The Rural Manuals

EDITED BY L. H. BAILEY

MANUAL OF TREE DISEASES

The Rural Manuals

EDITED BY L. H. BAILEY

MANUAL OF GARDENING — *Bailey*
MANUAL OF FARM ANIMALS — *Harper*
FARM AND GARDEN RULE-BOOK — *Bailey*
MANUAL OF FRUIT INSECTS — *Slingerland and Crosby*
MANUAL OF WEEDS — *Georgia*
THE PRUNING-MANUAL — *Bailey*
MANUAL OF FRUIT DISEASES — *Hesler and Whetzel*
MANUAL OF MILK PRODUCTS — *Stocking*
MANUAL OF VEGETABLE-GARDEN INSECTS — *Crosby and Leonard*
MANUAL OF TREE DISEASES — *Rankin*
MANUAL OF HOME-MAKING — *Van Rensselaer, Rose, and Canon*

OF

TREE DISEA

BY

W. HOWARD RANKIN, A.B.,
ASSISTANT PROFESSOR OF PLANT PATHOL
NEW YORK STATE COLLEGE OF AGRICULT
AT CORNELL UNIVERSITY

New York
THE MACMILLAN COMPA
1918

Set up and electrotyped. Published November, 1918.

Norwood Press
J. S. Cushing Co. — Berwick & Smith Co.
Norwood, Mass., U.S.A.

PREFACE

The steadily accumulating knowledge of the diseases of trees in the United States has never been brought together and made available to the general public. The intention of this Manual is to describe and suggest means of control for the tree diseases that have been most studied. Much remains to be learned about many of these diseases, and still many more have never been investigated. Therefore, in the treatment of this subject there are many unavoidable limitations which the trained reader will perceive. The diseases of fruit-trees, and of field and vegetable crops, have received the attention of plant pathologists in most parts of the country for many years. The results of these investigations have been made available to the growers of these crops in various ways. On the other hand, the diseases of forest, shade, and ornamental trees have been largely neglected until very recently.

Tree diseases cause enormous losses in the large tracts of forests on which we depend for timber. The timber owner has been slow to adopt the fundamentals of scientific forest practice, and so far methods for the control of forest-tree diseases have not begun to operate in reducing losses. The owners of shade and ornamental trees are constantly confronted with diseases which they wish to control. They have become accustomed to controlling insects, but the fundamentals involved in the appearance of a disease and the measures necessary to protect trees from further damage are largely puzzling to them.

An understanding of the cause of disease is essential to the undertaking of adequate control measures. That the tree is a living organism which requires water, food, air and sunlight is often overlooked. Many of the diseases outside the forest are due to the failure to recognize the importance of maintaining suitable conditions for tree growth. The soil must contain the proper supply of food materials, and be of a texture which will conserve the water and air that are necessary for healthy root development. Pavements and sod are frequently never considered as the cause of the decline and death of trees. Likewise, it is seldom appreciated that the smoke and poisonous gases in the atmosphere in cities kill many trees. Also the appearance of leaf-spots, cankers, wood-rots and root-rots in no way explain themselves unless it is understood that invisible parasitic plants are growing in the living tissues of the tree and causing their death. The technical facts regarding the relation between a tree and its environment are more easily comprehended than the life history of the parasites which cause diseases. Nevertheless, the tree owner must understand the nature of these organisms, the appearance of the symptoms they produce, and many other facts regarding diseases before he can intelligently attempt their control. It is hoped that the details concerning the diseases discussed in this book will assist to that end. The treatment has been made as simple as possible, and only the essentials regarding the disease, which are necessary to recognize and understand it, have been included. A glossary is appended, which will assist in explaining the more technical terms.

It has been necessary to treat the general and specific diseases separately. Those diseases which are more or less common to all kinds of trees are discussed in the first four chapters. The more specific diseases will be found in the chapters following, which are arranged alphabetically according to the common name of the various groups of trees. Cross-reference has been freely made in the different chapters to more complete discussions found elsewhere. This would be unnecessary if the book were to be read from cover to cover. The plan of the book is intended, however, to facilitate the diagnosis of a disease of a certain kind of tree and to group the diseases of this tree in one place where comparisons may be made. Under each of the host-chapters, the diseases are arranged according to the part of the tree affected and will be found in the following order: leaf, twig, branch, trunk and root diseases. The reader is advised to make free use of the index, which will facilitate the finding of those discussions unavoidably scattered.

It is regretted that specific information is not yet available on many common tree diseases. Most of the leaf-spot diseases have not been studied. Likewise, control measures are largely limited to eradication methods, so far as definite recommendations can be made. This apparently will always be the case for the diseases of the woody parts of trees, until means of naturally or artificially immunizing trees are devised. Spraying and dusting for leaf diseases will be practicable when these diseases are better understood. Such methods are expensive, however, and their use will be limited for this reason.

The author is indebted to Dr. F. D. Kern, who has read the discussions of the rust diseases and offered many helpful suggestions. Grateful acknowledgment is also made to Mrs. W. H. Rankin and to the following co-workers in the Department of Plant Pathology at Cornell University for many suggestions regarding the manuscript and for photographs loaned: Prof. H. H. Whetzel, Dr. L. R. Hesler, Dr. Donald Reddick, Dr. V. B. Stewart, Dr. C. T. Gregory, Dr. H. M. Fitzpatrick, and Miss Edwina Smiley.

W. HOWARD RANKIN.

CORNELL UNIVERSITY, ITHACA, NEW YORK,
September 1, 1918.

CONTENTS

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER IX

CHAPTER X

CHAPTER XI

CHAPTER XII

CHAPTER XIII

CHAPTER XIV

CHAPTER XV

CHAPTER XVI

CHAPTER XVII

CHAPTER XVIII

CHAPTER XIX

CHAPTER XX

CHAPTER XXI

CHAPTER XXII

CHAPTER XXIII

CHAPTER XXIV

CHAPTER XXV

CHAPTER XXVI

CHAPTER XXVII

CHAPTER XXVIII

CHAPTER XXIX

ILLUSTRATIONS

MANUAL OF TREE DISEASES

MANUAL OF TREE DISEASES

CHAPTER I

SEEDLING DISEASES AND INJURIES

From the very beginning of the life of a tree, the seedling is subject to many more or less serious diseases. Damping-off may cause death, even before the tiny plant has grown above the surface of the soil. Later, if damping-off is avoided, various blights are common in the seed- and transplant-bed. Although many pathogenes are known to cause seedling diseases, it is very difficult for the layman to identify the trouble any more accurately than by the general symptoms of damping-off or blight. Damping-off symptoms are mostly due to the activities of specific soil-harbored fungi. Blight symptoms may be produced by various rapidly spreading fungi, or by adverse moisture and temperature conditions. After a careful comparison of the blight symptoms produced by environmental conditions, with the usual symptoms caused by parasites, the layman should be able to distinguish between these two general types of seedling blights. In some cases, the seedlings of certain kinds of trees are affected by well-known specific leaf-, stem- or root-parasites which cause blight. These diseases are described in the chapter on the diseases of the species of tree affected. Otherwise, the damping-off and blights such as sun-scorch, winter-drying and freezing-to-death of seedlings of both coniferous and deciduous trees, are treated below.

Damping-Off

Caused by various species of fungi

The damping-off diseases have commanded serious attention from all persons who have attempted to grow seedlings, especially of conifers. Schreger, in an early compilation of the facts known about tree diseases, published in 1795, writes about the damping-off of beech seedlings. Since the growing of large quantities of seedlings for forest planting was first attempted in Europe, the earlier literature on damping-off appeared mostly in foreign languages. American nurserymen have grown small quantities for ornamental and shade tree stock for many years. The increasing demands for large quantities for forest planting were not supplied, however, by the production of the commercial nurserymen. It is thought that the small quantity produced and high prices demanded for the stock were due mainly to the difficulties of handling the damping-off diseases. To-day the growing of coniferous seedlings in federal and state nurseries has developed until millions of trees are produced yearly. It was during the development of these specialized nurseries that the damping-off diseases in this country were studied, and methods evolved for their control.

Damping-off is a universal seedling trouble. The fungi causing the disease are common soil-harbored organisms associated with decaying plant material. Seedlings grown in new soil may suffer from damping-off as severely as those in beds which produced diseased plants the previous year. The seedlings of coniferous trees in general show marked susceptibility, while those of deciduous trees are less often attacked. Beech and maple seedlings, however, often suffer. When no precautions are taken, damping-off may kill practically the entire stand of seedlings, especially when large numbers are grown under crowded conditions.

Phytophthora omnivora de Bary is the most common on both coniferous and deciduous tree seedlings. This latter fungus is widely distributed in this country and may be found to be of importance with further investigations on deciduous seedlings. It is to be assumed that many other species of fungi may also at times produce damping-off in tree seedlings, since *Thielavia basicola* (B. and Br.) Zopf and species of Botrytis, Colletotrichum, Volutella and other fungi have been discovered producing this disease in seedlings of other crops. Numerous inoculation experiments by various workers have established the power of the above mentioned pathogenes to cause this type of disease.

The causal fungi represent many widely different types of life history. The parasitism of these fungi is of a very primitive sort. This is evidenced by their usual saprophytic character, extreme destructiveness to the host-plant, wide host-range and the fact that they are limited in their activities to very young seedlings, which have not developed the more complex physical and chemical nature of older plants. These fungi exist ordinarily as common saprophytes on decaying vegetable matter in the soil and thus their mycelium is the main infective material. Various types of spores are formed by the different species of fungi concerned in damping-off, but they are rarely instrumental in the inoculation of healthy plants. These spores, however, are mainly useful in carrying the fungus over winter and through other conditions detrimental to vegetative growth. The entire life history of these fungi then, so far as explaining the appearance and development of damping-off in seedling-beds, is confined largely to the growth of the mycelium through or on the surface of the soil, from one plant to another. This manner of spreading is often well illustrated when all the plants in a single row are destroyed and only occasional plants in the adjacent rows are affected. Although some one or several of the damping-off fungi are generally present in all soils, their presence may not become evident if conditions are adverse to their development. All damping-off pathogenes are markedly influenced by temperature, soil moisture and the humidity of the atmosphere. A relatively high temperature, moist and compact soil and a humid atmosphere furnish ideal conditions for these fungi, while lower temperatures and drier conditions of soil and atmosphere may check successfully a destructive development of these organisms after some damage has already been accomplished.

Control.

Since damping-off may be caused by any one of numerous species of fungi and may occur under such variable conditions, no general rules for treatment can be prescribed which will apply in all cases. The control of damping-off may be effected by one of two general methods: (1) protection of the seedlings by maintaining conditions of temperature and moisture which interfere with the destructive development of the pathogenes; (2) eradication of the pathogenes from the soil of the seed-bed by means of disinfectants.

(1) Protection.

Every investigator agrees that much can be accomplished in the control of damping-off by giving careful attention to the manipulation of soil moisture, temperature and atmospheric humidity. At the same time, it is realized that one may find it difficult, in regulating the amount of moisture and other factors, to preserve the equilibrium necessary to grow seedlings, and at the same time to prevent the growth of the fungi. The following method of procedure is advised:

Each seed-bed should be provided with upright frame, with wire-mesh sides and removable top, which can be made into half-shade or full-shade by laying on laths.

The seed should be sown on the surface of the prepared soil and covered to the desired depth with clean dry sand obtained by digging three or four feet below the surface. This furnishes a surfacing for the bed which is sterile and easy to keep relatively dry.

The beds should be covered and kept moist enough to promote germination. After the seeds have germinated, partial shade should be furnished on bright days but should be removed in cloudy weather, in order to allow as much evaporation as possible from the surface of the soil. These precautions are especially important if it is warm and rainy. If the surface of the soil does not dry sufficiently, more clean coarse sand may be scattered over it.

(2) Eradication.

Two general eradication methods are recommended for the control of damping-off: (1) disinfection of the soil before planting, usually with formaldehyde; and, (2) for coniferous seedlings only, disinfection at the time of planting with sulfuric acid.

If damping-off has previously occurred in a bed, the best practice is to remove the top-soil and substitute new soil. This is desirable since a large accumulation of the resting spores of the causal pathogene is to be expected after a severe outbreak. The following steps are essential for thorough disinfection:

A solution of formalin should be made by adding one gallon of formalin (which should contain forty per cent formaldehyde by volume) to fifty gallons of water.

The soil should be prepared by forking or raking. The formalin solution may then be applied to the bed with a sprinkling-can, using about two quarts for every square foot of soil to be treated. If the nature of the soil is such that this amount cannot be put on in one application, as much as possible should be applied without making the soil muddy and the remainder added a few hours later.

The bed should be covered as securely as possible with heavy paper or other impervious material for forty-eight hours.

The active substance in the formalin solution is liberated as a gas (formaldehyde). The cover is necessary in order to retain this gas in the soil for a period sufficient to kill the pathogenes.

Three or four days after the cover is removed, the soil should be thoroughly forked and allowed to stand in a loosened condition for another day or two, after which the bed may be prepared for sowing the seed. It is important to time the application of the formalin so that the seed may be sown as soon as the operations above described are completed, since the soil may become contaminated again from surrounding soil. Experience shows that beds contaminated after disinfection may exhibit greater loss than those not disinfected. The increased virulence of damping-off fungi in disinfected beds is thought to be due to the lack of competition with other soil organisms which have been killed by the disinfectant. With ordinary care, however, under most conditions a clean crop of seedlings is assured if the disinfection is thorough. Even after carefully disinfecting the soil, all the measures advised above under Protection should be observed (see page 5).

The application of sulfuric acid to the soil at the time of seeding has given good results in controlling damping-off in coniferous seed-beds. Sulfuric acid should never be used on deciduous seedlings. The amount of acid used with safety will necessarily vary with the natural acidity or alkalinity of the soil. A too heavy application of sulfuric acid will cause injury to the seedlings. This method is more difficult to handle than the formalin treatment because in loose sandy soils the capillary movement of the water will bring the acid to the surface and produce there a concentrated solution, which must be counteracted by daily watering. With heavier soils, no watering seems necessary from the experiments so far reported. With the two uncertain factors in mind, the natural acidity or alkalinity and the physical nature of the soil to be treated, the grower must experiment under his own conditions before applying this method generally, else the chemical injury by the acid to the seedlings may be greater than the losses due to damping-off if no treatment were used. If this method can be handled without damaging the seedlings, two special advantages are gained over the other two methods given above. In the first place, dicotyledonous weeds rarely grow in the acid soil and the saving of the expense of weeding will often pay for the treatment. Secondly, the disinfectant is present in the soil throughout the critical damping-off period. This assures complete control since contamination of the beds from neighboring soil is not possible and, moreover, conditions of temperature and moisture favorable to seedling growth can be provided without danger.

The average amount of sulfuric acid is three-sixteenths of a fluid ounce of clear commercial sulfuric acid to each square foot of soil to be treated. A solution is made by adding three-sixteenths of an ounce of the sulfuric acid to each quart of water (this is at the rate of one part of acid to 170 parts of water). This solution should then be applied when the seed is sown at the rate of one quart to each square foot of soil. If the soil is light and sandy and conditions are favorable for excessive evaporation, light watering once or twice a day may be necessary to prevent acid-injury. In heavier soils no watering may be necessary. The strength recommended above is sufficient to disinfect a soil which is not strongly alkaline. If the soil is naturally acid, the three-sixteenths of an ounce to each square foot may be too much. It would, therefore, be advisable to divide a given bed into three parts, applying sulfuric acid to each part respectively in the following quantities, one-eighth, one-fourth and three-sixteenths of an ounce in a quart of water to each square foot. From this experiment it may be determined which strength can be safely employed under the existing soil conditions.

REFERENCES ON DAMPING-OFF

Hartley, Carl, and Pierce, R. G. The control of damping-off of coniferous seedlings. U. S. Dept. Agr. Bul. 453 : 1–32, pls. 1–2, fig. 1 1917.

Johnson, James. The control of damping-off disease in plant beds. Wisconsin Agr. Exp. Sta. Research Bul. 31 : 29–61, figs. 1–12. 1914.

Gifford, C. M. The damping off of coniferous seedlings. Vermont Agr. Exp. Sta. Bul. 157 : 143–171, pls. 1–4, figs. 1–10. 1911.

Jones, L. R. The damping off of coniferous seedlings. Vermont Agr. Exp. Sta. Ann. Rept. **20** : 342–347. 1908.

Hartley, Carl. Injury by disinfectants to seeds and roots in sandy soils. U. S. Dept. Agr. Bul. 169 : 1–35, pl. 1, figs. 1–2. 1915.

Spaulding, Perley. The damping-off of coniferous seedlings. Phytopathology **4** : 73–88, pl. 6, figs. 1–2. 1914.

Hartley, Carl, and Merrill, F. C. Preliminary tests of disinfectants in controlling damping-off in various nursery soils. Phytopathology **4** : 89–92. 1914.

Pettis, C. R. Problems in nursery practice. Proc. Soc. Amer. Foresters **4** : 43–44. 1909.

Scott, Chas. A. A practical method of preventing the damping-off of coniferous seedlings. Jour. Forestry **15** : 192–196, pls. 1–2. 1917.

SUN-SCORCH

Caused by over-transpiration and dry soils

Under the crowded conditions which usually exist in the seed- and transplant-beds, damage from sun-scorch is common and often destructive. Next to damping-off, sun-scorch is probably the most important general nursery trouble. A careful analysis of the causal conditions and the resulting behavior of the affected plants should make a case of sun-scorch relatively easy of diagnosis. For a discussion of this type of injury in older trees, see page 22.

Symptoms.

The entire plants or only the tops may be killed. The area of the beds involved where the entire plants are killed may be more or less circular. Contrary to the action of parasites, however, the trees over the affected area die simultaneously and there is no progressive enlargement of the area. When only the tops of the plants or the lower and older leaves die, the plants may recover, though they remain in a weakened condition and easily succumb to later sun-scorch conditions. The affected leaves become chlorotic, turn yellowish and then become dried and dark brown. The entire needles are not always involved and it is very common to find only the tips brown and dead. An accompanying symptom of sun-scorch is found in the roots, which die previous to the appearance of the symptoms in the tops. At the time the leaves are turning yellow, the root system already shows considerable injury.

Cause.

Sun-scorch results when the amount of water in the soil is not sufficient to replace rapidly the amount of water lost by excessive transpiration from the leaves. The extreme combination of conditions bringing about sun-scorch are sandy soil and continuous hot, dry winds, with little dew at night, and little rainfall. Under these environmental conditions the crowding of large numbers of trees into a small space and the lack of any shade during a part or the whole of the day predispose the plants to sun-scorch injury. Certain species of trees, such as Norway spruce and Douglas fir, are more susceptible than others, especially if they are growing in soil which is rapidly drained, as is the case in the center of arched beds. The injury develops rapidly and conclusive evidence as to the causal conditions should be obtainable by examining the amount of water present in the soil. The soil around the roots of the affected plants will usually be found much drier than that around adjacent healthy plants. There may be a sufficient total water supply above and below the rooting region, but if this supply is not readily available, the plants will suffer when transpiration is excessive.

Protecting the plants by mulching is an efficient means of preventing winter-drying. Where sufficient snow falls early in the winter, the beds may then be covered with burlap and the snow-mulch retained. Where more open winters are encountered and little snow can be depended on, a light mulching of straw, buckwheat-hulls and other materials may be used.

References

Hartley, Carl. The blights of coniferous nursery stock. U. S. Dept. Agr. Bul. 44: 1–21. 1913.

Hedgcock, G. G. Notes on some diseases of trees in our national forests. III. Phytopathology 3: 111–114. 1913.

Hartley, Carl. Notes on winterkilling of forest trees. Forest Club (Univ. Nebraska) Ann. 4: 39–50. 1912.

Freezing-to-Death

Caused by low temperatures

The most common type of low temperature injury to plants is the direct killing of the susceptible parts. A part of the water in the plant is frozen when temperatures below the freezing-point are reached, and more and more water is withdrawn from the cells when the temperature becomes lower. The frozen water occurs as ice crystals which are mainly found in the intercellular spaces, but may be within the cells if the freezing occurs rapidly. Freezing-to-death has been frequently noticed and discussed for centuries, even before the internal structures of plants were understood. It was also early noted that the formation of ice crystals within the plant always accompanied freezing-to-death. The accepted and seemingly logical explanation of the cause of the death of the plant was that the plant-cells were ruptured, or otherwise mechanically destroyed during the formation of the ice crystals. This explanation is totally incorrect, however, although the exact physiological effect on the plant which results in death is as yet undetermined.

Symptoms.

When plants suffer from low temperatures and ice crystals are formed within the tissues, the first noticeable effect in the foliage is a wilted or flaccid appearance. The affected tissues have a general water-soaked character as soon as the plants are thawed. When the tissues of the buds and stems of plants are killed by ice formation, no evidence of the injury may be seen immediately after thawing. Later, however, affected parts show the water-soaked and browning symptoms. The cells adjacent to the tissues killed remain healthy and there is no enlargement of the lesion.

Cause.

As stated above, the death of plant-cells due to low temperatures is not a result of mechanical action in the process of ice formation. Nor is the injury due to the rate of thawing, as was long supposed. Carefully planned investigations on this subject have shown that death results when a certain temperature is reached. The critical temperature at which death results varies for different kinds of plants and the various parts of the same plant. The injury is due to some physiological effect of the taking of the water from the cell and changing it into ice. The injury has been ascribed, by various investigators, to the precipitation of the proteids in the cells, the drying of the plasma-membrane, the plasmolysis of the nuclei and to various other effects. It is known that various tissues of the same plant will withstand different critical temperatures, that plants differ widely in their resistance to low temperature injury, and that the previous treatment of a given plant may make it more resistant or more susceptible to a given degree of temperature. Previous exposure of the plant to temperature just above the killing point makes it more resistant, while lowering the temperature rapidly causes the plant to succumb at a temperature higher than the usual critical temperature for that plant. The stem- and root-tissues develop added resistance to low temperatures if they mature properly in the autumn. The exact nature of this maturing process is not understood, but growth must cease and the tissues must pass slowly into the dormant stage. If the plant passes rapidly from the active vegetative condition into dormancy, the tissues are killed at a much higher temperature. The process of maturing in small seedlings is relatively much more rapid than in large trees. The roots are more liable to injury in the case of seedlings because they cease growth last and mature later than the aërial parts. They are also subject to injury because the feeding root-tips and tenderest rootlets are close to the surface of the soil. For a further discussion of freezing-to-death in older trees, see page 47.

In the case of early or fall frosts, a sudden drop of temperature below 32° Fahr. may cause injury. Broad-leaf trees are more susceptible to early frost-injury than conifers. Injury to seedlings may result in the spring from late frosts. Temperatures a little above 32° Fahr. may cause serious damage owing to the extreme susceptibility of the new tissue.

Control.

High ground should be selected for the site for the seed- and transplant-beds in regions where low temperatures are common. At the same time, where sandy soil and danger from sun-scorch may be encountered, a site which will avoid both high and low spots should be selected. Early in the autumn only slight care should be given the beds since the trees should be allowed to cease growth and enter the dormant condition. Loose mulches advised under winter-drying (see page 11) will protect the plants to some degree against freezing-to-death, especially by keeping the temperature more uniform and decreasing the rapidity of temperature changes. The mulch should be allowed to remain on the beds as long as is safe in the spring in order to retard the beginning of growth.

References on Freezing-to-Death

Chandler, W. H. The killing of plant tissue by low temperature. Missouri Agr. Exp. Sta. Research Bul. 8: 141–309. 1913.

Zon, R. G. Effects of frost upon forest vegetation. Forestry Quarterly 2: 14–21. 1903.

Hartig, R. Injuries due to atmospheric influences and fire. *In* Text-book of the diseases of trees, pp. 282–304, figs. 157–159. 1894.

Metcalf, H. Diseases of ornamental trees. U. S. Dept. Agr. Yearbook 1907: 483–494, pls. 58–60, fig. 52. 1908.

Galloway, B. T., and Woods, A. F. Diseases of shade and ornamental trees. U. S. Dept. Agr. Yearbook 1896: 237–254, figs. 53–57. 1897.

Smothering-Disease

Caused by *Thelephora laciniata* Fries

This disease is common and often destructive in seed-beds of spruce, fir and pine. It may, however, occur on trees of any species. The mycelium of the causal fungus does not enter and establish a parasitic relation with the living plant. It grows in the soil and uses decaying vegetable matter as food. A moist and continually humid atmosphere is necessary to furnish ideal conditions for the destructive development of this fungus. When the trees are planted thickly, this fungus produces an abundant growth of mycelium which adheres to the trees as confluent, incrusting, leathery layers. It may ascend to a height of six or eight inches and encompass the trees. At frequent intervals, more or less horizontal shelves project from the fungous layers attached to the seedlings. These shelves may be narrow and coarsely toothed or broad and rosette-like with a lacerated margin. In its active vegetative condition, the upper surface of the shelf is finely hairy and a rich dark brown with lighter zones of color. When old and somewhat dried, the entire fungous mass adhering to the trees becomes shrunken and a dirty dark brown.

The trees may be enveloped for only an inch or two above the soil with no considerable damage resulting, while at other times the entire plants or such a large part of their leaf-surface is covered that the trees die. The projecting shelves and the incrusting layers developed over the trees are the fruiting-structures of the fungus. The under and outer surface of the fungous layers is smooth and covered with branches of the mycelium which form spores at their tips. These spores are snapped off when mature and are distributed by the wind. In the seed-bed, however, the mycelium grows rapidly through the soil and thus distributes the fungus over large areas without the necessity of spore dissemination.

When injury from the smothering fungus occurs, it is advisable to remove the affected plants and those just adjacent, by lifting the soil containing them with a spade. Merely pulling the trees will leave the vegetative portion of the fungus in the soil where it can continue to spread. When the affected plants are removed, measures should also be taken to reduce the soil and atmospheric moisture in the beds, by draining off excessive soil-water and removing any structures which shade the beds. These measures must be limited, however, so as not to predispose the plants to sun-scorch (see page 9). Thinning the seedlings may be advisable under conditions in which the moisture factor cannot be otherwise easily controlled.

References

Hartig, R. Pseudo-parasites. *In* Text-book of the diseases of trees, pp. 35–36, fig. 8. 1894.

Freeman, E. M. The smothering fungus of seedlings. *In* Minnesota plant diseases, pp. 243–244. 1905.

CHAPTER II

LEAF DISEASES AND INJURIES

The diseases and injuries of leaves common, in varying degrees, to all kinds of trees are due mainly to three general causes: extremes of moisture and temperature, atmospheric impurities, and an improper or impaired supply of raw materials and water. Of these, the extremes of moisture and temperature are the most important, especially when the trees are under normal conditions of growth.

Conifers which keep their leaves throughout the winter may be injured by winter-drying as described under seedling diseases (see page 11). Freezing-to-death may cause destruction of the newly formed twigs and unfolding leaves of both conifers and deciduous trees when late frosts occur in the spring. Trees of all kinds often suffer severely from protracted drought periods because of the lack of sufficient soil-water. The scorching of the leaves occurs most commonly when dry hot winds cause excessive transpiration, as in the sun-scorch of seedlings (see page 9). The severity of such injuries depends largely on the natural requirements of the species and how well adapted a given tree is to its surroundings. Certain types of soils, the nature and direction of the slope and other such factors may predispose certain trees to winter-drying, late frost-injury or sun-scorch when other kinds of trees would not suffer.

The injuries due to temperature and its important accompanying effect on transpiration are peculiar to extremes in weather conditions and usually seen after them. The causes of such injuries must be considered with the symptoms for a correct diagnosis of the trouble, since usually no determinative symptoms are present. The ultimate factor of importance in most cases is an insufficient supply of water available to compensate for the loss by transpiration. Conditions bringing about such injuries may occur at any time of year when the leaves are on the tree.

Atmospheric impurities are mostly injurious in and near cities where gases of various kinds are allowed to escape without restriction. Soot from ordinary coal-smoke may cause damage if quantities of it are continually falling on trees.

The more abnormal the surroundings in which trees are placed, the more important and common become the injuries due to faulty nutrition. The symptoms of malnutrition, independent of other causes, are generally poor growth and the chlorosis or yellowing of the leaves. In addition to these types of injury which show prominently in the leaves, any diseased condition of the roots, trunk or branches which interferes with the necessary conducting of food materials to the leaves results in injury to the leaves. Consequently in diagnosing leaf-injury, the leaves alone should not be examined but the condition of the branches, trunk and roots should be studied to see whether they show the primary symptoms. The diseases of leaves caused by specific pathogenes will be found discussed under the kind of tree attacked.

Winter-Drying

Caused by simultaneous low soil temperatures and high air temperatures

Conifers which retain their foliage throughout the winter frequently suffer injury to the leaves of a part or all of the tree due to drying. After severe winters, trees may be found in exposed places which have been killed outright. The injury is very conspicuous and where generally prevalent it causes

due to winter-drying or to fungous attack is to note carefully the needles affected on a few trees and then watch the trees throughout the season. If no further spread of the trouble is apparent during the summer, one may usually be assured that the damage was due to temperature conditions and not to leaf-parasites.

Control.

Little can be done to protect trees from winter-drying. In the case of ornamental conifers, it should be remembered that this trouble is common in places exposed to the wind and that young trees with shallow root systems are most susceptible. Mulching the soil around small trees may be advisable during winters when there is little snow on the ground.

References

Stone, G. E. Winter-injuries, drought, sun-scorch, and bronzing of leaves. *In* Shade trees, characteristics, adaptation, diseases and care. Massachusetts Agr. Exp. Sta. Bul. 170: 199–212. 1916.

Morse, W. J. Winter injury of the white pine in 1908. *In* Notes on plant diseases in 1908. Maine Agr. Exp. Sta. Bul. 164: 21–28, fig. 4. 1909.

Hedgcock, G. G. Notes on some diseases of trees in our national forests. III. Phytopathology **3**: 111–114. 1913.

Spaulding, Perley. The present status of the white-pine blights. U. S. Dept. Agr. Bur. Pl. Ind. Circ. 35: 1–12. 1909.

Brooks, Charles. Pine blight. *In* Report of the Department of Botany. New Hampshire Agr. Exp. Sta. Ann. Rept. **19–20**: 370–371. 1908.

Hartley, Carl P. Notes on winterkilling of forest trees. Forest Club (Univ. Nebraska) Ann. **4**: 39–50. 1912.

Galloway, B. T., and Woods, A. F. Desiccation, or drying out, and low temperatures. *In* Diseases of shade and ornamental trees. U. S. Dept. Agr. Yearbook **1896**: 243–246. 1897.

Metcalf, Haven. Drying out. Effects of cold. *In* Diseases of ornamental trees. U. S. Dept. Agr. Yearbook **1907**: 486–487. 1908.

Late Frost-Injury

Caused by low temperatures in the spring

Low temperatures in the spring, after new growth has started, often result in what is commonly known as late frost-injury. This type of injury is especially noted on conifers. The young growing tips of the branches, with the newly unfolded succulent leaves, wilt, die and turn brown. Sycamores and other deciduous trees which start their growth early also are often injured by low temperatures in the spring. In the case of the sycamore, the symptoms of late frost-injury and the anthracnose disease (see page 333) are often confused. The injury caused by late frosts is due directly to the freezing-to-death of the susceptible succulent growth. The tissues of the growing tips of the twig and the young unfolding leaves are the most susceptible of any of the tissues of the tree. Only a very slight fall of temperature below the freezing point is sufficient to cause the withdrawal of enough water to result in death. For a more detailed description of the effects of low temperatures in causing freezing-to-death, see page 12.

Injury from late frost usually occurs on south slopes and in badly drained hollows known as frost-pockets. By planting susceptible species in locations usually free from frost and not exposed to the direct rays of the sun, a large part of the injury caused by late freezing may be avoided. Other methods of retarding the growth in the spring will also furnish some protection.

References

Schrenk, Herman von. On frost injuries to sycamore buds. Missouri Bot. Garden Ann. Rept. **18**: 81–83, pl. 7. 1907.

Morse, W. J. Winter injury of the white pine in 1908. *In* Notes on plant diseases in 1908. Maine Agr. Exp. Sta. Bul. 164: 21–28, fig. 4. 1909.

Drought-Injury and Sun-Scorch

Caused by high temperatures and dry soils

In midsummer the foliage of many kinds of trees often appears scorched. Pines and maples are commonly affected. The leaves of one side or of the entire tree may wither and turn brown. In general, this type of summer injury is similar to winter-drying (see page 18). The effects are the same and the causes similar. In winter-drying of conifers, a greater amount of water is lost than can be replaced because the ground-water is frozen. In the case of drought-injury and sun-scorch, water is lost from the leaves in quantities that cannot be replaced because of many conditions, such as: diseased or injured roots, a low water-table due to continued drought, or naturally dry and sandy soil. The injury usually occurs on the exposed side of the tree and commonly follows periods of hot dry winds. The sun-scorch of maple leaves has been found to follow immediately after an hour's exposure to high winds on hot days.

In the case of conifers, the needles of the affected parts of the tree turn uniformly brown. With deciduous trees, large or small spots may be killed, leaving the remainder of the blade healthy and green. Usually the edge of the leaf, or the portion midway between the main veins, suffers first. Then if the drought conditions continue, the entire leaf may be killed and turn brown. The bronzed appearance of maple leaves commonly seen is typical of sun-scorch injury. Although, as stated above, sun-scorch following drought conditions or exposure to hot drying winds is usually found to be due to damaged root systems or dry soil, it sometimes happens that trees not so predisposed suffer merely from the effects of rapid transpiration.

Reference

Stone, G. E. Sun scorch and bronzing of leaves. *In* Shade trees, characteristics, adaptation, diseases and care. Massachusetts Agr. Exp. Sta. Bul. **170**: 210–212. 1916.

Smoke- and Gas-Injury

Caused by the products of incomplete combustion of coal

Conspicuous injury to vegetation is noticeable around industrial centers where smoke and invisible poisonous gases are discharged into the air from chimneys. The manufacturing plants, large and small, office buildings, apartments, private residences, railroad locomotives, smelters, furnaces, kilns, and the like, are sources of smoke and gases, which in nearly every city or industrial center cause the death of certain species of plants, and chronic injury to other species for miles around. The topography of the country surrounding the source of smoke and gas determines the distribution and extent of the injury. Prevailing winds and natural air currents, caused by hills and valleys, may result in but little damage at the source of the smoke and cause severe damage at a distance where the smoke settles. The zones of acute injury are readily traceable by the remains of trees and other plants killed by the fumes. If the production of poisonous fumes has been continued over a long period, the last vestige of plant life may have disappeared. This is especially true where fogs are common, which cause the fumes to be held in concentrated form over the immediate locality. When the source of smoke is in a valley, more injury may result just beyond the brow of the surrounding hills than immediately adjoining the source. The determination of the amount of damage caused by chronic injury some distance away from the source of smoke is sometimes difficult. Much of the trouble in encouraging normal tree growth in the cities is traceable to chronic injury by smoke and gases. In the open country, away from the other pathologic factors which are met with in the cities, the effects of acute injury have been found to extend for a distance of ten to fifteen miles from the source of smoke and gases, and the chronic injury to a much greater distance, sometimes probably fifty or one hundred miles.

Trees vary greatly in their susceptibility to the poisonous substances in smoke. Conifers are more susceptible than deciduous trees. The following order, from most susceptible to less susceptible, is reported by one writer: Alpine fir, Douglas fir, lodge-pole pine, western yellow pine, limber pine, Rocky Mountain juniper and dwarf juniper. In like manner the same writer reports the deciduous trees in order of least to greater resistance, thus: white elm, sycamore, locust, yellow poplar, cottonwood, black gum, dogwood, red maple and white oak. In Des Moines, Iowa, the willows and cottonwoods were found to be the most resistant trees. Also in that city the following deciduous trees were more resistant than pines: locust, white elm, ash, sycamore, silver maple, bur oak, white oak, red oak and box-elder.

Symptoms.

The symptoms of smoke- and gas-injury are variable according to whether the injury is acute or chronic and according to the species and age of the tree. When smoke is dense, more damage may apparently come from the coating of soot formed on the leaves than from the gases accompanying the smoke. In such cases the foliage is covered with the tar-like coating of soot and the leaves appear sickly and dwarfed. The tree as a whole is usually scrawny and makes but little growth each year. When the injury is more acute, and apparently due to the poisonous gases emitted along with the smoke, the leaves turn brown in spots and die. In the case of coniferous trees, the needles turn brown from the tip. Deciduous leaves usually appear as if sun-scorched, the portion of the leaf between the main veins turning brown first. In general, trees exposed to smoke have much smaller leaves than normal trees and often the leaves are crumpled. The killing of part of the foliage and the dwarfing and twisting of other leaves cause a greatly reduced leaf-surface for the manufacture of food, and consequently the whole tree suffers. Diminished growth, both in width of the annual ring and in length of the twigs, is a general symptom resulting from the direct injury to the leaves. Some writers believe that the gradual accumulation of the poisonous products in smoke, lodging in the soil, may have a detrimental effect on the trees. Some indication as to whether or not smoke is causing damage in a given locality may be determined by observing the presence or absence of lichens and the common green Pleurococcus which normally grow on the north sides of trees and posts. These plants are very susceptible to smoke-injury and will not appear where smoke is present. The common garden bean is one of the most susceptible of annuals and the behavior of this plant may be taken as an indication of possible smoke-damage.

Cause.

The toxic property of smoke, and the accompanying invisible gases which issue with it from chimneys, is due to several substances, the most important of which is sulfur-dioxide. All coal contains some sulfur and when burned this escapes as a sulfur-dioxide gas. This gas is heavy and accumulates in the lower strata of the air. On further oxidation and contact with water, it dissolves and forms sulfuric acid which is corrosive and toxic to the living cells of the leaves. The cumulative effect of small amounts of sulfuric acid is to produce the burning symptoms noticed in acute injury, and cause the stunted and deformed foliage in more resistant plants.

Soot and ashes falling on foliage also carry with them a certain amount of sulfuric acid. Soot itself causes added injury by accumulating as a tarry coating on the leaves and thus diminishing their photosynthetic power. The particles of soot may also clog the stomates of the leaf and interfere with the normal exchange of gases necessary for starch formation. The amount of soot falling where smoke is abundant is enormous. In the vicinity of Indianapolis, Indiana, it was computed that 1200 tons of soot to the square mile were deposited in a year, which means ten and a quarter pounds to the acre every day.

Other toxic substances which may accompany smoke are carbon-monoxide, acetylene, ethylene, arsenic and various toxic organic compounds found in the particles of tar accompanying soot. The action of all these substances, where they accumulate in the soil, may cause direct or indirect injury to plants. It is thought that the elimination of the lower forms of plant and animal life in the soil may be the most important injurious factor, although the substances may be directly responsible for damage to growing trees by being taken in through the roots into the sap of the tree.

Control.

The prevention of smoke-injury is largely outside the power of the individual. However, it should not be difficult for an energetic community to secure relief from smoke conditions by establishing some sort of city control of the smoke nuisance. When the total elimination of smoke cannot be accomplished, smoke-resistant trees should be planted where conditions are worst. A careful study of the condition of those trees which remain in the vicinity of the source of the smoke will show what species should be chosen for replanting.

References

Bakke, A. L. The effect of city smoke on vegetation. Iowa Agr. Exp. Sta. Bul. 145: 383–409, figs. 1–22, map 1. 1913.

Stone, G. E. Effects of atmospheric gases on vegetation. *In* Shade trees, characteristics, adaptation, diseases and care. Massachusetts Agr. Exp. Sta. Bul. 170: 228–232. 1916.

Buckhout, W. A. The effect of smoke and gas upon vegetation. Pennsylvania Agr. Exp. Sta. Ann. Rept. **1900–1901**: 297–324. 1902.

Clevenger, J. F. The effect of the soot in smoke on vegetation. Mellon Inst. Indus. Res. and School Spec. Indus. Bul. 7: 1–26, pls. 1–8, figs. 1–2. 1913.

result, the affected tissue falls out entirely and the effect is known as shot-hole. When the spots become numerous the leaves may be killed and the tree is more or less defoliated.

Various types of fruiting-bodies, of the fungi causing leaf-spots, are developed on the dead tissue. These structures appear to the unaided eye as minute brown or black dots scattered over the area or grouped in clusters near the center of the spot. Spores are produced in or on these structures.

Cause.

Leaf-spots are caused by many species of fungi, usually of the genera Phyllosticta, Septoria, Cylindrosporium, Cercospora, Marssonia and Glœosporium. These genera represent groups in which the leaf-spot fungi are placed according to the microscopic characters of the fruiting-bodies and the spores, which are formed on the spots. The fruiting-bodies are simple inclosures (pycnidia) or spore-bearing layers of mycelium (acervuli). Because of the simplicity and variability of the structures, these fungi have been given numerous names. The confusion in classification has caused several names to be applied to the same fungus on the same tree and on different kinds of trees. In addition to the fruiting-structures mentioned above, the leaf-spot fungi in many cases develop perithecia and ascospores in the dead leaves on the ground during the autumn and winter.

Following is a list of parasitic fungi which have been described as causing leaf-spots. In some cases more recent investigations have proved that several of the names are synonymous. These are indicated when known:—

Alder
Cylindrosporium vermiforme Davis
Septoria alni Sacc.
Septoria alnicola Cooke
Septoria alnifolia E. and E.
Septoria maculans B. and C.
= *Rhabdospora maculans* (B. and C.) Sacc.

Ash

Cercospora fraxinites E. and E.
Cercosporella trichophila Davis
Cylindrosporium viridis E. and E.
Glœosporium aridum El. and Hol.
Glœosporium fraxineum Peck
Glœosporium fraxini Harkness
Marssonia fraxini El. and Davis
Phyllosticta fraxinicola Curr.
Phyllosticta viridis El. and Kel.
Piggotia fraxini B. and C.
Ramularia fraxinea Davis
Septoria Besseyi Peck
Septoria fraxini Desm.
Septoria leucostroma E. and E.
Septoria submaculata Winter

Basswood

Cercospora microsora Sacc.
Cercospora tiliæ Peck, see page 102.
Glœosporium tiliæ udem.
Phyllosticta stictica B. and C.
Phyllosticta tiliæ Sacc. and Speg.

Beech

Glœosporium fagi (Desm.) E. and E.
Glœosporium fagi americanum (Desm. and Rob.) E. and E.
Phyllosticta fagicola E. and M.

Birch

Cylindrosporium betulæ Davis
Glœosporium betularum E. and M.
Septoria betulicola Peck
= *Septoria betulæ* (Lib.) West
Septoria microsperma Peck

Buckeye

Glœosporium carpogenum Cooke
Guignardia æsculi (Peck) Stewart, see page 118.
= *Læstadia æsculi* Peck
= *Phyllosticta æsculi* E. and M.
= *Phyllosticta æsculicola* Sacc.
= *Phyllosticta paviæ* Desm.
= *Phyllosticta sphæropsoidea* Ellis

Butternut

Ascochyta juglandis Boltsh.
Cercospora juglandis K. and Schw.
Gnomonia leptostyla (Fr.) Ces. and De Not.
= *Marssonia juglandis* (Lib.) P. Magn.

Catalpa
Cercospora catalpæ Winter
Macrosporium catalpæ E. and M.
Phyllosticta catalpæ E. and M.
Chestnut
Marssonia ochroleuca B. and C.
= *Cryptosporium epiphyllum* E. and E.
= *Cylindrosporium castanicolum* (Desm.) Berl.
= *Glœosporium ochroleucum* B. and C.
Monochætia Desmazierii Sacc., see page 139.
Phyllosticta cantanicola E. and E.
Phyllosticta castaneæ E. and E.
Phyllosticta fusispora E. and E.
Septoria ochroleuca B. and C.
Elm
Cylindrosporium tenuisporum Heald and Wolf
Cylindrosporium ulmicolum E. and E.
Dothidella ulmea (Schw.) E. and E.
Dothidella ulmi (Duv.) Winter
Gnomonia ulmea (Sacc.) Thüm., see page 152.
Phleospora ulmi (Fries) Wallr.
Phyllosticta confertissima E. and E.
Phyllosticta erratica E. and E.
Phyllosticta melaleuca E. and E.
Phyllosticta ulmi West
Hackberry
Cylindrosporium celtidis Earle
Cylindrosporium defoliatum Heald and Wolf
Macrosporium antennæforme B. and C.
Phleospora celtidis El. and Martin
Phyllosticta celtidis El. and Kel.
Ramularia celtidis El. and Kel.
Septoria celti-Gallæ Gerard
Septoria gigaspora E. and E.
Hickory
Glœosporium caryæ El. and Dearn.
= *Gnomonia caryæ* Wolf
Marssonia juglandis (Lib.) Sacc.
Phyllosticta caryæ Peck
Locust
Cylindrosporium solitarium Heald and Wolf
Maple
Cercospora negundinis E. and E.
Cylindrosporium negundinis E. and E.
Glœosporium aceris Cooke

Glœosporium apocryptum E. and E., see page 226.
Glœosporium negundinis E. and E.
Glœosporium saccharinum E. and E.
Phyllosticta minima (B. and C.) E. and E., see page 226.
= *Phyllosticta acericola* C. and E.
= *Phyllosticta minutissima* E. and E.
= *Phyllosticta negundinis* Sacc. and Speg.
= *Phyllosticta saccharina* E. and M.
Rhytisma acerinum Fries, see page 223.
Rhytisma punctatum Fries, see page 225.
Septoria acerella Sacc.
Septoria acericola Desm.
Septoria acerina Peck
Septoria aceris B. and Br.
Septoria marginata Heald and Wolf
Septoria saccharina E. and E.
= *Ascochyta aceris* Lib.
= *Cylindrosporium saccharinum* E. and E.
= *Phleospora aceris* (Lib.) Sacc.
Septoria sallicæ Gerard

Oak

Ascochyta Quercus Sacc. and Speg.
Glœosporium nervisequum (Fckl.) Sacc., see page 237.
Glœosporium quercinum West
Glœosporium quernum Hark.
Glœosporium septorioides Sacc.
Leptothyrium dryinum Sacc.
Marssonia Martini (Sacc. and Ellis) P. Magn.
= *Glœosporium Martini* Sacc. and Ellis
Marssonia Quercus Peck
= *Glœosporium Quercus* Peck
Pestalozzia flagellata Earle
Phyllosticta agrifolia E. and E.
Phyllosticta apiculata Sacc. and Syd.
Phyllosticta livida E. and E.
Phyllosticta ludoviciana E. and M.
Phyllosticta phomiformis Sacc.
Phyllosticta Quercus Sacc. and Speg.
Phyllosticta Quercus-illicis Sacc.
Phyllosticta Quercus-prini E. and E.
Phyllosticta Quercus-rubræ Gerard
Phyllosticta tumoricola Peck
Phyllosticta vesicatoria Thüm.
Phyllosticta virens E. and E.
Phyllosticta Wislizeni E. and E.

