidence suggest that spore infection of conifer stumps does not occur as readily as with *Fomes annosus*.

In Britain a number of conifer species are susceptible to root and heart rot attacks by *P. schweinitzii*, especially Sitka spruce. In this tree, decay to eight feet and more is frequently recorded in semi-mature stands thirty to forty years old, where they are growing on the site-types previously mentioned. It is commonly found that, in an attacked Sitka spruce, a large proportion of its cross-sectional area at the butt is decayed (Plate 7, lower specimen). Other species attacked are Douglas fir, Scots pine and the larches. In all of these it is more common to find the decay in mature or near-mature trees than in pole-stage crops, in which damage is seldom severe. Because of the general low incidence of *P. schweinitzii* in the British Isles, susceptibility of the other commonly-planted conifer species is not fully known. To date, very few attacks have been recorded in Norway spruce or Silver firs, and none are known for Western hemlock, Lawson cypress, Western red cedar or for pines other than Scots pine.

The Fructification

This is usually a bracket, and grows from the sides of infected stumps or roots, or from the bases of infected, growing trees. Occasionally it is seen growing apparently on the litter surface, when it has a short central stalk or stipe, but in these cases it is always connected to an underground root. The fructification, which is fleshy and easily broken, is annual, first appearing in late summer or early autumn; it remains active for approximately two months. An average specimen, fully-grown, measures about twelve inches across, and has a deep, rusty-brown upper surface with a contrasting yellow rim. This surface resembles coarse brown velvet, and in the United States of America it is known as "The Velvet Top Fungus". The yellow rim, which is broad on young, growing specimens, becomes narrower with age, and gradually disappears as the mature sporophore dies. The underside is pale greyish-green and is easily bruised, and when active, exudes moisture droplets. It is broken by numerous, small, irregular channels, and is maze-like in appearance. The fructifications gradually die as winter approaches, but they remain *in situ* and can still be readily recognised in the following year, when they are much-dried and dark brown all over. On the litter surface in this state, they closely resemble old cow-pats. Plate 9 shows two specimens, one active (foreground), and the other an old specimen.

The Decay

(1) *Stain Stage*

In Sitka spruce this is usually detected as a yellowish discolouration in the sapwood or early heartwood of newly-felled trees. A pinkish stain may also be present. In Douglas fir, a pinkish-brown area in the butt, darker than the natural heartwood colour, is the first indication of root infection. It is seldom

clearly defined in either species, and can be seen in Plate 7, in both specimens, surrounding the area of decay.

(2) *Incipient Decay*

This is well illustrated in Plate 7, in the central area of the top specimen. In all species the affected wood appears dry, and there may be numerous, small, radial cracks when stems are seen in cross-section. Again, the infected area is often ill-defined, and the colour and texture of the rot do not differ greatly from normal wood. The most constant feature is the radial pattern of minute ridges or flakes of wood that result from the partial decay. These are more easily seen in Douglas fir than in Sitka spruce. No pockets are formed. At this stage a strong, sweetish smell is readily apparent on fresh-cut decayed specimens of all species. It has been likened to turpentine and to anise, and is at one and the same time sweet, sour, and resinous. It is a valuable diagnostic characteristic.

(3) *Advanced Decay*

In this stage it is readily recognised, and the term "Crumbly Rot" is an apt description for it, especially in Sitka spruce (Plate 7, bottom specimen). It is dry, very light in weight, and granular or crumbly in texture, not at all fibrous. In Sitka spruce it is light-yellow-brown in colour, but in Douglas fir it is darker brown or pinkish-brown. It can be easily dug out with the blade of a pocket knife and quickly crumbles when rubbed between the fingers. Radial cracks are large and often numerous, and are sometimes filled with pale yellow or creamish-white mycelial growths (Plate 7, lower specimen). These radial cracks tend to break up the wood into roughly cubical blocks (Plate 8), and in the final stage of decay these will sometimes fall out from the butt of a tree when it is felled. The characteristic sweet-sour smell remains apparent. In late stages of decay, when the wood is dust-dry and brittle, and the cubes are considerably shrunken, it becomes much darker in all species, and resembles mahogany in colour.

SUMMARY OF MAIN FEATURES OF THE DECAYS

Fomes annosus

Most often found in second rotation conifer crops. Dry, fibrous, yellow-brown to tan-brown. Small, regularly shaped, white oval pockets in longitudinal sections. No characteristic smell. Commonly found in larches, spruces, Western hemlock and Western red cedar.

Armillaria mellea

Generally found on old hardwood sites. Wet stringy rot, yellow-brown to orange-brown. Irregularly-shaped cream flecks in incipient stage. Thin black zone lines and/or black skins present. No distinctive smell. Commonly found in spruces, Western hemlock, and Western red cedar.

Polyporus schweinitzii

Most often found on ex-pine or ex-hardwood sites. Dry, crumbly, pale yellow-brown, becoming much darker in final stages. Cubical decay, no pockets formed. Whitish-yellow mycelium in cracks. Strong sweet-sour smell. Commonly found on Sitka spruce and Douglas fir.

This booklet has described the three most common and most damaging decays of standing conifers in Great Britain. The three fungi discussed account for nearly all of the softwood decay in British forests, but occasionally rot caused by other organisms will be encountered. Reference should then be made to the textbook entitled *Decay of Timber and its Prevention*, written by K. St. G. Cartwright and W. P. K. Findlay, of the Forest Products Research Laboratory, Department of Scientific and Industrial Research (H.M.S.O. 27s. 6d.) (by Post 30s. 6d.).

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