Rhytisma erythrosporum B. and C.
Septoria dryina Cooke
Septoria neglecta Earle
Septoria querceti Thüm.
Septoria serpentaria E. and M.

Poplar
Marssonia castagnei (D. and M.) P. Magn.
= *Trochila populorum* Desm.
Marssonia populi (Lib.) Sacc.
= *Glœosporium populi* (Lib.) Mont. and Desm.
Marssonia rhabdospora (E. and E.) Magn.
Phyllosticta maculans E. and E.
Septoria musiva Peck
= *Cylindrosporium oculatum* E. and E.
= *Phyllosticta populina* Sacc.
= *Septoria candida* (Fckl.) Sacc.
= *Septoria populi* Desm.
= *Septoria salicina* Peck
Septoria populicola Peck

Sycamore
Glœosporium nervisequum (Fckl.) Sacc., see page 333.
Phleospora multimaculans Heald and Wolf
Phyllosticta platani Sacc. and Speg.
Septoria platanifolia Cooke

Walnut
Ascochyta juglandis Boltsh.
Cylindrosporium juglandis Wolf.
Marssonia juglandis (Lib.) P. Magn., see page 339.
= *Gnomonia leptostyla* (Fr.) Ces. and De Not.
Phleospora multimaculans Heald and Wolf
Septoria juglandis B. and C.
= *Rhabdospora juglandis* (Schw.) Sacc.

Willow
Cercospora salicina E. and E.
Glœosporium maculans Hark.
Glœosporium salicis West
Marssonia apicalis Davis
Phyllosticta apicalis Davis
Ramularia rosea (Fckl.) Sacc.
Ramularia uredinis (Voss) Sacc.
Rhytisma salicinum Fries, see page 343.
Septoglœum salicinum (Peck) Sacc.
Septoria albaniensis Thüm.
Septoria salicina Peck

In general the life history of these fungi is similar for all the species. The spores causing primary infection in the spring may come from two sources. The ascospores developed on the dead leaves are forcibly ejected into the air and are borne by the wind. Usually the leaves of the lower branches are most heavily infected by these spores. Also, if the mycelium of the fungus should be one which affects the bark-tissues of the twigs, primary infection may result from spores produced in fruiting-bodies on the bark. During the spring and summer, the destructive spread of the fungi is due to the abundant spore-production in the fruiting-bodies on the dead areas of the leaves.

Wet seasons are particularly favorable for epiphytotics of leaf-spot diseases. This is due to the fact that abundant moisture is necessary to disseminate the spores and to induce germination. In this way several generations of spores are produced until the leaves are so generally affected that defoliation may result.

Control of leaf-spots.

In the forest no direct methods of control for leaf diseases are practicable. With shade and ornamental trees, however, the appearance of the tree or the protection from repeated defoliation, may warrant the expense necessary to control the fungus. All leaves which fall from affected trees should be raked together and burned in the autumn. If this is carefully done for some distance away from the trees, much of the primary infection will be avoided. In case the fungus also affects the twigs, all the dead and cankered twigs should be pruned off before the buds burst in the spring (see under control of leaf-blight and witches'-broom of sycamore, page 337). Even if these eradication measures are taken, the fungus may appear, especially in wet seasons, by spreading from surrounding trees, or because a sufficient number of spores were available for primary infection from bits of leaves or diseased twigs which were not burned. The eradication measures, therefore, should be supplemented by spraying or dusting, as the leaves unfold and grow to full size. For large trees, these measures are expensive and are not advised except under extraordinary circumstances. Directions for spraying and dusting will be found on page 357.

Powdery Mildews

Caused by fungi of the family Erysiphaceæ

The leaves and sometimes the twigs and fruits of many kinds of plants are attacked by the fungi of the family Erysiphaceæ, which cause powdery mildews. One or more of these powdery mildews attack the leaves of most kinds of deciduous trees in the United States. Two species of these fungi, *Microsphæra alni* and *Phyllactinia corylea*, occur generally throughout the country and may be expected on all kinds of broad-leaf trees. The following list of the powdery mildew fungi reported in this country on the different kinds of trees may be of interest, although without the aid of a microscope no definite characters are available for distinguishing one powdery mildew from another: —

Alder
  Erysiphe aggregata (Peck) Farlow (on female catkins), see page 86.
  Microsphæra alni (Wallroth) Salmon
  Phyllactinia corylea Karsten
Ash
  Phyllactinia corylea Karsten
Basswood
  Uncinula Clintonii Peck, see page 101.
Beech
  Microsphæra alni (Wallroth) Salmon
  Phyllactinia corylea Karsten
Birch
  Microsphæra alni (Wallroth) Salmon
  Phyllactinia corylea Karsten

Symptoms of powdery mildews.

Of the fifteen species or varieties of these fungi on trees in this country, all are confined to the upper or lower surface of leaves, except *Sphærotheca lanestris*, causing the brown mildew of leaves and twigs of oak, *Sphærotheca phytoptophila*, on buds, twigs and leaves of the witches'-brooms of hackberry, and *Erysiphe aggregata* on the fertile catkins of alders. In all of these species, also, the mycelium is white and appears powdery except that, with age, the mycelium of *Sphærotheca lanestris* becomes brown, and that of *Erysiphe aggregata* somewhat yellowish. The mycelium of all the species is entirely superficial and is visible in mass to the unaided eye. Under certain favorable conditions of growth, the mycelium becomes so abundant that definite white (or in some cases brown or yellow, as mentioned above) felts are formed. More often, however, the growth is not so plainly visible and the affected areas appear as blanched or slightly whitish and indefinite. In the early stages of development, the mycelium produces enormous numbers of white spores which cause the affected area to appear powdery. This character is the main diagnostic symptom for recognizing these mildews in the spring and summer.

As the season advances, the powdery white mycelium becomes less apparent in most cases and only traces can be detected. However, during late summer and autumn when these characters become less distinct, many small yellowish, globose bodies just visible to the eye begin to appear on the affected part of the leaf. These bodies become dark brown or black and are the fruiting-bodies which contain ascospores. Except when very young succulent growth is attacked, no material damage is done to the leaves. Young growth, however, may be stunted in development, as when *S. lanestris* occurs on oak twigs and leaves (see page 243).

Cause.

All the powdery mildew fungi belong to the same family and have similar life histories. The black fruiting-bodies containing the spores over-winter on the fallen leaves. They crack open the next spring, forcibly liberating the ascospores which are caught up by the wind and are carried away to infect the new developing foliage. Infection is brought about by the ascospores which lodge on leaves of the right kind of tree, if conditions of moisture and temperature are correct for germination. The germ tube penetrates the outer wall of an epidermal cell of the leaf and produces a thread of mycelium within the cell. Food materials are thus obtained by the fungus and the mycelium branches out from the external part of the germ tube, and forms a richly branching growth over the surface of the leaf. Here and there short lateral branches, called haustoria or suckers, penetrate into other epidermal cells to obtain food. In this way the fungus develops until its growth is visible to the eye and sometimes, from a single infection or by the intermingling of many individual infections, the mycelium may cover most of the leaf-surface. Numerous short erect branches are formed and from these are cut off large numbers of small spores which are so abundant that the thready character of the mycelium is masked, and the area appears powdery. These spores are disseminated by the wind and may start new infections. The mycelium and the spores, developed before the black fruiting-bodies appear, are so nearly alike for all powdery mildew fungi that they cannot be distinguished one from another. The microscopic characters of the black fruiting-bodies (perithecia) and the asci and ascospores which they contain serve to classify the mildews into several genera and species within genera.

Control.

Powdery mildews are easily controlled, since the mycelium is external and can be killed by applying toxic substances in a liquid or dust form. Gathering and burning the fallen leaves will reduce the amount of primary infection in the spring. During the summer, when it is desired to prevent the further development of these fungi, flowers of sulfur or preferably finely ground sulfur-flour may be dusted on the affected leaves. For large trees, blowers must be used which will produce a fog of the sulfur-dust that will settle all over the foliage. Lime-sulfur solution (1–50) with the addition of three pounds of iron-sulfate to each fifty gallons of the mixture is also effective. Bordeaux mixture and other copper mixtures are not advised. If possible, the application of sulfur-dust should be made in the early morning while the trees are still damp, and preferably at a time when weather conditions are to continue warm and dry. The fungicidal value of sulfur is much greater under such conditions. For fuller directions on spraying and dusting, see page 357.

Reference

Salmon, E. S. A monograph of the Erysiphaceæ. Mem. Torrey Bot. Club 9: 1–292, pls. 1–9. 1900. (Bibliography given.)

Leaf-Cast of Conifers

Caused by fungi of the genera Lophodermium, Hypoderma and Hypodermella

Several similar diseases of pine, larch, fir, spruce and juniper are known under the general name of leaf-cast. Other names, such as leaf-browning, leaf-reddening and cracking-scurf, have been applied to these diseases. In Europe the leaf-cast diseases of conifers have often assumed the nature of epiphytotics and serious damage is common in nurseries and in the forest. Before the cause of the leaf-cast diseases was known, they were confused with all types of leaf-browning of conifers. The Scotch pine is the most severely injured of the various conifers affected in Europe. In the United States the leaf-cast diseases have not assumed such general importance and are only found destructive to certain species in restricted areas. In California, white and Shasta red fir, lodge-pole, western yellow, and Jeffrey pine are frequently affected by leaf-cast. In the Northwest, leaf-cast occurs destructively on western yellow and white pine and on western larch. In eastern United States, white pine and balsam fir are sometimes affected.

Symptoms.

The general symptoms of leaf-cast are similar in a way to sun-scorch and other injuries which cause the needles to die and turn reddish or brown. In leaf-cast, however, the first indication of the disease is the appearance of yellowish or brownish bands or spots on the needles. The needles do not suddenly turn brown at the tips or in their entirety as is the case when a lack of water causes the death of the needles. Also in leaf-cast, the needles of a single bundle or twig are usually not all affected simultaneously. After a needle shows the brown spots, it soon turns yellow or brown and may fall off. Sometimes the twigs are affected and they are either stimulated to form witches'-brooms or are killed.

The fruiting-bodies of the causal fungi appear as roundish or elongate black pustules on the surface of the affected leaves. The fruiting-bodies may not be formed until the leaves fall to the ground. When closely examined, a narrow line will be seen running lengthwise of the fruiting-body and dividing it into halves. In the spring the two halves break apart at this line and fold backward, exposing the spores.

Cause.

The leaf-cast diseases of conifers are caused by several species of fungi belonging to the closely related genera, Lophodermium, Hypoderma and Hypodermella. In this country the following species have been found to cause leaf-cast: —

On white and pitch pine and hemlock in eastern United States, — *Hypoderma strobicola* Tubeuf = *Lophodermium brachysporum* Rostrup.

On balsam fir in eastern United States, and white and Shasta red fir in California, — *Lophodermium nervisequum* Fries.

On western larch in the Northwest — *Hypodermella laricis* Tubeuf.

On western yellow pine in the Northwest, — *Hypoderma deformans* Weir.

On lodge-pole pine in California, — Hypoderma sp.

On western yellow pine in California, — Lophodermium sp.

To the unaided eye, the fruiting-bodies of these fungi are all similar. The roundish or elongate black raised pustules mature during the winter. With the coming of warm spring rains, the fruiting-body splits along the median cleavage line and the two valve-like halves are folded back. In this condition the layer of asci containing ascospores is exposed. The spores are shot into the air and are disseminated by the wind. If all the spores are not ejected the first time, subsequent rain periods will cause further spore-ejection. In this way the periods of infection may be distributed in dry climates over the entire growing season. Where rain periods are more frequent in the spring, most of the infection occurs in May and June and the supply of spores is exhausted. The needles of the current season only are affected in the case of some of the leaf-cast diseases, while in others the older needles are affected and the young needles remain healthy. The mycelium in some cases enters the twigs and may induce the formation of witches'-brooms, or the affected twig may be killed outright.

Control of leaf-cast diseases.

In the forest no measures of control are practicable. In nurseries the trees may be sprayed with bordeaux mixture. The mixture should be applied before the rain periods which cause the ejection of the spores. In order to avoid the expense of spraying for these diseases, nurseries should be located at a distance from coniferous forests and thus avoid chances of infection.

For further details and references in literature concerning the leaf-cast diseases, see the discussions under pine diseases (pages 270 and 271) and fir diseases (page 159).

Sooty Molds

Caused by fungi of the family Perisporiaceæ

The leaves of many trees are often covered with a black sooty coating in midsummer. No serious damage is done to the tree unless the growth on the leaves becomes so abundant that it interferes with the functions of the leaf by shutting out the sunlight. The fungi causing this type of growth on leaves are closely related to the powdery mildew fungi (see page 34). The mycelium of the sooty mold fungi is, however, dark colored and appears to the eye as black. As in the case of the powdery mildews, the mycelium is superficial. No feeding rootlets are sent into the leaf-tissue, however, as in the powdery mildews, and the fungi are therefore not parasitic. They obtain sufficient nourishment from sugary solutions that are exuded from the leaves. Sugary exudations are only formed on leaves under certain conditions, and when these are absent the sooty molds do not occur. When aphids are present, sooty molds find excellent conditions for developing. These fungi may be controlled by spraying, and the recommendations given for powdery mildews should be followed (see page 37).

Silver-Leaf

Caused by *Stereum purpureum* Fries

Although the disease known as silver-leaf or silver-blight has not been shown to be as widespread or destructive on forest- and shade-trees as it is on fruit-trees, nevertheless it is known to occur on ash, chestnut and others. As a disease of fruit-trees and small-fruits, it has been studied in Europe since 1885 when it was first described in France. Apple, plum, peach, apricot, cherry, almond, currant, gooseberry and lilac are among the trees and smaller woody plants known to be affected. The stone-fruits are probably most seriously affected. The disease is known at present in France, England, Germany, Canada, northeastern United States, South Africa and New Zealand, but probably has a much wider distribution. It has been noticed in the forest and on trees outside the forest in north-eastern United States and the adjacent regions of Canada.

Symptoms.

The leaves of affected limbs are at first paler in color and finally become milk-white, lead-colored or silvery. The green color is not entirely lost but is only faintly evident in the silvered areas. The disease shows in two distinct types depending on the part of the tree first attacked. Usually the first symptoms of silver-leaf are confined to a single twig, and then from year to year other twigs, large branches and finally the entire tree show the disease. Before the entire tree is diseased, however, the twigs first affected die and the fruiting-bodies of the causal fungus appear on them as small white and purplish encrusting patches. At other times the roots are infected first and large branches develop silvered leaves suddenly, and very soon the entire tree becomes diseased. On cutting into the branches which show silvered leaves, the wood will be found to be dark brown. The connection between these symptoms is explained in the discussion below.

Cause.

The cause of silver-leaf long remained a mystery, largely because many scientists thought without experimentation that it was due to simple physiological disturbances. However, it has been definitely proved that the fungus, *Stereum pur-*

All dead wood, brush and stumps which may harbor this fungus and produce the fruiting-bodies should be removed and burned to eliminate the sources of spore-production.

References

Hesler, L. R., and Whetzel, H. H. Silver-leaf. *In* Manual of fruit diseases, pp. 368–373, fig. 108. 1917.

Güssow, H. T. Der Milchglanz der Obstbäume. Zeitschr. für Pflanzenkr. **22**: 385–401, pls. 5–6, fig. 1. 1912.

Brooks, F. T. Silver-leaf disease. Jour. Agr. Sci. **4**: 133–144. 1911.

Brooks, F. T. Silver-leaf disease (II). Jour. Agr. Sci. **5**: 288–308. 1913.

BODY AND BRANCH DISEASES AND INJURIES

Many diseases and injuries of the bark and wood are more or less common to all kinds of trees. Extremes of temperature, lightning, mistletoes, lichens and some species of fungi are some of the causal agents which affect trees in general. As in the case of the diseases and injuries common to the seedlings and leaves of many kinds of trees, the primary causal agents of the diseases affecting bark and wood are often difficult to determine. It is only by a careful analysis of the conditions surrounding the tree in question and by close observation of other trees in the vicinity that clues can be obtained. Also, in such cases, the knowledge of similar tree troubles may be essential in determining the exact cause. Many of the diseases and injuries of the branches and trunk affect the appearance of the leaves before direct attention is called to the primary injury.

In general, the presence or absence of fruiting-bodies of fungi on the bark is of but little value in determining whether or not the trouble is caused by a specific fungus. This is due to the fact that numerous species of fungi find excellent conditions for growth in dead bark and some species follow very closely any injuries to the bark. A trained pathologist must be closely observant to assert even tentatively that a fungus found on dead areas of bark is responsible for the lesion. The only sure way of proving the fungus to be the cause of disease is the usual procedure of isolating and growing the fungus in pure cultures and inoculating it into healthy plants. Often, however, an active pathogene shows characteristic parasitic tendencies, especially to the trained eye, which make diagnosis more certain. A comparison of the edge of a canker on chestnut caused by *Endothia parasitica* with that caused by winter-injury, lightning or mechanical agents will illustrate the general characteristics between an actively enlarging canker caused by parasitic fungus and an area of dead bark invaded by a saprophyte. From the outside such cankers may appear very similar, but on cutting into the margin of the cankered area the one caused by the active parasite shows a more or less gradual gradation between the color and organization of the tissues of the healthy light colored bark and the disorganized, usually brown-colored diseased bark. Usually also, the fine mats of mycelium can be seen advancing into uninjured and healthy bark-tissue. On the other hand, in the case of an area of bark killed by some other agent than an active parasite, the margin of the canker when cut into is usually definite and the distinction in color and other characters between the healthy and dead bark-tissues readily proves that the lesion is not becoming larger, and that any saprophytic fungus present in the dead bark is not advancing into healthy tissue.

In this chapter are discussed several of the most common diseases and injuries of trees. It should be remembered that the general health and appearance of the bark and wood of the tree depend naturally on the health and condition of the foliage on the one hand and the condition of the roots on the other. The stunted and dwarfed condition of trees, slow annual growth, deformed crowns, stag-head, dead branches, irregular branching and sucker development are all signs of abnormal conditions either at the source of starch production in the leaves or in the food supply and general soil conditions around the roots. The most common causes of such general symptoms of abnormal growth shown by the branches or trunk are: (1) smoke-, gas- and soot-injury to the foliage; (2) unbalanced relation between root and foliage system caused by cutting away surrounding trees, or by injudicious pruning and pollarding; (3) unbalanced water supply in the soil, caused by the physical condition of the soil, or insufficient water reaching the roots due to pavements and sod; (4) poisoning, due to natural or artificial gas escaping into the soil; (5) mal-nutrition, due to lack of certain essential food elements in soil or the over-balancing of the food supply by improper use of fertilizers, which causes toxic injury. Many of these tree troubles which are due to unbalanced physiological processes, improper soil, site and food supply, improper care in planting, pruning and the like, and the relation of trees to their neighbors are purposely omitted from discussion in this book.

Freezing-to-Death of Twigs and Bark

Caused by low temperatures

Twig-blight due to freezing-to-death is common with certain kinds of trees. Trees such as ash, oak, spruce and others which cease twig growth early in the autumn and form terminal buds, are usually resistant to freezing-injury. The wood and bark of the twigs have sufficient time to mature and become resistant to low temperatures. If, however, due to exceptionally warm and moist conditions in the late autumn, growth is resumed, the twigs may be severely injured by early frosts. Other kinds of trees, such as basswood, sycamore and elm, which do not naturally cease twig growth early in the autumn, are injured frequently by freezing. The twigs of the locust and certain willows continue growing until late autumn and freeze back every year.

The injuries of bark due to extremes of temperature are largely limited to those caused by freezing. Although conditions which cause temperature injuries to the leaves have a general effect on the health and development of the branches, the injury is not directly noticeable, unless the tree is seriously damaged by such leaf troubles year after year. It was formerly thought that the characteristic cankers in the bark of trees associated with extremes of temperature were of two sorts, called respectively, sun-scald, when the drying-out effect of the sun's rays was the cause, and winter-injury or freezing-to-death, when areas of bark were killed by extremely low temperatures in winter. It is now held that a very large proportion of such cankers are due to freezing-to-death and that sun-scald cankers caused by extremes of heat in summer are rare.

Cankers or dead areas of bark due to freezing often occur in crotches, on the south and southwest sides of the trunk, and around the base of the tree. 'Crotch-cankers are common and are thought to be due to the tissues at these places being more parenchymatous and much more slowly matured than the adjacent bark-tissues. Thus the bark at crotches is more susceptible to freezing-to-death, and injury occurs at a higher temperature than would cause injury to properly matured tissue. The cankered dead areas, often with the bark fallen away, on the south and southwest sides of the trunk are common in certain kinds of trees, notably the Norway maple. The injury occurs in late winter when the sun's rays in the afternoon raise the temperature of the bark above the freezing point, to be followed at night by a temperature below freezing. The difference in temperature between the north and south sides of a tree often amounts to as much as ten degrees. Several explanations can be offered to account for the injury: (1) with the daily rise in temperature new growth is started and the tissues formed are more susceptible to low temperatures at night; (2) repeated thawing and freezing of the tissues decrease their resistance to freezing; (3) the rapid fall from a high to a low temperature causes the death of the tissue at a higher temperature than if the rate of fall was more gradual; (4) the tensions set up in the bark and wood by the alternate increase and decrease of the temperature cause mechanical separation of the bark from the wood and this destroys the cambium region. The cankered areas commonly found at the base of the trunk are explained in the same way. Various species of saprophytic and semi-saprophytic fungi soon appear and produce their fruiting-bodies on the dead bark. The repeated attempts at callusing on the edge of the canker may fail, because the callus tissue, being largely parenchymatous, is susceptible to freezing-injury and is killed.

To prevent wound parasites from gaining a foothold and causing further damage to the tree, surgical methods should be used and the wound protected. For the proper procedure in removing the dead bark and shaping the wound, see page 351. As a dressing for such wounds it would be advisable to use pure white lead paint, renewing the dressing at least once every year. By using a white dressing instead of a black one, some added protection is afforded the callusing edges of the wound, since the sun's rays will not heat the bark to as high temperature.

References

Mix, A. J. Sun-scald of fruit trees, a type of winter injury. Cornell Univ. Agr. Exp. Sta. Bul. 382: 235–284, pls. 18 and 19, figs. 60 and 61. 1916.

Chandler, W. H. The killing of plant tissue by low temperature. Missouri Agr. Exp. Sta. Research Bul. 8: 141–309. 1913.

Hartig, R. The action of frost. *In* Text-book of the diseases of trees, pp. 282–294, figs. 157–158. 1894.

Zon, R. G. Effect of frosts upon forest vegetation. Forest Quarterly 2: 14–21. 1903.

Stone, G. E. Winter-killing. Massachusetts Agr. Exp. Sta. Ann. Rept. 18: 228–233. 1906.

Stone, G. E. Frost cracks, winterkilling of cork cambium and sun scald. *In* Shade trees, characteristics, adaptation, diseases and care. Massachusetts Agr. Exp. Sta. Bul. 170: 204–208, figs. 77–80. 1916.

Frost-Cracks

Caused by low temperatures

Fig. 1. — Frost-cracks in a maple, which have opened for several successive winters.

There are two sorts of frost-cracks which are common types of injury to trees caused by low temperatures. Some frost-cracks may rupture the bark and result in open splits in the trunk (Fig. 1). The callusing at the edges of this split and the repeated opening and healing usually result in a ridge of tissue which increases in prominence year after year (Fig. 2). At other times, frost-cracks which do not rupture the bark may occur in the wood. These either do not show externally or appear as slight frost-ridges. They are important when the trunk is to be utilized as lumber, since the defects cause the product to be of inferior quality. The splitting open of trunks is more common with some trees than others. Deciduous trees with

Fig. 2. — The same tree shown in Fig. 1, as it appears during the summer.

Sun-Scald

Caused by high temperatures and low humidity

The actual scorching of the bark of certain susceptible trees occurs under circumstances in which previously shaded smooth-barked limbs are suddenly exposed to the full insolation of the afternoon sun. Severe pruning or the removal of neighboring trees make possible such injury. Beech, spruce and pines are subject to sun-scald. This type of injury is due to the direct wilting and drying-out of the bark-tissues caused by excessive heat and the action of the wind. Small twigs may be killed in the same way, especially at times when the leaves sun-scorch (see page 22). Although this is the type of injury to which the term sun-scald should be restricted, it is more probable that the low humidity of the air and the drying action of the wind are more closely connected with the injury than the actual degree of temperature reached by the sun's action.

References

Hartig, R. Bark scorching, sun-cracks and deficiency of light. *In* Text-book of the diseases of trees, pp. 294–299, fig. 159. 1894.

Stone, G. E. Sun scald. *In* Shade trees, characteristics, adaptation, diseases and care. Massachusetts Agr. Exp. Sta. Bul. 170: 207–208. 1916.

Lichen-Injury

Caused by species of lichens

No definite work has been undertaken to determine the amount of damage caused by lichens. Opinions of writers vary, but many think that trees are injured by the severe infestations that sometimes occur, especially in places where the air is continuously humid. Under such atmospheric conditions and where the nature of the soil causes slow growth, the bark of trees may be covered with lichens of different kinds. It is thought that more rapidly growing trees, in good soil, form their bark so rapidly that it scales off and does not give the lichens time to become established in abundance. Both the foliaceous and crustaceous forms of lichens are found growing on bark, often to the extent that they entirely cover the trunk and limbs. The common supposition is that they are responsible for the poor condition of the trees on which they occur, but for the reason just stated it seems more likely that the tree is covered with lichens because it is slow-growing.

It is supposed, since the lichens do not penetrate the bark and establish any true parasitic relation with the tree, that any damage they cause is due to their mechanical interference with the respiration and transpiration processes which go on through the lenticels in the bark. The effects of shading and continuously holding moisture may be considered to increase the damage caused by lichens; consequently the crustaceous forms seem to be more injurious because they grow more tightly appressed to the bark.

The eradication of lichens can be easily accomplished by spraying the affected parts in the ordinary way with bordeaux mixture. The lichens will die within a few days. The best results are obtained if the spraying is done when the leaves are off the tree, since all parts of the infested trunk and limbs can be more surely and easily reached with the mixture. For directions for making bordeaux mixture, see page 358.

References

Waite, M. B. Experiments with fungicides in the removal of lichens from pear trees. Jour. Mycology 7 : 264–268, pls. 30–31. 1893.

Hartig, R. Pseudo-parasites. *In* Text-book of the diseases of trees, pp. 35–36. 1894.

Slime-Flux

Caused by the fermentation of oozing sap

Wounds of various kinds, in such trees as birch, elm and maple which bleed very profusely, may develop a chronic exudation of slimy mal-odorous ooze. Certain species of fungi closely related to the yeasts are commonly found in this ooze, along with other fungi and bacteria. Fermentation of the sap which is exuded from the fresh wound causes the death of the bark and wood adjacent to the wounded tissue and often large areas of bark are killed. It is not known what specific action the different organisms in the slime exercise in causing the death of the bark. It is supposed that they do not act as parasites but rather that the products of fermentation slowly produce the death of the adjoining tissues.

The most important step in preventing slime-flux is to care for any wounds before the ooze begins to form. Trees which bleed commonly should be watched so that any wounds that occur can be shaped and immediately prepared for rapid healing. If bleeding continues and a wound-dressing will not adhere, the surface of the wound may be cauterized with a gasoline torch. Old wounds which have developed slime-flux should be cleaned and treated in the same way. For directions regarding tree surgery methods, see page 345.

Mistletoe Diseases

Caused by species of Razoumofskya (Arceuthobium) and Phoradendron

Several species of parasitic flowering plants, belonging to the family Loranthaceæ, cause considerable damage to trees. The composite species *Phoradendron flavescens*, the American mistletoe, grows on many kinds of deciduous trees and shrubs in southern United States, while numerous species of the genus Razoumofskya (the dwarf mistletoes) grow on conifers, causing much damage in the forest, especially west of the Rocky Mountains.[1] In Europe members of the mistletoe family are important tree parasites.

[1] The generic name Arceuthobium is retained as one of the *nomina conservanda* of the International Rules for Botanical Nomenclature. Under the American Code, the name Razoumofskya is revived.

Spruce, pine, larch, fir and hemlock are attacked by more or less restricted species of Razoumofskya. These parasitic plants are very small and not easily recognized among the green needles of the host. When the mistletoe seed germinates, root-like sinkers are pushed down into the wood of the branch. The young mistletoe plant then obtains its water and food materials by robbing the host. The damage done by the dwarf mistletoes is largely due to the stimulus reactions set up. Excessive growth occurs in the part of the tree attacked, and large numbers of short bushy branches are produced which form what are commonly known as witches'-brooms. These brooms are often very large, and the excessive growth results in lessened vigor of the portion of the limb beyond the broom. When several brooms grow on a tree, its lumber value depreciates because of the diminished annual growth. Another damaging effect is due to the weight of the brooms when covered with ice and snow, causing them to break off, leaving wounds which are easily infected by various wood-rot fungi.

Following is a list of the dwarf mistletoes (species of Razoumofskya) which grow parasitically on conifers in the western United States: —

On fir (Abies)
- *R. Douglasii abietina* (Engelm.) Piper. Rocky Mountains and western United States
- *R. occidentalis abietina* (Engelm.) Coville. Pacific Coast and Utah

On fir (Pseudotsuga)
- *R. Douglasii* (Engelm.) Kuntze. Rocky Mountains and Pacific Coast

On hemlock
- *R. tsugensis* Rosend. Northwestern United States

On larch
- *R. laricis* Piper. Northwestern United States

On pine (five needle soft pines)
- *R. cyanocarpa* (A. Nelson) Rydberg. Western United States
- *R. Blumeri* (A. Nelson) Standley. Arizona

On pine (piñon, nut pines)
- *R. divaricata* (Engelm.) Coville. Central and southern Rocky Mountains and California

On pine (three and two to three needle, pitch pines)
R. campylopoda (Engelm.) Piper. Pacific Coast
R. cryptopoda (Engelm.) Coville. Central and southern Rocky Mountains
R. americana (Nutt.) Kuntze. Rocky Mountains to Sierra Nevada Mountains

FIG. 3. — Mistletoe (*Phoradendron pauciflorum*) growing on white fir.

The only representative of the dwarf mistletoes occurring in eastern United States is *R. pusilla*, which causes witches'-brooms on spruce. A discussion of this disease will be found on page 321.

Several species of the genus Phoradendron attack the junipers in southwestern and western United States. These mistletoes are sometimes found also on fir, cypress and incense cedar. They are much larger plants than the dwarf mistletoes and make a part of their own food materials, since they have green leaves. The main damaging effects of these mistletoes are the starving of the portion of the limb from the point of attack outward and the production of brittle swellings which allow the limbs to be easily broken off by wind or excessive weight (Fig. 3).

Practically all kinds of deciduous forest- and fruit-trees are attacked by the mistletoe, *Phoradendron flavescens*, in southern United States. This mistletoe is a large form and has green leaves. The berries are sticky and are distributed by birds. The roots from the germinating seed penetrate the wood and establish the parasite. The chief damaging effects arise from the starving of the branch beyond the point of attack and the shading of the foliage of the host. The branch at the point of attack becomes larger and greatly deformed. Sometimes on certain hosts, abnormal branching occurs and witches'-brooms are formed.

Following is a list of the parasitic leafy mistletoes (species of Phorodendron) of the United States arranged under the kind of trees they attack:—

Alder
- *P. Engelmanni* Trelease. Texas
- *P. macrophyllum* Cockerell. Arizona
- *P. longispicum* Trelease. California and Arizona

Apple
- *P. macrophyllum* Cockerell. Arizona
- *P. flavescens* Nuttall. Central and southeastern states

Ash
- *P. macrotomum* Trelease. Florida
- *P. Eatoni* Trelease. Florida
- *P. macrophyllum* Cockerell. Arizona
- *P. Cockerellii* Trelease. New Mexico and Texas
- *P. longispicum* Trelease. California and Arizona
- *P. flavescens* Nuttall. Central and southeastern states

Basswood
- *P. flavescens* Nuttall. Central and southeastern states

Beech
- *P. flavescens* Nuttall. Central and southeastern states

Birch
- *P. flavescens* Nuttall. Central and southeastern states

Buckeye
- *P. flavescens* Nuttall. Central and southeastern states
- *P. villosum* Nuttall. Pacific Coast
- *P. longispicum* Trelease. California and Arizona

Cedar
- *P. Libocedri* Howell. California, Oregon and Nevada

Cherry
- *P. flavescens* Nuttall. Central and southeastern states
- *P. macrotomum* Trelease. Florida
- *P. macrophyllum* Cockerell. Arizona

Chestnut
- *P. flavescens* Nuttall. Central and southeastern states

Cypress
- *P. pauciflorum* Torrey. California and Arizona

Elm
- *P. flavescens* Nuttall. Central and southeastern states

Fir
- *P. pauciflorum* Torrey. California and Arizona

Gum (Nyssa)
- *P. flavescens* Nuttall. Central and southeastern states
- *P. macrotomum* Trelease. Florida

Hackberry
- *P. flavescens* Nuttall. Central and southeastern states
- *P. Engelmanni* Trelease. Texas.
- *P. macrophyllum* Cockerell. Arizona

Hickory
- *P. flavescens* Nuttall. Central and southeastern states

Honey locust
- *P. flavescens* Nuttall. Central and southeastern states

Juniper.
- *P. juniperinum* Engelmann. Colorado, Utah and New Mexico
- *P. ligatum* Trelease. Nevada and Pacific Coast
- *P. capitellatum* Torrey. New Mexico and Arizona
- *P. Bolleanum* Eichler. Texas
- *P. densum* Torrey. Pacific Coast

Locust
- *P. flavescens* Nuttall. Central and southeastern states
- *P. macrophyllum* Cockerell. Arizona
- *P. villosum* Nuttall. Pacific Coast
- *P. longispicum* Trelease. Pacific Coast

tips of the affected branches may be pruned off, thus removing permanently the infected parts of the tree. However, if the tree is badly infested and new plants persist in appearing, this procedure results in excessive pruning and a deformed tree. It is said that the parasites may be successfully eliminated by the first method and the tree left to its natural form of growth if proper and constant attention is given to the work.

In the forest where these pests often occur on twenty-five to fifty per cent of the stand of conifers, it is essential that forest management plans should incorporate the elimination of all affected trees during lumbering operations. Seed trees which are left should be chosen with regard to their freedom from mistletoe.

References

Bray, W. L. The mistletoe pest in the southwest. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 166: 1–39, pls. 1 and 2, figs. 1–7. 1910.

Weir, J. R. Mistletoe injury to conifers in the northwest. U. S. Dept. Agr. Bul. 360: 1–39, pls. 1–4, figs. 1–27. 1916.

Weir, J. R. Larch mistletoe: some economic considerations of its injurious effects. U. S. Dept. Agr. Bul. 317: 1–25, figs. 1–13. 1916.

Hedgcock, G. G. Notes on some diseases of trees in our national forests. V. Phytopathology 5: 175–181. 1915.

Hartig, R. Phanerogams. *In* Text-book of the diseases of trees, pp. 23–34, figs. 1–7. 1894.

Trelease, W. The genus Phoradendron, pp. 1–224, pls. 1–245. Univ. of Ill. 1916.

Electrical Injuries

Caused by current electricity and lightning

Trees may be more or less seriously injured by contact with service wires carrying current electricity and by strokes of lightning. In both types of injury the actual killing of the living tissues of the tree is due to the production of heat when the current meets with the high resistance of the tissues. Much of the damage often ascribed to overhead wires is not so much due to electrical injury as to the severe and unscientific pruning along pole-lines.

Two types of injury due to current electricity are recognized. Alternating and direct currents of low voltage, carried in insulated wires, cause but little damage, except when local burning occurs at places where the insulation is rubbed away by contact with the tree. The resistance of the bark and wood is so great that the amount of the low voltage current which passes down the tree and into the ground is not sufficient to raise the temperature sufficiently to kill living cells. The damage is due rather to the combination of mechanical and burning injury at the point of contact, resulting in rough open wounds which become weak points in the limb and centers of infection for wood-rot fungi.

Direct current electricity causes more damage than does the alternating current. High voltage, uninsulated feed and trolley wires carrying direct current, when the charge is positive, cause local burning but do not kill the tree. The short circuiting is more complete in wet weather, when the tree is covered with a film of water. In cases in which the rails of electric railroads carry the positive charge, and the trolley and feed wires the negative, the effect of contact of the wires with a tree is more serious and often results in death. The difference in effect is due to the root surface being imbedded in the soil-water which is a good conductor and the high voltage positive current is transmitted to the roots of the tree which expose a large surface. For this reason, more current enters the tree than in the case in which the wires carry the positive charge, and severe burning of the living tissues occurs in the roots and at the base of the trunk, often killing the tree.

Lightning acts in the same way as current electricity, except that a large variety of other effects may also occur. The usual type of lightning-injury is a groove plowed in the bark and wood down the trunk. This groove is straight when the wood-fibers are straight and may run round the tree when the grain is spiral. At times, various other types of injury may occur, such as: stripping of all the bark from the tree, shattering of the top of the tree, splitting and otherwise shattering the entire tree, and shattering the base and allowing the tree otherwise uninjured to fall over. All of these types of violent injury are caused by lightning in a way that is not understood. It is known that lightning discharges are of high voltage. When the damage is greatest at the base of the tree, the positive charge was probably carried by the earth, and when the top is shattered, the positive charge was in a stratum of air or a cloud above the tree. Many divergent opinions concerning the susceptibility or immunity of different species of trees to lightning stroke have been stated. Recent investigations in this country and in Europe have shown that trees of all kinds are liable to lightning stroke and that those which are isolated, on high ground, or are more deeply rooted than surrounding trees are the most liable to be struck. The idea that trees of a certain species are more often struck than others is usually due to the fact that they are more abundant or more dominant than other species.

Another less common type of lightning-injury is when groups of trees die within a few days after the stroke and others around these die during the next few years. This type of injury is explained by the fact that the positive charge was in the earth and when the flash occurred the tissues of the roots and the bark at the base of the tree were killed. A few of the trees were injured to the extent that they died quickly, for want of water and raw food materials from the soil; others around which did not receive such a heavy shock were only injured in such a way that they were prevented from sending prepared food to the roots and died later. This type of injury then is similar to the effects produced by girdling.

The matter of protecting shade-trees from damage by electric currents carried by wires is of importance in every city. Any device made of a substance which is a non-conductor (porcelain, or rubber) and which keeps the wires from coming into contact with the limbs, will prevent short circuiting. If the additional injury caused by rubbing is to be avoided, some arrangement must be made for locating the wires so that they are taut and do not come within three or four inches of the limbs.

References

Stone, G. E. Electrical injuries to trees. Massachusetts Agr. Exp. Sta. Bul. 156: 1–19, pls. 1–5. 1914.

Plummer, Fred G. Lightning in relation to forest fires. U. S. Dept. Agr. Forest Ser. Bul. 111: 1–39, pls. 1–2, figs. 1–16. 1912.

MacDougal, D. T. Effect of lightning on trees. Proc. N. Y. Bot. Gard. **3**: 1902.

Hartig, R. The effects of lightning. *In* Text-book of the diseases of trees, pp. 302–304. 1894.

Galls

Caused by various insects, fungi and bacteria

Fig. 4. — Galls on branch of oak.

Trees of all kinds often develop large or small galls of various types on the trunk and limbs. The causal agents in many cases have not been studied, but it is supposed that certain insects, fungi and bacteria are frequently responsible for the irritation which results in the overgrowth in the tissue. Mechanical injuries may in some cases also cause galls. The causal agent initiates abnormal division of the cells and the tissues may continue the over-development for years after the cause is gone. The limb-galls of poplar are known to be caused in some cases by the crown-gall bacterium (see page 304). The galls commonly found on oak are probably initiated by insects (Fig. 4). Galls are usually formed of abnormal wood and bark. They may frequently serve as a place of entrance for wood-rotting fungi when the bark is injured.

Wood-Rots

Caused by fungi of the order Hymeniales

The wood in the roots, trunk and branches of trees is a very stable and durable substance. While still a part of the living tree, the heartwood is of but little value to the tree except for support and is essentially dead tissue. During the life of the tree and after it is made into timber and its various derivative products, wood remains durable and intact except when fire, insects and wood-decaying fungi destroy it. Were it not for these three destructive factors, the wood in the living tree would remain sound until utilized and would then be useful for an indefinite time, until ordinary weathering and abrasion made it worthless. By eliminating the factor of decay in all forms of timber now in use, the saving in the annual cut for replacement would amount, for the United States as a whole, to nearly a hundred million dollars. Stated in another way we would need to produce less than half the timber now used if the factor of decay were eliminated. In the forest, under the present systems of management in this country, the losses from wood-rots reduce enormously the yield of timber. Likewise, with trees outside the forest, wood-rots are more or less destructive, and are the factor which largely determines the length of life of the tree. In the forest and outside, many of the fungi which cause decay of the heartwood also extend their activities into the sapwood and bark. When the latter tissues are attacked, certain parts of the trees die because of the interference with the necessary transportation of food materials, between the roots and leaves.

The fungi which destroy wood are mostly of one general type and are commonly known as the bracket-fungi or polypores. Some of the toadstools also are wood-destroyers. Several species of these two types of fungi are known which enter the wood of living trees and cause its decay. A few of these are active parasites, which advance into and kill living tissue in the sapwood and bark. The others attack only the heartwood. Numerous other closely related bracket-fungi and toadstools never enter the wood of living trees but exist as saprophytes, destroying wood after the tree is dead either in the forest or while it is in use as a timber product. Some of these latter forms often appear to be parasitic, when they are found growing on a living tree which is severely injured. The parasitism is only apparent, however, since the wood is exposed to weathering and is essentially in the same condition as if the tree were dead. The various important wood-rots are described under the kind of tree commonly affected, but since the life history of all of the causal fungi is essentially the same, a general discussion of the mode of infection, nature of the process of wood-decay, production of fruiting-bodies, dissemination of the spores and methods of control is given here to avoid repetition or lack of detail concerning these points under the individual discussions.

Mode of infection.

Normally the tree is protected from invasion of wood-destroying fungi by the bark. But whenever the bark is injured to the extent that the sapwood or heartwood is exposed for any considerable length of time, infection may occur by the lodgment and germination of the spores on the exposed wood. Conifers and some deciduous trees are capable of producing resinous and gummy substances, where the sapwood and bark are wounded. These substances when exuded in quantity cover the wounded area and protect it from infection. For this reason such trees are usually free from wood-rots until heartwood is formed. The larger part of the deciduous trees form no such protective wound exudations, and injuries which cause the exposure of the sapwood often result in infection by some sapwood-rotting fungus. Wounds of all sorts may be caused in the forest by browsing animals, woodpeckers, boring insects, wind, snow and ice breakage of limbs, fire scars at the base, and natural pruning of limbs, while out of the forest many additional agencies may cause wounds. Some wood-destroying fungi attack commonly the wood of the roots. Wounds in the roots afford places of infection, and from the roots the mycelium may spread upward into the lower part of the trunk. But the most common mode of entrance for fungi is by way of the wood exposed when branches are broken or pruned-off, either naturally or artificially. The proper method of cutting the limb so as to leave no projecting stub cannot be too greatly emphasized in the case of shade and ornamental trees (see page 346). The wound must be flush with the parent limb in order that the callus may cover it. In the meantime, while the callusing is taking place, the exposed wood should be covered with a wound-dressing (see page 348). Total disregard for these two procedures in pruning leaves the way open for most of the damage to valuable trees by wood-rotting fungi. In the forest a certain amount of wounding may be avoided, but the main method of control is by the removal of the sources of infection.

The spores of a fungus causing wood-rot of a certain kind of tree, after lodging upon exposed sapwood or heartwood of that tree, will germinate in the presence of moisture and develop a mycelium which grows into the wood. The sapwood-rotting fungi immediately spread their mycelium in all directions and soon large dead areas result. The species which attack the heartwood preferably, develop mycelium which reaches down through the wood of the branch stub into the heartwood of the

only partially decayed wood. Another common distinguishing mark which may accompany wood-decay is the production of black lines or discolored zones which usually mark the place where the most active changes are occurring in the delignification process. The colored zones are due to dark colored oxidation products which stain the mycelium and cell-walls of the wood.

FIG. 5. — Under surface of a polypore, showing open ends of spore-bearing tubes. Enlarged (several times).

The mycelium of wood-rotting fungi uses the dissolved wood-tissue as food material. After a considerable amount of this food is obtained and stored, the production of the fruiting-bodies begins. For this purpose a tissue-like development of closely tangled mycelium, in the shape of a knob, usually forms at the original point of infection. The food materials from all directions are transported to this point and the fruiting-body develops an upper sterile surface and a fertile suspended layer of spore-bearing tissue on the under surface. In the case of the toadstools the spores are borne on the sides of pendent plates or gills (Fig. 8, page 81), and in the bracket-fungi or polypores, they are borne on the inner surface of perpendicular tubes which are open at the lower end and are visible to the naked eye as small holes in the lower surface of the fruiting-body (Fig. 5). Besides the characteristic action of the mycelium of the different species of fungi causing the wood-rots, the characters of the fruiting-bodies serve to identify the causal fungus, if they are definitely associated with the rot. The correct determination of the different species of bracket-fungi is, however, not easy in some cases. The number of species of annual forms represented in the United States is greater than that of the perennial forms. A generic distinction between the annual and perennial forms is recognized and they have been named respectively Polyporus (po-lip′-pore-us) and Fomes (fo-meez). Other genera have been split off from these two, which probably represent a more natural classification. Since, however, the simpler and more artificial classification is still used by laymen and most scientists, the genera Polyporus and Fomes are used in the discussion of the wood-rot fungi in this book. For a synonymy of polypore names, see the appendix, page 364. The species of Polyporus usually produce a more or less fleshy or corky fruiting-body which is soon destroyed by insects or decay and rarely functions in producing spores for more than the single season. The species of Fomes, on the other hand, form hard, woody structures which develop a new layer of tubes on the under surface each year as long as food material is being obtained by the mycelium, in its advance into normal wood. In this manner the size of the fruiting-body increases yearly and its age may be determined by counting the layers of tubes when the fruiting-body is split perpendicularly.

Dissemination of the spores.

The spores of the bracket-fungi are borne in groups of four, each on a tiny spine, at the ends of branches of the mycelium which project from the inner sides of the tubes. When mature, these spores are shot from their attachment with just enough force to bring them to the center of the tube, and then they drop out of the open end at the bottom. The wind, or even the slightest breeze, serves to carry the spores for long distances, since they are very light and buoyant. Millions of spores are disseminated from a single fruiting-body during a few days after they become mature. They are somewhat sticky and adhere to any object with which they come in contact. The larger part of them never reach suitable places where infection may be accomplished. However, a sufficiently large number is produced that a few usually find lodgment where infection is possible. Wounds such as the splintered ends of the branch-stubs which hold moisture readily are most likely to become infected. The spores are very short-lived and suitable conditions of moisture must be encountered in order to have germination take place. The germ-tube of the spore produces short branches of mycelium which immediately begin the decay of the wood at the point of infection, and as soon as a firm foothold is gained, a copious growth of the mycelium occurs, which spreads rapidly.

Control of wood-rots.

Wood-rot diseases are more abundant and destructive in the forest than in individual trees grown for shade or ornament. Conditions in the forest are ideal for the development of these fungi. All sorts of wounds are available for infection and thus dissemination and germination of the spores is more efficient in causing a higher percentage of infection. Another factor which makes wood-rots more serious in the forest is that great quantities of fallen trunks and branches are present on which fruiting-bodies of most of the wood-rot fungi continue to be produced in great abundance. Outside the forest, the absence of these conditions makes infection less common. A few of the wood-rots, however, are important diseases of shade-trees.

In controlling these rots, tree surgery methods are effective if the wood-rot is not too far advanced and if the expense is considered justified by the value of the tree. The methods for eliminating heartwood- and sapwood-rots are discussed under tree surgery, page 345. The necessary care in pruning to leave a wound which will heal most rapidly and protecting the wound in the meantime by the use of wound-dressings are important measures for reducing wood-rots to a minimum. These operations are also more fully discussed under tree surgery methods. The immediate destruction of newly developing fruiting-bodies of all kinds in the vicinity of trees to be protected will reduce greatly the amount of infection.

In the forest, the factors concerned in the complex of soil, atmospheric and biologic relations, influence greatly the yield and quality of timber that is realized. Methods of forest management in this country have seldom taken into consideration many of these vital factors, one of the most important of which is the control of the wood-rotting fungi of living trees. The subject of forest pathology is too complex to be adequately dealt with in a small space and is outside the field of this book. A simple method of disease control in the forest is the elimination of all diseased trees at the time cutting operations are in progress. For some types of forests and systems of selection for cutting, this procedure is nót economically possible. Thus it will be possible to control the loss factor due to decay only when all the complex relations existing in the forest have been studied for different types and localities. Before control measures can be incorporated into scientific forest regulation, such points as the following must be determined: the relations which determine the rate of growth and general health of the trees, the extent, nature and cause of wounds, the life history of the wood-rotting fungi, the relative susceptibility of different species and different age classes, and many other relative factors.

References

Schrenk, Hermann von. Fungous diseases of forest trees. U. S. Dept. Agr. Yearbook 1900: 199–210, pls. 21–25. 1901.

Meinecke, E. P. Forest pathology in forest regulation. U. S. Dept. Agr. Bul. 275: 1–62. 1916.

CHAPTER IV

ROOT DISEASES AND INJURIES

The roots serve both for anchorage and for gathering from the soil the water and dissolved raw materials needed by the tree in its growth. The structure of certain types of soil, and the food materials contained, often determine the kinds of trees which will grow best in it. However, it is not the intention to discuss here the adaptability of different species to soil-types or of the poor growth or injuries resulting from a lack of such adaptability. Although a tree may be growing in suitable soil and obtaining from it the proper materials for normal growth, there are other factors which often intervene to cause injuries to the root system. Any such injuries to the roots of the tree may impair certain functions or destroy living tissues and cause various symptoms of disease to appear in the aërial portions of the tree.

In diagnosing tree troubles, the possibility of root diseases should be considered and care should be taken to ascertain whether or not the condition of the roots may be the primary cause of the difficulty. Impairment of the root functions may be due to such conditions as: too much water in the soil, causing drowning; too little water because of sod, pavements, or packed soil above the roots; poisonous gases or over-abundance of certain food materials applied to the roots with fertilizers; and the attacks of certain parasitic fungi and bacteria which invade and kill living tissue. These various injurious factors work more or less slowly, and the usual symptoms noticed in the parts above ground are: slow growth, thin foliage, sun-scorch of the leaves, early fall of leaves in autumn, death of certain entire branches, stag-head, and lichens on the bark. When such general symptoms of decline occur without apparent association with a cause in the branches, leaves or atmospheric conditions, the presence of a root trouble may be suspected.

Drying and Drowning

Caused by too little and too much water in the soil

Trees must obtain at all times enormous quantities of water from the soil, during the period when the leaves are expanded. With a normal water supply and a healthy root system, a tree is naturally so balanced in its development of roots and leaf-surface, that it is able to supply the water lost in transpiration from the leaves, except under the most abnormal atmospheric conditions. But if the supply of water is limited because the natural rainfall does not soak into the soil, the leaves may transpire more water than the roots can take up in a given length of time. This condition will cause sun-scorch of the leaves and if repeated year after year may cause the death of the tree (see page 22).

The other extreme of too much water in the soil may result in more speedy death of the tree. The tips of the roots, which are in contact with the soil-particles and absorb water and food materials, must at the same time obtain a ready supply of air to make healthy growth and perform their function of absorption. The older parts of the roots must also have access to a supply of air in order that the living tissues they contain may function in growth and transporting food materials and water to the parts above ground. If the amount of water in the soil is excessive, it drives out the air, thus disturbing the balance of air and water necessary to plant growth. This results in slow or rapid death of the roots by drowning. The leaves may show sun-scorch injury the same as when too little water is present.

This may seem peculiar, since there is an over-abundance of water in the soil, but it is explained by the fact that the transporting of the water to the trunk is dependent on the healthy condition of the roots and when these are injured, the power to absorb water is diminished accordingly. Therefore, although there is plenty of water in the soil, it cannot be supplied to the leaves.

The remedy for such conditions of abnormal water supply may be undertaken after the symptoms are noted, if the recovery of the tree seems possible. When heavy sod, tight paving or compact soil is the cause of too little of the normal rainfall reaching the roots, artificial means must be used for watering. The best method is to keep the sod broken up, but when this is not desirable, upright sections of tile may be placed at intervals flush with the sod and the necessary water furnished by running water into these from a hose. It should be remembered that the feeding rootlets are under the edges of the branches and not up close to the trunk of the tree. The tile should, therefore, be placed at intervals in a circle under the tips of the branches. A certain amount of artificial fertilizing may also be accomplished through the tiles. When the soil contains too much water, the ordinary methods of drainage should be employed.

Reference

Graves, A. H. Root rot of coniferous seedlings. Phytopathology **5**: 213–217, figs. 1–2. 1915.

Freezing-to-Death

Caused by low temperatures

Many kinds of trees are more or less injured by the freezing of the roots. White pine, maple, elm and ash are particularly susceptible.

even a lower point. The injury caused to the roots is the type known as freezing-to-death (see page 12). The water in the cells is withdrawn during the formation of ice crystals between the cells. As the temperature becomes lower, the physical pull incident to ice formation causes a larger amount of water to be withdrawn from the living cells than they can endure without being killed. Since the root system of most kinds of trees may extend from a few inches to several feet below the surface, it is natural that shallow-rooted trees will show the first and most serious injury provided the minimum temperature for the roots of that species is reached. Also, the amount of damage to the root system of a given tree depends on whether its roots are largely superficial or are found at varying depths.

Control.

Winter-injured roots should be uncovered and the dead parts pruned off. The wounds should be treated with a wound-dressing, and the soil conditions around the tree made conducive to the rapid regeneration of new roots by fertilizing. Mulching may be practiced to protect the soil around susceptible trees from freezing deeply.

Reference

Stone, G. E. Winter injuries of roots. *In* Shade trees, characteristics, adaptation, diseases and care. Massachusetts Agr. Exp. Sta. Bul. 170: 200–204. 1916.

Gas-Injury

Caused by illuminating gas

Trees are commonly injured by the poisonous effect of illuminating gas on the roots, when leaks in gas-pipes are not promptly repaired. The effect is usually cumulative and the tree may show no sign of the injury until some time has elapsed.

Symptoms.

The symptoms are general in nature, being about the same as those produced when any agency causes a gradual death of the root system. Partial freezing-to-death of the roots and cumulative gas-injury cause similar symptoms. The turning yellow or brown of the foliage is a common symptom, probably due entirely to the interference with the conduction of the necessary supply of water. Later, the living tissues in the root and trunk will be found dry and turning brown, showing that the lack of water and the poisonous properties of the gas combined have killed the tissues. At this stage various branches die and saprophytic fungi attack the dead bark. The length of time which it takes for a tree to die from gas-poisoning depends entirely on the amount of gas in the soil. Even a small quantity of gas present continuously will produce serious injury within two or three years. Conifers are much more resistant to gas than deciduous trees. At times, the former recover after the injury becomes apparent, while deciduous trees which begin to develop the symptoms of poisoning rarely recover, even if the leak is repaired.

Cause.

The injury to the roots caused by illuminating gas is probably of two kinds: first, true asphyxiation, since the air necessary to the roots is replaced by the gas; and second, the living tissues are poisoned. Many toxic substances are contained in the different kinds of illuminating gases. These substances when dissolved in the soil-water are absorbed into the root and the cumulative effect is shown in the death of the cells.

Control.

The remedy for gas-injury is to stop the leakage and stir the soil until all the gas has escaped. If only a portion of the root system and trunk is killed, the tree may be saved by the use of surgical methods to remove the dead tissue (see page 345).

References on Gas-Injury

Stone, G. E. Effects of illuminating gas on trees. *In* Shade trees, characteristics, adaptation, diseases and care. Massachusetts Agr. Exp. Sta. Bul. 170: 220–228, figs. 93–97. 1916.

Stone, G. E. Effects of illuminating gas on vegetation. Massachusetts Agr. Exp. Sta. Ann. Rept. 25: 1: 45–60, figs. 1–3. 1913.

Shoe-String Root-Rot

Caused by *Armillaria mellea* (Fries) Quelet

The shoe-string or honey-mushroom root-rot is common throughout the United States on many kinds of coniferous and deciduous trees. It has been noted especially on oak, pine, chestnut, larch, sycamore, poplar, locust, hemlock, birch, alder, maple and many kinds of fruit-trees and shrubs. In some sections of the country, especially in south central United States and on the Pacific Coast, orchard-trees are commonly affected and killed. The disease is most destructive in orchards on land recently cleared of oak. In Europe this disease is also common on cedar, pine, fir, peach, cherry, olive, grape and many other kinds of woody plants. There seem to be no definite host relations for the activities of the fungus causing this root-rot. It is known to attack the potato.

No very accurate facts are available as to the parasitic potentialities of the honey-mushroom. It occurs everywhere on stumps and dead wood and is commonly found on trees in poor health or badly wounded. The relation between the decline of the tree and the attack of this fungus is hard to determine. However, abundant evidence is at hand that young thrifty trees in the forest and orchard are often killed, when there is no doubt that the honey-mushroom was directly and primarily the cause of the decay of the roots. It is, therefore, reasonable to expect that on further investigation this root-rot will be fully shown to be a primary cause of the decline and death of the trees. In many cases, however, it may play only a sec-

roots (Fig. 6). The strands may be traced to points at which they enter the roots. At these points the white mycelium inside the black strands spreads out and runs in all directions in the bark and sapwood. Thin white sheets of mycelium are found in the cambium region (Fig. 6). The tissues of the cambium and bark are destroyed and replaced by the white sheets. The mycelium also penetrates the medullary-rays and sapwood and causes a wet white rot. After the bark is killed, the black shoe-strings are formed abundantly between the bark and wood. They anastomose in all directions and form a network. The decayed area of sapwood and bark is bordered by a brown zone.

Fig. 7. — Young toadstools of *Armillaria mellea* attached to shoe-strings.

The fruiting-bodies of the fungus are honey-colored toadstools or mushrooms. They appear on the sides of the trunk, exposed roots or directly from the ground. Close examination will show their attachment to the black shoe-strings (Fig. 7). The toadstools occur in clusters, attached to one another at the base of the stalks. The stalks are somewhat swollen at the base and have a fragile collar just beneath the cap. The upper surface of the cap is smooth and yellowish or brownish. The under surface is composed of radiating pendent plates or gills of the same color (Fig. 8).

Cause.

The shoe-string root-rot of trees is caused by the mushroom, *Armillaria mellea.* The spores are borne on the sides of the gills or plates on the under surface of the fruiting-body (Fig. 8). The tree-roots are infected in several ways. The spores may cause infection through wounds at the base of the tree or in exposed roots. The black strands running through the soil may also penetrate the bark of the roots. In this manner the fungus spreads through the soil from the roots of one tree to another. This mode of infection accounts for the occurrence of circular areas of diseased trees. Since the fungus also commonly occurs as a saprophyte on dead wood, the fruiting-bodies are produced in great abundance on prostrate trunks and on old stumps for several years after the affected tree is dead.

FIG. 8. — Mature fruiting-body of *Armillaria mellea*, showing gills on under surface.

Control.

Root diseases are difficult to control since the condition of the roots cannot be readily ascertained. By destroying the toadstools and removing the diseased roots or parts of roots, the individual tree may be saved. In the orchard or forest, diseased trees or groups of trees may be surrounded by isolation trenches, a foot or two deep. All roots bridging the trench must be removed and the trench kept free of débris and fruiting-bodies. The trench must be dug far enough away from the affected trees to insure the absence of diseased roots outside of the area to be isolated.

References

Long, W. H. The death of chestnuts and oaks due to Armillaria mellea. U. S. Dept. Agr. Bul. 89: 1–9, pls. 1–2. 1914.

Schrenk, Hermann von, and Spaulding, P. Root-rots. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 22–24. 1909.

Hesler, L. R., and Whetzel, H. H. Armillaria root-rot. *In* Manual of fruit diseases, pp. 96–102, figs. 26–27. 1917.

Hartig, R. Agaricus melleus L. *In* Die Zersetzungserscheinungen des Holzes etc., pp. 59–62, pl. 11. 1878.

Hartig, R. Agaricus (Armillaria) melleus L. *In* Wichtige Krankheiten der Waldbäume, pp. 12–42, pls. 1–2. 1874.

Lawrence, W. H. Root diseases caused by Armillaria mellea in the Puget Sound country. Washington Agr. Exp. Sta. Bul. (special series) 3: 1–16, figs. 1–5. 1910.

Piper, C. V., and Fletcher, S. W. Root diseases of fruit and other trees caused by toadstools. Washington Agr. Exp. Sta. Bul. 59: 1–14, figs. 1–5. 1903.

Horne, W. T. The oak fungus disease of fruit trees. California State Com. Hort. Monthly Bul. **3**: 275–282, figs. 79–81. 1914.

Horne, W. T. Fungous root rot. California State Com. Hort. Monthly Bul. **1**: 216–225, figs. 85–91. 1912.

Horne, W. T. Oak fungus or Armillaria mellea in connection with nursery stock. California State Com. Hort. Monthly Bul. **4**: 179–184, figs. 31–33. 1915.

Barss, H. P. Mushroom root rot of trees and small fruits. First Biennial Crop Pest and Horticultural Report (Oregon Agr. Exp. Sta.) **1911–1912**: 226–233, figs. 23–38. 1913.

Mycorhizas

Caused by various species of fungi

An interesting type of parasitic relation between certain species of fungi and the living roots of many kinds of trees con-

formed on the surface of the ground. Several kinds of toadstools and puff-ball fungi have been proved to be mycorhizal fungi. Ectotrophic mycorhizas are recognized by the short, stubby, lateral rootlets, which are covered with the fungus mantle and may be white, brown, yellow or red. The same tree may show several different kinds of mycorhizas, each caused by a different species of fungus. When the mycorhizal production is profuse, whole clusters of the stubby roots may form a coral-like structure. The endotrophic mycorhizas on maple roots form bead-like swellings, often in chains. The mycelia of some endotrophic mycorhizas have been found to produce fruiting-bodies, which place them in the genus Phoma.

Reference

McDougall, W. B. On the mycorhizas of forest trees. Amer. Jour. Bot. 1: 51–74, pls. 4–7, fig. 1. 1914. (Bibliography given.)

Roots Parasitized by Flowering Plants

Several species of flowering plants attach their root-like organs to the roots of other plants and trees, and draw a certain amount of food materials from them. All degrees of parasitism are found, from the species of the broom-rape family (Orobanchaceæ) which develop no leaves or chlorophyl and are entirely dependent on other plants for food, to those types which develop normal green foliage above ground, and sometimes grow without forming any attachments to the roots of other plants. Certain species of Comandra have been found to be of the latter type. Their roots normally develop disc-like attachments, which connect the tissues of the Comandra roots with the roots of various other plants. They have been found attached to the roots of the following trees: maple, birch, chestnut, poplar, oak and sumac. Very little damage is done to the tree. Examples of the former type, mentioned above, where all the food materials required by the plant are obtained through the connected roots, include the common beech-drop (see page 108), indian-pipe and many other plants belonging to various families of the flowering plants.

References

Hedgcock, G. G. Parasitism of Comandra umbellata. Jour. Agr. Res. 5: 133–135. 1915.

Harshberger, J. W. Vegetal agents of disease. *In* A text-book of mycology and plant pathology, pp. 298–306, figs. 117–123. 1917.

CHAPTER V

ALDER DISEASES

SEVERAL native species of alder (Alnus) are common forest-trees in the Northwest and Rocky Mountain region. They grow in river-bottom lands and on mountain sides. In eastern United States, the European alder is used as an ornamental and in some localities has become naturalized.

The alder is particularly subject to wood-rot diseases. The common white and the brown checked wood-rots often cause death by destroying the sapwood. The leaf-blisters, deformation of the catkins and catkin powdery mildew attract attention when they occur, but they do only slight damage to the tree. The alder also is one of the non-leguminous plants on which the nitrogen-fixing bacteria form root-tubercles. The several shrubby species of alder are subject to the same diseases as the larger trees.

POWDERY MILDEW OF CATKINS

Caused by *Erysiphe aggregata* (Peck) Farlow

In northeastern United States, the female catkins of alder are often covered with a powdery mildew. A similar, if not identical, fungus attacks the twigs of alder in Europe. The catkins are covered with a white or yellowish coating of mycelium which later may be dotted with clusters of small black fruiting-bodies. The life history and methods of control of the powdery mildew fungi are discussed on page 37. Two other species of the powdery mildews occur on alder leaves.

poplar, willow, maple, butternut, walnut, oak and hickory are the most commonly affected by this wood-rot. Specific mention of this disease in alder is less frequent in this country because of the slight economic importance of the species of alder. For a description of the symptoms of the common white wood-rot, see under poplar diseases, page 305.

Root-Tubercles

Caused by *Bacillus radicicola* Beijerinck

The roots of alder commonly show large clusters of short stubby roots. These abnormal roots represent a diseased condition by which the alder benefits. The dwarfed roots are inhabited by the same bacterium which causes the root-tubercles of clover, bean, cowpea, locust and other leguminous plants. The bacteria gain entrance to the young lateral rootlets by way of the root-hairs. They multiply within the cells of the cortex of the root and stimulate this tissue to over-growth. They live parasitically and obtain their food materials from the protoplasm and cell sap of the alder roots, but they do not kill the cells they inhabit. These bacteria take the free nitrogen gas from the air and combine it with other substances. After this is accomplished, the alder roots eventually receive this combined nitrogen and the tree uses it in its metabolic processes. In this way large quantities of nitrogen are obtained indirectly from the air by the alder. The higher plants cannot utilize nitrogen gas from the air and the plants which are parasitized by the nitrogen-fixing bacteria are thus greatly benefited. Such a mutual-benefit relation between the alder and the bacteria is known as symbiosis, although strictly speaking the bacteria are parasitic even though they do not cause the death of the root-tissues.

Reference

Spratt, Ethel R. The morphology of the root tubercles of Alnus and Elæagnus, and the polymorphism of the organism causing their formation. Ann. Bot. **26**: 119–128, pls. 13–14. 1912.

CHAPTER VI

ARBOR-VITÆ DISEASES

Two species of arbor-vitæ (Thuja) are common forest-trees in northeastern and northwestern United States. They occur in moist river-bottom lands and along mountain streams. The western arbor-vitæ grows to a much larger tree than the eastern species. Both species are extensively used as ornamentals.

The eastern arbor-vitæ is especially free from diseases. The wood and roots of the living tree are seldom decayed and no leaf or twig-diseases of any importance are known. The western arbor-vitæ, on the other hand, is destructively attacked by a leaf-fungus. The younger trees may be killed outright. In the nursery, arbor-vitæ is subject to a common blight which also affects juniper. Ornamental arbor-vitæ seldom suffer from fungous diseases but frequently are injured by freezing-to-death, sun-scorch and other general troubles (see index).

SEEDLING-BLIGHT

Caused by Phoma sp.

At least three species of Thuja, including the eastern and western arbor-vitæ, are affected by this seedling-blight. The same disease is common on juniper. Young arbor-vitæ trees up to four years old are affected in the same manner as juniper (see page 190). Cankers are formed which girdle the stem, causing the plants to die. The disease often becomes epiphytotic and causes serious losses in nursery-beds. Control measures have not been determined.

Leaf-Blight

Caused by *Keithia thujina* Durand

The leaf-blight or black leaf-spot of western arbor-vitæ is common and destructive, especially to young trees, throughout its range in northwestern United States. In dense stands and in localities where humid conditions prevail, this disease causes the death of a large percentage of the seedlings less than four years old. In late summer the lower branches of older trees when affected by this blight appear as if scorched by fire. In some localities the foliage of the upper parts of the trees also may be affected. This is, however, essentially a disease of seedlings. The affected parts are those which are covered by snow until late in the season.

Symptoms.

In spring and summer the affected leaves show from one to three more or less circular brown cushions bursting through the epidermis. Later these bodies turn black. The affected leaves die and turn brown in late summer. The twigs bearing the brown leaves also fall, leaving the branches bare. In autumn the black bodies in the older leaves often fall out, leaving holes, and these leaves turn gray.

Cause.

The leaf-blight or black leaf-spot of the western arbor-vitæ is caused by the fungus *Keithia thujina*. This fungus is closely related to the tar leaf-spot fungi of maple and willow and the black-specked leaf-spot fungus of maple. The black fruiting bodies on the leaves crack open, irregularly, and expose the ascospore-bearing surface within. The ascospores are wind-blown and infection usually occurs in the autumn. Moist weather is necessary for the discharge of the spores.

ously damaged by this root disease throughout their range. The wood of the affected roots is at first yellowish and cheesy but later it becomes red-brown and brittle. The rot sometimes extends up into the trunk. A more complete description of this disease is given under pine diseases, on page 294.

CHAPTER VII

ASH DISEASES

SEVERAL species of ash (Fraxinus) are common forest-trees in most parts of the United States. White, green and black ash are the important timber-trees. These are common throughout eastern and central United States. The same three species mentioned above are frequently used for shade and ornament.

Ash is exceptionally free from destructive diseases. The rust of the leaves occurs sporadically and may assume an epiphytotic nature. Little damage is caused to the trees, however, unless defoliation occurs two or three years in succession. Several parasitic fungi cause leaf-spots on ash (see page 29). Only one wood-rot is described as important in ash. This disease is rarely found in the East but is destructive on the western limits of the white ash. The slow growth which the ash makes in that region seems to predispose the trees to this disease. Where the trees grow more rapidly, they are seldom affected. The roots of ash frequently are killed by low temperature (see page 74).

LEAF- AND TWIG-RUST

Caused by *Puccinia fraxinata* (Link) Arthur

The leaf- and twig-rust of red, green and possibly other species of ash is striking because of its effect on the leaves and twigs and its epiphytotic nature. It is common, at least in eastern and central United States, but varies greatly in abundance from year to year. In central Iowa and eastern Nebraska, this disease was so abundant in 1885 that it was difficult to find leaves not affected. The next two summers scarcely any of the rust could be found. In 1888 it was again abundant in the same region. An epiphytotic of this disease was reported in 1887 around Washington, D. C., with very little of the rust in that region the next year. No recent reports of such outbreaks have been published.

FIG. 9. — Ash-rust. Fruiting-bodies of causal fungus on swollen petiole.

Symptoms.

This rust causes swellings which are irregular or more or less globose. They appear on the petioles of the leaves and on the twigs (Fig. 9). Swollen areas are also formed on the leaves which are much distorted. Soon after the swellings are formed they are covered by numerous blister-like protrusions, which break open, leaving cup-shaped areas filled with yellowish powder (Fig. 9). This stage of the rust is called the cluster-cup stage. The yellow powdery material is composed of the spores (æciospores) of the fungus. The distortion of the petioles and leaves, covered with the yellow cluster-cups, make this disease conspicuous.

Cause.

Ash-rust is caused by *Puccinia fraxinata.* This fungus requires two kinds of host plants to complete its life history. The spores produced in the cluster-cups on the ash do not reinfect the ash, but must find lodgment on the marsh or cord-grasses (Spartina) in order to continue their development. On the grass plant, spores are produced which infect the ash the next spring.

white, while for a time the summer-wood remains brownish. Shortly, however, the summer-wood becomes whitish and in the final stages of the decay the wood is soft and crumbly.

The perennial sporophores of the causal fungus are formed at old branch wounds. They are usually small bracket-shaped bodies. The upper surface is hard, dark brown or black and marked by concentric folds. The under surface is velvety, straw-colored and covered with large circular pores. The inner structure of the fruiting-body is white or light brown, according to its age. A new layer of tubes is added to the lower surface each year.

Cause.

The white heartwood-rot of white ash is caused by *Fomes fraxinophilus.* This fungus is rarely found on any other tree. Living green ash trees have been observed with the fruiting-bodies on them and it is possible that a rot of similar nature as that caused in white ash may be found in green and other ashes. The spores borne within the tubes on the under surface of the fruiting-body fall out of the pores and are blown about by the wind. When they find lodgment on exposed heartwood of the white ash, a new mycelium may be initiated. The initial stages in the decomposition of the fibers result in a brown liquid which stains the wood. Later this colored liquid disappears and the mycelium delignifies the cell-walls and dissolves most of the cellulose. The fungus is not known to occur as a saprophyte. For further details concerning the life history and control of the wood-rotting fungi of living trees, see page 64.

References

Schrenk, Hermann von. A disease of the white ash caused by Polyporus fraxinophilus. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 32: 1–20, pls. 1–5, fig. 1. 1903.

Schrenk, Hermann von, and Spaulding, P. White heart-rot of ash caused by Fomes fraxinophilus. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 46–47. 1909.

CHAPTER VIII

BALD CYPRESS DISEASES

The bald cypress or Taxodium is an important timber-tree in southern and southeastern United States. It is frequently used as an ornamental. The pecky heartwood-rot is the only known disease of any importance which attacks this tree.

Pecky Heartwood-Rot

Caused by *Fomes geotropus* Cooke

The pecky heartwood-rot of bald cypress is a common disease and is recognized by every one who handles cypress timber. The disease is also known by the names peggy-, botty- and bot-cypress and the peck or puck of cypress. Bald cypress trees throughout their range are more or less affected by this disease. It seems, however, to be more common and destructive in the extreme southern states. It has been estimated that one-third of the cypress timber available is damaged by this wood-rot. Older trees are most often affected and, in many cases, the tops of the trees are decayed without damage to the principal timber portion. The number of trees showing more or less peckiness has been found to vary from practically 100 per cent of the stand in Florida and Louisiana to smaller percentages toward the northern limits of the range of cypress in North Carolina, Indiana and Missouri. Since the pecky wood has been found to be practically as durable as the normal unaffected wood, it is used for rough lumber and as ornamental finishing for rustic effects. The general worm-eaten appearance of the pecky wood leads to the impression that the injury is due to wood-boring insects.

Symptoms.

The tops of trees one hundred and twenty-five years old or older are frequently affected. The rot is also found in the butts. Younger trees are rarely affected by this disease. The first indications of the rot are localized areas yellowish in color and about one-fourth inch wide and several inches long. The wood between the yellowish areas is unchanged. Decomposition of the wood elements in the yellow areas proceeds until definite cavities are formed. These cavities are partially filled with a yellow-brown powder and occasionally white mycelium and fibrous masses of partially decayed wood are found mixed with the brown powder. Sometimes the pockets are found entirely empty. The pockets extend lengthwise with the grain of the wood and are about one-fourth of an inch wide and four or five inches long. They are very smooth-walled and nearly cylindrical and blunt ended. Peckiness is usually confined to the upper part of the trunk and older branches. In very old individuals, the wood at the base of the tree may be affected. The pockets are not always found at the center of the tree but may be located on one side or extend around the trunk leaving the center unaffected. The pockets may be several inches apart and scattered through the cross-section; or densely aggregated in the older wood or in certain annual rings. The badly affected trees are not appreciably weakened and are rarely blown over. The wood between the pockets is slightly darker in color than the normal wood but it is unchanged structurally. Recently it has been learned that the hollows sometimes found in the butts or trunks of cypress seem to be due to the complete destruction of the wood between the pockets.

The fruiting-bodies of the fungus causing the peckiness are

For further details concerning the general life history and control of the wood-rot fungi, see page 64.

Reference

Schrenk, Hermann von. A disease of Taxodium distichum known as peckiness, also a similar disease of Libocedrus decurrens known as pin-rot. Missouri Bot. Gard. Ann. Rept. **11**: 23–77, pls. 1–6. 1900.

CHAPTER IX

BASSWOOD DISEASES

The several species of basswood or linden (Tilia) are common in eastern and central United States. These trees, as well as several European basswoods, are extensively used as shade and ornamental trees in the same region.

No serious diseases affect the basswood. Several leaf-spots and one powdery mildew affect the leaves occasionally. The sapwood may be destroyed and the trees killed where woodpeckers damage the bark and allow fungi to enter. In the South the roots of the basswood are often decayed by a fungus which is common in heavy soils.

Powdery Mildew

Caused by *Uncinula Clintonii* Peck

This powdery mildew fungus attacks the leaves of basswood in northeastern and north central United States. The mycelium is visible on both sides of the leaf, causing diffused powdery white patches. Small black fruiting-bodies which are just visible to the unaided eye are scattered over the whitish area. This species, although indistinguishable from other powdery mildew fungi, except by microscopic characters, is so far the only one reported on basswood leaves. The life histories and methods of control of powdery mildew fungi are discussed on page 37.

Leaf-Spot

Caused by *Cercospora tiliæ* Peck

The leaves of the basswood are often affected by this disease. Large brown dead areas are formed at the tip or along the margin of the leaf (Fig. 10). A broad yellowish border surrounds

Fig. 10. — Leaf-spot of basswood.

the spot. The fruiting bodies of the causal pathogene are inconspicuous. For the general life history and control of leaf-spot fungi, see page 33.

Abundant growths of the sterile mycelium, which is coarse, loosely matted and reddish brown, cover the affected roots. It also grows over decaying sticks and other matter on the surface of the ground. The mycelial growth has the appearance of a quantity of tangled hair.

The mycelium spreads through the soil and is transported in various ways by cultivating tools. It is said to display exceptionally destructive tendencies in wet, badly drained soils and during rainy periods. Loosening the soil, deep plowing and drainage are said to reduce losses by retarding the spread of the mycelium in the soil.

Reference

Galloway, B. T., and Woods, A. F. Southern root-rot. *In* Diseases of shade and ornamental trees. U. S. Dept. Agr. Yearbook 1896: 248–249. 1897.

CHAPTER X

BEECH DISEASES

The beech (Fagus) is a common tree throughout eastern and central United States. The American and different varieties of the European beech are often used as ornamentals.

No serious diseases of the leaves of beech are known. Several fungi cause leaf-spots occasionally and a sooty mold fungus often occurs on the leaves (see pages 27 and 41). The beech is subject, however, to several wood-rot diseases. The yellowish sapwood-rot and common white wood-rot are very destructive in the forest. The roots are parasitized by the flowering plant commonly known as beech-drop. This parasite, however, does not cause any damage.

Yellowish Sapwood-Rot

Caused by *Fomes fomentarius* Fries

This sapwood-rot is common on beech, yellow birch and to a lesser extent on other deciduous trees of northeastern and north central United States. The fungus causing the decay is also an important and rapid timber-destroyer throughout its range. Where beech or birch is predominant and any unusual amount of injury has occurred because of fire or limb breakage, this sapwood-rot is found in great abundance and causes large losses in timber values. It is also a common disease in Europe.

Symptoms.

The decay produced is distinctly a sapwood-rot at first, starting in the outer layers next to the bark. As a result of the activities of the fungus, the wood is reduced to a soft, light yellowish punk. Black lines are formed between the decayed and unaffected wood in places, or they may persist in the completely decayed portion. The rot extends into the heartwood toward the center of the tree. Where splits or checks occur in the decayed portion, a chamois-like sheet of closely woven yellowish mycelium is formed which fills the space and can with care be removed in large pieces. Trees are usually first affected in the upper half.

FIG. 11. — Fruiting-body of *Fomes fomentarius*.

The sporophores or punks of this fungus, which are formed on the trunks of affected trees, usually occur in large numbers on each tree, the number varying with the extent of the decay. The sporophores are not confined to old branch wounds as usually is the case with heartwood-rotting fungi, but emerge from apparently uninjured bark of the trunk. They are easily recognized, being distinctly hoof-shaped and light to dark gray on top. The lower surface is light brown, with rather large regularly arranged circular pores. Both surfaces are smooth and velvety when young. A new layer of tubes is added each year, which extends beyond the previous year's growth, producing an arched ridge (Fig. 11). The margin of the sporophore is rather thin and the tube-surface is somewhat concave.

Uniform White Sapwood-Rot

Caused by *Hydnum septentrionale* Fries

This sapwood-rot is sometimes found in beech and maple. The affected wood is white, soft and uniformly rotted. Brown zones border the decayed area. Sometimes single and double black lines are irregularly distributed in the white rotted wood. Large, heavy, fleshy fruiting-bodies are formed on the side of the tree. A thick sheet of mycelium grows over the bark and from this project numerous small brackets with the under surface covered with teeth. The entire structure is white or yellowish. For further details concerning this sapwood-rot, see under maple diseases, page 234.

White Butt-Rot

Caused by *Fomes applanatus* Fries

The heartwood of the roots and base of the trunk of beech is occasionally destroyed by this rot. The decayed wood becomes a little lighter in color than the normal wood. It is solid and when split longitudinally numerous sinuous whitish tunnels are apparent (Fig. 12). The decayed area is bordered by a broad discolored zone. The sporophores of the causal fungus are woody shelf-like bodies with a brownish or gray, smooth upper surface and a white under surface. For further details concerning this wood-rot, see under poplar diseases, on page 310.

Parasitized Roots

Caused by *Epiphegus virginiana* Barton

The roots of beech are parasitized by a peculiar flowering plant, beech-drop (*Epiphegus virginiana*). This plant belongs to the family Orobanchaceæ, which comprises about one hundred and fifty species, all of which are parasitic on roots of other plants. The beech-drop is confined to America and is found throughout the range of the beech. The plants grow abundantly under beech trees in the woods but it is doubtful whether much appreciable damage is done to the tree. In this respect they may be compared with the mycorhizas of tree-roots (see page 82). The beech-drop plant is much branched, leafless, purplish-brown and stands from four to twelve inches high. Small purplish flowers are borne on the stems in racemes. In the soil the stem ends in a white bulb-like or elongate rhizome which is covered with numerous twisted, stiff outgrowths known as grapplers. They serve for support and may absorb water and mineral nutriment. All beech-drop plants, however, if carefully dug, will be found to be attached to small beech roots. The tissues of the rhizome of the parasite are fused with those of the beech root so completely that at the point of attachment it cannot be definitely recognized to which plant they belong. The beech root is enlarged for some distance each way

FIG. 12. — Beech wood decayed by *Fomes applanatus*.

from the point of attachment and often the end of the parasitized root dies, leaving the beech-drop apparently attached to the end of a root. Food material for the development of the beech-drop is drawn from the beech root, and a large amount of starch is formed and stored in the underground rhizome. The entire plant dies during the fall and winter and apparently is propagated as an annual by over-wintering seed. When desired, the plants may be eradicated by pulling. This should be done before the seeds are formed so as to prevent a crop the next season.

Reference

Schrenk, Hermann. Parasitism of Epiphegus virginiana. Amer. Micros. Soc. Proc. 15 : 91–128, pls. 1–10. 1894. (Bibliography given.)

waxy-yellow and finally become brown and almost black. They may be abundant and thickly cover the under side of the leaves.

Cause.

The rust of birch leaves is caused by *Melampsoridium betulæ.* This fungus occurs also in Europe, where it is known that the basidiospores produced from the over-wintering teliospores on the birch leaves cause the infection of the young needles of larch and produce a blister-rust. The stage on larch has been found rarely in this country but very probably exists more generally and has been confused with the other rusts of larch (see page 212).

Yellow Leaf-Blister

Caused by *Magnusiella flava* (Farlow) Sadebeck

This leaf-blister disease occurs on white and paper birch in northeastern United States. Small light yellow blisters are formed on the leaves. The mycelium of the pathogene enters the tissue of the leaf and causes a stimulus which results in an increase in number and size of the cells. The increased size of the affected tissue results in the bulging blisters in the leaf. The fungus produces asci containing ascospores on the surface of the blisters.

For the control of this disease, the same methods used for peach leaf-curl should give equally good results (Hesler, L. R., and Whetzel, H. H., Manual of fruit diseases, p. 277).

Red Leaf-Blister

Caused by *Exoascus bacteriospermus* (Johanson) Sadebeck and *Taphrina carnea* Johanson

Two species of the leaf-blister fungi are found on *Betula nana.* The first mentioned has also been found on *Betula glandulosa.* Although these pathogenes have been described only briefly from a few collections in northeastern United States, Canada and Greenland, they may be more generally distributed and common on other species of birch. The lesions are confined to the leaves and consist of large reddish brown blistered areas, which may cause the leaf to curl. The mycelium is confined to the space which it makes for itself between the cuticle and the epidermal cells. Due to the parasitic activities of these fungi, the tissues of the leaf are stimulated to an increase both in number and size of the cells. This results in the bulging and curling of the leaf between the more rigid veins.

For the control of these diseases, the same methods that are used for peach leaf-curl should give results (Hesler, L. R., and Whetzel, H. H., Manual of fruit diseases, p. 277).

Powdery Sapwood-Rot

Caused by *Polyporus betulinus* Fries

Many species of birch are subject to this sapwood-rot throughout the northern hemisphere. Yellow, white and paper birch are commonly affected in the United States. Although the fungus causing this rot is very common on injured and dead birch trees, its importance in causing serious damage to healthy trees is questioned. The fungus does not enter through branch wounds and other injuries where heartwood is exposed and, therefore, never causes a heartwood-rot of the living tree. This rot is similar to the yellowish sapwood-rot caused by *Fomes fomentarius*. In the case of both of these fungi, badly injured or weakened trees are attacked and the sapwood is the first part of the trunk decayed. Later, the fungi extend their activities into the heartwood and the entire woody cylinder of the trunk is destroyed. These wood-rots are nevertheless important in the forest since the timber value of the species they affect rapidly deteriorates as soon as the trees become mature or injured.

Symptoms.

The decayed wood is yellowish and cracks radially and tangentially. The rot is uniform and in the final stages it is very light in weight and easily crushed to a powder.

The sporophores of the causal fungus are very common on birch. They are corky annual bodies and are quickly destroyed by insects. From the point of attachment to the trunk, they

FIG. 13. — Fruiting-body of *Polyporus betulinus.*

hang as bell-shaped bodies varying from three to ten or more inches across. The outer surface of the sporophore is smooth and light to dark mottled gray in color (Fig. 13). The margin is incurved and projects below the under surface. The lower surface is white or yellowish and roughened by ragged projections. The pores are small and the entire layer of tubes separates easily from the fruiting-body.

host species. The characteristics of the rot and the sporophores of the causal fungus are described under poplar diseases, page 305. The hoof-shaped type of sporophore is more common on birch. The sapwood of birch is invaded and the trees die. For a general discussion of the life history, dissemination of the spores, mode of infection and control of the wood-rotting fungi, see page 64.

Brown Heartwood-Rot

Caused by *Fomes fulvus* Fries

This heartwood-rot has been found common in river birch in Missouri and Arkansas. Other trees are affected by the same rot, especially species of Prunus. It is common also in fruit-trees of the genus Prunus and in the olive in Europe. But little information is available on the rot as it occurs in this country. The decayed wood is brown for several feet upward and downward from the point where the sporophores are formed. In the final stages of the decay the rotted wood crumbles easily. Plate-like sheets of mycelium which are common in the brown checked wood-rot are lacking in the case of this disease.

The sporophores are formed at wounds. They are perennial, hard, woody and more or less hoof-shaped. The tops of the older sporophores are smooth and very hard. Fine concentric fissures are present but the top does not become roughened. The lower surface is reddish brown and covered with minute pores.

For the general life history and control of wood-rotting fungi, see page 64.

Reference

Schrenk, Hermann von, and Spaulding, P. Red heart-rot of birch caused by Fomes fulvus. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 47. 1909.

White Butt-Rot

Caused by *Fomes applanatus* Fries

The heartwood of the base of the trunk and the roots of birch is sometimes destroyed by this rot. The decayed wood is marked by numerous sinuous, white-stuffed tunnels which run in the horizontal direction (see Fig. 12, page 109). The sporophores of the causal fungus are woody, shelf-like bodies with a brownish, smooth upper surface and a white under surface. This heartwood-rot is more fully described under poplar diseases, on page 310.

CHAPTER XII

BUCKEYE DISEASES

The four species of buckeye or Æsculus native in the United States are not important forest-trees. The Ohio and yellow buckeye grow to be large trees in the river-bottom lands in the central and southern states. A closely related European species, the horse-chestnut, is extensively used as an ornamental.

Leaf-blotch is the most destructive disease affecting buckeye and horse-chestnut. This disease occurs every year throughout the range of the Ohio and yellow buckeye. The horse-chestnut is often severely affected and defoliated in the northeastern states. A powdery mildew is also common on these trees. The California buckeye is subject to a leaf-blight and witches'-broom disease. The wood and roots of the buckeye are rarely diseased.

Leaf-Blotch

Caused by *Guignardia æsculi* (Peck) Stewart

Throughout central, southern and eastern United States, Ohio and yellow buckeye and the horse-chestnut are commonly affected by this leaf-blotch. The disease is also known in southern Europe. It is probable that the disease is present to some extent on the other species of buckeye. A large percentage of the foliage of horse-chestnut trees in parks and along streets is affected every year. In the nursery this disease interferes seriously with the growing of horse-chestnut stock. Repeated

ascospores are formed in the dead leaves after they fall to the ground. These spores mature at about the time the new leaves appear in the spring and are disseminated by the wind and spattering drops of rain. The lower leaves of young trees and sometimes of older ones are the first to show infections in the spring, because they are closer to the source of spore-production. The first lesions soon develop the other type of fruiting-bodies on the dead areas mentioned above. These appear as minute black dots. In this stage the fungus is known as *Phyllosticta sphæropsoidea.* The spores are extruded from the fruiting-body and are mainly distributed to healthy foliage by wind and rain. By repeated generations of this kind of spores, all the leaves on a tree may become infected in a short time. Continued or periodically rainy seasons are especially favorable for an epiphytotic, since moisture conditions necessary for germination are furnished for each new crop of spores. At such times the foliage from a distance appears as if scorched by fire and considerable defoliation may result.

Control of leaf-blotch.

In the nursery it has proved beneficial, in preventing to some extent the amount of primary infection, to plow under or rake together and burn all dead leaves around the trees. This practice can be applied to shade-trees and thus eliminate to a large degree the source of early infections. Even when such measures are taken, a slight amount of infection may result from bits of leaves left on the ground or from early infections on trees in the vicinity. It is, therefore, necessary to supplement these measures by coating the leaves with some efficient fungicide at the time weather conditions and the development of the leaves are conducive to infection. Spraying with lime-sulfur (1–50) or bordeaux mixture (5–5–50) will prevent infection. The foliage is so dense, however, that thorough spraying cannot be done without drenching the foliage. This may lead to unsatisfactory results for two reasons: spray mixtures do not act as efficiently if the foliage is drenched, and lime-sulfur may cause burning. Dusting nursery trees with a mixture of finely ground sulfur and powdered arsenate of lead, in the proportion of ninety parts of sulfur to ten of lead powder, has proved effective in controlling this disease. It may, therefore, be assumed that dusting shade and ornamental trees will be equally effective. For further directions on spraying and dusting for the control of leaf-diseases, see page 357.

References

Stewart, V. B. The leaf blotch of horse-chestnut. Cornell Univ. Agr. Exp. Sta. Bul. 371: 411–419, pl. 10, figs. 85–92. 1916.

Stewart, V. B. The leaf blotch disease of horse-chestnut. Phytopathology 6: 5–19, pls. 2–4, fig. 1. 1916.

Powdery Mildew

Caused by *Uncinula flexuosa* Peck

The leaves of the buckeye and horse-chestnut are affected by a powdery mildew, in eastern, southern and central United States. The powdery white mycelium usually occurs only on the under surface of the leaf in diffused spots. The black fruiting-bodies of the fungus are just visible to the unaided eye and are found scattered over the mildewed areas late in the summer. For a discussion of the general life history and methods of control of powdery mildew fungi, see page 37.

Curled Leaf-Blight and Witches'-Broom

Caused by *Exoascus æsculi* (Ell. and Ev.) Patterson

This disease is described on the California buckeye. It occurs in several localities in California. The most noticeable symptom is the production of many large witches'-brooms. The leaves which are borne on the twigs composing the broom are killed before they mature and appear as frost-injured. The mycelium is perennial in the twigs. The leaves of the normal branches also become spotted and curled. Small yellowish blisters are formed which later turn to a dull red.

The fungus causing this disease is a close relative of the leaf-blister fungus on oak (see page 239). The disease on the buckeye does not cause very much damage to the trees, since the leaves naturally remain on the tree only from April to early summer.

Reference

Harkness, H. W. The curled leaf (*Ascomyces deformans*). Zoe 1: 87–88. 1890.

White Sapwood-Rot

Caused by *Collybia velutipes* Curtis

The sapwood of horse-chestnut is sometimes destroyed by this toadstool. The wood becomes whitish and soft. The spores of the fungus find entrance through wounds in the bark. The fruiting-bodies of the causal fungus are toadstools with yellow or brownish tops and gills. The bases of the stalks are covered with a brown or black velvety growth of hairs. A fuller discussion of this disease will be found under basswood diseases, on page 103.

fruiting-structures on the under sides of the dead areas. Spores from these structures are produced in abundance during wet weather and are disseminated by rain. After the leaves fall, perithecia are formed and from these ascospores are available in the spring for primary infection. The name applied to the perithecial stage is *Gnomonia leptostyla* (Fries) Ces. and De Not. For a further discussion of leaf-spots and their control, see page 27.

Common White Wood-Rot

Caused by *Fomes igniarius* Fries

The butternut is sometimes affected by the common white wood-rot, which occurs in many kinds of deciduous trees, especially poplar, beech, oak and maple. The sporophores of the fungus and the characteristics of the rot are similar for all the kinds of trees affected and are described under poplar diseases, page 305.

Brown Checked Wood-Rot

Caused by *Polyporus sulphureus* Fries

Butternut is occasionally affected by the brown checked wood-rot, caused by the sulfur fungus. Many other kinds of trees are affected by the same disease. The sulfur-yellow, annual fruiting-bodies of the fungus together with the brown powdery character of the rotted wood make it easy to identify this disease. The tops of trees and large limbs may be killed by the invasion of the sapwood and bark. A more complete discussion of this wood-rot will be found under oak diseases, page 247.

CHAPTER XIV

CATALPA DISEASES

The two species of catalpa grow naturally in southeastern and central United States. Both species are used as ornamentals. A few leaf-spot diseases cause some damage to catalpa according to the locality and the season (see page 30). Otherwise the tree is not subject to serious diseases, except in plantations where the yellow wood-rot is destructive. The predisposing of the catalpa to this wood-rot, by planting the trees closely, illustrates the importance of branch wounds as infection courts for the heartwood-rotting fungi. The rapidity with which this rot progresses in the living tree compared with the well-known durability of catalpa timber points to the existence of some condition within the tree which favors the development of the causal fungus.

Yellowish Wood-Rot

Caused by *Polystictus versicolor* Fries

This destructive heartwood-rot of the hardy catalpa may be found wherever the trees grow. The disease is not common in trees growing in the open. In close stands, however, the limbs are killed by shading and after they break away, holes are left which soon become infected by the spores of the fungus causing this rot. The causal fungus is a very common saprophyte, which grows everywhere on the wood of deciduous trees. It may often occur as a semi-parasite in the bark and sapwood of deciduous trees when they have been severely injured. Otherwise the catalpa is the only tree in which this fungus is known to cause a distinctive heartwood decay.

Symptoms.

The affected trees may be recognized by the holes in the trunk where the old branch stubs have rotted. Insects and birds remove the decayed wood and use the hollowed-out areas in the trunk for habitations. In cross-sections of the trunk, the first indications of the decay show as pale colored areas. The spring-wood of the annual rings becomes reddish with small whitish areas. Later both the spring- and summer-wood of the annual rings are similarly affected. The decayed wood then becomes straw-yellow and is very soft and brittle. The decayed area enlarges rapidly and eventually the sapwood may be invaded. The decay may extend into the branches and roots. Coppice is usually affected if the wood of the stump is decayed.

The fruiting-bodies of the causal fungus are formed where the bark is dead or on the affected wood when it is cut from the tree. They are thin, tough shelving structures, hairy on top and marked with variable yellowish and brown shiny zones. The under surface is yellowish or white and covered with small pores. The fruiting-structures are annual bodies but they persist through the winter and may revive and shed spores in the spring.

Cause.

The yellowish soft wood-rot of hardy catalpa is caused by the fungus *Polystictus versicolor*. The spores from the tubes on the under surface of the fruiting-bodies are wind-borne and cause infection when they lodge in branch wounds. When the trees are planted close together, the lower shaded branches die and remain attached to the tree for some time. When

(see page 125). The control is the same for both of these diseases.

Reference

Schrenk, Hermann von. II Diseases of the hardy catalpa. *In* The hardy catalpa. U. S. Dept. Agr. Bur. Forestry Bul. 37 : 49–58, pls. 23–30, figs. 1–2. 1902.

CHAPTER XV

CEDAR DISEASES

The white cedar of the Atlantic Coast and incense cedar of the Pacific Coast are affected by several destructive diseases. These two trees belong to different genera (Chamæcyparis and Libocedrus). The diseases affecting the white cedar do not occur on the incense cedar and *vice versa*. They are discussed together in this chapter merely for the convenience of grouping them under the name common to both.

The two rust diseases (witches'-broom and branch-swellings) on the white cedar cause serious deformation of the trees and even death when they occur. The incense cedar is also affected by a rust-fungus which causes witches'-brooms. The incense cedar is subject to a destructive heartwood-rot, which is similar in appearance to the pecky heartwood-rot of bald cypress. The brown felt-blight of incense cedar is important at high altitudes.

Eastern Leaf-Rust

Caused by *Gymnosporangium fraternum* Kern

The white cedar is sometimes affected by this leaf-rust, along the Atlantic Coast from Massachusetts to New Jersey. No damage is done to the trees. The symptoms are confined to the spore-masses of the pathogene which break through the epidermis of the affected leaves. These spore-masses appear in the spring and are small brown cushion-shaped pustules about an eighth of an inch in diameter. The life history of the causal pathogene is completed on the leaves of chokeberry

(Pyrus). The teliospores borne on the brown cushions germinate and the basidiospores which are formed in this process are blown away and cause the infection of the chokeberry leaves. Æciospores produced on this host plant then cause infection of the cedar leaves later in the season if they chance to lodge on them. A more detailed explanation of the life history and control of the rust-fungi belonging to the same genus as this pathogene will be found under juniper diseases, on page 192.

Western Leaf-Rust

Caused by *Gymnosporangium nootkatensis* (Trelease) Arthur

Along the Pacific Coast in the Northwest, the yellow cedar is affected by this leaf-rust. The symptoms are similar to the eastern leaf-rust described above. The life history of the causal pathogene is completed on the leaves of species of apple and mountain ash. For a more detailed description of the habits and control of the rust-fungi of this genus, see under eastern leaf-rust, above, and juniper diseases, on page 192. The life history of this rust-fungus differs, however, from all of the other species of the genus Gymnosporangium, in that urediniospores are formed on the cedar leaves. The teliospore-cushions have not been found but undoubtedly occur on the cedar leaves associated with the urediniospores.

Brown Felt-Blight

Caused by *Herpotrichia nigra* Hartig

Incense cedar is one of the many conifers subject to this disease in the Northwest. The leaves and twigs are covered with a dark brown mat of mycelium (Fig. 16). The mycelium also enters the leaf-tissues. Young trees and the lower branches of older ones are killed and under conditions favorable for the development of the causal fungus, the trees appear as scorched

are the most important diseases of white cedar. As in the case of the other rust-fungi of cedar and juniper, an alternate host is necessary for the completion of the life history of the fungus. The witches'-brooms are never formed unless bayberry, sweet-fern or wax myrtle shrubs (Myrica) are in close proximity to the cedars.

Symptoms.

The infected branches of the cedar become slightly swollen and produce many short laterals which form a compact broom-like growth. In the early spring, orange spore-horns about an eighth or a quarter of an inch long project from the bark of the distorted branches.

Cause.

The witches'-brooms of white cedar are caused by the rust-fungus, *Gymnosporangium myricatum*. The life history of this fungus is similar to that of the other cedar and juniper rusts except that the alternate stage is developed on species of Myrica. With this exception the life history described on page 192 will apply in general to this species.

Control.

Since this rust-fungus requires the presence of both the white cedar and species of Myrica in close proximity in order to carry out its life history, a simple means of protecting the cedars is afforded by destroying the bayberry, sweet-fern or wax myrtle shrubs. If these plants can be eliminated for a distance of several hundred feet or a mile from the white cedars, no further exchange of spores will be likely and the cedars will be safe from infection.

References

Harshberger, J. W. Two fungous diseases of the white cedar. Proc. Acad. Nat. Sci. Phila. **1902**: 461–504. 1902.

Fromme, F. D. A new Gymnosporangial connection. Mycologia **6**: 226–230. 1914.

Western Twig-Blight and Witches'-Broom

Caused by *Gymnosporangium Blasdaleanum* (Diet. and Holw.) Kern

The incense cedar is attacked by this rust disease and considerable damage is caused in some regions. The other trees attacked by the same rust, in the other stage of its life history, are cultivated apple, pear, quince, mountain ash and wild species of apple, haw and service-berry. It is most destructive on the cultivated pear. The relation between the stages of this fungus on the two types of hosts, one the incense cedar and the other the plants of the apple family, is explained on page 192, where the life history of these rusts is discussed.

Symptoms.

Two different effects are produced by this rust. When the smaller twigs are infected, the first symptoms in early spring are the small reddish brown spore-cushions which appear on the surface of the scale-like leaves. During rainy weather these cushions gelatinize and coalesce, forming yellowish masses over the leaves. The leaves of the infected twig then turn yellow and the twig dies.

When larger branches are infected, dense clusters of upright branches are produced. The fungus fruits in the manner described above on the younger twigs of the brooms and the twigs are killed. Most of the damage caused by this rust on the incense cedar is due to the development of the witches'-brooms which at times seriously deform the tree.

Cause.

The twig-blight and witches'-broom of incense cedar are caused by the rust-fungus, *Gymnosporangium Blasdaleanum*. The teliospores formed on the spore-cushions on the cedar germinate and produce basidiospores, which when blown to the apple host cause infection of the leaves. The æciospores formed sometime later infect the cedar leaves in the summer and autumn. The fungus over-winters as mycelium in the cedar leaves. Further details concerning the life history of rusts of this type will be found under juniper diseases, on page 192.

References

Jackson, H. S. A Pacific Coast rust attacking pear, quince, etc. Second Biennial Crop Pest and Horticultural Report (Oregon Agr. Exp. Sta.) **1913–1914**: 204–212. 1915.

Jackson, H. S. A new pomaceous rust of economic importance, Gymnosporangium Blasdaleanum. Phytopathology **4**: 261–269, pls. 12–13. 1914.

Branch-Swelling

Caused by *Gymnosporangium botryapites* (Schw.) Kern

The white cedar on the Atlantic Coast from Massachusetts to New Jersey and Pennsylvania and in southern Alabama is often affected by this disease. The branch-swelling and witches'-broom diseases of white cedar are the most serious to this tree. Because, however, of the peculiar life history of the rust-fungi which cause them, they are not generally prevalent. The spores formed on the cedar branch-swellings cause the infection of the leaves of the service-berry and another type of spores formed on these leaves in turn causes infection of the branches of the white cedar. Thus it is seen that this fungus cannot exist unless the service-berry is in close proximity to the cedars.

Symptoms.

The infected branches become swollen to two or three times the normal size. The swellings are spindle-shaped and may be several inches long. In the spring, brown pustules about an eighth by a quarter of an inch burst through the bark of the

trunk being most often decayed. Trees less than one or two feet in diameter are not usually attacked.

Symptoms.

The appearance of the affected wood is very similar to the pecky heartwood-rot of cypress (see page 97). Long lens-shaped pockets are formed parallel with the grain of the wood. The pockets are filled with a brittle brown mass of decayed wood. The surface of the pockets is smooth and the wood immediately surrounding is sound. The first evidence of the decay is the darkened color of certain areas varying from one to ten inches long and from one-fourth to one inch wide. The affected wood in these areas is quickly reduced to a brown charcoal-like mass. The pockets vary in arrangement and number much as in the pecky heartwood-rot of cypress, and a similar brown humus-like powder is found in the cells around the margin. The sporophores of the causal fungus are hoof- or bell-shaped bodies appearing at knot-holes in affected trees. They are large bodies, several inches across, soft and spongy when young and later becoming tough and chalky. The upper surface is at first light brown in color but soon becomes darker brown, especially around the margin. The under surface is yellow or yellow-green and turns brown with age. The pores are small. The fruiting-bodies are soon destroyed by insects.

Cause.

The pecky heartwood-rot of incense cedar has been shown to be associated with the fruiting-bodies of the polypore, named *Polyporus amarus*. This fungus was previously called *Polyporus Libocedrus* von Schrenk. The spores borne in the tubes on the under surface of the fruiting-body cause infection of the heartwood of the cedar at branch wounds. The sapwood is not affected. For the details of the general life history and control of wood-rots, see page 64.

The pecky rots of incense cedar and cypress are, as pointed out above, very similar in many respects but are now known to be caused by different species of fungi.

References

Schrenk, Hermann von. A disease of Taxodium distichum known as peckiness, also a similar disease of Libocedrus decurrens known as pin-rot. Missouri Bot. Gard. Rept. **11**: 23–77, pls. 1–6. 1900.

Hedgcock, G. G. A new polypore on incense cedar. Mycologia **2**: 155–156. 1910.

CHAPTER XVI

CHESTNUT DISEASES

The chestnut was until recently one of the important forest-trees of New York, Connecticut, Pennsylvania and the Alleghany Mountain region southward to Alabama. Besides its commercial value as timber, the chestnut was important also in its natural range as a much-favored ornamental. As an orchard-tree, the varieties of the American and foreign species are of relatively less importance.

Fifteen years ago the chestnut was not subject to any very destructive diseases. With the appearance of the Endothia canker or blight, however, the very existence of the species seemed threatened. During the first ten years of the spread of the fungus causing this disease, all the chestnut trees over hundreds of square miles were killed. The disease is now prevalent over practically the entire range of the chestnut and apparently only a negligible number will escape destruction. It is unusual for a parasite to be so adapted that all the individuals are equally susceptible to its attack. Many limiting factors of resistance, temperature, moisture, seasonal conditions, disseminating agents and the like serve to hold parasitic fungi in check. The fungus causing the canker, however, is the extreme example of an introduced parasite which is perfectly adapted to the host and the environmental conditions of eastern United States.

With the passing of the chestnut, it is scarcely necessary to consider other less important diseases of this tree. · Several leaf-spot diseases are common on chestnut. In the North

But little is known of the life history of this parasite. The spores produced in the black dot-like fruiting-bodies on the spots have been proved to infect other healthy chestnut leaves. In this way the fungus is probably disseminated by the rain washing and spattering the spores. A perithecial stage of the fungus is probably developed in the dead leaves on the ground from which primary infection may be brought about in the spring. This point is, however, undetermined.

Control.

Apparently no attempts have been made to control this disease. General suggestions for the control of leaf-spot diseases are given on page 33 and may be of some application to this disease.

Reference

Graves, A. H. The large leaf spot of chestnut and oak. Mycologia 4: 170–174, pl. 69, fig. 1. 1912.

Twig-Blight

Caused by *Sphæropsis malorum* Berkeley (= *Physalospora cydoniæ* Arnaud)

This twig-blight is more common and destructive on chestnut oak. It occurs occasionally on chestnut in central eastern United States. Cankers are formed on the small branches and twigs. The leaves wilt and turn brown in midsummer. A fuller description of this disease and its control will be found under oak diseases, on page 244.

Endothia Canker

Caused by *Endothia parasitica* (Murr.) Ander. and Ander.

All the species of the genus Castanea are susceptible to this destructive fungus. The trees included in this group are: the common American chestnut, the eastern chinquapin, the

European and the Japanese chestnut and the western chinquapin (genus Castanopsis). Pure strains of the Japanese varieties are resistant while all the other species are very susceptible. From an economic standpoint, the American chestnut is by far the most important species.

The Endothia canker has also been known by the common names, chestnut-blight and chestnut bark-disease. It was first noticed in the New York Zoological Park in 1904. Since that time it has spread for hundreds of miles, north, west and south. It has proved to be the most destructive and rapidly spreading tree disease known. The areas which have been swept by the epiphytotic so far, are left apparently without a single living chestnut tree. After many years of speculation as to the past history of this disease, it was discovered in northern China in 1913 and later in Japan. It is of slight importance in its native home. There is little doubt now that the Japanese chestnuts imported into this country brought with them this unnoticed disease of the Orient. The increased destructiveness of the disease in this country is due to the greater susceptibility of the American chestnut. Many examples of epiphytotics due to newly imported pathogenes are now a matter of record and make the regulation of the interchange of plant products one of the important phases of plant disease control.

Symptoms.

The tissues of the bark, including the cambium, are invaded and killed. The dead areas of bark, or cankers, are especially conspicuous on the younger limbs where the normal bark is smooth and green. They may be seen at a distance because of the reddish color of the dead bark in contrast to the healthy green bark. Usually the cankered area is slightly sunken, due to the killing and drying of the tissues. On young rapidly growing coppice, however, swollen areas (hypertrophy cankers) with the bark split open lengthwise are commonly found. During midsummer the cankers enlarge at the rate of about one-half inch in diameter each week. The usual shape of the canker is ellipsoidal (Fig. 17). The margin of the canker is usually regular and somewhat raised. On smooth bark, the thin cork-layer is wrinkled, forming concentric rings about the central point of the canker. As the canker becomes larger, the bark splits and after a time falls away in shreds, leaving the wood bare.

Fig. 17.—Endothia canker of chestnut.

When the fungus is working in the living tissues under the rough bark, there are no outward indications of its presence until the fruiting-structures are produced in crevices of the bark. If the bark is peeled from the edge of a canker, the tawny mycelial fans are readily seen (Fig. 18). The invaded tissues are changed to a light brown in contrast to the normal light colored healthy tissue of the bark. The thick bark is reduced to a mass of shreds which are a uniform dark brown. The first layers of wood under the cankered areas also become brown.

The effects of the disease on the general appearance of the tree are most noticeable during the summer when the trees are in leaf. In localities in which the disease is common, large numbers of the newly affected branches and twigs are girdled by the cankers during the late summer and the brown shriveled leaves hang to the limbs. This most striking

Cause of Endothia canker.

The canker of chestnut is caused by the perithecium-forming fungus *Endothia parasitica*, formerly called *Diaporthe parasitica*. The mycelium may grow parasitically in the bark, cambium and sapwood of all parts of the chestnut tree above ground or saprophytically on bark, twigs and dead parts of chestnut and other trees. In the northern states new cankers may originate at any time of the year from March to October. The dissemination of the fungus to healthy trees or healthy parts of the same tree is accomplished by many different agencies. The spores or the mycelium itself may be carried by the wind, water, birds, quadrupeds, insects and often by man. The spores and mycelium live through the winter uninjured and are ready for dissemination in the spring when many primary infections are started. The agency most largely concerned in the rapid spread of this fungus from tree to tree is the wind, while water is important in washing the spores from a canker in the top of a tree to other parts of the same tree and to others close by. A few of the millions of spores produced on a single canker find lodgment on the bark of other chestnut trees after a shorter or longer journey from the place where they were produced. Bringing the spores into contact with the healthy bark is not all that is sufficient, however, for the spores must find a wound of some kind to accomplish infection. The spores germinate during periods of moist weather and the short germ-tubes enter the soft tissue of the bark through the wound. If there is no wound in the cork-layer, the germ-tubes of the spores are unable to penetrate. An abundant growth of mycelium rapidly develops from the germ-tube and in a few days thin fan-like plates composed of thousands of threads of mycelium, growing side by side, push out into the soft tissues of the bark which lie between hard fibrous layers (Fig. 18). The cells are killed a little in advance of the mycelium by certain poisons which are excreted. Therefore, as these mycelial fans grow out from the point of infection in all directions, the tissues of the bark are killed and soon a rapidly enlarging canker becomes apparent.

About a month after infection is accomplished, the surface of the small canker becomes covered with numerous small blisters (Fig. 19). These blisters are produced by balls of mycelium formed under the cork-layer. Within these balls are formed one of the types of spores (the conidia). During moist conditions, following rains, long, twisted, yellow tendrils are pushed out from the ruptured bark over each blister (Fig. 19). The tendrils are a mass of the very small spores dried into this shape after being squeezed through a small opening. The next rain or dew causes these tendrils to separate into the thousands of spores in each and they then may be washed or spattered about by the water or carried by animate agents. Any one of these spores germinating where the germ-tube may enter wounded bark-tissue may initiate a new canker.

FIG. 19. — Spore-horns of chestnut canker fungus.

On older and larger cankers, the blisters and yellow tendrils of spores are confined to the margin, while nearer the center, reddish brown pustules of mycelium are pushed out through the bark. They measure when fully developed one-sixteenth of an inch or more in diameter and have numerous papillæ on the upper surface, each with a black dot in the tip (Fig. 20). Within the brown pustules, buried below the surface of the bark, are formed thirty or more cavities (perithecia), within each of which are produced in great abundance another type of spore (the ascospores). These spores are confined in small delicate sacs, eight spores in each sac or ascus. During rainy periods, these sacs swell and a certain number are forced up through a tube leading from each cavity to the black mouths at the tips of the papillæ. Once outside, the sacs burst and the eight spores in each are shot into the air where they are carried away by the wind to great distances. It is these wind-blown ascospores which account for the extreme rapidity of spread of this fungus and make certain the infection of all trees in the vicinity.

FIG. 20. — Perithecial stage of chestnut canker fungus.

The living tissues of the bark and the cambium are killed and the mycelium enters the first layer or two of the sapwood. The indirect effect, when these tissues are killed entirely around a limb, is the withering and dying of the parts above. The tree is thus killed by the successive girdling of the limbs and finally by cankers developing on the trunk.

Control of Endothia canker.

After the chestnut canker had developed into a destructive epiphytotic in Connecticut, New York, New Jersey and Pennsylvania, many investigations were begun to determine the facts with regard to the disease and especially with a view toward its control. A method was proposed of eliminating

the American chestnut may yield a resistant variety which can be grown with relative immunity to this disease. The advertisements of resistant chestnuts at this time, however, are misleading, since none has been developed.

References

Anderson, P. J., and Rankin, W. H. Endothia canker of chestnut. Cornell Univ. Agr. Exp. Sta. Bul. 347: 531–618, pls. 36–40, figs. 77–101. 1914.

Anderson, P. J., and Babcock, D. C. Field studies on the dissemination and growth of the chestnut tree blight fungus. Pennsylvania Chestnut Tree Blight Com. Bul. 3: 1–32. 1913.

Clinton, G. P. Chestnut bark disease. Connecticut Agr. Exp. Sta. Rept. 36: 359–453, pls. 21–28. 1913.

Giddings, N. J. The chestnut bark disease. West Virginia Agr. Exp. Sta. Bul. 137: 209–225, figs. 1–12. 1912.

Heald, F. D. The symptoms of chestnut tree blight and a brief description of the blight fungus. Pennsylvania Chestnut Tree Blight Com. Bul. 5: 1–15, pls. 1–16. 1913.

Metcalf, H., and Collins, J. F. The control of the chestnut bark disease. U. S. Dept. Agr. Farmers' Bul. 467: 1–24, figs. 1–4. 1911.

Rankin, W. H., Field studies on the Endothia canker of chestnut in New York State. Phytopath 4: 233–260, pl. 11, figs. 1–2. 1914.

Anonymous. Treatment of ornamental chestnut trees affected with the blight disease. Pennsylvania Chestnut Tree Blight Com. Bul. 2: 1–7. 1912.

Strumella Canker

Caused by *Strumella coryneoidea* Sacc. and Winter

This canker occurs on chestnut but is more destructive on various species of oak. On chestnut the sunken cankers are distinguishable from the Endothia canker or blight, but in general the tree is very similarly affected. The first signs of the developing canker on smooth-barked trees appear as yellowish or brownish slightly raised areas around a branch stub. Many black nodules an eighth of an inch in diameter are formed on the surface of the affected bark. When the bark is peeled from the cankers, sheets of pure white or only slightly tan-colored mycelium are exposed. No indications of mycelial fans are found as in the Endothia canker. The cankers soon girdle the trunk and the parts above die. Large elliptical conspicuous cankers with depressed centers surrounded by concentric calluses are also formed on chestnut but not so commonly as on the red and black oak. These cankers and the fungus causing them are described on page 245.

Brown Checked Wood-Rot

Caused by *Polyporus sulphureus* Fries

The heartwood and sapwood of chestnut are often decayed by the sulfur fungus. The same rot is common in oak, maple, walnut, butternut, locust, alder and other trees. The wood is reduced to a red-brown, powdery mass which separates into cubes. The sporophores are conspicuous, annual, orange and sulfur-yellow colored bodies which form at wounds or on the bark where the fungus has decayed the sapwood. The tops of the trees or large limbs may be killed by the girdling action of the mycelium in destroying the sapwood and bark. A fuller description of the symptoms and cause of brown checked wood-rot which are similar for all the trees affected is given under oak diseases, page 247.

Straw-Colored Heartwood-Rot

Caused by *Polyporus frondosus* Fries

This heartwood-rot may be found in the base of the trunks of chestnut. The trees do not become hollow. The advancing decay first shows as long, slender, white streaks. Later the wood becomes tan- or straw-colored and is held together by the less affected medullary-rays. The sporophores of the causal fungus arise from the ground around the affected tree. They are large, fleshy, globose structures with many overlapping shelves borne on branches arising from a single central stalk. For further details concerning this heartwood-rot, see under oak diseases, page 259.

White Piped Butt-Rot

Caused by *Polyporus croceus* Fries
(= *P. Pilotæ* Schw.)

The heartwood of the base of chestnut and oak is often attacked by this white piped-rot. It is also occasionally found in the tops of the trees. The rot extends into the roots and is one of the most destructive wood-rots of the butts of oak in the Ozark Mountains. This disease has been found in chestnut and oak in various localities in eastern and central United States and probably is generally distributed over this area. When chestnut trees have dead limbs in the top, the decay may be found in the upper portion of the trunk. The coppice method of reproduction of the chestnut is responsible for the prevalence of this rot in the base of the trees.

Symptoms.

The affected wood is at first brownish and water-soaked. Later white areas appear between the spring- and summer-wood. These areas become larger and the wood between is firm and dark brown. Finally the white areas enlarge and become hollow cavities with white margins. The brown wood between the pockets at this stage is brittle and breaks apart easily into concentric layers. The sporophores of the causal fungus are buff- or orange-colored and are found sometimes on living trees or on fallen trees and old logs. They are soft and watery annual shelf-like bodies, three to six inches across.

Cause.

The white piped butt-rot of chestnut and oak is caused by *Polyporus croceus* or *Polyporus Pilotæ*. Infection usually

CHAPTER XVII

ELM DISEASES

FIG. 21. — Leaf-spot of elm.

THE elms (Ulmus) are common forest and ornamental trees east of the Rocky Mountains. They are exceptionally free from specific diseases caused by parasites. Wound-rots and slime-flux are common in the crotches of the large limbs. Chaining is often necessary to prevent splitting at the crotches.

LEAF-SPOT

Caused by *Gnomonia ulmea* (Sacc.) Thüm.

This is the most common of the leaf-spot diseases of elm. In wet seasons, the spots become so abundant that defoliation results. The fungus causing this disease usually occurs abundantly every season on the leaves in late autumn just before the leaves fall.

The first indications of the spots are seen on the upper surface of the leaf. The dead leaf-tissue is grayish, and either scattered over the spot or grouped in the center are one or more black pustules (Fig. 21). The under surface of the leaf shows no evidence of the spot until later in the season, when brown dead areas appear with a few raised pustules.

After the leaves fall to the ground, fruiting-bodies containing ascospores develop which are the source of primary infection the following spring. The pycnidia of many species of fungi are found on elm leaves and it is not known which one of these is connected with the Gnomonia. For a further discussion of leaf-spots and their control, see page 27.

FIG. 22. — Powdery mildew of elm.

POWDERY MILDEWS

Caused by *Uncinula macrospora* Peck, *Microsphæra alni* (Wallr.) Salmon and *Phyllactinia corylea* (Pers.) Karst.

Three species of the powdery mildew fungi attack the leaves of elms in the United States. In the case of all three species the characteristics, so far as visible to the unaided eye, are similar. The first two species mentioned above occur on both sides of the leaf, while the last usually affects only the under side. The spots are usually not distinct and the mycelium may be only slightly noticeable (Fig. 22). The black fruiting-bodies are formed in patches or scattered over the leaf in all three species but require microscopic examination to determine their specific characters. The life histories and methods of control of the powdery mildew fungi are discussed on page 37.

Brown Wood-Rot

Caused by *Pleurotus ulmarius* Bull.

The white elm is often affected by this brown wood-rot. The toadstool fruiting-bodies of the causal fungus are commonly seen in the autumn projecting from pruning wounds and crotches between limbs. The heartwood is first affected and later the decay extends into the sapwood. The wood becomes brown and is easily separated into its respective annual rings. The cell-walls of many of the fibers of the wood are destroyed or partially delignified.

The sporophores of the fungus are large, fleshy annual structures attached to the wood of the tree by a long and more or less eccentric stalk. The top is convex, smooth, and varies from white to yellow or brown. On the under surface are many radiating gills or pendent plates which are notched at the point of attachment to the stalk. It is on these gills that the spores are formed.

Reference

Learn, C. D. Studies on Pleurotus ostreatus Jacqu. and Pleurotus ulmarius Bull. Annales Mycol. **10**: 542–556, pls. 16–18. 1912.

In all these diseases the general symptom is the production from the under surface of the needles in early summer of white bladdery pustules or blisters. Although found rather commonly throughout the range of the firs, none of these diseases is known to cause any great damage. A yellowing of the foliage and defoliation may occur at times. The different species of rust-fungi causing these diseases require certain other kinds of plants on which to complete their life history. In all the species the spores (æciospores) developed in the white blisters on the fir cause the infection of the other host plant if it is in the close vicinity. On this second host urediniospores are formed in small reddish or yellowish spots in midsummer and in the autumn the teliospores develop either within the epidermal cells or on the outside of the leaf or stem. The teliospores over-winter and germinate in the spring, producing basidiospores which when blown to the fir infect the young needles.

Fern rust.

The most common and generally prevalent of the blister-rust fungi of fir needles have alternate stages on species of ferns and belong to the genus of fungi known as Uredinopsis. The blister-stage on the fir needles is known as *Peridermium balsameum* Peck and *P. pseudo-balsameum* (D. and H.) Arthur and Kern. These rusts occur on balsam fir in the northeastern states and on Alpine, grand and noble fir in the Northwest.

Recent investigations have shown that these blister-rusts are the alternate stages of five previously recognized species of Uredinopsis on ferns as follows: —

U. osmundæ Magn. on species of Osmunda;
U. mirabilis (Peck) Magn. on species of Lorinseria and Onoclea;
U. struthiopteridis Strömer on species of Anchistea and Matteuccia;
U. phegopteridis Arthur on species of Phegopteris;
U. Atkinsonii Magn. on species of Asplenium and Dryopteris.

These rusts are not distinguishable from one another in the æcial stage on the fir needles, and further investigation may prove that they should be reduced to one species with racial differences as to the fern hosts preferred.

A very similar blister-rust of the second-year needles occurs in the northwestern states on Alpine and grand fir and has been found to be due to *Uredinopsis pteridis* Weir and Hubert on species of Pteridium. The life history of this species is different from those above mentioned in that the teliospores do not over-winter. The basidiospores form in late summer but the fir needles infected in the autumn do not show the white blisters until early the following spring.

In the other species the young newly formed needles are infected in the spring by basidiospores from over-wintered teliospores, and the white blisters are formed later in the same season. On the fern leaves the urediniospores show as yellow or brownish rust-spots.

Fireweed rust.

Another of the white blister-rusts occurring to some extent on fir needles in this country as well as in Europe is caused by *Pucciniastrum pustulatum* (Pers.) Dietel. This pathogene has its uredinial and telial stages on species of Epilobium, especially *E. angustifolium*, the great willow-herb or fireweed. Although the fungus occurs on several species of Epilobium, teliospores are known certainly to occur only on *E. angustifolium.*

Blueberry rust.

A common blister-rust of fir needles in Europe is caused by *Calyptospora columnaris* (Alb. and Schw.) Kühn. It has its alternate stages on species of Vaccinium. On these latter plants the stems are attacked and become swollen. The infected stems grow erect and become much taller than surrounding bushes. The stems are at first reddish and later become brown or black. The teliospores are formed in the epidermal cells of the stems and over-winter there. The germ-tubes bearing basidiospores are pushed out the following spring and infection of the fir needles is accomplished when the basidiospores are blown to them. The white blisters appear on the needles in late spring. The affected needles may appear yellowish and usually drop off in late summer. The blister-stage on the fir is known as *Peridermium columnare* Schmidt and Kuntze. This fungus is common throughout the United States on blueberry but is rarely found on firs.

Unconnected rusts.

Two blister-rust fungi attacking fir needles (Abies) in northwestern United States have been named provisionally *Peridermium ornamentale* Arthur and *P. Holwayi* Sydow. These two forms may represent only a single species, however, as they are very similar microscopically. The alternate stages of these rusts are as yet unknown.

References

Weir, J. R., and Hubert, E. E. Observations on forest tree rusts. Amer. Jour. Bot. **4**: 327–335, figs. 1–2. 1917.

Clinton, G. P. Heterœcious rusts of Connecticut having a peridermium for their æcial stage. Connecticut Agr. Exp. Sta. Ann. Rept. **1907–1908**: 369–396, pls. 25–32. 1908.

Arthur, J. C., and Kern, F. D. North American species of Peridermium. Bul. Torrey Bot. Club **33**: 403–438. 1906.

Fraser, W. P. Cultures of some heterœcious rusts. Mycologia **3**: 67–74. 1911.

Fraser, W. P. Cultures of heterœcious rusts. Mycologia **4**: 175–193. 1912.

Fraser, W. P. Further cultures of heterœcious rusts. Mycologia **5**: 233–239. 1913.

Fraser, W. P. Notes on Uredinopsis mirabilis and other rusts. Mycologia **6**: 25–28. 1914.

Hedgcock, G. G. Notes on some western Uredineæ which attack forest trees. Mycologia **4**: 141–147. 1912.

any prolonged wet period until the spores are all disseminated. For further details concerning the leaf-cast diseases of conifers, see page 38.

Reference

Spaulding, P. Notes upon tree diseases in the eastern states. Mycologia 4 : 148–151. 1912.

Rust Witches'-Broom

Caused by *Melampsorella elatina* (Alb. and Schw.) Arthur

This rust disease causes witches'-brooms on various species of fir (Abies) throughout their range in the United States. It also occurs commonly in Canada, Mexico and Europe. The young affected twigs are dwarfed and develop numerous upright laterals forming a broom-like growth. If the twigs are infected at a place where no buds are present, only gall-like enlargements of the bark are formed. The fungus grows out into the branches and leaves of the broom. The leaves remain small and yellowish. There develop in midsummer from the under surface of these dwarfed leaves two rows of white blisters. The leaves then fall, leaving the broom bare during the winter. New growth of the twigs and new infected leaves are formed the following season. In this manner the broom develops for several years and produces a crop of spores each season.

The spores (æciospores) from the fir needles infect species of Alsine and Cerastium. On these plants very small orange-red or yellowish pustules are formed in late summer. Urediniospores are produced in these pustules which may infect other plants of the same species. Teliospores are formed later in whitish or pale reddish spots on the under surface of the leaf. They germinate the following spring producing basidiospores which may infect the fir twigs. The mycelium is perennial in both sorts of hosts.

Control.

This witches'-broom of fir may be controlled by eradicating all sandwort and chickweed (Alsine and Cerastium) from the immediate vicinity of the firs.

Reference

Hartig, R. Æcidium (Peridermium) elatinum. *In* Text-book of the diseases of trees, pp. 179–182, figs. 109–112. 1894.

Gray Mold Twig-Blight

Caused by *Botrytis cinerea* Fries

This disease of the current season's twigs is most important on Douglas fir, although other firs, pine, spruce, larch and hemlock may be affected. The disease is common in certain localities in Europe and North America, both in nurseries and in the forest. It has been reported as destructive, especially to Douglas fir in nurseries, forest plantings and to some degree on the older trees, in several countries of Europe. In the forests of northwestern United States it occurs on Douglas fir, grand fir, western larch and western hemlock. It has not assumed great importance in any area but causes considerable cumulative damage.

Symptoms.

The most obvious general symptom of this disease is the withering, curling and dying of young twigs of the season. Seedlings and young trees may be killed. Late in the season black bodies the size of a pin-head are formed on the affected twigs and on the leaves, especially at the base of the season's growth. The twigs of young pine may be dwarfed, the needles remaining short and the twig becoming twisted. Under moist conditions, a more or less luxuriant mycelial growth occurs, forming a gray mold over the affected leaves and twigs.

Cause.

The gray mold twig-blight of conifers is caused by the fungus *Botrytis cinerea.* The name first given to this fungus on conifers was *Botrytis Douglasii* Tubeuf. In some publications this fungus is erroneously called *Sclerotinia Fuckeliana* (De Bary) Fuckel, due to a suspected connection of the Botrytis with this ascomycete. Spores are borne in abundance on the gray mold-like growth of mycelium over the affected parts. These spores are wind-disseminated and serve to distribute the fungus during the summer. The small black, more or less globose bodies formed on the twigs and needles are called sclerotia. They are resting structures composed of mycelium which is rich in reserve food material and covered by a black rind-tissue of mycelium. The fungus over-winters in this way and many upright branches bearing spores are sent out from the sclerotia in the spring.

The mycelium within the needles and twigs causes at first an enlargement of some of the tissues and later their death. Abundant atmospheric moisture is required for the general and destructive distribution of the fungus in a given region. Fogs are conducive to epiphytotics. This is due to atmospheric moisture stimulating an abundant growth of superficial mycelium which is necessary for the formation of the spores. Also these same conditions insure that a larger percentage of the spores can germinate and cause infection.

Control.

Since the severity of attack is largely dependent on a continuously humid atmosphere, any measures which will lead to a greater circulation of the air will serve in a measure to control this disease. Damp soil and close planting should be avoided for the more susceptible trees. In the nursery and in young plantations weeds and any plants or artificial structures which shade the trees should be removed.

larch and pine in the United States. The symptoms in fir are similar to those in spruce which are described on page 324. The pockets are larger than those found in spruce and the wood is

FIG. 23.—Pecky wood-rot; early stage in Douglas fir.

FIG. 24.—Pecky wood-rot in Douglas fir.

largely destroyed. In Douglas fir the pockets are at first circular white areas (Fig. 23). Later the pockets increase greatly in number and finally the wood is honeycombed (Fig. 24). Somewhat different symptoms are shown in larch and pine and are described on pages 215 and 291 respectively.

The life-history, dissemination of the spores and mode of infection of the wood-rotting fungi are treated in a general discussion on page 64.

Red-Brown Sapwood-Rot

Caused by *Fomes pinicola* Fries

The red-brown sapwood-rot is one of the most common diseases of spruce, pine, fir, larch and hemlock, wherever these trees grow. The fungus causing this wood-rot occurs less frequently in living trees than it does on dead standing trees and logs. It is thought that the fungus usually attacks living trees which are badly wounded or in generally poor health. Vigorous healthy trees are more rarely affected. The decay progresses very rapidly and the wood is reduced to a light easily pulverized mass. The wood of beech, birch, maple and other deciduous trees is also destroyed by this fungus.

Symptoms.

In longitudinal section, the first evidence of the decay shows as whitish spots or streaks irregularly placed. The white spots have reddish brown centers. At this stage the wood is punky and brittle. The spread of the mycelium from these centers soon results in a uniform red-brown, easily pulverized mass of loose fibers. The decayed wood shrinks in all directions, leaving numerous cracks which are filled with white mycelial felts. These felts are largely responsible for holding the decayed wood from falling to pieces.

The fruiting-bodies of the fungus are formed abundantly and are the most conspicuous of the various shelf-fungi in coniferous forests. When growing from wounds on living trees, they are usually hoof-shaped. On logs and dead wood they are broader and thinner. The upper surface is marked by broad rounded concentric folds, each representing the result of a year's growth. From the center of the top to the margin, the color varies from black to brown and reddish brown. The rounded margin is yellowish in the early summer and later becomes reddish yellow or deep red. The surface of this bright colored zone appears as if varnished. The under surface is yellowish brown and covered with minute pores.

Cause.

The red-brown sapwood-rot of conifers is caused by the fungus *Fomes pinicola.* Infection occurs in wounds which expose the sapwood of the tree. The wood fibers are not destroyed completely but are reduced to weak thin-walled structures with numerous cracks and fissures. The life history and control of wood-rotting fungi is more fully discussed on page 64.

References

Schrenk, Hermann von. Polyporus pinicola (Swartz) Fr. *In* Some diseases of New England conifers. U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 25 : 24–31, pls. 3–5, fig. 2. 1900.

Atkinson, G. F. Polyporus pinicola. *In* Studies of some shade tree and timber destroying fungi. Cornell Univ. Agr. Exp. Sta. Bul. 193 : 222–227, figs. 80–81. 1901.

Hedgcock, G. G. Notes on some diseases of trees in our national forests. IV. Phytopathology 4: 181–188. 1914.

Stringy Red-Brown Heartwood-Rot

Caused by *Echinodontium tinctorium* Ellis and Everhart

The destructive stringy red-brown heartwood-rot of fir, spruce and western hemlock is a common disease of these trees in western United States. White, Alpine, grand, noble and Douglas fir, Engelmann spruce and western hemlock are known to be affected by this wood-rot. The older stands of firs in the northwestern forests are so badly damaged by this rot that they are practically worthless.

Symptoms.

The first indication of this heartwood-rot is noticeable in the branch stubs through which the fungus finds entrance to the heartwood. The wood of the branch stubs is a rusty brown

The sporophores of the causal fungus are formed at the rusty knots and are large hoof-shaped bodies, gray or black above and with numerous large and firm straw-colored or gray spines on the under surface (Fig. 25). The inner substance of the bodies is bright rusty red. The American Indian used the red fungous material for making war paint and thus this fungus has been named the Indian paint-fungus.

Cause.

The stringy red-brown heartwood-rot of western conifers is caused by *Echinodontium tinctorium*, a member of the toothed fungi (Hydnaceæ). The spores are borne on the outer surface of the teeth on the under side of the fruiting-body. Infection occurs when the spores lodge on the exposed wood of broken branch stubs. For further details concerning the life history and control of the wood-rotting fungi, see page 64.

Reference

Meinecke, E. P. Forest tree diseases common in California and Nevada. U. S. Dept. Agr. Forest Service. Unnumbered publication, pp. 1–67, pls. 1–24. 1914.

Brown Pocket Heartwood-Rot

Caused by *Fomes roseus* Fries

The heartwood of fir is frequently destroyed by the brown pocket-rot. This disease occurs also in juniper, larch, spruce, pine and hemlock and occasionally in arbor-vitæ, beech and maple. Long, cylindrical and pointed pockets of brown charcoal-like decayed wood are formed. The fruiting-bodies of the causal fungus are either thin and shelf-like or thick and hoof-shaped. The under surface of the fruiting-body is rose-colored. This heartwood-rot is more fully described under juniper diseases, page 204.

Brown Heartwood-Rot

Caused by *Fomes officinalis* Fries (= *Fomes laricis* (Jacq.) Murrill)

Douglas fir is often severely damaged by this heartwood-rot in the Northwest. Larch, pine and other conifers are affected by the same disease throughout western United States. The decayed wood resembles the brown checked wood-rot caused by *Polyporus sulphureus* (see page 247). In the final stages of decay, the heartwood is brownish or red-brown. Felts of mycelium form in checks in the brown wood (Fig. 26). The fruiting-bodies of the causal fungus are large hoof-shaped or globose, with a rough chalky upper surface. The inner substance of the sporophore has a bitter taste. A more complete discussion of this heartwood-rot will be found under larch diseases, page 216.

Fig. 26. — Brown heartwood-rot of Douglas fir.

Brown Root- and Butt-Rot

Caused by *Fomes annosus* Fries

This rot of the wood of the roots and lower part of the trunk of fir is occasionally found in the forests of the Northwest. Pine, spruce and other conifers are also sometimes affected wherever these trees grow. The wood is discolored and changes from bluish to yellowish and finally becomes red-brown. White pockets with black centers appear in the spring-wood of the rings. Later the pockets coalesce and the brown summer-wood is left in separated sheets. The perennial sporophores are shelving or resupinate and are found attached to the diseased roots. The upper surface of the shelving form is light brown and the under yellowish. For further details concerning this root-disease, see under spruce diseases on page 329.

Red-Brown Root- and Butt-Rot

Caused by *Polyporus Schweinitzii* Fries

This root-rot occurs also on pine, larch, spruce, hemlock and arbor-vitæ throughout the range of these trees. It is next in importance to the pecky wood-rot of conifers caused by *Trametes pini*. The heartwood of the roots and lower part of the trunk becomes at first yellowish and cheesy and later is red-brown and brittle, resembling charcoal in structure. This wood-rot is more fully discussed under pine diseases, on page 294.

Yellow Root-Rot

Caused by *Sparassis radicata* Weir

This yellow or brownish root-rot of fir, spruce, pine and larch has been recently described as common in northwestern United States. It seems to be equally as important in that region as the shoe-string and brown root-rots, caused by *Armillaria mellea* and *Fomes annosus*. The fungus causing the yellow rot is peculiar in having a long perennial root-like attachment of fungous mycelium which arises from the diseased roots. Other species of the same group of fungi have been suspected of caus-

borne over the surface of the leaf-like plates of the fruiting-body. For further details concerning the life history and control of wood-rotting fungi, see page 64.

Reference

Weir, J. R. Sparassis radicata, an undescribed fungus on the roots of conifers. Phytopathology 7: 166–177, figs. 1–5. 1917.

CHAPTER XIX

HACKBERRY DISEASES

Two species of hackberry (Celtis) occur in eastern and central United States. These trees are not important forest species and in many sections they are shrub-like. West of the Mississippi River, the hackberry is commonly used for shade and ornament. The most important disease of this tree is the witches'-broom. Several leaf-spot fungi and powdery mildews are common on hackberry. Although no wood- or root-rots have been recorded as affecting the hackberry, doubtless some of the more common wood diseases of other deciduous trees may also be found in them. The small amount of attention that has been given to the diseases of the hackberry is due to its unimportance as a timber-tree.

Powdery Mildews

Caused by *Uncinula parvula* Cooke and Peck, and *Uncinula polychæta* (Berk. and Curt.) ex Ellis

Besides the powdery mildew fungus which is associated with the formation of the prominent knots and witches'-brooms, two other species of the same group attack the leaves of the hackberry. The one, *Uncinula parvula,* is reported throughout the United States, while the other species, *Uncinula polychæta,* is apparently confined to the southeastern states. The former species causes inconspicuous powdery growths on both sides of the leaf. The black fruiting-bodies are very small and usually confined to the under surface of the leaf, while in the latter species dense irregular white patches are formed on the under sides of the leaves, and the black fruiting-bodies are large in comparison with those of the former species. The life histories and methods of control of powdery mildew fungi are discussed on page 37.

Witches'-Broom

Caused by a gall-mite and *Sphærotheca phytoptophila* Kellerman and Swingle

The hackberry is affected, in central United States, by an important witches'-broom disease. Although mainly important because of the unsightly appearance of affected ornamentals, some damage to the tree must result from the loss of energy spent in the development of the brooms. Also due to the death of the branches or their breakage, wounds are formed which allow wood-rot fungi to enter. The lower branches are most commonly affected, although at times brooms are found throughout the crown. Hundreds of brooms are sometimes found on a single tree, causing serious deformation.

Symptoms.

Two general types of brooms are formed. The open type consists of irregular swellings or knots at the base of a branch from which many short stubby twigs arise. The leader remains healthy, however, and grows to its normal length and other knots with diseased laterals are formed on it at intervals. A closed type of broom results when the leader is diseased and fails to develop normally. For several years, after the first knot with its diseased laterals is formed, the new laterals from the base of those of the previous year cause a compact broom of many deformed and dwarfed branches all arising from a large irregular mass of gall-tissue. Smaller galls may be developed also further out on the diseased laterals.

the diseased condition and may be jointly responsible for the deformation. Two such intimately associated agents, one an insect and the other a fungus, are unusual and deserve more careful study than has been given them. Practically nothing is known concerning the life history of these two parasites and their interrelations, more than has been discussed under symptoms. Both conidia and perithecia are formed by the mildew fungus. The structure, life history and control of the powdery mildew fungi are more fully discussed on page 34. In the case of this disease, control measures seemingly would be confined to cutting out the diseased twigs and brooms. Spraying or dusting could not be expected to yield satisfactory results.

References

Kellerman, W. A., and Swingle, W. T. Branch knot of the hackberry. *In* Report of the Botanical Department. Kansas Agr. Exp. Sta. Ann. Rept. **1**: 302–315, pls. 4–6. 1889.

Halsted, B. D. Notes upon Sphærotheca phytoptophila Kell. and Swingle. Jour. Mycology **5**: 85–86. 1889.

Salmon, E. S. Sphærotheca phytoptophila Kellerm. and Swingle. *In* A monograph of the Erysiphaceæ. Mem. Torrey Bot. Club. **9**: 76–79. 1900.

CHAPTER XX

HEMLOCK DISEASES

Four species of hemlock or Tsuga occur in the forests of the United States. The two eastern hemlocks are important trees, especially in the northeastern states. The western species are confined to the northwestern states and are large trees. All four species are frequently used as ornamentals.

Although several fungous diseases are occasionally found on hemlock, it is less severely affected in general than pine, spruce and fir. In the Northwest, the young trees are killed by a root-rot and the older ones are often affected by the stringy red-brown heartwood-rot. In the East, the leaf-blight, rusts and wood-rots cause but little damage.

Seedling Root-Rot

Caused by *Rhizina undulata* Fries

The roots of three- to five-year-old seedlings of species of hemlock, pine, larch and fir are frequently attacked in the forests of the Northwest by *Rhizina undulata*. The fungus has been found in several eastern states attached to roots of conifers but its connection with any root disease is not definitely established. The same disease is common in Europe on seedlings of various conifers and has been known for many years.

Symptoms.

The fruiting-bodies of the fungus are formed annually and grow on the surface of the ground. They are variable in size, measuring often two or three inches across, irregular in shape, with an undulating, rich brown upper surface bordered at the margin by a narrow white zone (Fig. 27). In wet weather the upper surface becomes mucilaginous. The under surface is more or less fused with the soil. Long white strands of mycelium, arising from the under surface, can be traced to diseased roots. Affected seedlings growing in nursery-beds or in the forest are killed in isolated groups. On pulling the trees, the roots are found to be closely matted with white mycelium. This characteristic, together with the soil being held together by the matted mycelium and the roots being more or less resinous, make this root disease practically indistinguishable

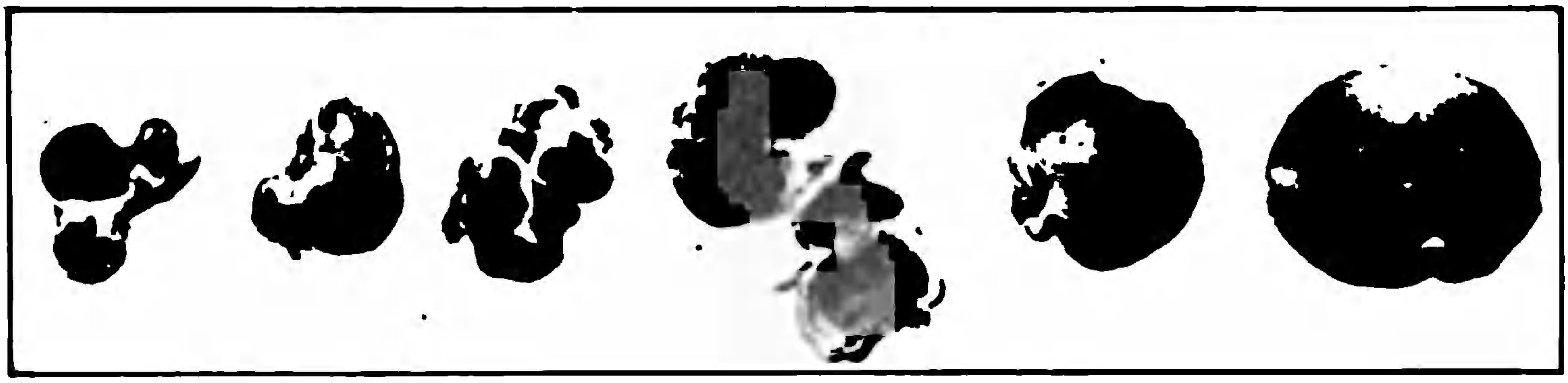

FIG. 27. — Fruiting-bodies of *Rhizina undulata*.

from the common shoe-string root-rot caused by *Armillaria mellea*. This latter fungus is common as a root-rotting fungus of both conifers and deciduous trees and sometimes attacks young seedlings (see page 78). Often, however, the fruiting-bodies of the Rhizina occur plentifully around and envelop the stems of affected seedlings.

Cause.

The pathogene causing this seedling root-rot is an ascomycetous fungus which forms spores in closely packed asci. These stand upright and form the brown upper surface of the fruiting-body. The spores are forcibly shot upward into the air and are blown away. Falling on the ground, they germinate and the abundant white mycelium that is formed penetrates the root-tissues and causes the seedling to die.

Brown-Mold Leaf-Blight

Caused by Rosellinia sp.?

The importance and prevalence of this disease of hemlock is so far not known. It has been found in North Carolina. The needles of the lower branches become yellow. The affected twigs show a growth of yellowish-brown or grayish mycelium covering the bark and investing the bases of the yellow needles. The dead needles either fall off or are held by the tangle of mycelium. Small dome-shaped fruiting-bodies of the fungus are found slightly sunken in the mycelium. Although not definitely determined, this fungus apparently belongs to the genus Rosellinia. It has not yet been definitely established that the brown mycelium is directly responsible for the diseased condition.

Reference

Graves, A. H. Notes on the diseases of trees in the southern Appalachians III. Phytopathology 4: 63–72, pl. 5, fig. 1–10. 1914.

Leaf and Cone Blister-Rusts

Caused by *Pucciniastrum minimum* (Schw.) Arthur, and *P. myrtilli* (Schum.) Arthur

Two species of the blister-rust fungi attack the green parts of the eastern and Carolina hemlock. These rusts are very similar in appearance and have been found in widely separated localities throughout the range of the two eastern hemlocks. The leaves and cones may be at times so heavily infected that the leaves fall and the cones fail to mature viable seeds. This happens only in the case of individual trees which stand close to the alternate host plants which these fungi require for the completion of their life history.

Symptoms.

Although these two species of fungi differ sufficiently so they can be recognized by their microscopical characters, the general appearance of fruiting-structures and the effect on the tree is very similar. The leaves of young trees or of the lower limbs of older trees are much oftener affected than the tops of older trees. Sometimes one-half of the cones may be affected. The most conspicuous symptom of these diseases is the production, on the leaves or cones of golden-yellow or reddish colored blisters in June and July. These blisters burst through the epidermis of the affected parts and when abundant their color stands out prominently against the dark green of the healthy foliage. The spores borne in the blisters sift out as a fine powder and are blown away by the wind.

Cause.

Two species of the rust-fungi are known to cause the blister-rust of the leaves and cones of hemlock. The life history of these species varies slightly in that different kinds of shrubs are required for their further development.

The first species mentioned, *Pucciniastrum minimum,* occurs on the leaves and cones. This fungus was known on the hemlock previously as *Peridermium Peckii* Thümen. The spores from the blisters on the leaves cause the infection of the leaves of species of Rhododendron. On this host plant, very small yellowish spots are developed on the under sides of the leaves. The spores produced in early spring on the rhododendron leaves infect the newly developed leaves and cones of the hemlock.

The second species, *Pucciniastrum myrtilli,* is known to occur only on the leaves. This fungus was also previously known as *Peridermium Peckii.* The blisters on the hemlock leaves are more reddish than those of the other species. The spores from the blisters infect the leaves of species of blueberry. On this host plant are formed small yellowish spots on the under sides of the leaves. Later light brown spots appear in the same areas. The spores produced the following spring from the brown spots cause the infection of the young hemlock leaves.

Control.

By keeping rhododendrons and blueberry bushes away from hemlock trees, these blister-rusts can be prevented. The heaviest infection of the hemlock occurs when one of these alternate host plants stands within a few feet.

Reference

Spaulding, P. Diseases of the eastern hemlock, Proc. Soc. Amer. Foresters 9: 245–256. 1914. (Bibliography given.)

Leaf-, Cone- and Twig-Rusts

Caused by *Melampsora abietis-canadensis* (Farl.) Ludwig, and *Necium Farlowii* Arthur

In addition to the two blister-rusts of hemlock (page 180) two other rust-diseases occur on these trees. In Nova Scotia instances have been noted in which the leaves and twigs of the entire top of the tree were killed by the later fungus.

Symptoms.

The first species, *M. abietis-canadensis,* causes a rust on the leaves, cones and twigs similar in appearance to the blister-rusts. This fungus was known on the hemlock previously as *Cæoma abietis-canadensis* on the leaves and as *Peridermium fructigenum* on the cones. The spores from the pustules produced in early summer on the affected parts of the hemlock cause the infection of the leaves of the large-tooth aspen. On this second host small orange or brown-

Red-Brown Sapwood-Rot

Caused by *Fomes pinicola* Fries

Hemlock is sometimes affected by this sapwood-rot. It occurs also in spruce, pine, fir and larch. Coniferous wood of all kinds is destroyed by the fungus causing this rot, and the sporophores are very abundant on fallen logs and dead standing trees. The wood is reduced to a red-brown powdery mass held together by numerous plates of mycelium. The sporophores have a red varnished margin and a cream-colored under surface. Further details concerning this wood-rot will be found under fir diseases, page 165.

Stringy Red-Brown Heartwood-Rot

Caused by *Echinodontium tinctorium* Ellis and Everhart

The western hemlock is destructively affected by this heartwood-rot. Firs and spruce are also commonly decayed by the same fungus. In the first stage of decay, the wood is discolored and spongy. The wood then becomes red-brown and the spring-wood of the annual ring is dissolved, leaving the summer-wood in separated cylinders one inside of the other. Later these sheets of summer-wood are destroyed and the tree becomes hollow. For further details concerning this heartwood-rot, see under fir diseases, page 166.

Brown Pocket Heartwood-Rot

Caused by *Fomes roseus* Fries

The eastern and western hemlock are sometimes affected by this heartwood-rot, which is also found in juniper, fir, larch, spruce, pine and occasionally in arbor-vitæ. It occurs practically throughout the entire country wherever conifers are important forest-trees. Long, cylindrical and pointed pockets of brown charcoal-like rotted wood are formed in the heartwood. The fruiting-bodies of the causal fungus vary from small thin shelves to larger hoof-shaped bodies. The upper surface is black in the older fruiting-bodies, while the new layer of tubes on the under surface is rose-colored. For further details concerning this heartwood-rot, see under juniper diseases, page 204. The fungus continues to grow in fallen trees and the fruiting-bodies are more commonly found on dead wood than on living individuals. The sapwood is also decayed in dead trees and logs.

Cuboidal Wood-Rot

Caused by *Polyporus borealis* Fries

This heartwood-rot does not seem to occur abundantly, since but little mention of it is found in literature. It is reported in New York but no definite statements on its importance and range are available. Red spruce is also known to be affected by this wood-rot.

Symptoms.

In the early stages of the decay, long parallel strands or cords of white mycelium, lying close together, push their way through the wood in the radial and tangential directions. The white strands then disappear, leaving channels in the wood. Because of these perforations and the shrinkage of the wood, it breaks into minute cubes. On the border of the affected wood, the mycelium reaches out into the normal wood in very fine strands. These then develop into the thicker white cords described above (Fig. 28).

The fruiting-bodies are formed on the trunk or at the base of the tree. Usually several shelf-like bodies one above the other occur together, forming a cluster. The upper surfaces of the shelves are white and shaggy. The under surfaces are covered with small roundish or sinuous openings. The entire fruiting-body is white or yellowish and soft and spongy.

Cause.

The cuboidal wood-rot of hemlock and spruce is caused by the fungus, *Polyporus borealis*. The spores from the tubes opening on the under side of the fruiting-body are blown about by the wind. Infection takes place at wounds. The heart-

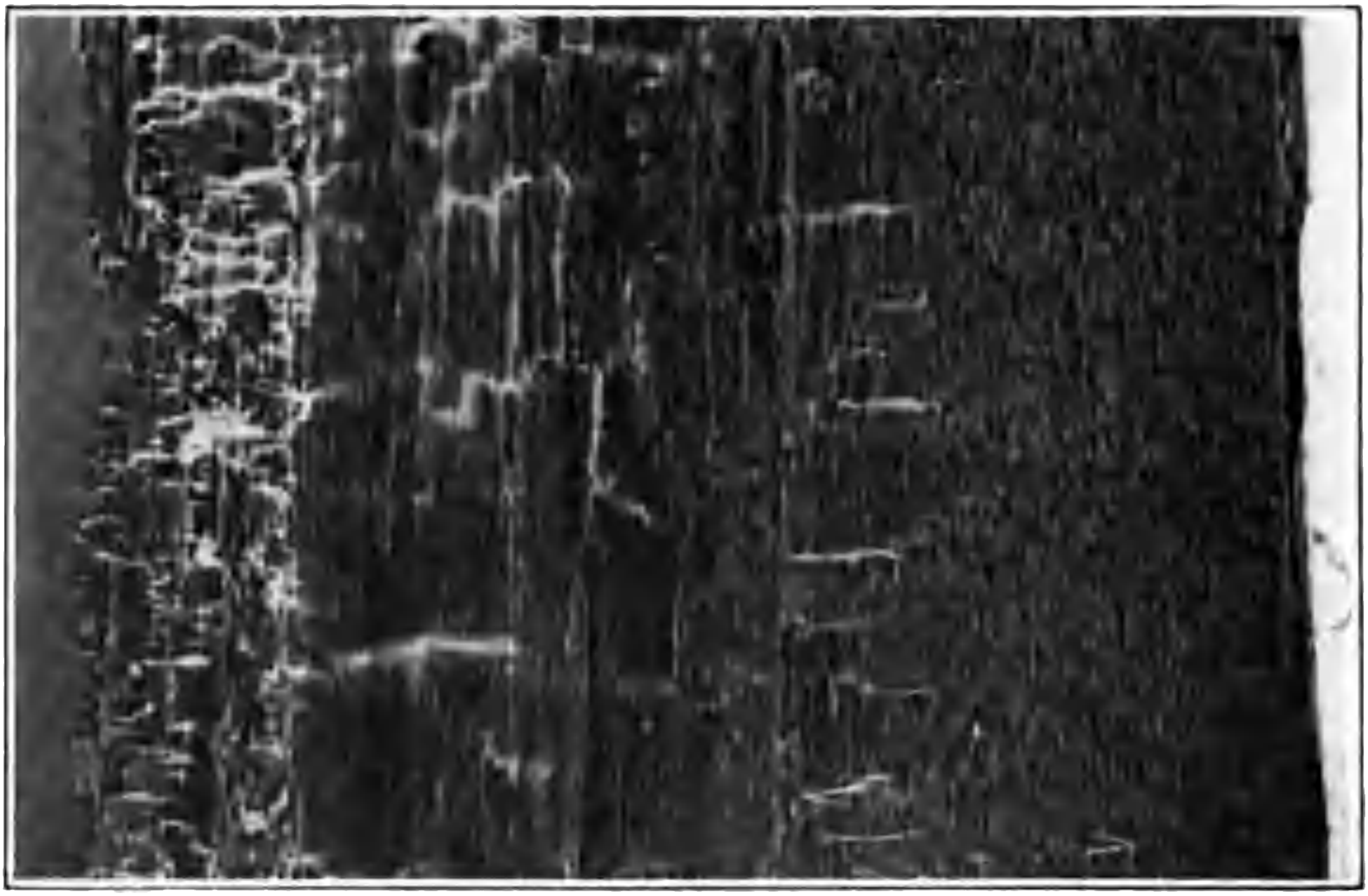

Fig. 28. — Cuboidal wood-rot of hemlock.

wood may be affected from the top to the base of the tree. The sapwood is decayed and the smaller limbs killed at the top of the tree. For further details concerning the life history and control of wood-rotting fungi, see page 64.

References

Atkinson, G. F. Polyporus borealis. *In* Studies of some shade tree and timber destroying fungi. Cornell Univ. Agr. Exp. Sta. Bul. 193: 202–208, figs. 56–63. 1901.

Hartig, R. Polyporus borealis Fr. *In* Die Zersetzungserscheinungen des Holzes etc., pp. 54–58, pl. 10. 1878.

CHAPTER XXI

HICKORY DISEASES

Several species of hickory (Carya or Hicoria) occur as common trees in eastern United States. Several fungi cause leaf-spots of hickory (page 30). Besides these, the leaf-mildew, witches'-broom and common white wood-rot are the only diseases of importance of these trees. Although these diseases and probably others are common on hickory practically no mention of them is made in literature.

Leaf-Mildew and Witches'-Broom

Caused by *Microstroma juglandis* (Bereng.) Sacc.

The leaves of hickory and walnut in eastern United States are often affected by this disease. Early in the summer the leaflets show a white powdery mildew on the under side. The invaded area of the leaflet is yellowish and defoliation may result. Recently the formation of witches'-brooms on shag-bark hickory has been shown to be another symptom of this disease. Brooms are sometimes numerous on the trees and are as much as a yard across. The leaves which appear on the brooms in the spring are yellowish green above and covered with the white powdery growth of the fungus below. The leaflets are smaller than normal and curled. They fall prematurely and leave the brooms bare in midsummer. The fungus causing this disease is supposed to be a simple basidiomycete forming numerous short stalks bearing spores on the under sides of the leaf.

Reference on Leaf-Mildew and Witches'-Broom

Stewart, F. C. Witches-brooms on hickory trees. Phytopathology 7: 185–187, fig. 1. 1917.

Common White Wood-Rot

Caused by *Fomes igniarius* Fries

The heartwood of hickory is sometimes reduced to a white soft punk by the false-tinder fungus. This rot is more common and destructive to beech, poplar, oak and maple. The sporophores and appearance of the white rotted wood are described under poplar diseases, page 305.

CHAPTER XXII

JUNIPER DISEASES

SEVERAL species of juniper (Juniperus) occur as important forest-trees over the entire United States. These trees and the horticultural varieties of the native and exotic species are the most common conifers used for ornament. In the genus Juniperus are included the low junipers.

The juniper is subject to several important wood-rots and rust-diseases. Several destructive heartwood-rots of juniper are especially common in the Southwest. The rust-diseases of juniper are important both from the economic and ornamental standpoint. Many of the rust-fungi belonging to the genus Gymnosporangium grow parasitically in the leaves, branches or trunk of juniper. Several types of over-growth occur in the affected tissues. These diseases are interesting because of the complicated life history of the different species requiring various other plants as alternate hosts. As certain of these fungi cause the rust-diseases of apple, pear and quince, their control is an orchard as well as an ornamental tree problem.

SEEDLING TWIG-BLIGHT

Caused by Phoma sp.

Junipers grown in nursery-beds are subject to a twig-blight which has been destructive in certain seasons in Kansas, Nebraska, Iowa, Illinois and Pennsylvania and may be expected in other localities. By artificial inoculation with the causal

fruiting-stage, as described under symptoms, is known. Spores are produced in abundance from the fruiting-bodies (pycnidia) during wet weather and may be washed or spattered by rain to neighboring trees. The first infections take place in the lateral twigs, which are quickly killed. The mycelium then spreads into the main stem and proceeds upward, killing the outer wood-tissues and cambium on one side of the tree and running out into other laterals.

Control.

Experiments so far tried in spraying with lime-sulfur and bordeaux mixture for the control of this disease have not been successful. The period of infection extending throughout the growing-season and the nature of the scale-like leaves and the twigs preclude much hope of good results from spraying. Careful eradication of all diseased and neighboring trees may, to some extent, reduce losses by stopping the enlargement of the spots in the beds.

Reference

Hahn, G. G., Hartley, Carl, and Pierce, R. G. A nursery blight of cedars. Jour. Agr. Res. 10: 533–539, pls. 60–61. 1917.

Leaf- and Stem-Rusts (General)

Caused by species of Gymnosporangium

Several species of the rust-fungi belonging to the genus Gymnosporangium cause more or less important diseases of juniper and cedar. These fungi are strictly parasitic and never grow except in the living tissue of some plant. They are, therefore, confined to the range of the species of juniper and cedar, which are found in the north temperate zone in North America, Europe, Asia and northern Africa. Another important peculiarity of these fungi which further restricts the range of each species is that they each require certain kinds of broad-leaf trees and shrubs as alternate hosts. Unless the necessary alternate host is present in close proximity to the juniper or cedar, the rust cannot exist, since the life history of the fungus cannot be completed. Trees and shrubs of the order Rosales, family Pomaceæ, are the most common alternate hosts of these fungi.

The life history of all the Gymnosporangium rusts is similar and is described here to avoid repetition below. As stated, these fungi are parasitic throughout their life. They live for a time on a certain species of juniper or cedar and produce spores (basidiospores) which can only cause infection of the leaf, twig or fruit of a certain few or perhaps only a single species of the wild or cultivated apple-like trees, such as apple, pear, quince, haw, mountain ash and service-berry. Here the fungus lives only for a short time and produces spores (æciospores) which do not reinfect other trees of the same kind but can only infect the required juniper or cedar. Thus it is seen that the spores produced on each of the two kinds of hosts are innocuous to the same host and must find lodgment on trees of the other type in order to continue the life history.

These rust-fungi over-winter as mycelium in the juniper or cedar leaves or stems. The next season after infection occurs, most of these fungi cause some type of over-growth of the tissues. Such abnormalities are brought about as long swellings or globose galls on the stems, witches'-brooms and leaves transformed into brown globose growths known as cedar-apples. A few of the species cause no abnormal growth and are evident only by the fruiting-structures. The fungi form spores (teliospores) in the early spring on masses of mycelium pushed out from the bark of the twig or epidermis of the leaf. These spore-masses may be in the form of cushions or ridges in the crevices of affected bark or, in the case of the cedar-apples, they consist of long horn-like projections, sometimes an inch or more in length. They appear at first dark brown, due to the color of the teliospores on the surface. In wet weather the spore-masses become jelly-like and the individual spores germinate, each producing several secondary spores (basidiospores) which are shot off into the air. These spores are carried away by the wind and may find lodgment on the leaves, twigs or fruit of the proper alternate host. Under favorable conditions of moisture, the basidiospores germinate and the tissue of the pomaceous host is penetrated and a new growth of mycelium started. The area of tissue invaded is limited to a small spot which becomes somewhat swollen and light yellow in color (Fig. 29). A short time after these symptoms become apparent, long whitish tubes of fungous tissue are pushed out all over the affected areas (Fig. 30). These tubes sometimes split and form a fringe around cup-like depressions in the leaf, twig or fruit, in which are formed powdery masses of yellow spores (æciospores). These dust out, are borne by the wind and may continue the life history of the fungus if they lodge on the leaves or twigs of the proper species of juniper or cedar.

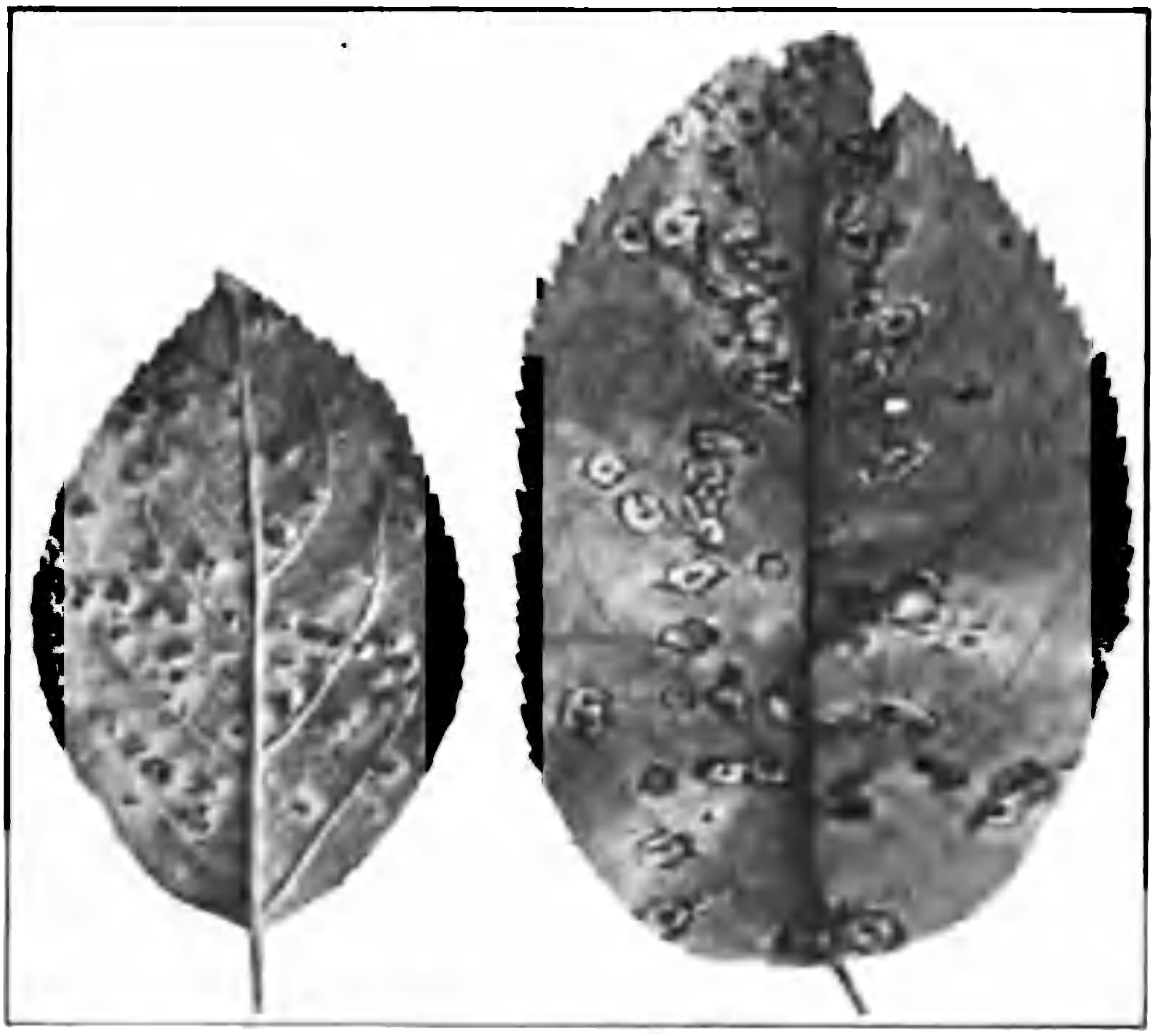

FIG. 29. — Cedar-apple fungus on wild apple leaves.

These rust-fungi are important because they deform the tree when galls, witches'-brooms or cedar-apples are formed in abundance. The tissues of the affected branches die eventually and leave dead areas where wood-rot fungi may enter. On the apple-like hosts, which include not only many important cul-

Leaf- and Twig-Rusts

Caused by species of Gymnosporangium

A few species of the rust-fungi belonging to the genus Gymnosporangium attack the green twigs and leaves of various junipers without causing any over-growth of the affected parts. The symptoms of these diseases are confined to the brown spore-masses developed either on the leaf or between the leaves. The life history of these forms is similar to the other species of the same genus and is discussed on page 192. Below are given the hosts and characteristics, in brief, of these diseases.

In Colorado, Utah and New Mexico, the Utah juniper is attacked by *G. inconspicuum* Kern. A yellowing of the leaves on the affected twigs may be noticed and in early spring small brown cushion-like spore-masses, the size of a pin-head, are formed from between and around the margins of the appressed scale-like leaves. The alternate stage occurs on species of service-berry.

In Colorado a similar appearing species, *G. multiporum* Kern, attacks the Utah and one-seed juniper. The alternate hosts are not known.

In Texas several species of juniper are attacked by *G. exiguum* Kern. Short brown conical spore-masses, a sixteenth of an inch long, are pushed out from the affected leaves. The alternate host is *Cratægus Tracyi*.

In northeastern and north central United States, *Juniperus sibirica* is attacked by *G. Davisii* Kern. Spore-masses appear as small brown pustules on the leaves or at the base of leaves on the twig. The alternate stage occurs on species of mountain ash.

A foreign species, *G. koreaense* (P. Henn.) Jackson, recently has been found established in Oregon on an imported juniper, *Juniperus chinensis*. Spore-masses form on the leaves of the juniper. The alternate stage occurs on cultivated quince and introduced Asiatic species of quince and pear.

CEDAR-APPLES

Caused by *Gymnosporangium juniperi-virginianæ* Schw. and *G. globosum* Farlow

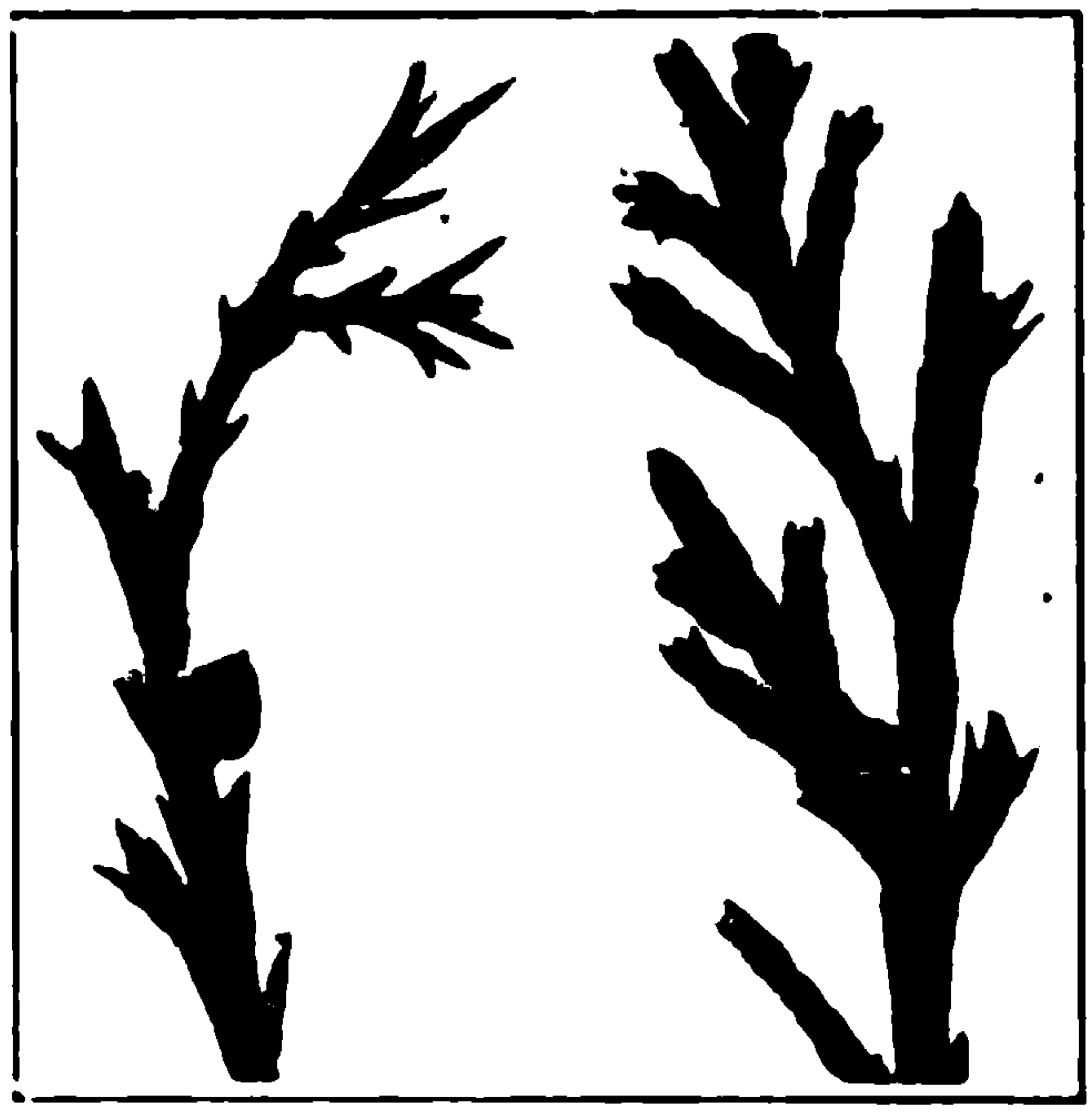

FIG. 31. — Cedar-apples, early stages of development.

The two diseases of the red juniper known as cedar-apples or cedar-flowers are similar in nature and are found commonly in eastern and central United States. The first pathogene mentioned above has its alternate stage on the cultivated apple and other species of Malus, while the latter pathogene occurs on various species of haw, mountain ash and the cultivated apple, and pear. The junipers are often covered with hundreds of the brown, globose galls which spoil the appearance of ornamental trees and result in more or less damage to the twigs and general vigor of the tree. The two pathogenes are the cause of apple and pear rust respectively and cause serious losses in yield when they cause defoliation. Climatic conditions and the proximity and abundance of the two kinds of hosts in the same locality are the determining factors which influence the severity of these diseases on both hosts.

FIG. 32. — Cedar-apple in late autumn, one year after infection.

Symptoms.

Brown-colored bodies called cedar-apples or cedar-flowers are produced on the small twigs of the red juniper. When very young, the galls can be seen to start as outgrowths of the juniper leaves (Fig. 31). The tissues of the leaf are stimulated to overgrowth and finally form, in a single season, the large cedar-apples, which are often an inch in diameter (Fig. 32). In this

Fig. 33. — Cedar-apple in spring of second year, showing expanded spore-horns.

condition they pass the winter, and the following spring brown horns of spores are pushed out from the surface of the cedar-apples (Fig. 33). In the former species these horns are about one inch long and cylindrical, while in the latter fungus they are about one-half inch long and are flattened or wedge-shaped.

Rust Witches'-Brooms

Caused by *Gymnosporangium Nidus-avis* Thaxter, *G. juvenescens* Kern and *G. Kernianum* Bethel

Three witches'-broom diseases are caused by species of rust-fungi on different junipers. The first species mentioned above causes witches'-brooms of the red juniper in eastern and central United States. The brooms are simply tufts of many branches which are formed from the part of the parent branch affected by the rust-fungus. The leaves of the brooms are usually of the pointed, awl-shaped, juvenile type. The second species causes large brooms on the red and Rocky Mountain juniper in the Rocky Mountains and in northwestern and north central United States. The leaves of these brooms also are of the juvenile type. The third species causes globose, compact brooms on the Utah juniper in western Colorado. The leaves on the brooms on this tree are scale-like.

The life history of all three species is similar to the other rusts of this type occurring on junipers and is discussed on page 192. The spore-masses in the first species appear as linear cushion-like brown masses bursting the bark of the affected branches, while in the other two species they are small hemispherical brown bodies, the size of a pin-head or smaller and arise from between the leaves or in the leaf-axils. Various species of service-berry are the alternate hosts for these three species. The first species is known to infect the quince also.

Branch-Galls

Caused by several species of Gymnosporangium

Abrupt swellings of the stems of the various species of juniper are often caused by species of the rust-fungi belonging to the genus Gymnosporangium. Other species of the same group of rusts cause cedar-apples and long fusiform branch-swellings, and a few produce spore-cushions on the normal green twigs and scale-like leaves. The life history of these fungi is described on page 192. The main characteristics of the forms causing abrupt swellings are given below.

The red juniper is affected in southeastern and south central United States by *Gymnosporangium trachysorum* Kern. Small knots or galls as large as an inch in diameter and an inch and a half long are formed on the small branches. The spore-horns are pushed out from these galls and are wedge-shaped and less than a half inch long. The alternate stage occurs on species of haw.

In the same region the red juniper is attacked by *Gymnosporangium floriforme* Thaxter. Small gall-like excrescences as large as one-half inch across and occasionally globose swellings an inch in diameter are formed on the branches. The horns of spores are cylindrical and pointed and vary from an eighth to one-half inch in length. One species of haw (*Cratægus spathulata*) is known to be the alternate host for this rust.

Along the coast of the Gulf of Mexico from Mississippi to Florida, several species of juniper often show reddish brown globose galls, a quarter to one-half inch in diameter. The fungus causing this gall is *Gymnosporangium bermudianum* (Farlow) Earle. This species is peculiar and is different from all others of this group in that no alternate host is required for its development. Both the teliospores and æciospores are formed on the same galls on the juniper. The cluster-cup stage is followed by teliospore masses smaller than a pin-head.

In northwestern United States and adjacent Canada, the dwarf juniper and *Juniperus sibirica* are attacked by *Gymnosporangium juniperinum* (L.) Mart. Hemispherical swellings half an inch to two inches long are formed on the larger branches and more or less globose galls an inch in diameter appear on the smaller branches. The spore-masses are flat and cover large areas of the galls. The alternate hosts are species of mountain ash.

In the same region as above, the Rocky Mountain juniper is attacked by *Gymnosporangium Betheli* Kern. Irregular gall-like knots are produced which are two or three times the diameter of the normal branch. Several knots breaking out adjacent to each other form galls similar to the black knots common on plum and cherry. Short wedge-shaped spore-horns about an eighth of an inch long are pushed out from the bark of the galls. Several species of haw are known to be the alternate hosts for this rust.

In northwestern and southwestern United States, the Rocky Mountain, Utah and one-seed junipers are attacked by *Gymnosporangium Nelsoni* Arthur. Hard woody globose galls as large as two and one-half inches are formed. The spore-masses are flattened and about an eighth of an inch high. The alternate hosts of this species are the quince, pear and species of service-berry.

The red juniper in northeastern and north central United States is attacked by *Gymnosporangium corniculans* Kern. Irregularly lobed excrescences as large as an inch in diameter are produced. The spore-horns are conical and about one-eighth of an inch high. The alternate hosts are species of service-berry.

Fusiform Branch-Swellings

Caused by species of Gymnosporangium

In addition to cedar-apples and galls or knots, several species of the rust-fungi cause long spindle-shaped swellings of the branches of species of juniper. The life history of these fungi is discussed on page 192 and only the hosts and outstanding characteristics of the diseases are given below.

In eastern, southeastern and central United States, the red and dwarf juniper and *J. sibirica* are commonly affected by *Gymnosporangium germinale* (Schw.) Kern. The branches are slightly enlarged, often for several inches in length. The spore-

host for this species is *Porteranthus* (*Gillenia*) *stipulatus* (Muhl.) Britton.

White Bark

Caused by *Cyanospora albicedræ* Heald and Wolf

This disease is common on the mountain juniper throughout its range in Texas. White patches, either small or extensive, occur on the bark of the young twigs and larger branches of young trees. The twigs are killed after the white areas have encircled them. Many of the branches, or the entire tree, may be killed in this manner. Shading seems to make the twigs and branches more susceptible. Upon the whitened areas of the bark numerous grayish pustules are formed, containing the fruiting-bodies of the fungus. After the bark is decayed, the pustules stand out prominently. Projecting from the upper surface of the grayish pustules are one to three short beaks which represent the openings of the fruiting-bodies buried in the pustules. Ascospores are formed in these fruiting-bodies and ooze out through the openings during moist weather.

Reference

Heald, F. D., and Wolf, F. A. The whitening of the mountain cedar, Sabina sabinoides (H. B. K.) Small. Mycologia 2: 205–212, pl. 31, figs. 1–3. 1910.

Brown Pocket Heartwood-Rot

Caused by *Fomes roseus* Fries

This heartwood-rot was first described as a disease of juniper, but recently has been found commonly in fir, larch, spruce, pine, hemlock and occasionally in arbor-vitæ, birch and maple, over practically the entire United States wherever conifers are important forest-trees. It may be confused in some trees with the red-brown root- and butt-rot caused by *Polyporus Schweinitzii* (see page 294), unless the fruiting-bodies are present to identify it.

Symptoms.

The wood of the juniper is characteristically affected. Long cylindrical and pointed pockets of brown charcoal-like decayed wood are formed. At first these pockets are more or less separated and vary from one to several feet in length. Later they may increase in diameter and merge with neighboring pockets, forming large irregular decayed areas. The decayed wood in juniper is dark brown but in other trees may be lighter if the normal wood is light colored. It breaks into cubes and is easily powdered. With a knife blade the charcoal-like cubes may be scraped from the cavity, leaving it smooth. The wood around these cavities is normal and of the natural color.

Fig. 34. — Fruiting-bodies of *Fomes roseus.*

The fruiting-bodies of the causal fungus on juniper are produced in the holes in the trunk where branch stubs are inclosed. They conform to the size and shape of the hole. When formed on logs, they vary from thin shelves to thick hoof-shaped rose-colored bodies which are usually small (Fig. 34). The upper surface may become black with age while the margin and under surface of newly formed pores is pinkish red. The internal structure is flesh-colored or pinkish.

The pores in the under surface are minute and the tubes very short.

Cause.

The brown pocket-rot of conifers is caused by the fungus *Fomes roseus* (formerly called *Polyporus carneus* Nees). The fruiting-bodies described above are perennial and are formed from dead areas on living trees or on the dead trees after they fall. Infection seems to take place mostly near the base of the tree and the rot is confined to the lower part of the trunk. The wood is destroyed in the pockets by the extraction of the cellulose. The lignin remains and the fibers retain their entirety, although the walls are much thinner than normal. For a fuller description of the life history and control of wood-rotting fungi, see page 64.

References

Schrenk, Hermann von. Red rot, or pecky cedar (Polyporus carneus). *In* Two diseases of red cedar, caused by Polyporus juniperinus n. sp. and Polyporus carneus Nees. U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 21 : 16–20, pls. 5–7, fig. 3. 1900.

Hedgcock, G. G. Notes on some diseases of trees in our national forests. IV. Phytopathology 4 : 181–188. 1914.

White Pocket Heartwood-Rot

Caused by *Fomes juniperinus* Schrenk

Junipers are affected by this destructive heartwood-rot in central United States. At times, the trees are made hollow for several feet up and down the trunk. Trees more than twenty-five years old are more often attacked than younger individuals.

Symptoms.

Varying with the stage to which the decay has progressed, the affected trees show one or more large holes at the center or are

References on White Pocket Heartwood-Rot

Schrenk, Hermann von. White rot of the red cedar (Polyporus juniperinus n. sp.). *In* Two diseases of red cedar, caused by Polyporus juniperinus n. sp. and Polyporus carneus Nees. U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 21: 9–16, pls. 1–4, figs. 1–2. 1900.

Hedgcock, G. G., and Long, W. H. Preliminary notes on three rots of juniper. Mycologia 4: 109–114, pls. 64–65. 1912.

Yellow Wood-Rot

Caused by *Fomes Earlei* (Murrill) Sacc. (? = *Fomes juniperinus* Schrenk)

This wood-rot is similar in appearance to the white heartwood-rot of the red juniper. The yellow wood-rot occurs more or less commonly in Arizona, New Mexico, Texas and Colorado in mountain, one-seed and Utah juniper. The rot is most destructive in New Mexico, and at times the tree is so weakened that it breaks over.

Symptoms.

Long longitudinal holes several inches in diameter are formed in the heartwood. The holes are partially filled with decayed wood matted together with light brown mycelium. The wood around the holes is yellowish or light brown in color. Both the heartwood and sapwood may be invaded and destroyed, although the holes are usually confined to the heartwood.

The sporophores of the causal fungus are attached to the affected tree. They emerge from the furrows or depressions in the bark, usually within ten feet of the ground. They are hoof-shaped to cylindrical, woody bodies, brownish to black and deeply checked on top and yellowish beneath. The inner substance of the sporophore is brownish or orange-yellow. The pores on the under surface are rather large and circular.

Cause.

The yellow wood-rot of the species of juniper found in the Southwest is caused by a fungus named *Fomes Earlei*. There is but little difference between this fungus and *Fomes juniperinus*, causing the white pocket heartwood-rot of red juniper in eastern United States. Very few sporophores of *Fomes juniperinus* have been found, although the rot caused in red juniper is common. Sporophores of *Fomes Earlei* are common where the trees are affected. It is believed by some that the two species are identical but because very few specimens of *Fomes juniperinus* are available for comparison, this has not been fully determined. The rots are somewhat different although similar in many respects. These differences may be due, however, to the host and do not necessarily indicate that the fungi causing them are different species. Further details concerning the life history and control of wood-rot fungi will be found on page 64.

Reference

Hedgcock, G. G., and Long, W. H. Preliminary notes on three rots of juniper. Mycologia 4: 109–114, pls. 64–65. 1912.

Stringy Brown Wood-Rot

Caused by *Fomes texanus* (Murrill) Hedgcock and Long

This wood-rot affects both the heartwood and sapwood of mountain, Utah and one-seed juniper. The rot is very destructive and common in Texas and New Mexico.

Symptoms.

The first signs of the decay are evident as small pockets of light brown tissue in the spring-wood of the annual rings. These pockets soon merge and the spring-wood becomes reddish brown and is partially or entirely destroyed. This action leaves concentric zones of badly rotted and apparently sound wood which is characteristic of this wood-rot. Hollow trunks are not formed. The less affected summer-wood of the rings and the wood bordering the decayed area are yellowish brown. The sapwood and bark are affected and permeated by the reddish yellow mycelium.

The sporophores of the causal fungus appear from crevices in the bark where the fungus has emerged from the sapwood and inner bark. They are hoof-shaped or cylindrical woody bodies with a light yellowish or brown to black checked upper surface. The yearly growth of the sporophore is apparent in the concentric furrows on the upper surface. The under surface is light yellowish and the pores are very small. The inner structure is yellowish.

Cause.

The stringy brown wood-rot of junipers in the Southwest is caused by the fungus *Fomes texanus*. No definite studies are reported on the method of infection. The general life history and control of the wood-rot fungi are discussed on page 64.

Reference

Hedgcock, G. G., and Long, W. H. Preliminary notes on three rots of juniper. Mycologia 4: 109–114, pls. 64–65. 1912.

Basal Heartwood-Rot

Caused by *Poria Weirii* Murrill

This heartwood-rot is the most important basal decay of the western red cedar throughout northwestern United States. After the tree falls, the heartwood and sapwood of the entire tree are soon destroyed by the same fungus. In the first stages of decay, the wood is uniformly split into its separate annual rings. The affected wood is brown and brittle.

The causal fungus forms fruiting-bodies on the fallen trunks of the affected trees. These fruiting-bodies are brown and

CHAPTER XXIII

LARCH DISEASES

The three native species of larch or Larix are important forest-trees in northeastern and northwestern United States. The eastern and European larch are frequently used as ornamentals. The eastern larch is commonly affected by several wood- and root-rots. Of these, the pecky wood-rot and red-brown sapwood-rot are most destructive. The leaf-rusts are rare. In the Northwest, the larch is not only subject to several wood- and root-rots but is also seriously damaged by a dwarf mistletoe which causes large swellings and witches'-brooms. The seedlings are often killed by a fungus which causes a root-rot.

Seedling Root-Rot

Caused by *Rhizina undulata* Fries

Seedlings of the western larch are killed by this root-rot in northwestern United States. It may be found also in some northeastern states since the fungus is known to occur in this region. The diseased roots of seedlings from three to six years old are matted together by an abundant growth of white mycelium. The fruiting-bodies of the pathogene are formed on the surface of the ground. They are dark brownish, undulating structures with a light colored margin when young. A fuller description of this disease is given under hemlock diseases, page 177.

Leaf-Rusts

Caused by *Melampsora Bigelowii* Thüm. and *M. Medusæ* Thüm.

The needles of larch are sometimes affected by two similar rusts. These diseases have been found in various localities and may be expected throughout the northern states from the Atlantic to the Pacific. The fungi causing these two diseases are closely related to the several other rust fungi of pine, spruce, fir and hemlock.

Symptoms.

The rusts of larch are so similar that they cannot be identified without the use of a microscope. The affected needles in early spring show small whitish pustules bursting through the epidermis. The epidermis of the leaf covering of the pustules breaks open and the spores within are blown away by the wind as a fine dust. The needles then turn yellow and may fall off.

Cause.

The rust diseases of larch are caused by *Melampsora Bigelowii* and *M. Medusæ.* Besides the stage produced on the larch leaves, each of these fungi requires a period of growth on other kinds of plants. The spores (æciospores) from the pustules caused by the first mentioned species infect the leaves of several kinds of willows. In the latter named species the æciospores infect the leaves of certain poplars. On the willows and poplars other spores (urediniospores) are produced which continue the life history of the fungi. Over-wintering teliospores on these two hosts germinate in the spring and produce basidiospores which infect the young leaves of the larch. These facts in the life history of the two rust fungi make it evident that the appearance of the diseases on the larch is dependent on the presence of poplars or willows in close proximity.

A blister-rust of larch needles which also occurs rarely in this country is caused by *Melampsoridium betulæ* (Schum) Arthur. This fungus attacks birch in the United States but the stage on larch does not seem to be common. It is known on both birch and larch in Europe.

Mistletoe Burl and Witches'-Broom

Caused by *Razoumofskya laricis* Piper

The mistletoe disease of larch is common and destructive in northwestern United States. It is especially abundant in open stands and causes but little damage in the dense forests. In moist and fertile areas, the larch attains full development and is only rarely deformed by the mistletoe. On the other hand in regions of light rainfall, variable temperature, low humidity, dry soil and especially in open stands, the growth of the mistletoe is favored and the tree suppressed. Measurements made of unaffected and badly infested trees show that the rate of growth of the larch may be reduced to one-half the normal.

Symptoms.

Young and old larches are affected. The seeds of the mistletoe produce infection if they fall on the green twigs. Burls are produced in the trunk and larger branches due to the irritation caused by the roots of the mistletoe. Infected younger branches are stimulated to produce abnormal twigs, forming witches'-brooms. The foliage area of the tree is reduced by the deforming of the branches and the general development of the tree is suppressed.

Cause.

This burl and witches'-broom disease is caused by one of the species of dwarf mistletoe, *Razoumofskya laricis*. The roots of the parasite penetrate the bark and wood and grow down the branch for some distance, sometimes entering larger branches or the trunk. The irritation caused by the roots of the parasite results in an increased growth of the affected parts. The parasitic plants are inconspicuous, never being more than about four inches tall. A cluster of yellowish

of the causal fungus are formed abundantly on the diseased trees and on fallen logs. They have a red varnished margin and a cream-colored under surface. Fuller details concerning this heartwood-rot will be found under fir diseases, page 165.

Brown Heartwood-Rot

Caused by *Fomes officinalis* Fries (= *Fomes laricis* (Jacq.) Murrill)

This brown heartwood-rot is common and very destructive in western United States in larch, pine, Douglas fir and other conifers. In California and Nevada, sugar pines are the most destructively attacked. In the Northwest, Douglas fir, western larch, lodge-pole and western yellow pine are often seriously affected. The rot resembles to some extent the brown checked wood-rot caused by *Polyporus sulphureus* (see page 247).

Symptoms.

The affected heartwood is brownish or red-brown in color. Felts of the mycelium of the fungus form in cracks in the wood. The sporophores of the causal fungus are not formed abundantly on the affected trees. They are large hoof-shaped or globose bodies with a white, roughened, chalky upper surface. The white material will rub off like powdered chalk. The fruiting-bodies when young are soft and watery but become very brittle when old. The inner structure is white, bitter to the taste and has a distinct mealy odor. The under surface is convex, whitish and covered with small pores.

Cause.

The brown heartwood-rot of conifers in the western forests is caused by *Fomes officinalis*. This fungus also is known by the name *Fomes laricis*. Infection takes place when the spores from the tubes on the under side of the fruiting-body lodge in open wounds where heartwood is exposed. For further detail concerning the general life history and control of the wood-rotting fungi, see page 64.

Reference

Meinecke, E. P. Forest tree diseases common in California and Nevada. U. S. Dept. Agr. Forest Service. Unnumbered publication, pp. 1–67, pls. 1–24. 1914.

Brown Pocket Heartwood-Rot

Caused by *Fomes roseus* Fries

This heartwood-rot is common in larch as well as in fir, spruce, pine and hemlock, in almost every section of the country where these trees grow. The rot may be confused at times with the red-brown root- and butt-rot caused by *Polyporus Schweinitzii* (see page 294). The decayed wood is brown, easily powdered and looks like charcoal. At first long cylindrical or pointed pockets of decayed wood are formed. Later these pockets may join and large areas of the heartwood are uniformly brown rotted. The fruiting-bodies of the causal fungus are produced at branch stubs on affected trees or on the sides of fallen timber. They may be either small and thin structures or large hoof-shaped bodies. The under surface is rose-colored. For further details concerning this heartwood-rot, see under juniper diseases, page 204.

Red-Brown Root- and Butt-Rot

Caused by *Polyporus Schweinitzii* Fries

Fir, pine, spruce, hemlock and arbor-vitæ in addition to the larch are affected by this wood-rot wherever these kinds of trees grow. It is next in importance to the pecky wood-rot of these trees. The affected heartwood of the roots and lower part of the trunk is at first yellowish and cheesy but later becomes red-brown and brittle. This wood-rot is more fully described under pine diseases, page 294.

Yellow Root-Rot

Caused by *Sparassis radicata* Weir

In the Northwest the roots of larch are often destroyed by this root-rot. Fir, spruce and pine are affected by the same disease. The bark and sapwood of the roots are killed. Yellowish fan-shaped plates of mycelium are found in the bark. The medullary-rays and heartwood are also decayed and become yellow or brown. The fruiting-bodies of the causal fungus are peculiar. They are attached to the diseased roots by long, fleshy stalks. New fruiting-bodies are formed each year from the tip of the stalk. They are large, white, compact, fleshy structures covered with curled and lacerated leaf-like plates. These thin plates stand upright on the upper portion of the fruiting-body or horizontally from the sides. The spores of this fungus are borne over the entire exposed surface of the fruiting-body. For further details concerning this root-rot, see under fir diseases, page 170.

yellow to light straw-yellow at the edge of the band. When the bands have reached the cambium and bark, compact red-brown felts of mycelium replace the destroyed tissues. In tangential section the narrow bands show as yellow lens-shaped areas with red centers. The radial bands of decay become more numerous and finally coalesce, and in this way all the heartwood and sapwood is decayed.

The sporophores of the pathogene appear at various places on the bark where the mycelium has penetrated the sapwood

FIG. 35. — Upper surface of fruiting-body of *Fomes rimosus*.

and bark. They are at first small, red-brown, hard knobs. Each year a new layer of pores is added to the under surface. After several years' growth large brackets or hoof-shaped bodies are formed. The upper surface is dark brown or black and much roughened by numerous fissures which divide the surface into irregular squares (Fig. 35). The under surface is dull red-brown and extends upward over the edge of the sporophore in a smooth roll. The pores on the under surface are barely visible.

Cause.

The yellow wood-rot of locust is caused by the fungus *Fomes rimosus*. It is similar in appearance to *Fomes igniarius* except when it is broken open the older layers of tubes do not show the white filling. The spores from the tubes on the under surface of the sporophore infect the locust at branch stubs or through the tunnels made by the locust borer. The mycelium, after destroying the central portion of the heartwood, reaches out along the medullary-rays and initiates the bands of decay. The yellow wood-rot fungus is not known to continue growing in dead wood and timber made from affected wood is said to last as long as sound timber. For further details concerning the life history and control of wood-rotting fungi, see page 64.

References

Schrenk, Hermann von. A disease of the black locust (Robinia pseudacacia L.). Missouri Bot. Gard. Ann. Rept. **12**: 21–31, pls. 1–3. 1901.

Schrenk, Hermann von, and Spaulding, P. Black locust disease caused by Fomes rimosus. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 45–46. 1909.

Brown Checked Wood-Rot

Caused by *Polyporus sulphureus* Fries

The heartwood and sapwood of locust is often reduced to a red powdery mass by the sulfur fungus. Oak, chestnut, walnut, butternut, maple and alder are the other principal kinds of trees commonly affected by the same rot. The sapwood and bark may be invaded and the tops of the trees or large limbs are thus killed. The sulfur-yellow and orange-colored fruiting-bodies of the causal fungus are produced in late summer from wounds or from the bark where the mycelium has invaded the sapwood. The reddish colored decayed wood splits into small cubes with plate-like sheets of mycelium filling up the cracks between. This wood-rot is similar in its effect on the different kinds of trees and is more fully described under oak diseases, page 247.

Root-Tubercles

Caused by *Bacillus radicicola* Beijerinck

Locust roots often show small globose swellings. These structures are abnormal lateral rootlets which are inhabited by the nitrogen-fixing bacterium. The bacteria gain entrance to the root through the root-hairs. They multiply in the cortex cells and stimulate the tissues to over-growth. A discussion of the relation between the host and parasite will be found under alder diseases, on page 88.

maple are rarely if ever affected, even when growing among red and silver maples which are severely infected. This substantiates the results of investigations in Europe which show that there are various strains of the tar-spot fungus. These strains show preference for certain species of maples, but in other respects are indistinguishable from one another.

Symptoms.

The first evidence of the developing spots on the maple leaves are light green or yellowish areas. In the summer the spots become black on the upper surface of the leaf due to the black mycelium of the fungus. The surface of the tar-like spots is wrinkled with anastomosing furrows and somewhat raised above the surface of the leaf. The spots are usually a quarter or half inch across (Fig. 36).

Fig. 36. — Tar leaf-spot of maple.

Cause.

The tar leaf-spot of maples is caused by the fungus *Rhytisma acerinum*. Spores are borne free on the upper surface of the black mass of fungous tissue as it develops on the leaf. It is not known whether these spores infect other leaves or not. But from the number of leaves affected on some trees, it seems certain that these spores must account for the general prevalence of the infections. When the spotted leaves fall to the ground, the mycelium inside the black spots develops ascospores. These are mature in the spring. With the return of warm weather, the black layer of fungous tissue cracks open and the edges fold back, exposing the fruiting-layers within. The spores are probably shot into the air as are most ascospores. The young maple leaves are infected by the ascospores which lodge upon them and germinate.

Control.

Very little trouble will be experienced from this disease if the affected leaves are destroyed by burning in the autumn. Unless this is carefully done and all the affected leaves under and around the trees are destroyed, the few remaining ones may cause some infection in the spring. In exceptional cases, as in nurseries, spraying with bordeaux mixture as the leaves develop may be desirable. For general directions on spraying, see page 357.

REFERENCES

Stewart, F. C. Black spot, Rhytisma acerinum (Pers.) Fr. *In* Notes on New York plant diseases, 1. New York Agr. Exp. Sta. (Geneva) Bul. 328 : 364. 1910.

Schrenk, Hermann von, and Spaulding, P. Tar-spot. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149 : 19. 1909.

BLACK-SPECKED LEAF-SPOT

Caused by *Rhytisma punctatum* Fries

The silver maple of eastern United States (*Acer saccharinum*) and the broad-leaf maple (*A. macrophyllum*) of the Pacific Coast are occasionally affected by this leaf-spot. It does not seem to be as abundant as the tar leaf-spot. During the summer light green or yellowish areas about a half inch in diameter appear in the leaf. Later several isolated black spots the size of a pin-head develop on the upper surface of the spot. In the autumn the affected area remains yellowish green after the remainder of the leaf has faded or turned bright colored. The fungus causing this leaf-spot is a near relative of the tar leaf-spot fungus (see page 223). Spores are developed in the same manner and control measures are the same for both diseases.

Leaf-Spots

Caused by *Phyllosticta minima* (B. and C.) E. and E., *Glœosporium apocryptum* E. and E., and other fungi

The leaves of maple are subject to a number of leaf-spot diseases (see page 30). The two fungi named above are common in eastern United States and may be found every year.

Fig. 37. — Leaf-spot of maple caused by *Phyllosticta minima*.

tinguished from one another except by the microscopic characters of the black fruiting-bodies which are just visible to the unaided eye. The mycelium of both fungi causes powdery white, more or less definite spots on the under sides of the leaves. The life histories and control of powdery mildew fungi are discussed on page 37.

Leaf-Blight

Caused by Glœosporium sp.

This leaf-blight has been observed on Norway maple (*Acer platanoides*) in Connecticut, New York and Virginia. No studies have been made on the disease and but little is known

Fig. 39. — Leaf-blight of maple caused by Glœosporium sp.

concerning it. The leaves show yellowish and brown dead areas along the main veins (Fig. 39). Later the leaves wilt and fall from the tree. Minute brown spots form along the veins. These are the fruiting-bodies (acervuli) of the causal fungus. The spores from these structures are disseminated by the rain. It is to be expected that perithecia with ascospores are formed in the leaves on the ground during the winter. The twigs have not been found affected. This disease is similar to the leaf- and twig-blight of sycamores described on page 333. The control measures are the same for both of these diseases.

Canker

Caused by *Nectria cinnabarina* Fries

Maples are commonly affected by this canker. Other deciduous trees may also be attacked by this disease but it never assumes great importance owing to the causal fungus being only weakly parasitic. Twigs, small branches and young trees may be killed by the girdling action of the fungus.

Symptoms.

Small depressed dead areas of bark around wounds or branch stubs are the first evidences of the developing canker (Fig. 40). Flesh-colored or pink hemispherical bodies are produced on the dead bark. Later the same pustules become chocolate-brown. If the fungus continues to spread, rolls of callus are formed around the affected area each year, until an open canker is produced which may girdle the limb. The mycelium grows most luxuriantly in the sapwood, causing a dark greenish discoloration (Fig. 41). The bark adjacent to the

Fig. 40. — Nectria canker on maple.

affected sapwood dies and the mycelium invades the dead bark, forming its fruiting-bodies on the outside. The canker develops slowly and may at any time cease to enlarge. The exposed wood is then finally overgrown by the callus. This canker is especially common in severely wounded or recently pruned trees.

Fig. 41. — Cross and longitudinal sections through a Nectria canker on maple.

Cause.

The canker of maples is caused by the fungus *Nectria cinnabarina.* Spores are borne over the outside of the flesh-colored pustules during the summer. After the pustules become chocolate-brown, perithecia are formed which produce ascospores. These spores are matured over winter and produce infection in wounds in the spring.

Control.

The cankers can be removed by surgery (see page 351). All dead bark and twigs should be cut away at the same time, since the causal fungus occurs everywhere as a common saprophyte. Pruning wounds should be at once protected by a wound dressing (see page 348).

Reference

Schrenk, Hermann von, and Spaulding, P. Nectria cinnabarina. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 21–22. 1909.

of cotton, potato and various field crop plants. The fungus is known to form spores on branches of the mycelium but the manner and place of fruiting and method of infection in the maple is unknown.

Control.

Surgical methods are advised when this disease is to be controlled (see page 345). Several diseased trees in a group have been observed and the destruction of badly affected individuals is necessary to prevent the fungus spreading to healthy trees near by.

Common White Wood-Rot

Caused by *Fomes igniarius* Fries

Silver and striped maple are more commonly affected by this white wood-rot than the red and sugar maple. Poplar, beech and oak are the most seriously affected of the many species of deciduous trees which are susceptible to this fungus. Beech and maple in mixture in the Adirondack Mountains are often diseased to the extent that the stands will never be worth cutting. Outside the forest, this disease is not so common. The sapwood may be invaded and the tops of the trees or large limbs killed. The sporophores and decay are similar for all kinds of trees and are described under poplar diseases, page 305.

Brown Checked Wood-Rot

Caused by *Polyporus sulphureus* Fries

Maples are at times affected by the sulfur fungus which causes the brown checked wood-rot. Oak, chestnut, walnut, butternut, locust and alder are also frequently affected by the same rot. The wood is reduced to a reddish powdery mass which splits in cubes, separated by sheets of mycelium. The sporophores of the causal fungus are orange and sulfur-yellow in color. They form from branch wounds or directly from the bark in late summer. The sapwood and bark are often invaded and destroyed, causing the tops of the trees or large limbs to die. The symptoms of the brown checked wood-rot are similar for all kinds of trees and are described under oak diseases, page 247.

White Strand Wood-Rot

Caused by *Polyporus squamosus* Fries

Many kinds of deciduous trees are reported as seriously damaged by this white rot in Europe. Those specially mentioned are maple, oak, elm, walnut, basswood, willow, ash, birch, horse-chestnut and beech. In the United States, no authentic information is available on this wood-rot, except that the fungus is found in some cases growing from wounds in living trees.

Symptoms.

The heartwood and sometimes the sapwood of the trees are decayed. Trees in which the rot has affected the conduction tissue of the sapwood show marked decline and are often killed. The wood is characteristically rotted. It is almost white and marked with pure white narrow strands of mycelium running in the radial, tangential and longitudinal directions, causing the wood to be split into small cubes. In general this character is similar to the rot produced by *Polyporus borealis* in the wood of conifers (see page 185).

The annual fruiting-bodies are easily recognized. They are soft and watery and almost circular with a short stout stem at one side attaching them to the tree. The top is slightly convex and is covered with overlapping brown scales, while the under surface is white and honeycombed.

Cause.

The white strand wood-rot of maples is caused by the fungus *Polyporus squamosus;* so named because of the scales on the top of the fruiting-bodies. It is commonly known as the scaly or saddle-back fungus. Infection is effected by the spores, which are wind-blown, lodging and germinating on exposed wood, especially at broken or pruned branch stubs. The less lignified elements of the wood-tissue are destroyed and strands of mycelium fill the long channels thus opened up in the wood. These strands run through the wood, replacing the medullary-rays and spring-wood, thus causing the white bordered cubes which are seen in cross and longitudinal sections. The life history and control of the wood-rot fungi will be found discussed on page 64.

References

Schrenk, Hermann von, and Spaulding, P. White-rot caused by Polyporus squamosus. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 48–49. 1909.

Buller, A. H. R. The biology of Polyporus squamosus, Huds., a timber destroying fungus. Jour. Econ. Biology. 1: 101–138, pls. 5–9, figs. A–F. 1906.

Uniform White Sapwood-Rot

Caused by *Hydnum septentrionale* Fries

A white sapwood-rot of maple and beech is occasionally found in eastern and central United States. This rot has not been studied and described and is not very important. The affected wood is soft and uniformly white. Brown zones separate the affected area from the normal wood. Black lines are sometimes found running in various directions in the rotted wood.

The white fruiting-bodies of the fungus are very conspicuous. They are large, flat, fleshy structures often a foot or two long and a foot across. They are composed of a thick sheet of mycelium adhering to the side of the tree with numerous closely overlapping projecting shelves. The individual shelves

rays are destroyed and the porous portion of the annual rings is delignified and partially dissolved. The denser summerwood of the rings is least affected. The result of this action is that the affected wood is light in weight and breaks easily into flakes.

The sporophores of the causal fungus are fleshy, annual, shelving structures with radiating plates or gills on the under surface. The sporophores are more or less sessile and appear in clusters at wounds where the affected wood is exposed. They are often found at the junction between two limbs. The upper surface is smooth, slightly rounding and white or grayish in color. The gills on the under surface extend on to the stalk-like attachment to the wood. For more complete details concerning the life history and control of the wood-rotting fungi, see page 64.

Reference

Learn, C. D. Studies on Pleurotus ostreatus Jacqu. and Pleurotus ulmarius Bul. Annales Mycol. 10 : 542–556, pls. 16–18. 1912.

White Butt-Rot

Caused by *Fomes applanatus* Fries

The heartwood of the lower part of the trunk and roots of maple is sometimes destroyed by this rot. The decayed wood is whitish, light in weight and has many white-stuffed tunnels running in the horizontal direction. The sporophores of the causal fungus are shelf-like, woody bodies, with a smooth brownish upper surface and a white under surface. Further details concerning this heartwood-rot will be found under poplar diseases, on page 310.

CHAPTER XXVI

OAK DISEASES

OVER fifty species of oak (Quercus) are native in the United States. Many of these are important timber-trees. No region is without one or more species of oak, except the northern Rocky Mountains and the treeless plains. Although many kinds of oak occur on the Pacific Coast and in the Southwest, the most important forest-species grow in eastern and central United States. Many oaks are used for shade and ornament.

The oak is more destructively affected by wood- and root-rots than any other important deciduous timber-tree. These diseases are also common in oaks used for ornament. Many species of fungi cause leaf-spots and powdery mildews. White oak, especially in the East, is more or less seriously affected by leaf-blight caused by the same fungus which occurs on sycamore (see page 333). This disease often results in defoliation. In the South the leaf-blister is very common and often destructive. The twig-blight and Strumella canker described below cause the death of many oaks in the East.

LEAF-BLIGHT

Caused by *Gnomonia veneta* (Sacc. and Speg.) Klebahn

Several kinds of oaks, especially the white oak, are attacked commonly by this leaf-blight. Sycamores (or plane-trees) are more seriously affected by the same disease. The spots developed on the leaves may vary from small isolated light brown areas to large coalescing spots which involve a large portion of the leaf (Fig. 44). When the spots occur on the veins, large areas are killed and the tip of the leaf frequently dies. The dead areas become light brown and very much wrinkled. Minute darker brown pustules the size of a pinhead or smaller are scattered over the dead area. Small globules of sticky spores are developed from these pustules in rainy weather and the spores may be washed to all parts

FIG. 44. — Leaf-blight of oak.

of the tree, causing the infection of other leaves. The twigs are sometimes affected, but this symptom is less frequent in oak than in sycamore. The life history of the causal fungus is imperfectly known and is discussed under sycamore diseases, page 333. Control measures are also the same as for this disease on sycamore.

and often become confluent, causing the leaf to curl. So far as is known, there is only the one period of infection and no subsequent spread to the other leaves of the tree occurs. Practically all the leaves of the tree may be infected, however, and where the blisters are numerous the leaves fall.

Cause.

Leaf-blister of oak is caused by the fungus *Taphrina cærulescens*. This fungus belongs to the family Exoascaceæ, all the members of which are parasitic and cause leaf-curls, leaf-blisters, plum-pockets, witches'-brooms and other types of over-growths. The common orchard disease, peach leaf-curl, is caused by a closely related form and is similar to oak leaf-blister in many ways. There are no fruiting-bodies formed by these fungi. The spores are borne in asci which stand free on the surface of the blistered or curled area. From the production of the spores which takes place as the blisters are forming, until infection occurs the next season, nothing is known concerning the life history of this entire group of fungi. No other stage of development is suspected but it is thought that the spores simply rest until the next spring and are present in some way so that they can infect the unfolding leaves. In the case of peach leaf-curl, cold wet weather following a warm period, at the time the buds are bursting, causes epiphytotics. Similar weather conditions may result in more extensive infection in the case of oak leaf-blister, but no observations are recorded on this point.

The mycelium does not enter the tissue of the oak leaf. It simply penetrates the cuticle of the lower epidermis and lies in contact with the outer walls of the epidermal cells. The enzymes of the fungus diffuse into the leaf and cause a marked reaction on the part of the leaf-tissues. The lower epidermal and spongy mesophyl cells increase in number and the palisade and upper epidermal cells increase greatly in size, causing the leaf at the infected point to become much thicker. The expansion of the affected area laterally, due to the increased number and size of the cells, causes it to bulge and thus the blister is formed. All the cells of the mycelium then increase greatly in size and push the cuticle off. Within each mycelial cell which is now an ascus, the spores are formed.

Control.

Apparently no spraying experiments of value have ever been made for the control of leaf-blister of oaks. The method used to control peach leaf-curl should be tried. It is, therefore, suggested that the trees be sprayed with bordeaux mixture 4–4–50 or lime-sulfur 1–8 at any time after the leaves fall and before the buds swell. The spraying should be thorough, since the solution must coat every twig and bud to accomplish the desired results. Peach leaf-curl is easily controlled by a single application of any good fungicide in this way. The spores must, therefore, in some way be present on the outside of the twig or bud scales and the spray mixture kills them. (See Hesler, L. R., and Whetzel, H. H. Manual of fruit diseases, pp. 277–283. 1917.)

Reference

Wilcox, E. M. A leaf-curl disease of oaks. Alabama Agr. Exp. Sta. Bul. 126: 171–187, pl. 1, figs. 1–3. 1903. (Bibliography given.)

Powdery Mildews

Caused by *Microsphæra alni* (Wallr.) Salmon, *M. alni* var. *extensa* (Cooke and Peck) Salmon, *Phyllactinia corylea* (Pers.) Karst. and *Erysiphe trina* Harkness

Four species of powdery mildew fungi (besides the brown mildew, see page 243) are known to attack the leaves of oaks in the United States. The first and third species mentioned above occur commonly throughout the country on the leaves of many kinds of trees (Fig. 46). The second species is a variety of the first, seemingly confined to eastern, southern and central United States, while the fourth is so far reported only from California. All of these fungi cause powdery white patches on

Fig. 46. — Powdery mildew on oak leaf.

both sides of leaves, but do little damage. The black or brownish fruiting-bodies can be seen scattered or in clusters over the affected area of the leaf. The life history and methods of control of powdery mildew fungi are discussed on page 37.

Twig-Blight

Caused by *Sphæropsis malorum* Berkeley (= *Physalospora cydoniæ* Arnaud)

This twig-blight is common on chestnut oak in central eastern United States. White oak and chestnut are also occasionally affected by the same disease. The smaller branches and twigs of trees of all ages may be killed.

Fig. 47.—Twig-canker on oak caused by *Sphæropsis malorum*.

Symptoms.

The leaves wither and turn brown. The mycelium of the causal pathogene grows in the bark and sapwood. The diseased bark becomes sunken and wrinkled (Fig. 47). Small black fruiting-bodies break through the outer bark. Under the dead bark, the sapwood is dark colored. The mycelium extends for several inches in the sapwood above and below the bark-lesion. This is evident to the unaided eye as a black streak when the bark is peeled from the twig.

Cause.

The fungus causing this twig-blight is known as *Sphæropsis malorum*. It occurs as a weak parasite or saprophyte on the bark and twigs of many kinds of woody plants. The New York apple canker, black-rot and frog-eye leaf-spot of apple are caused by this fungus. Spores ooze from the black fruiting-bodies produced on the dead bark and may be washed by the rain to other parts of the tree. The fungus also rarely produces a perithecial stage which is known as *Physalospora cydoniæ*.

Control.

The diseased twigs and branches should be pruned from the tree. This may be done most efficiently in midsummer, as the dead leaves show more plainly. Early the next spring after the new leaves appear, all leafless twigs and branches should be removed. If these measures are not taken, large trees may often be killed after a few years. Care should be exercised to prune the twigs at least six inches below the cankered area, since the mycelium which spreads in the sapwood must all be removed (see under symptoms).

Reference

Ingram, Della E. A twig blight of Quercus prinus and related species. Jour. Agr. Res. 1: 339–346, pl. 38, figs. 1–7. 1914.

Strumella Canker

Caused by *Strumella coryneoidea* Sacc. and Winter

This canker of oak has been found to be common and destructive in Pennsylvania. Although not definitely reported elsewhere, the fungus is known to occur in Missouri, Massachusetts and New York. Its range may thus be supposed to include northeastern United States. In Pennsylvania the canker is found on white, scarlet, red, yellow and chestnut oak. It also occurs destructively on the American chestnut. The most damage is reported on red and yellow oak.

Symptoms.

Two types of cankers with intermediate gradations are described. The most conspicuous form is found on red and yellow oak and resembles the European apple-tree canker, caused by *Nectria galligena*. The development of the cankers of this type is slow. They are elliptical in outline and consist of a depressed decayed center surrounded by concentric folds of callus. The tissue around the canker is irregularly swollen, causing badly deformed trunks.

The cankers gradually girdle the trunk and the trees are either blown over or die. Suckers are formed in abundance just below the cankers. On young smooth-barked trunks, another type of canker is formed which is at first a light yellowish raised area of bark and later develops into a sunken dead surface which quickly girdles the stem. When the bark is peeled from these cankers, thin sheets of white or pale brownish mycelium are exposed.

On the surface of the affected bark of both types of cankers are numerous small black nodules which are the fruiting-bodies of the causal fungus.

Cause.

This canker of oaks and chestnut is caused by the fungus *Strumella coryneoidea*. No ascus stage has been found connected with this species and it is known only by the conidial fruiting-bodies. Inoculations have not been made with this fungus to determine fully its pathogenicity. The fungus is found invariably associated with the cankers and has been isolated and grown in pure culture. The black nodules on the cankers which have not girdled the trunk do not produce spores and are abortive. As soon as the trunk is girdled, however, numerous brownish powdery pustules burst through the bark. The spores of the fungus are borne free on the surface of these pustules and are believed to be carried by the wind. The mycelium penetrates the wood deeply and causes a weakening of the trunk. Infection usually occurs through a small branch stub and from this center the mycelium spreads in all directions.

Control.

No definite control measures are suggested for this canker. The ordinary surgical methods of canker treatment, however,

accompanies the decay, the affected wood splits into cubes by radial and circumferential cracks. The mycelium then grows into and fills the cracks and forms tightly woven sheets (Fig. 48).

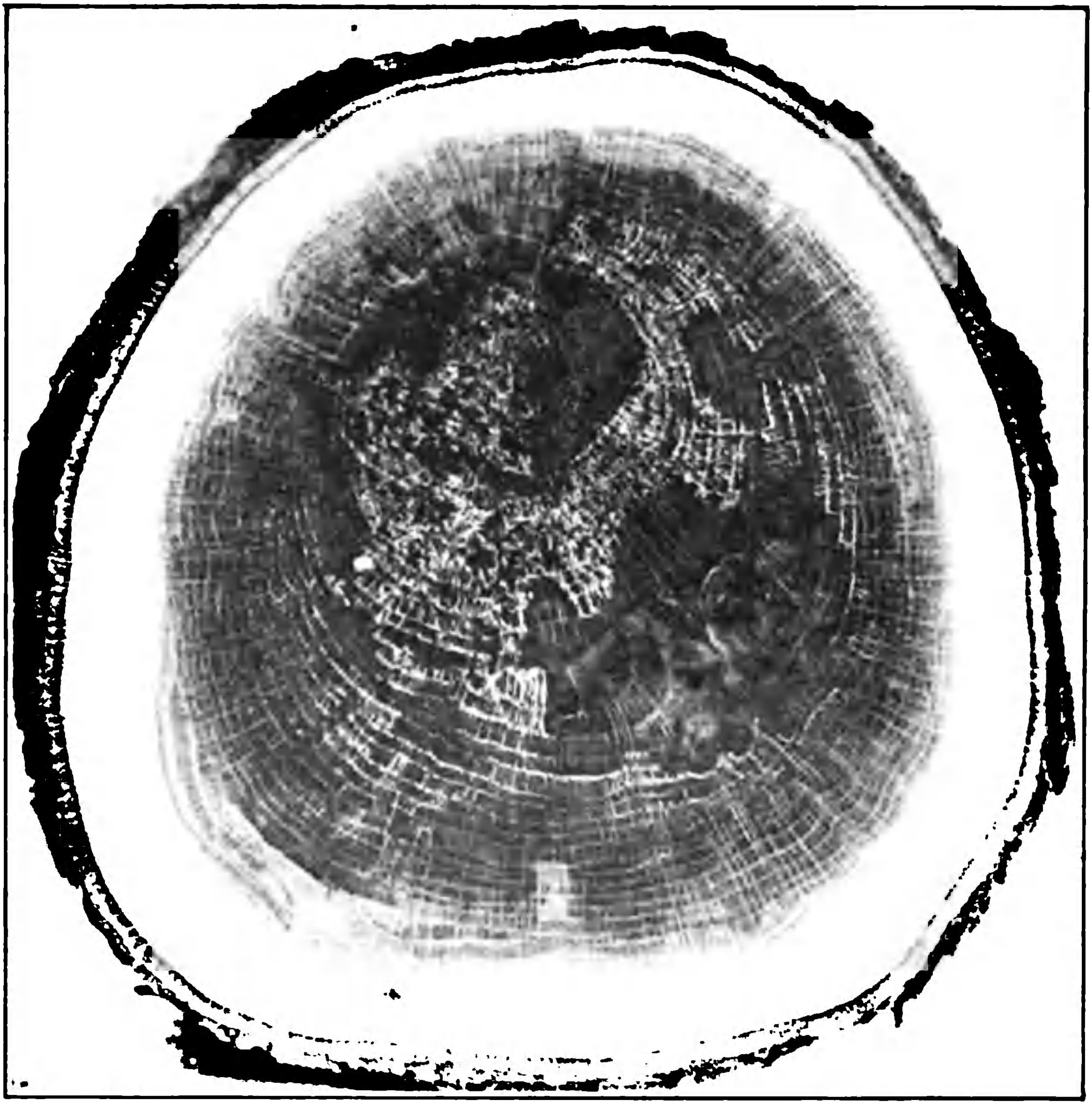

FIG. 48. — Brown checked wood-rot in oak.

The sporophores of the sulfur fungus are easily recognized. They emerge in late summer from old branch wounds or directly from the bark where the mycelium has decayed the sapwood. At first they appear as one large or several small sulfur-yellow, soft and watery knobs of mycelium. These quickly grow larger and form a number of individual or closely over-lapping shelves, from one to several inches wide (Fig. 49). The upper surface of the shelves is bright orange-yellow marked with redder areas, while the under surfaces are sulfur-yellow and appear honeycombed. The substance of this mature fruiting-body is tough but very watery. Insects rapidly invade it and through their work and decay caused by bacteria and possibly other fungi, the fruiting-body is quickly destroyed. What remains of it soon dries and becomes white and brittle. The mycelium in the wood lives from year to year and produces these yellow sporophores annually. The young sporophores, collected before the shelves are fully matured, are among the best of the edible fungi.


FIG. 49. — Fruiting-bodies of *Polyporus sulphureus* on an oak.

Cause.

Brown checked wood-rot is caused by the fungus known as *Polyporus sulphureus*. The spores from the tubes on the under surface of the sporophores are wind-blown and infect the exposed heartwood at branch wounds. Certain deposits left by the mycelium of the fungus cause the reddish brown discoloration. For further details concerning the life history and control of the wood-rot fungi, see page 64.

References on Brown Checked Wood-Rot

Schrenk, Hermann von, and Spaulding, P. Red heart-rot caused by Polyporus sulphureus. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149 : 37–39. 1909.
Schrenk, Hermann von. Polyporus sulphureus (Bull.) Fr. *In* Some diseases of New England conifers. U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 25 : 40–44. 1900.
Atkinson, G. F. Polyporus sulphureus. *In* Studies of some shade tree and timber destroying fungi. Cornell Univ. Agr. Exp. Sta. Bul. 193 : 208–214, figs. 64–70. 1901.
Hartig, R. Polyporus sulphureus Fr. *In* Die Zersetzungserscheinungen des Holzes etc., pp. 109–113, pl. 14. 1878.

Common White Wood-Rot

Caused by *Fomes igniarius* Fries

Oaks, especially those species belonging to the black oak group, often are found with the heartwood reduced to a white punk. Beech and poplars, especially the aspen and balm of Gilead, are the most destructively and commonly affected of the various kinds of deciduous trees attacked by this fungus. In Europe this is the most important of the wood-rots of the oak in the forest. In the United States, the brown checked wood-rot of oak seems to be more destructive. This is especially true outside the forest, where shade and ornamental oaks are concerned. The sapwood of oak is more commonly invaded than is the sapwood of the other trees affected, resulting in stag-head and dead limbs. The sporophores and nature of the rot which are similar for all kinds of trees are described under poplar diseases, on page 305.

White Pocket Heartwood-Rot

Caused by *Polyporus Rheades* Fries (= *Polyporus dryophilus* Berkeley)

The heartwood of many species of oaks and sometimes of poplars is destroyed by this disease. Although found in oaks practically over the entire United States, this rot is particu-

The under surface is brown as is the inside structure, including the granular core.

Cause.

The white pocketed rot of oaks and poplars is caused by the fungus *Polyporus Rheades* which is also known by the name *P. dryophilus*. The sporophores described above are annual. The rot may be confined largely to the branches and upper part of the trunk or the tree may be rotted from the base to top. Infection occurs most commonly in broken branches, from which the mycelium extends down into the trunk. When infection takes place through dead side branches or at the base of the tree, through fire scars, the rot may extend the entire length of the trunk. For fuller details concerning the life history of wood-rot fungi and the nature of the decay caused by them, see page 64.

References

Hedgcock, G. G., and Long, W. H. Heart-rot of oaks and poplars caused by Polyporus dryophilus. Jour. Agr. Res. 3: 65–80, pls. 8–10. 1914.

Schrenk, Hermann von, and Spaulding, P. Piped-rot of oak and chestnut. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 39–40, pl. 5. 1909. (Note: The piped-rot of oak described is due to *P. Rheades* and that of chestnut to *P. croceus*.)

Hartig, R. Polyporus dryadeus Fr. *In* Die Zersetzungserscheinungen des Holzes etc., pp. 125–128, pl. 17. 1878. (This is a discussion of the rot due to *P. Rheades* and not *P. dryadeus*.)

String and Ray Butt-Rot

Caused by *Polyporus Berkeleyi* Fries

This heartwood-rot of the base of oak trees is found throughout eastern and central United States. It is not known to be as common or destructive as several of the other wood-rots of oaks. Mature and over-mature trees are affected. It is never found in the tops of trees but is limited to the base of the trunk and the larger roots. The decay extends from the surface of the ground upward in the heartwood for a distance of one to a few feet and in its final stages leaves a large hollow cavity.

Symptoms.

When badly rotted trees are cut, they fall after the thin shell of heartwood is cut through and the trunk carries with it the partially rotted hollow cylinder of wood from the stump. The odor of the freshly cut rotted wood is very strong and resembles anise oil. The first indication of the decay is seen in longitudinal section as a yellowish or whitish area from four to eight

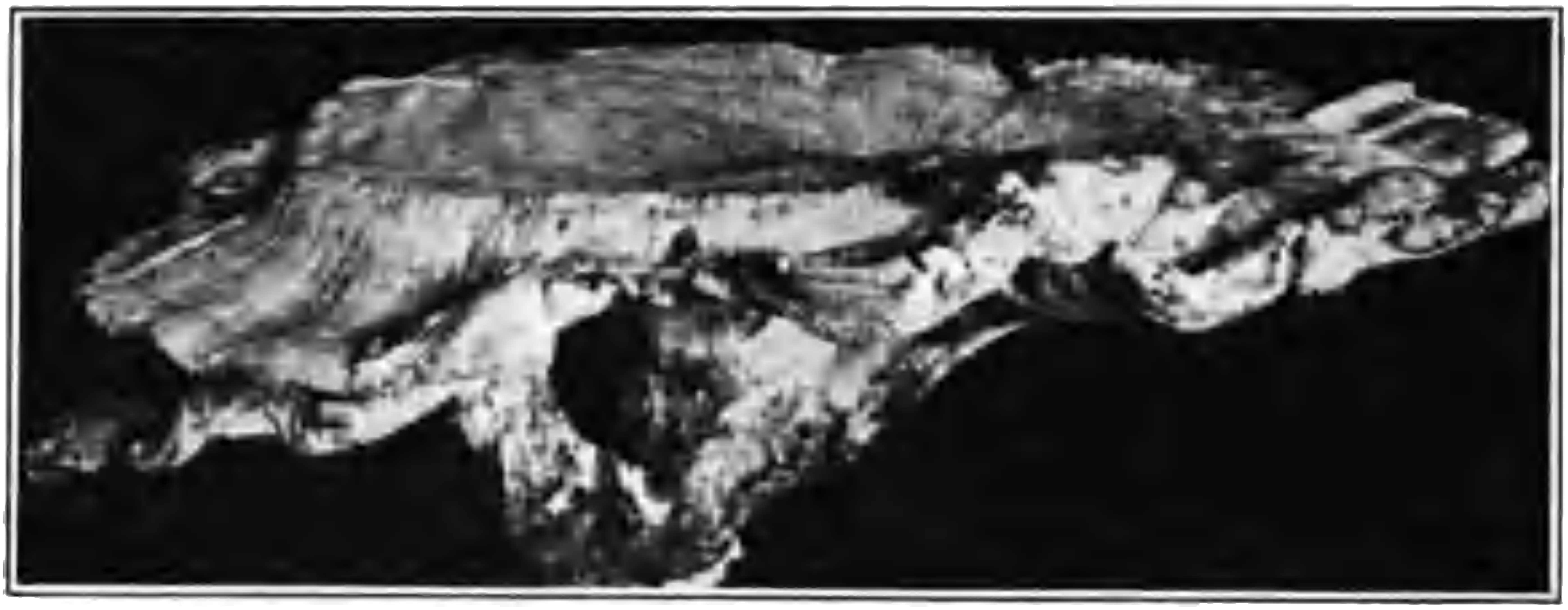

FIG. 50. — Fruiting-body of *Polyporus Berkeleyi.*

inches long. The summer-wood in this region is delignified and the individual fibers are separated by the dissolving of the cementing layer between them. As the decay progresses the dense whitish summer-wood is completely destroyed. This leaves the medullary-rays and strands of porous spring-wood intact. The interwoven rays and strings of wood are brownish at first but soon are covered with whitish mycelium. The strands slowly become more brittle and finally collapse, leaving a hollow cavity. The decayed area becomes larger and is bordered by a zone of whitish wood with the string and ray rot stage projecting into the hollow cavity.

The sporophores arise from the exposed larger roots or may appear to come from the soil near the base of the tree. In all cases, however, they will be found attached by mycelial strands to the roots. The sporophores are usually large and may occur as two to five overlapping shelves or as a single more or less circular, expanded, toadstool-like body supported on a thick stalk (Fig. 50). The center of the upper surface is depressed where it is attached to the stalk. The upper surface is white or yellowish, while the under surface is whitish and covered with large angular honeycomb-like pores.

Cause.

The string and ray butt-rot of oaks is caused by *Polyporus Berkeleyi*. The spores are borne around the inner surfaces of the angular pores of the sporophores. Infection takes place in wounds at the base of the tree, such as fire-scars. The life history and control of wood-rotting fungi are discussed more fully on page 64.

Reference

Long, W. H. Three undescribed heart-rots of hardwood trees, especially of oak. Jour. Agr. Res. 1: 109–128, pls. 7–8. 1913.

Wet Heartwood-Rot

Caused by *Hydnum erinaceus* Fries

Oak and other deciduous trees are affected by this wet heartwood-rot. White and red oaks are most commonly affected. The disease is common in central United States and is sometimes found in other parts of the country.

Symptoms.

In the early stages of this decay, the wood becomes lighter in color and the woody tissue between the medullary-rays is destroyed. Later the entire structure of the wood disappears and there remains only a white soggy mass. Large cavities

discolored region and develop into white pockets. They are located partially in the porous spring-wood of one ring and in the summer-wood of the adjoining ring. Later the pockets become hollow and have a white lining. They become larger in time until finally limited by reaching a large medullary-ray on each side. Only a narrow layer of brownish wood separates the adjoining pockets. In longitudinal sections, the pockets are seen to be from three to five times as long as wide. The discolored area extends from one to six feet beyond the region showing the pockets. In the first stages of the decay, this rot closely resembles the white piped butt-rot caused by *Polyporus croceus* (see page 258). The latter rot usually extends its activities more rapidly upward than radially, causing the decay of a few annual rings, while the honeycomb-rot in white oak, at least, spreads uniformly in both directions. Freshly cut wood affected by this rot is said to have the odor of old honeycomb.

The sporophores are rarely available to identify this rot in living trees, except when a large area of the affected heartwood is exposed. Sporophores develop on the felled timber in a year or two and continue to form for several years. They are from a quarter of an inch to two inches wide, rather thick shelving bodies occurring one over the other in long rows. The upper surface is at first downy and light yellowish brown, later becoming smooth and gray. Concentric furrows mark the upper surface into zones which vary in color. The under surface is light yellowish brown and smooth.

Cause.

The honeycomb heartwood-rot of oaks is caused by the fungus, *Stereum subpileatum*. The fruiting-bodies described above are annual structures which become dry and persist through the winter and may revive the following season. The spores are borne over the entire smooth under surface of the shelves. The fungus finds entrance into the tree where heartwood is exposed at fire-scars, branch wounds and the like. While usually found in the base of the trees, it sometimes occurs in the tops. The sapwood of the living tree is not affected, but when the tree is felled the mycelium grows into the sapwood and causes a similar decay.

Control.

In the forest this rot can be controlled by preventing fires, which are responsible for the scars that furnish a ready entrance point for infection. Likewise it is essential to remove or burn dead and diseased oaks that are standing, as well as cull logs, for on these the sporophores will continue to form for several years. These measures will also keep several of the other butt-rots and heartwood-rots of oaks under control.

Reference

Long, W. H. A honeycomb heart-rot of oaks caused by Stereum subpileatum. Jour. Agr. Res. 5: 421–428, pl. 41. 1915.

Soft Heartwood-Rot

Caused by *Polyporus obtusus* Berkeley

Black oaks in eastern and central United States are affected by this heartwood-rot. Several trees are usually found affected in a group where the disease occurs.

Symptoms.

The affected heartwood is lighter in color than the normal wood and finally becomes almost white. The wood does not check and retains its normal fibrous character. It, however, is weak and breaks easily. The rot progresses rapidly and the trunks are weakened so that they snap off during wind-storms.

The fruiting-bodies appear annually on the side of the trunk. They are more or less hoof-shaped and at first white and spongy.

Later they become yellowish or brown. The upper surface and the rounded edge and outer margin of the lower surface are hairy. The remainder of the under surface is covered with roundish or sinuous pores, the edges of which are irregular, making the under surface rough.

Cause.

The soft heartwood-rot of black oaks is caused by *Polyporus obtusus*. The spores borne within the tubes on the under sides of the fruiting-bodies are blown about by the wind. Infection usually takes place by the spores entering the tunnels made in the wood by the insect, *Prionoxystus robiniæ*. From the tunnels the mycelium spreads upward and downward in the wood. The fruiting-bodies are usually produced at the insect burrow where infection occurred. For further details concerning the life history and control of wood-rot fungi, see page 64.

References

Spaulding, P. A disease of black oaks caused by Polyporus obtusus Berk. Missouri Bot. Garden Rept. **16**: 109–116, pls. 13–19. 1905.

Schrenk, Hermann von, and Spaulding, P. Soft rot of oaks caused by Polyporus obtusus. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 41–42, fig. 5. 1909.

White Piped Butt-Rot

Caused by *Polyporus croceus* Fries (= *P. Pilotæ* Schw.)

This wood-rot is found in oak and chestnut. The wood of the roots and base of the trunk is most commonly affected, although when dead branches are common it may be found in the upper part of the trunk. It has proved destructive in Arkansas, Virginia and New York and probably is generally distributed throughout eastern and central United States. The decayed wood is at first filled with white areas which en-

of the shelves of the fruiting-body cause infection in wounds at the base of the tree. The life history and control of the wood-rot fungi will be found discussed on page 64.

Reference

Long, W. H. Three undescribed heart-rots of hardwood trees, especially of oak. Jour. Agr. Res. 1: 109–128, pls. 7–8. 1913.

White Wood-Rot

Caused by *Fomes Everhartii* (Ellis and Gall.) Schrenk

This wood-rot has been found common in black jack oak and probably occurs in other species. It has not been fully described. It is said to resemble closely the common white wood-rot caused by *Fomes igniarius*. The rot extends into the sapwood. The sporophores of the causal fungus also resemble those of *Fomes igniarius*. They are shelf-like and rarely hoof-shaped. The upper surface is at first brown, but later becomes black and checked by many fissures. The under surface and margin are brown. The pores in the under surface are very small.

Reference

Schrenk, Hermann von, and Spaulding, P. Heart-rot of oaks caused by Fomes Everhartii. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 48, pl. 3. 1909.

White Butt-Rot

Caused by *Fomes applanatus* Fries

The heartwood of the lower part of the trunk and roots of oak is sometimes destroyed by this rot. The wood becomes whitish and light in weight but retains its fibrous structure. The rotted wood when split shows numerous sinuous white-stuffed tunnels resembling the work of insects. The sporophores of the causal fungus are often found at wounds near the base of the trunk. The form on oak is usually thick, with a dark gray, rough upper surface, an acute margin and a slightly roughened, white under surface. This heartwood-rot is more fully described under poplar diseases, on page 310.

White Root-Rot

Caused by *Polyporus dryadeus* Fries

Many species of oaks are affected by a white root-rot which occurs apparently throughout the range of the oaks in the United States and Europe. Although not as important as many of the other wood- and root-rotting fungi, oaks growing under adverse conditions are often found affected. The ultimate result of the attack is the death of the tree or it may be uprooted during wind-storms.

Symptoms.

The first indication of the rot is a reddish or brownish coloration of the inner bark-tissues. The adjacent sapwood then becomes reddish brown and watery. The discoloration advances into the wood and the color of the decayed areas changes to white. The bark becomes loosened and shreds into strips. The rot finally involves the larger roots and extends into the butt of the tree but does not progress above the surface of the ground. The smaller roots are completely decayed and look like pith. They are light in weight and when twisted break into concentric layers. Older partially decayed roots, in longitudinal section, show the white or cream-colored rotted bark and wood bounded by a dark brownish zone one to three inches wide which marks the progressing area of change from normal wood to white punk. The radial and longitudinal whitish bands appearing in the affected wood are due to the mycelium of the fungus which is aggregated in the porous regions of the annual rings. White patches of mycelium appear on the surface of the outer bark of affected roots. The largest roots may be rotted to the center and the decayed wood is finally spongy and easily crushed.

The sporophores of the causal fungus form on exposed roots when the tree is blown over or at the very base of the trunk, arising at the surface of the ground. They are large, irregularly shaped masses of a corky or woody texture (Fig. 51). When developing, they are watery, and large drops of water

Fig. 51. — Fruiting-body of *Polyporus dryadeus*.

often form on the outer growing margin. These drops leave depressions in the surface. The upper surface is uneven and light brown, changing with age to darker brown and black. The under part is oblique to the surface of the ground in the thicker forms and more or less horizontal in the thinner forms. The pores in the under surface are soon stuffed with mycelium, making them invisible. The outer margin of the sporophore is thick and rounded. Insects soon destroy the under surface and outer margin but the

CHAPTER XXVII

PINE DISEASES

Over thirty species of pine (Pinus) occur as forest-trees in the United States. No region of the country where trees grow is without representatives of this important group. A large part of the timber of the country is made from pines. The various native pines and many exotic species and varieties are used for ornamentals.

Pine is subject to many destructive diseases wherever it grows. The most important of these are root-rots, wood-rots, blister-rusts, mistletoe injury, leaf-cast and various types of winter-injury. The importance of these types of diseases varies with the species and region of the country in question. Pecky wood-rot and the different blister-rusts of the branches and trunks probably cause the most damage. The white pine of the northeastern states was reasonably free from important diseases until the introduction from Europe of the blister-rust fungus. Pines outside of the forest often suffer severely from winter-drying and other types of injury due to extremes in temperature.

Seedling Root-Rot

Caused by *Rhizina undulata* Fries

The seedlings of several species of pines in the forests of northwestern United States are killed by this root-rot. The fungus is also present in several eastern states and may cause similar damage. The roots of seedlings three to six years old are killed. Examination shows the roots and a quantity of soil to be matted together by white mycelium. Brown fruiting-bodies are formed on the surface of the soil around diseased trees. This fungus is more fully discussed under hemlock diseases, page 177.

Leaf Blister-Rusts

Caused by fungi of the genus Coleosporium

Several species of the genus Coleosporium grow in the needles of pines, occasionally causing defoliation. These rust-fungi require, in addition to the pine, some other kind of plant on which to continue their life history. Such an alternation of hosts is not uncommon in the rust-fungi. In the case of the Coleosporium leaf-rusts of pine, æciospores are produced in the yellow blisters pushed out from the pine needles. These spores cannot reinfect the pine, but they may cause infection of the leaves of certain near-by flowering plants. Here the development of the fungus is continued and urediniospores are formed. The urediniospores infect other plants of the same kind and by a succession of several generations of these spores the rust may become prevalent during the summer for a considerable distance away from the pine which developed the æciospores. In the autumn a brown layer of another type of spores (teliospores) is formed on the plants which produced the urediniospores. The teliospores germinate while they are still attached to the host and minute basidiospores are formed. These spores are short-lived and are blown about by the wind. If they come into contact with the needles of the proper species of pine, they may initiate a new infection. Thus the seasonal life history of the fungus is completed.

By eliminating the flowering plant, which must be present for the fungus to complete its development, the rust is incapable of existing. The minimum distance for the successful interchange of spores between the pine and the alternate host is variable. Control is sometimes accomplished when all the flowering plant hosts are removed, so that none exists within a thousand feet of the pines. A safer distance would be a quarter or a half mile, depending on the contour of the land and the nature of the surrounding vegetation. The elimination of all the plants of the kind required by the blister-rust fungi is not easily accomplished. Nevertheless, it is an efficient and sure method of control, if the eradication is thoroughly done. For a further discussion of the factors involved in carrying out eradication methods, see under blister-rust of five-needle pines, page 274.

Many of the species of Coleosporium that are known in the uredinial and telial stages on various weed plants have not been connected with the blister-rust stage on pine needles. Either this has not been found and described, or the relation between the stages on the pine and weed host has not been definitely proved to represent the life history of a single species. When all the stages are known, the fungus is called by its Coleosporium name. When only the blister-rust stage is known on the pines, it is classified in the large form genus Peridermium and is given a temporary specific name.

Below are given brief descriptions of the blister-rusts of the needles of pines, with their distribution, the species of pine affected and the alternate weed hosts, so far as these facts are known. In most cases these blister-rusts cannot be identified except by microscopic examination.

An inconspicuous blister-rust is known to occur in Maryland on scrub pine. The name of the causal fungus is *Coleosporium inconspicuum* (Long) Hedgcock and Long. The alternate weed-hosts on which its life history is completed are the tickseeds (*Coreopsis verticillata* and *C. major*).

Scotch pine needles are affected by *Coleosporium sonchi-arvensis* (Persoon) Lev. This disease has been reported only from Wisconsin. The fungus was imported from Europe. The yellow blisters are small, being about one-sixteenth of an

nate weed hosts are found throughout the country. This rust is similar to several other blister-rusts which affect the pitch pine. The yellow pustules project above the surface of the needles from one thirty-second to one-sixteenth of an inch. The alternate weed hosts are species of goldenrod and wild aster. The rust is able to maintain itself on these weeds without the presence of the pitch pine, by the wintering-over of the urediniospores which reinfect the goldenrod and aster.

A prominent leaf blister-rust of pitch pine is caused by *Coleosporium campanulæ* (Persoon) Lev. and is known from New Jersey and central Indiana southward to central North Carolina. It differs from the other blister-rusts of pitch pine in that the yellow pustules on the needles are much larger and tongue-shaped. They are from one-sixteenth to one-eighth of an inch long and project above the surface about one-sixteenth of an inch. The alternate weed host is the tall bellflower (*Campanula americana*).

Another blister-rust of pitch and Norway pine is caused by *Coleosporium delicatulum* (Arthur and Kern) Hedgcock and Long. It is found along the Atlantic coast from Massachusetts to Florida. It may have a much wider range than this, since its alternate stages on the weed host, species of Euthamia, have been found from Maine to Kansas and southward to West Virginia and Texas. The leaves of the pines show in the spring very small yellow blisters, from one thirty-second to one-fourth inch long and scarcely protruding above the epidermis of the needle.

Short-leaf, long-leaf, pitch and loblolly pine are affected by a needle blister-rust in central eastern and southeastern United States, caused by *Coleosporium ipomϾ* (Schw.) Burrill. The pustules on the pine needles are flattened, narrow and about one-sixteenth of an inch long. The life history is completed on many species of morning-glory (Ipomœa).

Short-leaf and loblolly pines in Georgia and North Carolina have been affected by a needle blister-rust caused by *Coleosporium terebinthinaceæ* (Schw.) Arthur. The pustules are tongue-shaped and project about one-sixteenth of an inch from the needles. The life history of this fungus is completed on rosin-weed (species of Silphium).

The needles of scrub and probably of short-leaf pine from Pennsylvania to Illinois and southward are attacked by *Coleosporium helianthi* (Schw.) Arthur. The blisters are tongue-shaped and project from the leaf about one-sixteenth of an inch. The life history of the fungus is completed on sun-flower (Helianthus).

The needles of long-leaf, loblolly and pitch pine are attacked by *Peridermium fragile* Hedgcock and Hunt. The blisters are narrow and inconspicuous. The alternate host for the completion of the life history of this fungus is not known.

In Florida the needles of loblolly and spruce pine are attacked by *Peridermium minutum* Hedgcock and Hunt. The blisters are low and a little narrower than long. The alternate host for the completion of the life history of this rust is unknown.

The needles of piñon are attacked by *Coleosporium ribicola* (C. and E.) Arthur, practically throughout the range of this species in Colorado, New Mexico and Wyoming. The blisters appear on the pine needles while snow is still present. The alternate hosts of this fungus are species of currant and gooseberry (Ribes). The pustules on the currant and gooseberry leaves are larger and more prominent than the felt-rust (see page 274).

References

Arthur, J. C., and Kern, F. D. North American species of Peridermium. Bul. Torrey Bot. Club, 33: 403–438. 1906.

Arthur, J. C., and Kern, F. D. North American species of Peridermium on pine. Mycologia 6: 109–138. 1914.

Hedgcock, G. G., and Hunt, N. Rex. New species of Peridermium. Mycologia 9: 239–242. 1917.

Hedgcock, G. G. Notes on some western Uredineæ which attack forest trees. Mycologia 4: 141–147. 1912.

Leaf-Rust

Caused by *Gallowaya pini* (Galloway) Arthur

The leaves of scrub pine are commonly affected by this rust throughout its range in central eastern United States. This disease differs from the blister-rusts of pine needles in the teliospores being borne on the pine and no alternate host being required (see page 265). Yellow spots occur near the tips of the leaves. On these spots are formed linear, reddish orange pustules which burst through the epidermis. These pustules may be a half inch long. The bright color soon fades and they are inconspicuous. The teliospores germinate in the spring, producing basidiospores which infect other scrub pine needles.

Leaf-Cast of White Pine

Caused by *Hypoderma strobicola* Tubeuf

White pine is sometimes injured in eastern United States by this leaf-cast. Pitch pine and hemlock are reported to be affected by the same disease. The affected needles at first show yellowish spots and later turn reddish yellow and brown. The tissues of the twig may also be killed. Later in the season several small elliptical black fruiting-bodies appear on the outer surface of the needles. The fruiting-bodies are mature the following spring. They split open and the spores are shot into the air during prolonged rain periods. For further details concerning the leaf-cast diseases, see page 38.

References

Graves, A. H. Leaf blight. Lophodermium brachysporum Rostrup. *In* Notes on diseases of trees in the southern Appalachians 1. Phytopathology **3**: 133–139, figs. 5–10. 1913.

Spaulding, P. The present status of the white-pine blights. U. S. Dept. Agr. Bur. Pl. Ind. Circ. 35: 1–12. 1909.

Twig-Blight

Caused by *Cenangium ferruginosum* Fries

This disease is reported as common and destructive in Europe on Scotch, Austrian and white pines and on European silver fir. In this country very little mention of it has been made. It is reported on white pine in Ohio and the causal fungus has been found on long-leaf, western yellow and Monterey pine. On these latter trees the fungus was not shown to be parasitic. Mature trees are more often affected than younger ones and the disease is unknown on trees less than five years old. In Europe this disease is said to occur in epiphytotics which sweep over large forest areas.

Symptoms.

The terminal buds of affected twigs die in the spring. Later the older needles turn red and die from the base to the tip. The dead needles fall and leave the twigs bare.

Small fruiting-bodies are formed on the dead twigs and branches. In wet weather the fruiting-bodies open and are cup-shaped, measuring about one-eighth of an inch across. During dry weather they close and are more or less globose. In this condition they are dusty brown or black but when they are open the inner surface of the cup is yellowish or dirty greenish yellow.

Cause.

This twig-blight of pine is supposed to be caused by the fungus *Cenangium ferruginosum.* Asci containing ascospores are borne on the yellowish inner surface of the fruiting-bodies. The ascospores are forcibly ejected and borne by the wind for long distances. Other types of fruiting-bodies, resembling those described above, are also formed which produce simple spores. These, however, are not known to play any important part in the life history of the fungus. There is some question whether this fungus is primarily responsible for this disease.

It seems more probable that winter-drying and other types of winter-injury may account for the injury and that the fungus is secondary and only semi-parasitic.

Control.

The only measure of control known is to prune off the dead twigs and burn these, together with all other brush and refuse from coniferous trees that may be in the vicinity.

References

Fink, Bruce. Injury to Pinus strobus caused by Cenangium abietis. Phytopathology 1: 180–183, pl. 26. 1911.
Schwarz, Frank. Die Erkrankung der Kiefern durch Cenangium Abietis, pp. 1–126, pls. 1–2: 1895.

Mistletoe Burls and Witches'-Brooms

Caused by *Razoumofskya campylopoda* (Englem.) Piper, and *R. americana* (Nutt.) Kuntze

Western yellow and lodge-pole pine are affected respectively by these two dwarf mistletoe parasites. In northwestern United States much damage results from the diseased condition they cause. The general result of burl and witches'-broom formation is a reduction in foliage which causes slow growth and finally death when infection is heavy. Likewise, the diseased areas of bark offer ready places of entrance for insects and wood-rotting fungi. Trees of all ages are affected. Trees with the lower branches or trunk affected early in life suffer more severely than those infected later. The brooming of the lower branches diverts a large part of the growth energy of the tree and the tops are dwarfed and die, causing stag-headed or spike-topped trees.

Symptoms.

The roots from the germinating mistletoe seeds enter the leafy twigs or through wounds in the bark of older branches.

Swellings of the limb are first formed and later many abnormal branches are sent out and ragged broom-like growths are produced. Burls at the base of the branches and on the side of the trunk also develop where the roots of the parasite find a foothold. The mistletoe plant may die but the stimulus still continues to cause the abnormal growth. The brooms may become so heavy when burdened with ice and snow that the limb breaks. The needles of the old brooms are usually smaller and shorter-lived than on healthy branches. For a general discussion of the mistletoe diseases of trees, see page 54.

Reference

Weir, J. R. Mistletoe injury to conifers in the northwest. U. S. Dept. Agr. Bul. 360: 1–38, pls. 1–4, figs. 1–27. 1916.

Blister-Rust of Five-Needle Pines

Caused by *Cronartium ribicola* Fischer de Waldheim

The fungus causing the blister-rust of five-needle pines is native in Europe. With the extensive use of the American white pine in western Europe for forest-planting, it became widely distributed on this tree and was soon recognized as an important enemy of the white pine. As early as 1890 and 1900, it was prevalent in all the countries of western and northern Europe and was known in Siberia and Japan. The fungus is supposed to have been originally confined to the Swiss stone pine of Europe, which is not very seriously affected by it. In Germany, France, England and other countries of western Europe the blister-rust soon became so prevalent and destructive that the further use of the American white pine in reforestation was largely abandoned. Previous to this time large numbers of white pine were grown in the forest nurseries, and this disease was found to affect seriously a large percentage of the trees in some regions.

rant or gooseberry bushes in order to continue the cycle of development. Spores are then produced throughout the summer on these plants which cause the infection of other gooseberries and currants. In the autumn another type of spores (teliospores) is developed on the affected currants and gooseberries and from these are formed basidiospores which cause the infection of the young branches of five-needled pines. The distribution of this fungus on the pines, therefore, is dependent on the presence or absence of gooseberries and currants, and if present the amount of damage done is somewhat dependent on their abundance. Unfortunately several species of these plants occur as common weeds practically throughout the range of the five-needle pines in the United States.

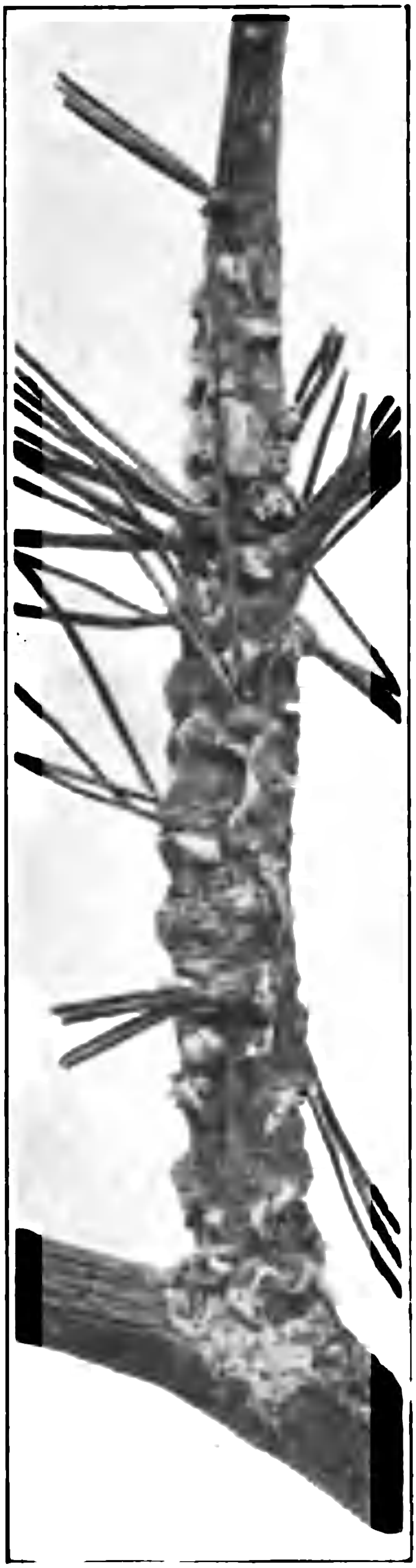

FIG. 52. — Blister-rust on twig of white pine.

Symptoms.

The young leaf-bearing twigs are infected and the mycelium grows in the bark and may extend into the larger branches and trunks. The affected bark is usually swollen, but the tissue remains normal and healthy in appearance for two or three years. In the second or third spring after infection occurs, the prominent fruiting-pustules of the fungus appear on the bark (Figs. 52 and 53). These blister-like pustules are irregularly hemispherical or elongate, one-eighth to one-half inch across and orange-colored.

The covering of the blisters breaks and a fine yellow powder of thousands of spores dusts out and is blown away by the wind. The blister stage on the pine is formed in early spring and by midsummer the white coverings of the blisters disappear and only rounded depressions remain in the bark to mark their location. The area of bark from which the blisters are produced usually dies but the mycelium extends into the surrounding healthy bark. The yellow blisters are produced year after year from the newly invaded bark until on older trees cankers several feet long are sometimes formed. Usually the branch or trunk is soon girdled and the parts of the tree beyond the girdled point die. The fungus cannot exist except in living tissue and, therefore, is not harbored after the affected part of the tree is killed. Young trees with the trunk affected show a stunted and compact growth and a slight yellowish color instead of the normal green.

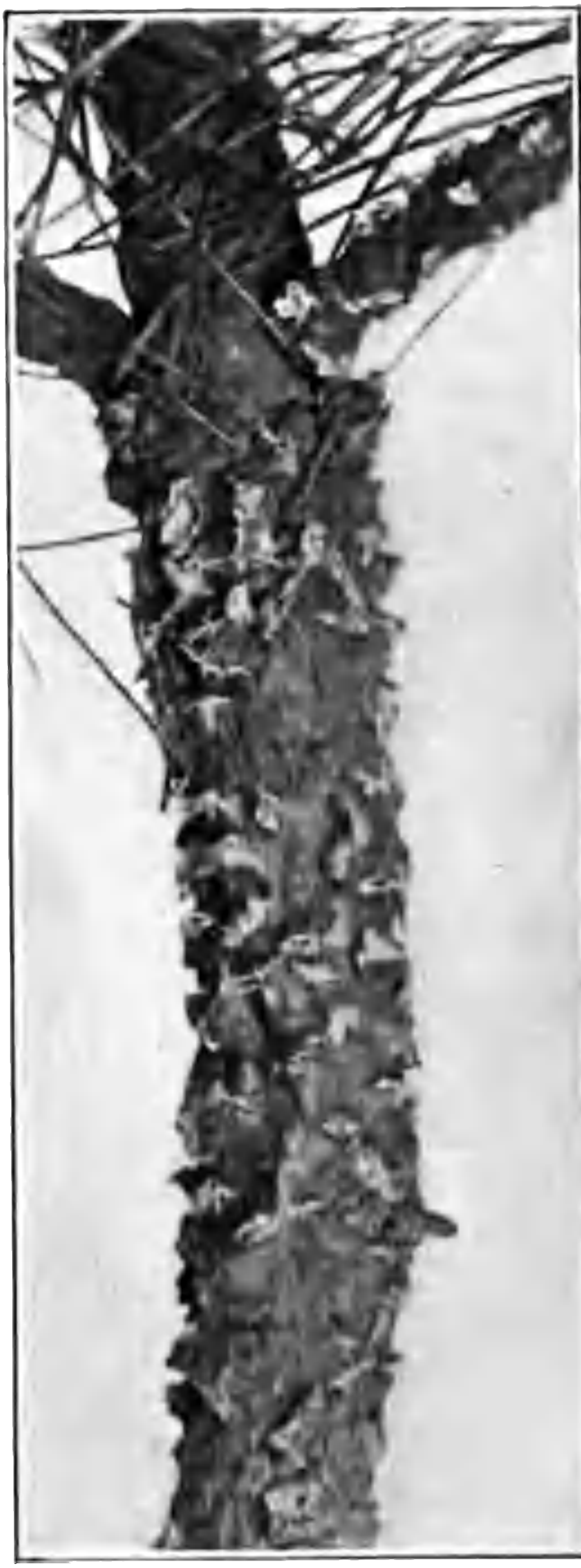

FIG. 53. — Blister-rust on trunk of young white pine.

Infected currant and gooseberry leaves show slightly yellowish spots which are more distinct on the under surface. Small yellowish blisters are pushed out from the lower epidermis and when the covering is broken, a rounded mass of yellow spores (urediniospores) is exposed (Fig. 54). Later in the

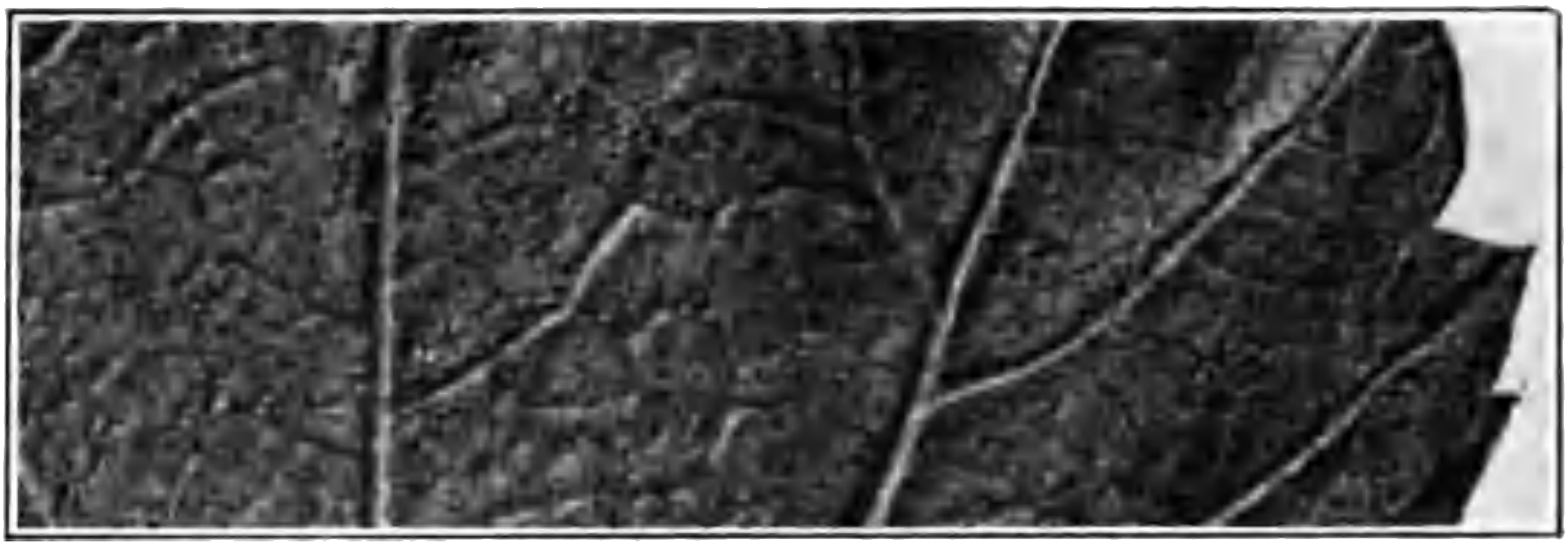

Fig. 54. — *Cronartium ribicola* (uredinial stage) on under side of currant leaf.

season, from the same lesions several slender brown bristle-like structures are pushed out from the under sides of the leaves (Fig. 55). When the affected areas of the leaf are numerous, these brown bristles so completely cover the under side of the leaf that it appears as coarse brown felt, and thus the common name for this disease on currants and gooseberries is felt-rust. But little damage is caused to the affected bushes, although defoliation may occur earlier than normally when the leaves are heavily infested. The species of currant and gooseberry vary

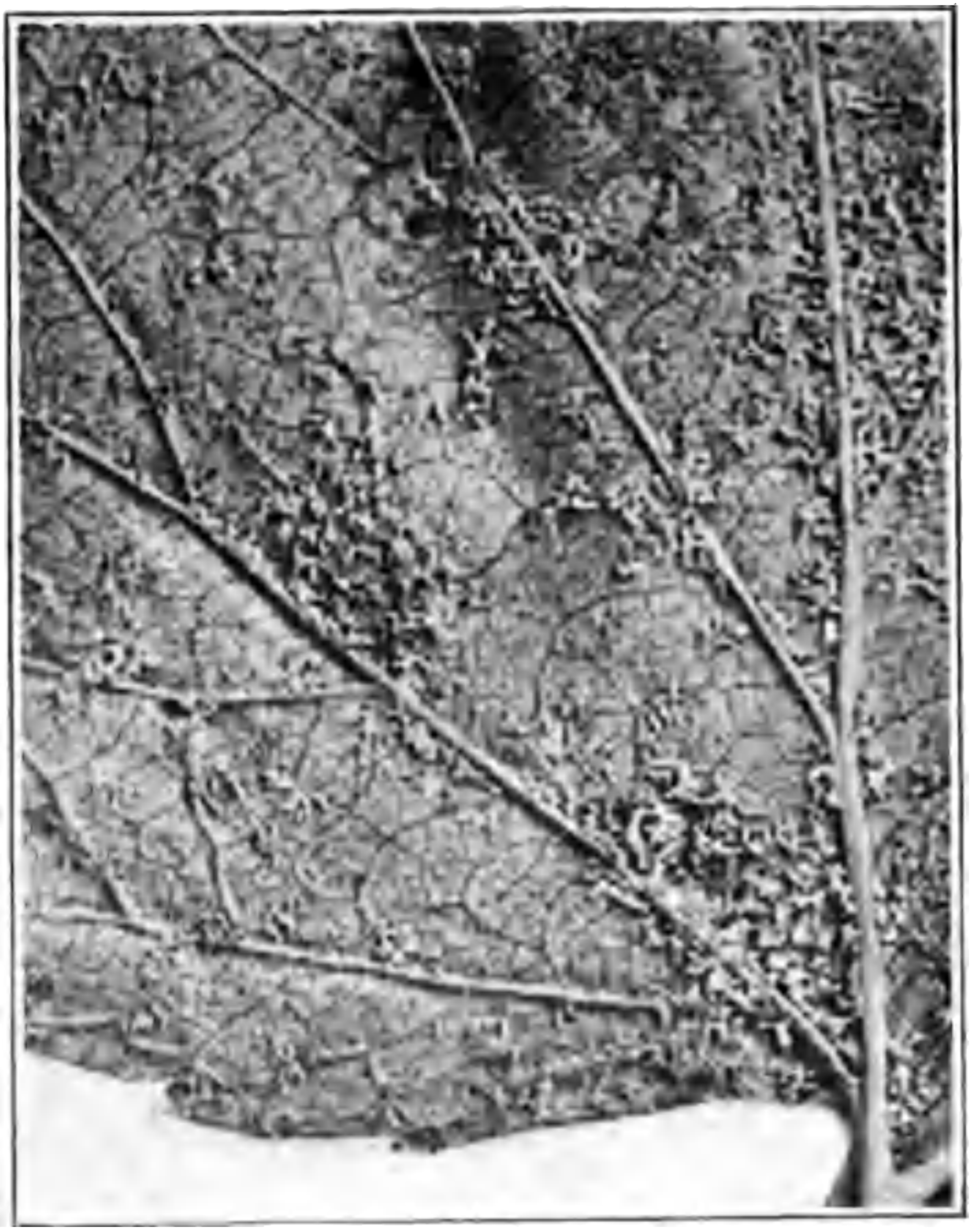

Fig. 55. — *Cronartium ribicola* (telial stage) on under side of currant leaf. Felt-rust.

expected to spread as rapidly in a given season as it would in more open country.

Control.

Although repeated attempts had been made since 1896 to secure a federal law which would prevent the entry of foreign stock likely to harbor and introduce dangerous fungi and insects, such a law was not enacted until 1912. The blister-rust fungus had by that time become established in various localities in northeastern United States. The extermination of the fungus was attempted where it was known. In New York all the known areas where foreign white pine stock was planted were inspected yearly. The diseased trees and all currant and gooseberry bushes within five hundred feet of them were destroyed. When the fungus was found prevalent in western Massachusetts in the fall of 1915, more extensive surveys were planned for 1916 and as the result, the fungus was found to be generally prevalent throughout the territory east of the Hudson River and Lake Champlain. In 1917 it was found practically throughout New York state. Despite the previous attempts at its eradication in isolated areas and any efforts that may be made at general control in the future, the fungus is now so well established in this country that it will continue to spread and exist wherever conditions are favorable.

In certain regions in which the white and other five-needle pines are important as ornamentals, the native wild species of gooseberry and currant are very scarce. Such conditions exist in the lower Hudson River valley and on Long Island. In these regions this disease could easily be controlled if the cultivated garden varieties of gooseberry and currant were eliminated. However, when one neighbor grows one of these plants and the next has five-needle pines to protect, no generally satisfactory agreement will be reached in most cases. The elimination of currants and gooseberries for a distance of one-half mile from the pines will probably control this rust. If this distance is not possible, a separation of five hundred feet or more will be partially beneficial.

In forested areas where wild currants and gooseberries are common, the further growing of white pine may have to be abandoned. The elimination of the bushes over extensive areas will probably never prove as profitable as planting or encouraging natural reproduction of some other species of tree suited to the conditions. Where currants and gooseberries are not very abundant and the experiment of eliminating them is thought practicable, results may be obtained if the work is vigorously prosecuted year after year. The total cost and the possibilities of failure must influence the planning of this kind of control when timber values alone are to be considered.

References

Spaulding, P. The blister rust of white pine. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 206: 1–88, pls. 1–2, figs. 1–5. 1911. (Bibliography given.)

Spaulding, P. The white-pine blister rust. U. S. Dept. Agr. Farmers' Bul. 742: 1–15, pl. 1, figs. 1–5. 1916.

Spaulding, P. New facts concerning the white-pine blister rust. U. S. Dept. Agr. Bul. 116: 1–8. 1914.

Spaulding, P. Foresters have a vital interest in the white-pine blister rust. Proc. Soc. Am. For. 11: 40–47. 1916.

Atwood, G. G. Emergency bulletin on the blister rust of pines and the European currant rust. New York Dept. Agr. Hort. Bul. 2: 1–15, pls. 1–2. 1909.

Paul, B. H. The pine blister. New York Conservation Com. Bul. 15: 1–18, figs. 1–8, map. 1. 1916.

Sweet-fern Rust

Caused by *Cronartium comptoniæ* Arthur

This rust disease occurs on two- and three-needle pines in eastern United States and is commonly known as blister-rust. It is found on the native pitch, scrub, loblolly, western yellow, jack, lodge-pole, Jeffrey, Norway and short-leaf pines and on the imported Scotch, Austrian and mugho pines. Only very young trees are generally affected and it is most important as a nursery and young plantation disease. It is known to have caused the death of a large number of the susceptible pines in certain nurseries in Massachusetts, Connecticut, New York and Michigan. The common weeds, sweet-fern (*Comptonia asplenifolia*) or sweet-gale (*Myrica Gale*) must be in the vicinity of the pines for this fungus to complete its life history. If this plant is not present, the unaffected trees will not be endangered by the diseased pines.

Symptoms.

This rust produces symptoms on two- and three-needle pines very similar to the blister-rust which occurs on five-needle pines (see page 276). Small branches and the trunks of young trees are affected. Slight enlargements are usually formed. On these swollen areas yellowish blisters are pushed out in early spring. The arched covering breaks and the orange-colored spore-mass inside dusts out as a fine powder and is blown away.

On the sweet-fern and sweet-gale (*Comptonia asplenifolia and Myrica Gale*), small yellowish pustules are formed on the under sides of the leaves in summer, followed later by brown bristles which project from the same spots. These structures are similar to those formed on gooseberry and currant leaves affected with felt-rust (see page 277).

Cause.

The sweet-fern rust of two- and three-needle pines is caused by the fungus *Cronartium comptoniæ* (=*Peridermium comptoniæ* Orton and Adams), a close relative of the blister-rust fungus on white pine. The life history and control of this rust-fungus is similar to the white pine blister-rust except that it has

duced which may be several inches long except in very young trees where no swellings are noticeable. The trunk may become infected by the fungus extending into it from infected branches. The fruiting-bodies appear on the affected bark in early spring. They are yellowish blisters, usually about a quarter of an inch or smaller in diameter and may be longer than broad. The covering of the blister breaks and the spores are blown away as a fine orange-colored powder.

The spores from the yellow blisters infect the leaves and younger stems of species of Comandra. Small yellowish or reddish pustules are formed on light colored areas of the leaf and a little later brown bristles project from the same spots. The plants are dwarfed and often premature defoliation occurs when the leaves are badly affected.

Cause.

The Comandra rust of pines is caused by the fungus *Cronartium comandræ* (=*Peridermium pyriforme* Peck). The æciospores formed in the blisters on the pine bark cause the infection of the leaves and young stems of Comandra. On that host urediniospores are formed which infect other Comandra plants. The urediniospores are closely followed by the production of the bristle-like teliospore columns, the individual cells of which germinate and produce the basidiospores. These latter spores are wind-borne and may cause the infection of the pines, if they are near by. Both the pines and species of Comandra must be present in the same locality for this fungus to exist on the pines.

Control.

The elimination of the species of Comandra from the vicinity of nurseries and young plantations is necessary if this disease is to be controlled. In the forest the diseased trees may be destroyed as a measure of protection for the young growth coming on. However, a few will always escape detection and if the Comandra plants are abundant, several pines may become infected during a season when only one existed in the spring.

REFERENCES

Arthur, J. C., and Kern, F. D. The rediscovery of Peridermium pyriforme Peck. Science 38 : 311–312. 1913.
Hedgcock, G. G., and Long, W. H. A disease of pines caused by Cronartium pyriforme. U. S. Dept. Agr. Bul. 247 : 1–20, pls. 1–2, fig. 1. 1915.
Hedgcock, G. G., and Long, W. H. Two new hosts for Peridermium pyriforme. Jour. Agr. Res. 5 : 289–290, pl. 27. 1915.
Orton, C. R., and Adams, J. F. Notes on Peridermium from Pennsylvania. Phytopathology 4 : 23–26, pl. 3. 1914.

CASTILLEJA RUST

Caused by *Cronartium coleosporioides* (D. and H.) Arthur

This blister-rust disease occurs from the Rocky Mountains to the Pacific Coast Range and from Canada to Mexico. It is exceedingly destructive to lodge-pole and western yellow pine. Large knots and cankers are formed on lodge-pole pine which at times are similar to the oak rust of pines (see page 287). The trunks of many trees five inches in diameter are girdled by the cankers, which may be from two to eight feet long. The bark soon dies and the death of the tree or branch follows. Fifty per cent of the stand is sometimes seriously affected. This fungus requires the presence of the weeds, *Castilleja miniata* and other species of the same genus, in the vicinity of the pine in order to complete its development. When these plants do not exist, this fungus cannot affect the pines.

Symptoms.

Both young and old trees are affected. Small trees in the nursery show but little enlargement of the affected branches or trunk. Large orange-colored blisters burst through the bark, and the spores within are shed as a fine powder. The affected limbs of older trees may show but little swelling or, as in the case of lodge-pole pine, large knots or galls and cankers are produced (Fig. 56). After the first crop of blisters is formed, the bark usually dies and the mycelium extends its activities to the healthy bark around the dead area. This process of enlargement of the canker or gall continues until the limb or trunk is girdled and death results.

FIG. 56. — Blister-rust or Castilleja rust on lodge-pole pine.

On the under sides of the leaves of species of Castilleja, small yellowish spots appear during the summer. Later numerous brownish bristles are pushed out from these spots. The appearance of the leaf is very similar to currant and gooseberry leaves affected with felt-rust (see page 277).

Cause.

The blister-rust which affects western pines and species of Castilleja is caused by the rust-fungus *Cronartium coleosporioides* (= *Peridermium filamentosum*, the Rocky Mountain form of *Peridermium Harknessii*). The life history of this rust is similar to that of *Cronartium ribicola* described on page 279. The æciospores germinate and infect the Castilleja leaves. Urediniospores propagate the fungus on this host throughout the summer and the teliospores and basidiospores are formed in late summer. Infection of the pine takes place in the autumn.

witches'-brooms are formed. The smaller branches and twigs are infected through injuries in the bark and abrupt globose or gradual spindle-shaped swellings are produced. The globose type of gall is found more commonly on scrub, jack, short-leaf, lodge-pole, sand, Piñon, Norway and spruce pine, while the more gradual swellings are found on Coulter, western yellow, Monterey, gray, loblolly and pond pine. When the swelling originates at the base of a branch, the adjacent tissue of the trunk is affected and large burls are formed. The part of the tree above these enlargements of the trunk and branches is ultimately killed. A single tree may have from one to hundreds of galls and several witches'-brooms. Young seedlings are often affected and killed.

The fungus fruits abundantly in the spring by forming prominent yellowish blisters over the surface of the globose or spindle-shaped swellings. These are united into continuous convoluted ridges which resemble the appearance of brain-tissue. The covering of the blisters is broken and a large quantity of orange-colored powder dusts out and is blown away by the wind.

The leaves of many species of oaks are affected by the same fungus. During the summer, small yellowish or reddish pustules are formed on the under sides of the leaves. Later from the same pustules numerous brown bristles are pushed out. The leaves of the oak are not appreciably injured by the fungus.

Cause.

This blister-rust disease is caused by the fungus *Cronartium cerebrum* (=*Peridermium cerebrum*, *P. fusiforme* and the Pacific Coast form of *P. Harknessii*). The fungi causing the blister-rusts of pines are closely related species having similar life histories. The life history of the white pine blister-rust fungus (page 279) serves equally well for this species with the exception that the æciospores cause the infection of the leaves of species of oaks instead of the currant and gooseberry. Some investigations point to the possibility that this fungus may be an exception to the rule in requiring the presence of the oak in order to have the infection of pines occur. This fact, together with the conditions observed in California and Oregon when the pines are often infected with no oaks near, leads to the supposition that the oak may not be necessary in the life cycle. Likewise, the fungus persists over winter on the evergreen oaks on the Pacific Coast. The leaves harbor the mycelium and new fruiting-bodies are developed in the spring around the dead areas produced the previous year.

The destructive action of the fungus on pines is caused by the flow of resin from the diseased tissue into the conducting tissue of the branch and trunk. This shuts off the food and water supply and causes the death of the parts above. The affected bark of the enlargement dies after a few years and insects and wood-rot fungi enter at these places.

Control.

Where oaks and pines grow in close proximity, the control of this disease may be accomplished by eliminating the oaks, unless it is definitely proved that the oak is unnecessary in the life history. The elimination of the trees showing one or more galls of this disease is advisable at the time of cutting.

References

Weir, J. R. Observations on the pathology of the jack pine. U. S. Dept. Agr. Bul. 212: 1–10, pl. 1, figs. 1–4. 1915.

Graves, A. H. Notes on diseases of trees in the southern Appalachians II. Phytopathology 4: 5–10, pl. 2, fig. 1. 1914.

Meinecke, E. P. Peridermium Harknessii and Cronartium Quercuum. Phytopathology 6: 225–240, figs. 1–2. 1916.

Hedgcock, G. G., and Long, W. H. Identity of Peridermium fusiforme with Peridermium cerebrum. Jour. Agr. Res. 2: 247–249, pl. 11. 1914.

U.

Piñon Blister-Rust

Caused by *Cronartium occidentale* Hedgc., Bethel and Hunt

For many years a species of Cronartium has been known on currants and gooseberries in Colorado, for which no blister-rust stage on pines could be found. Recently the blister-rust caused by this fungus has been discovered on nut and single-leaf pine. This disease is neither common nor destructive on these trees, so far as observed. Slight swellings are formed. The blisters which push through the bark in the spring are not prominent. As a result of the formation of the blisters, the bark is broken into irregular flakes and the inner bark dies. The æciospores infect currants and gooseberries and produce symptoms on these hosts which are indistinguishable from those on the same plants, produced by *Cronartium ribicola* (see page 277). The fungus has been named *Cronartium occidentale*. It has not been found to infect five-needle pines, although it has been observed for years on gooseberries and currants in close proximity to these pines.

Basal Canker

Caused by Phoma sp.?

In many localities in northeastern United States, more or less circular areas have been noted in which all the white pine are dead. Around these blanks some trees are often found which have yellowish and scanty foliage. Closer examination usually shows that the base of the tree at the surface of the ground has been girdled. The bark is dead and markedly constricted. Fruiting-bodies of a species of Phoma are generally found on the bark. There is some evidence that this disease occurs only in the vicinity of ant-hills and it is suggested that the ants, their burrowings in the ground, or the aphids with which the ants associate, have some connection

bark, not being affected in the pine, cause the formation of the fruiting-bodies to be limited to branch wounds where the branch stub forms an outlet for the mycelium.

Red-Brown Sapwood-Rot

Caused by *Fomes pinicola* Fries

Pines, as well as spruce, fir, larch and hemlock, are everywhere commonly affected by this red-brown sapwood-rot. The organism causing the rot also grows saprophytically and is the most common fungus on coniferous wood. The wood is reduced to a red-brown powdery mass which is held together by the many sheets of mycelium which run in all directions. The sporophores of the causal fungus have a red varnished margin and cream-colored under surface. Further details concerning this disease will be found under fir diseases, on page 165.

Brown Heartwood-Rot

Caused by *Fomes officinalis* Fries (= *Fomes laricis* (Jacq.) Murrill)

In western United States pine is destructively attacked by this brown heartwood-rot. Larch, Douglas fir and other conifers are affected by the same rot. Sugar, western yellow and lodge-pole pine are more damaged than other species. The decay resembles to some extent the brown checked wood-rot caused by *Polyporus sulphureus*. The decayed wood is brown or red-brown, and felts of mycelium form in checks in the wood. The sporophores of the causal fungus are not formed abundantly. They are large, globose or hoof-shaped bodies with a white chalky upper surface. The inner substance is bitter and has a mealy odor. Further details concerning this heartwood-rot will be found under larch diseases, on page 216.

Brown Pocket Heartwood-Rot

Caused by *Fomes roseus* Fries

Pines are commonly affected by this heartwood-rot. Juniper, spruce, fir, larch and hemlock are also affected by the same disease. In the first stages, long, cylindrical pockets of brown charcoal-like wood are formed. Later the pockets may coalesce and the wood is uniformly brownish and splits into cubes. The fruiting-bodies of the causal fungus are either thin and shelf-like or hoof-shaped. The under surface is rose-colored. Further details concerning this heartwood-rot will be found under juniper diseases, on page 204.

Red-Ray Wood-Rot

Caused by *Polyporus Ellisianus* (Murr.) Long

This wood-rot of western yellow pine has recently been studied in New Mexico and Arizona, where it is common in suppressed and over-mature trees. It is variously known as red-heart, red-rot, gray-rot and top-rot. This disease is thought to have a wide distribution, since it has been found in South Dakota in western yellow pine, in Vermont in white pine, and the fungus is known from the states of Washington and New Jersey. In many respects this decay-process resembles the yellow wood-rot of locust.

Symptoms.

In the early stages the central core of the heartwood is partially decayed and is reddish brown. Later, the red-brown wood becomes gray or whitish and is thoroughly disintegrated and easily pulled apart. At this stage it is also possible to squeeze water from the decayed mass. In cross-sections of affected trunks, the whitish stage is surrounded by a red-brown area. Radiating from this uniformly affected area are reddish colored rays extending like spokes of a wheel toward the bark. In longitudinal section these rays of decay are seen to have a whitish core of completely decayed tissue. If the wood is split tangentially these rays appear as red elliptical areas with whitish centers. The rays become larger until they finally coalesce. The whitish rotted cores become so completely disorganized that cavities are left which are bordered by white rotted wood. By this manner of spreading, the fungus very quickly extends its activities radially, although some time elapses between the pushing out of the rays and the time when, by gradual enlargement, they coalesce.

The fruiting-bodies of the fungus causing this rot are formed annually on the under sides of logs lying on the ground. They are white and usually resupinate incrusting layers.

Cause.

It is thought that the fungus causing the red-ray wood-rot is the same as the one called *Polyporus Ellisianus*, although this has not been definitely determined. Infection results in old branch wounds at the top of the tree, and the mycelium spreads upward and downward, often producing a rotted area in the wood twelve to twenty feet long from a single infection. A more detailed discussion of the nature of wood-rots and the life history of the fungi causing them is given on page 64.

Reference

Long, W. H. A preliminary report on the occurrence of western red-rot in Pinus ponderosa. U. S. Dept. Agr. Bul. 490: 1–8. 1917.

Red-Brown Root- and Butt-Rot

Caused by *Polyporus Schweinitzii* Fries

This root- and butt-rot occurs in pine, fir, larch, spruce, hemlock and arbor-vitæ, wherever these trees grow. The destruction it causes to these conifers is second in importance

The control of this root-rot would require such measures as are described under the shoe-string root-rot (see page 78).

References

Schrenk, Hermann von. Polyporus Schweinitzii. *In* Some diseases of New England conifers. U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 25 : 18–24, pls. 1–2. 1900.

Hedgcock, G. G. Notes on some diseases of trees in our national forests. IV. Phytopathology 4 : 181–188. 1914.

Hartig, R. Polyporus mollis Fr. *In* Die Zersetzungserscheinungen des Holzes, etc., pp. 49–53, pl. 9. 1878.

Yellow Root-Rot

Caused by *Sparassis radicata* Weir

Pines are seriously damaged in the Northwest by the yellow root-rot. In the same region fir, spruce and larch are also affected. Yellow sheets of mycelium are formed in the bark of the affected roots. Later the sapwood and in some cases the heartwood of the roots is decayed. Large, white, fleshy fruiting-bodies are produced on the ground, which are connected with the diseased roots by long tuber-like growths. Further details concerning this root-rot will be found under fir diseases, on page 170.

Brown Root- and Butt-Rot

Caused by *Fomes annosus* Fries

Pines are occasionally affected by this root- and butt-rot. The wood of the roots and butt of the pine is decayed, but the fungus does not extend its activities into the trunk because of the high resin-content of the wood. The wood becomes in turn bluish, yellowish and red-brown. White pockets with black centers are visible for a time in the brown wood, but later these coalesce and leave the brownish summer-wood of the annual rings as separated sheets. The sporophores of the causal fungus occur on exposed or buried roots. They are perennial, shelving or resupinate bodies with light brown upper surface and a yellowish tube-layer. For further details concerning this disease, see under spruce diseases, on page 329.

CHAPTER XXVIII

POPLAR DISEASES

A VARIETY of common names is used to designate the dozen or so species of Populus native in the United States. The diseases of these trees are common to the different species and the name poplar is used to designate the group except when certain species are indicated. Poplars are important forest-species. The common cottonwood is frequently used for shade and ornament in regions in which trees are not abundant, because of deficient rainfall. This tree is especially adapted to dry soils and formerly was used extensively as a street tree, until it was found to damage sewers and drainage pipes by clogging them with its roots. The European white and black or Lombardy poplar are planted frequently as ornamentals.

Poplars are subject to several types of diseases. The leaf-rusts are destructive to young trees and seriously interfere with their growth in the plains region. The newly introduced European fungus which causes the poplar canker has already proved to be a menace to young trees in the nursery. It is also destructive on trees which are recently transplanted. The importance of this disease cannot at present be prophesied, since apparently it has not been in this country for any length of time. In the forest the common white wood-rot is the most destructive disease of poplars.

LEAF-RUSTS

Caused by *Melampsora Medusæ* Thüm., *M. abietis-canadensis* (Farl.) Ludwig and *M. albertensis* Arthur

Three leaf-rusts of poplars are common in the United States. Two of these occur practically throughout the country, while

hemlock or fir has not been proved necessary for the appearance of the rusts on poplars, although such an association of the two required hosts is believed essential for the existence of these rusts. If this is true, this rust can be avoided by keeping larch, hemlock and fir separated from poplars by a distance of several hundred feet.

Powdery Mildew

Caused by *Uncinula salicis* (DC.) Winter

The powdery mildew of poplar leaves is found throughout the United States, but no great damage is done to the tree. It occurs also throughout Europe and Asia and over its entire range it affects the willows as well. The mycelium grows on both sides of the leaves and forms either effused or definitely circumscribed white powdery areas. The life histories and control of the powdery mildew fungi are similar for all species and are discussed in general on page 37. There is apparently only this one powdery mildew found on poplar. Some kinds of trees are affected by two or more species.

Yellow Leaf-Blister

Caused by *Taphrina aurea* Fries

The leaves of several species of poplar are affected by the yellow leaf-blister. In Europe the black poplar is affected. The size of the blisters may vary from very small to an inch in diameter. They are yellow at a certain stage in their development, due to the fruiting-structures of the causal fungus. Later the color of the blisters changes from yellow to brown. The mycelium of the fungus is confined to the space it makes for itself between the cuticle and epidermal cells, usually of the lower side of the leaf. No branches of the mycelium enter the leaf-tissue, but the parasitic effects of the fungus exert a stimulus which results in an increase in number and size of the mesophyll cells of the leaf, causing the blister. The mycelium is not perennial and new infections are caused by the spores which are produced on the surface of the blister and winter-over.

Catkin-Deformation

Caused by *Taphrina Johansonii* Sadebeck

The fertile catkins of different species of poplar are affected in similar manner as those of alders (see page 87). The elements of the catkin become larger than normal and at a certain stage are covered by the yellow fruiting-structures of the causal fungus.

Canker

Caused by *Dothichiza populea* Sacc. and Briard

This canker of black or Lombardy poplar and the common cottonwood has recently been found destructive in nurseries and on large trees planted for shade and ornament. The disease was first reported and studied in Europe, where it is known to be especially destructive to the cottonwood in France and Italy. It has now been found in the United States in New Hampshire, Massachusetts, New Jersey, New York, Pennsylvania, Delaware, Maryland, Ohio and New Mexico.

Apparently it originated in nurseries in this country which have imported the ornamental Lombardy poplar, and from these centers diseased trees have been shipped to various regions, thus distributing the fungus. Since the disease has only recently been discovered and because of its destructiveness could hardly have been overlooked previously, it seems certain that the causal pathogene has been newly imported and is just beginning to show its potentialities in this country. Its seriousness in the native poplar stands is yet to be determined. The large number of trees killed in nurseries and the serious effects produced on recently planted or old established trees around the nurseries point to the possibility that this disease may assume an epiphytotic nature.

Symptoms.

Trees recently transplanted and young nursery trees are most seriously affected. Older and well-established trees resist the disease to some extent and the cankers develop more slowly. The cankers occur on the trunk, limbs and small twigs. The diseased bark is slightly sunken and somewhat darker in color than the healthy bark. Cankers are commonly found around the base of twigs and limbs. The inner bark-tissues and cambium are killed and these dead tissues are brown. The canker enlarges rapidly and finally may girdle the trunk or limb. Small raised pustules are formed on the diseased bark. A hole is evident in the top of each pustule and from this hole long twisted brown or cream-colored tendrils of spores are pushed out. On the trunks and limbs of old trees, the cankered area of bark falls away, leaving the bare wood surrounded by callus.

The general effect of the disease on the trees is the killing of the twigs and smaller limbs and the disfiguring of the trunk and large limbs by the formations of open wounds. Suckers are developed from below the cankers, causing an ill-formed tree. Thus, while only the younger trees are killed outright, the older ones are made useless as ornamentals. In the forest the continued activities of such a fungus might constitute a menace to the successful production of commercially valuable trees, by interfering with the normal healthy development of the older trees and preventing the natural reproduction from reaching maturity. As yet, however, this disease has not been reported in the forests on the timber poplars.

LIMB-GALL

Caused by *Bacterium tumefaciens* E. F. Smith and Townsend

Poplar is only one of the many kinds of woody and herbaceous plants affected by this gall. The disease occurs commonly on fruit-trees, roses, daisies, beets and many other kinds of cultivated and wild plants. The over-growth in the

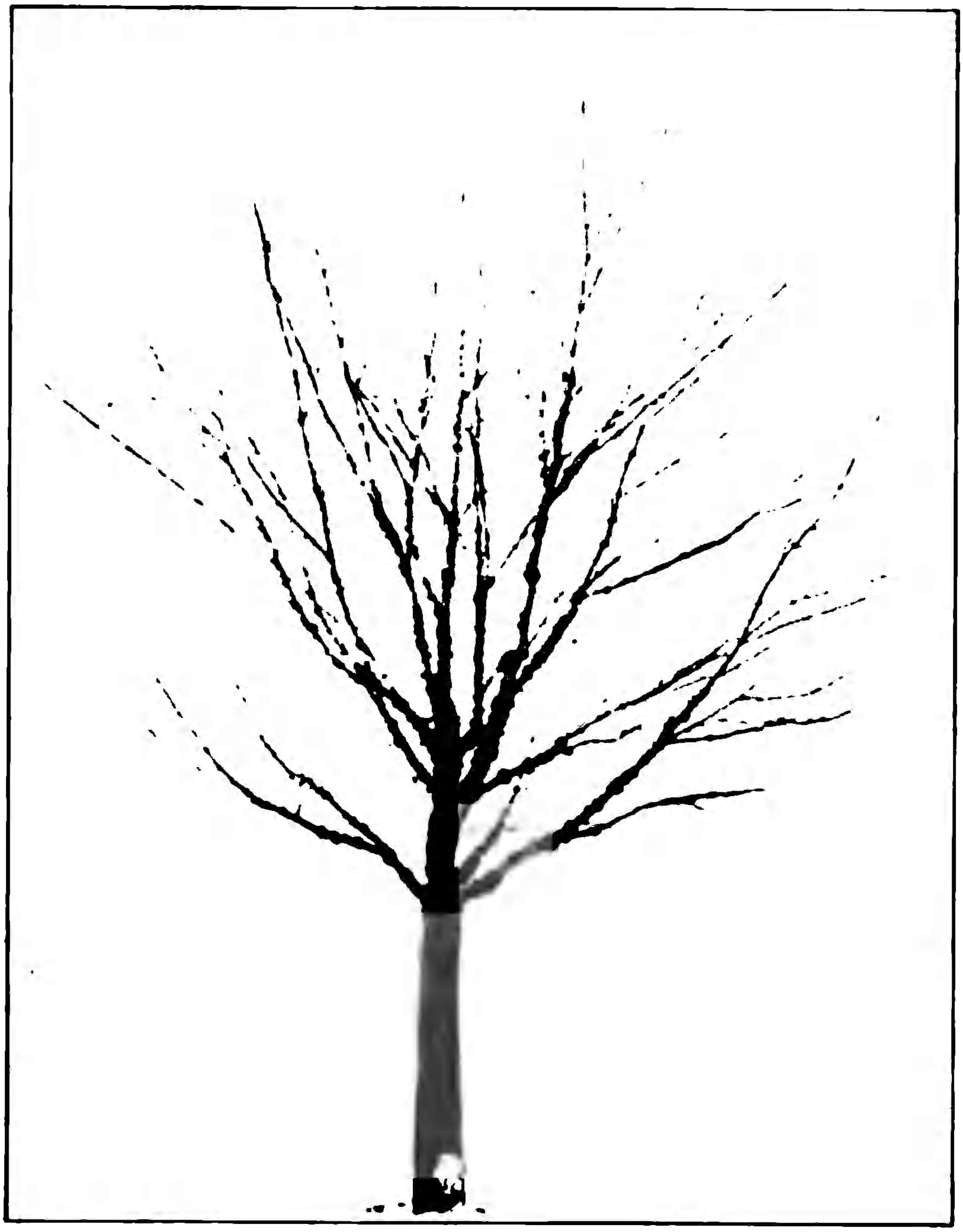

FIG. 57. — Limb-galls on poplar.

affected plant-tissue assumes different characters and the disease is variously known as: crown-gall, limb-gall, crown-knot, root-gall, hairy-root and woolly-knot. In general it is called the plant-cancer. Many trees are commonly found with limb-galls of various sizes (Fig. 57). No definite proof is available whether or not these various galls are due to the plant-cancer bacterium. Galls have been produced, however, on poplar limbs artificially and the organism has been isolated from galls on poplar occurring in nature. The galls are hard, woody structures variable in size. The surface is rough and covered with small knobs of tissue. The causal organism is a species of bacterium. Little is known of its life history, so far as its dissemination and resting stages are concerned outside the host plant. The effect of the organism on the plant-tissue has been made the subject of classical studies which have revealed many interesting analogies to human cancer.

References

Smith, E. F., Brown, N. A., and Townsend, C. O. Crown-gall of plants: its cause and remedy. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 213: 3–215; pls. 1–36, figs. 1–3. 1911.

Smith, E. F., Brown, N. A., and McCulloch, L. The structure and development of crown gall: a plant cancer. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 255: 3–60, pls. 1–109, figs. 1–2. 1912.

Common White Wood-Rot

Caused by *Fomes igniarius* Fries

White wood-rot caused by the false-tinder fungus (*F. igniarius*) is the most common wood-rot disease of deciduous trees. It is the cause of enormous losses in hardwood forests because of the destruction of the timber of the trees. Since also the sapwood may be affected, it becomes an equally important disease of valuable individual trees. It does not seem, however, to be very common outside of the forest areas and does not equal in importance the brown checked wood-rot in the relative damage caused to shade and ornamental trees. The following kinds of trees are known to be affected by the common white wood-rot: beech, poplar, willow, maple, birch, butternut, walnut, hickory and oak. Its range of hosts is larger than any other wood-rotting fungus and its distribution is limited only by the combined range of its hosts, for it is found on all the continents of the world and occurs from

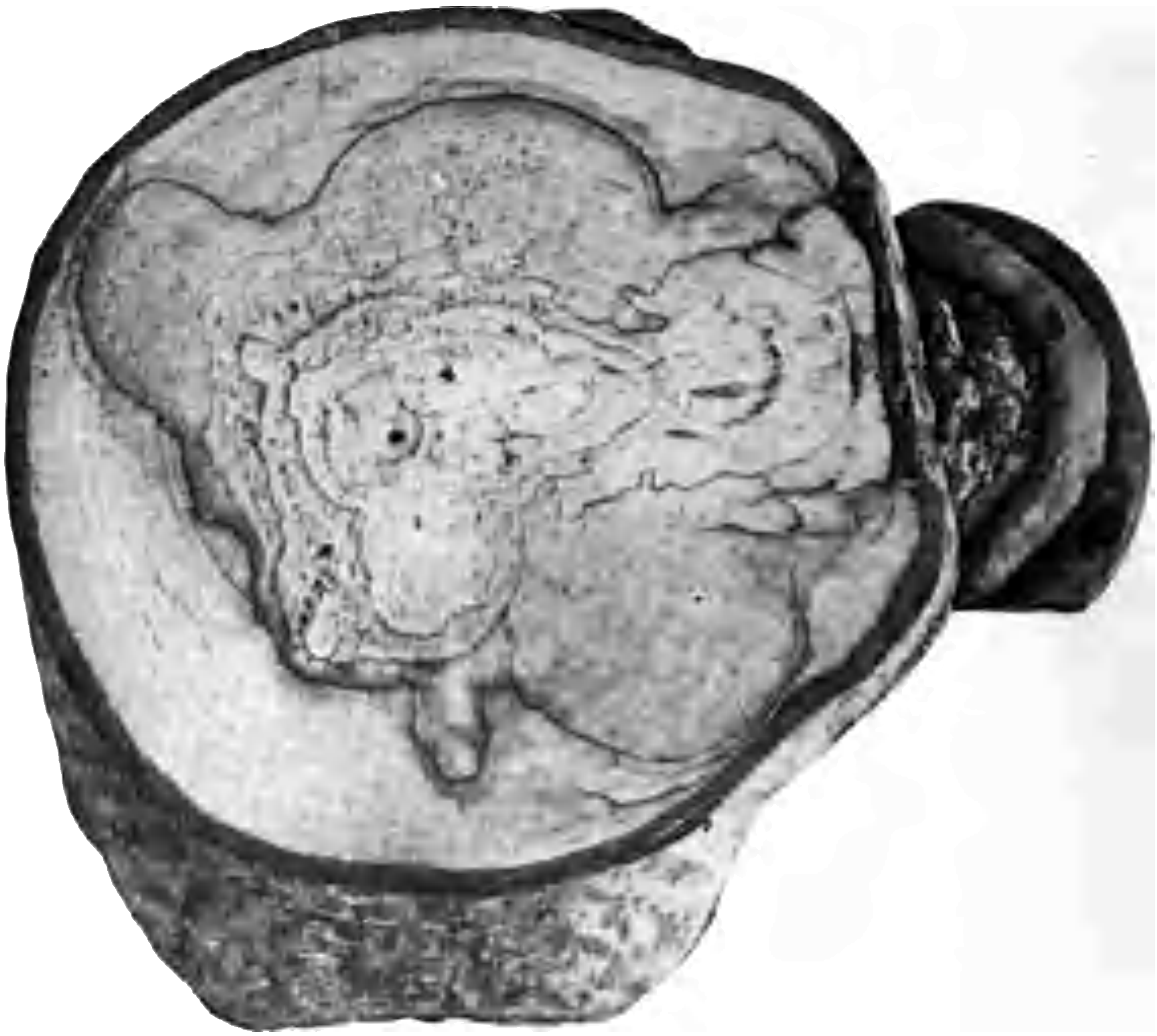

FIG. 58. — Common white wood-rot in maple, with a young fruiting-body of the causal fungus at the right.

tropical regions far into colder arctic zones, both to the north and south.

In Europe it is the most common disease of the oak and the most dangerous wood disease of fruit-trees of the genera Pyrus and Prunus. In this country beech, poplar and oak are the most commonly and destructively affected. Fruit-trees, es-

bark are invaded by the mycelium and the living tissues are killed.

Fruiting-bodies of two kinds are formed by the causal fungus. They are sometimes considered as two separate species. One form is distinctly hoof-shaped with a jet-black and extremely checked, charcoal-like upper surface (type of *Fomes igniarius*, Fig. 59), while the other is more shelf-like, with the gray to black upper surface marked with concentric arched

FIG. 60. — Fruiting-body of *Fomes igniarius*. This form is sometimes called *Fomes nigricans*.

ridges and is slightly checked (type of *Fomes nigricans*, Fig. 60). The under surfaces of both types of fruiting-bodies are identical, being reddish brown and velvety. The open ends of the spore-bearing tubes show as minute circular openings, barely visible to the unaided eye. The fruiting-bodies form at branch stubs which have not healed over. A new layer of tubes is added each year and large fruiting-bodies of this fungus have been found which showed eighty layers of tubes. When the fruiting-body is broken, the layer of tubes is seen to be stuffed with white material (Fig. 61).

Cause.

The common white wood-rot of deciduous trees is caused by the fungus *Fomes igniarius* (= *Fomes nigricans*). The spores from the tubes on the under surface of the sporophores are wind-blown and cause infection through branch wounds where heartwood is exposed. The mycelium delignifies the wood elements and partially destroys the cellulose. For a more detailed discussion of the life history and control of the wood-rot fungi of living trees, see page 64.

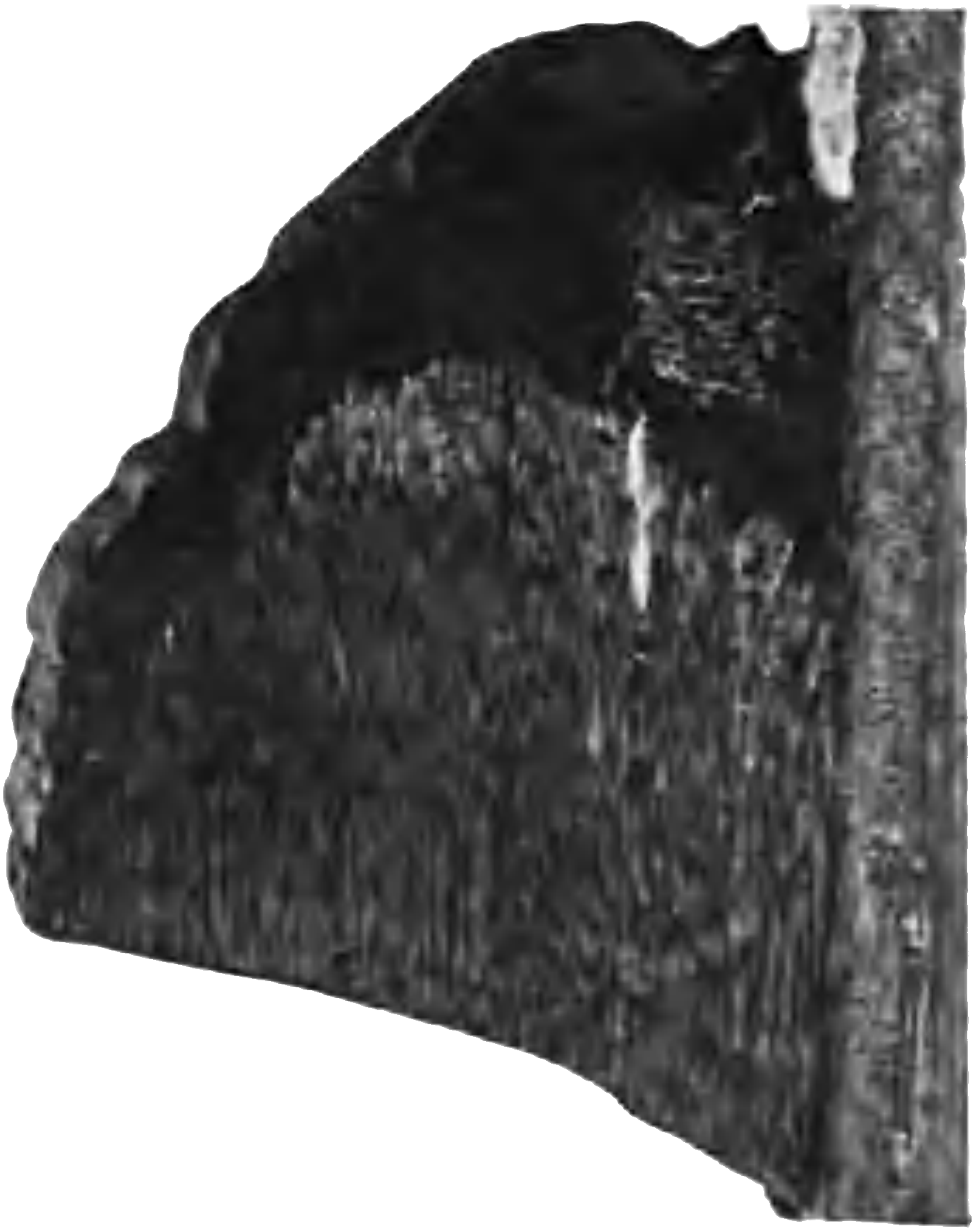

Fig. 61. — Lengthwise section through fruiting-body of *Fomes igniarius*.

References

Schrenk, Hermann von, and Spaulding, P. White heart-rot caused by Fomes igniarius. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149 : 25–37, pls. 1–3. 1909.

Schrenk, Hermann von, and Spaulding, P. Heart-rot caused by Fomes nigricans. *In* Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149 : 42–44. 1909.

Atkinson, G. F. Polyporus igniarius. *In* Studies of some shade tree and timber destroying fungi. Cornell Univ. Agr. Exp. Sta. Bul. 193 : 214–222, figs. 71–79. 1901.

Hartig, R. Polyporus igniarius Fr. *In* Die Zersetzungserscheinungen des Holzes etc., pp. 114–123, pls. 15–16. 1878.

Hesler, L. R., and Whetzel, H. H. White heart-rot. *In* Manual of fruit diseases, pp. 72–76, figs. 20–21. 1917.

White Pocket Heartwood-Rot

Caused by *Polyporus Rheades* Fries (= *Polyporus dryophilus* Berkeley)

This heartwood-rot is sometimes found in poplar, especially in the Northwest, following the common white wood-rot caused by *Fomes igniarius* (see page 305). In oak this heartwood-rot is common and destructive in the Southwest. The rot is confined to the upper part of older trees and may involve the sapwood. In cross-sections of affected poplars, the spring-wood of the annual rings is whitish while the summer-wood is light brown. The medullary-rays also become white. In longitudinal section these white bands of decayed tissue cause a mottled appearance. Small irregularly shaped brown areas appear here and there. The white areas enlarge until but little brownish wood remains between them. No cavities are formed since the white delignified fibers are not entirely destroyed. The sporophores of the causal fungus are shelf- or hoof-shaped when they occur at branch wounds and are more or less globose when formed directly on the bark. They are brown and have a granular sandstone-like core which reaches back into the sapwood. For further details concerning this heartwood-rot, see under oak diseases, on page 250.

White Butt-Rot

Caused by *Fomes applanatus* Fries

The fungus which causes this important white butt-rot of many kinds of deciduous trees is the most common bracket-fungus growing everywhere on dead wood. It is the most generally known of the polypores because of the practice of using the under surface of the sporophore for amateur etching. Recently it has been learned that this fungus attacks the wood of the roots and base of many trees, especially poplar, beech, oak, birch and maple. The amount of damage caused

surface. When fresh and soft, the lower surface turns brown when bruised. When broken the inner substance is found to be rusty brown and punky, with a distinct stratification of the annually formed layers of tubes. A thicker and more ungulate form with a black checked top and thin margin and a slightly concave under surface is commonly found growing from wounds in the base of living oak trees. This form, while being classified under the same name as the typically flat sporophore, differs greatly from it in general appearance and may represent a closely related species or at least a distinct variety.

Cause.

White butt-rot of poplar, oak, beech and other deciduous trees has been found to be caused by the bracket-fungus, *Fomes applanatus*. Sporophores are formed near the base of the tree at wounds or on exposed roots. The fruiting-bodies are perennial, a new layer of tubes being formed on the under surface each year. Infection seems to occur, usually, near the base of the tree and the decay does not extend very far up into the trunk. Trees in moist situations seem to be more often affected than those on drier land. A general discussion of the life history and control of the wood-rotting fungi will be found on page 64.

References

Heald, F. D. A disease of the cottonwood due to Elfvingia megaloma. Nebraska Agr. Exp. Sta. Ann. Rept. 19 : 92–100, pls. 1–4. 1906.

Hedgcock, G. G. Notes on some diseases of trees in our national forests. IV. Phytopathology 4 : 181–188. 1914.

CHAPTER XXIX

SPRUCE DISEASES

Six or more species of spruce (Picea) grow as forest-trees in the United States. They are important timber-trees and occur most abundantly in the northern states, although their range extends southward in the mountains to North Carolina, Tennessee, Colorado and California. Spruce is also extensively used as an ornamental.

Several diseases cause damage to spruce in the forest. The most important disease affecting these trees is the pecky wood-rot. Red-brown sapwood-rot and other diseases of the wood are also important. Several rust-fungi attack the leaves, twigs and cones of spruce. Two of the rusts cause witches'-brooms. Other minor diseases cause more or less loss in different sections of the country. As an ornamental, spruce is usually a healthy tree.

Seedling Twig-Blight

Caused by *Ascochyta piniperda* Lindau

This blight has been a common source of loss in seed-beds in Europe for many years but has only recently been reported in this country. It is known to occur in North Carolina on white and red spruce seedlings. More or less severe damage to seedlings of Norway and Sitka spruce are reported from Germany, Russia and Austria. It is also proved that a disease of the twigs of older spruce trees in the forest in Europe is caused by the same fungus. On both seedlings and older trees, this disease is sometimes confused with frost-injury which it resembles. One of the main differences noted in the field which will distinguish this blight from frost-injury (see page 12) is that not all the twigs of a given tree are uniformly affected. Also the more or less definitely affected areas in the seed-bed point to its spread from an original center of infection. Although this disease has not been found in this country on older trees, the symptoms are included in this discussion and are not materially different from the effect produced in seedlings.

Symptoms.

The blight becomes apparent in seedlings and on older spruce trees early in the spring while the tissues of the rapidly growing shoots and new leaves are succulent. Infection may take place at any point in the new growth, usually at some distance back from the tip. The affected area of the shoot turns brown and shrivels and the leaves die and fall off. The shoot is weakened at the point of infection and the weight of the still healthy tip causes it to bend over. Infection may occur at the base of the new shoot and the entire shoot will droop. The diseased condition soon advances the entire length of the shoot, however, and the leaves are shed. The course of the disease is confined to the period of two or three weeks after the new growth is completed. Small black pustules break through the dead bark or appear at the leaf-scars during the summer.

Cause.

Twig-blight of spruce is caused by the fungus *Ascochyta piniperda*, formerly called *Septoria parasitica*. Only the conidial stage is known and this appears on the dead twigs. The spores are formed in the black fruiting-bodies mentioned above. Presumably these spores over-winter and produce primary infection of the new growth the next spring. Some ascospore stage may be expected to be found on the dead needles or cast-off twigs on the ground and these spores may also function in carrying the

urediniospores develop. Later in the autumn small bright red or yellowish clumps of teliospores are formed on the leaves and these spores over-winter and produce basidiospores in the spring. These latter spores infect the young spruce needles. The affected needles become yellowish and soon produce two irregular rows of white blisters on the under surface.

The three species of closely related rust-fungi causing these diseases were known by the following names for the stage on the spruce before the stages on the heath plants were connected with them: *Peridermium abietinum* (Alb. and Schw.) Thüm. = *M. abietina* (Alb. and Schw.) Arthur; *P. decolorans* Peck = *M. ledicola* (Peck) Arthur; *P. consimile* Arthur and Kern = *M. cassandræ* (Peck and Clinton) Arthur.

References

Arthur, J. C., and Kern, F. D. North American species of Peridermium. Bul. Torrey Bot. Club **33**: 403–438. 1906.

Fraser, W. P. Cultures of some heterœcious rusts. Mycologia **3**: 67–74. 1911.

Fraser, W. P. Cultures of heterœcious rusts. Mycologia **4**: 175–193. 1912.

Clinton, G. P. Heterœcious rusts of Connecticut having a Peridermium for their æcial stage. Connecticut Agr. Exp. Sta. Ann. Rept. **1907–1908**: 369–396, pls. 25–32. 1908.

Leaf-Rust

Caused by *Chrysomyxa Weirii* Jackson

The leaves of Engelmann spruce are affected by a rust disease in the Northwest. This leaf-rust differs markedly from the blister-rusts of spruce (see page 315). The affected needles show yellowish spots on which develop prominent orange or brownish waxy pustules which break through the epidermis. The teliospores formed in these pustules germinate and produce basidiospores which infect other spruce needles. No alternate host is required in the life history of this rust and the æciospore and urediniospore stages are omitted.

Brown Felt-Blight

Caused by *Herpotrichia nigra* Hartig and *H. quinqueseptata* Weir

Although this disease has been noted in European literature as important on spruce, juniper, larch and mountain pine for many years, it is only recently that any mention has been made of it in the United States. In this country, as in Europe, it is found only at high altitudes from six to eleven thousand feet above sea level. So far, it is reported in the northwestern states on species of spruce, fir, juniper, cedar (Libocedrus), arbor-vitæ and hemlock. A similar disease which cannot be distinguished as to its symptoms from this one occurs in the same region on species of pine. The brown felt-blight of pine is caused by a different species of fungus, however, and is discussed briefly under pine diseases, on page 271. Both in Europe and the United States, the damage caused by this blight is considerable and young trees and the lower branches of older trees suffer most, although in some localities entire stands are badly affected and have the general appearance of having been swept by fire. Even when the damage is not so severe, the annual increment of wood is lessened and the general health of the trees impaired.

Symptoms.

A brown felt-like mass of mycelium spreads extensively over the leaves and twigs, causing them to become matted together and completely covered (Fig. 16, page 131). In the case of young trees, all the foliage may become covered. The lower branches of older trees are more commonly affected than the upper part. The mycelium enters the leaf-tissue and the leaves are killed through the combined action of the internal food-gathering mycelium and the thick covering over the leaves which shuts out the light and produces a high humidity. The mycelium may pass from one tree to another where branches touch each other. Small fruiting-bodies of the fungus causing the disease are found buried in the felt of mycelium.

Cause.

Three different species of fungi cause brown felt-blight of conifers, namely: *Herpotrichia nigra,* common to Europe and the United States on various conifers, except pines; *Herpotrichia quinqueseptata,* newly described on spruce in the Northwest; and *Neopeckia Coulteri,* found only on species of pines. The effect of all three species is similar and they cannot be distinguished except by microscopic examination of the spores.

The life history of these fungi is interesting. Only one spore stage is known. The fruiting-bodies (perithecia) are buried in the felt of mycelium and contain ascospores. The time of infection is not definitely known but young seedlings and the lower limbs which are buried in snow most of the winter are the most generally affected parts. Whether infection takes place under these conditions is a matter of conjecture. The mycelium spreads very rapidly during the summer. A case is described in which a branch of Alpine fir was entirely covered by the growth of mycelium in a single season. The mycelium enters the leaves and marked changes are brought about in the mesophyl-tissue. An abundant growth of external mycelium is also produced which covers the entire surface of the leaves and twigs and binds them together into a mass. By the advance of this epiphytic growth of mycelium over the surface of healthy needles, it is possible that the fungus brings about humidity relations which make possible the infection of the leaf and the development of the internal feeding mycelium. Thus after obtaining its start in a few needles buried in the snow, this fungus may in this way prepare its own conditions for infection and cause physiological changes in the leaves which render them more susceptible.

Cone-Rust

Caused by *Melampsoropsis pyrolæ* (DC.) Arthur

The young green cones of spruce are sometimes attacked by this rust-fungus which occurs very commonly throughout northern United States on species of wintergreen. The cones of black, red, white and Engelmann spruce have been found affected in northeastern United States and in Colorado. The wide distribution of the same fungus on its other host, the wintergreen, signifies, however, that it may be expected to occur anywhere in northern United States from the Atlantic to the Pacific. It is common in Europe also. Basidiospores from over-wintering teliospores on the leaves of wintergreen infect the green scales of the young cones in the spring and a few weeks later roundish, whitish blisters burst through the epidermis of the affected scales. Spores (æciospores) from these blisters infect the leaves of wintergreen. The under surfaces of the wintergreen leaves are often densely covered with the reddish pustules of the urediniospores. The fungus can live over in the persistent leaves of the wintergreen and thus the life history may be carried on without the stage on the spruce cones.

References

Fraser, W. P. Cultures of heterœcious rusts. Mycologia 4 : 175–193. 1912.

Arthur, J. C., and Kern, F. D. North American species of Peridermum. Bul. Torrey Bot. Club 33 : 403–438. 1906.

Rust Witches'-Brooms

Caused by *Peridermium coloradense* (Dietel) Arthur and Kern, and *P. boreale* Arthur and Kern

These rust diseases, which often result in large witches'-brooms, are common in the mountain regions of central western and northwestern United States on Engelmann and Colorado blue spruce. The first species of fungus mentioned above is also found on black spruce in the northeastern states. The mycelium is perennial in the twigs of the spruce and they are dwarfed. Two irregular rows of whitish or slightly pinkish blisters are formed in early spring on the under sides of the needles of the affected twigs and brooms. Although it is expected that these fungi have another stage in their life history on some flowering plant, this has as yet not been discovered.

Reference

Arthur, J. C., and Kern, F. D. North American species of Peridermium. Bul. Torrey Bot. Club **33** : 403–438. 1906.

Mistletoe Witches'-Broom

Caused by *Razoumofskya pusilla* (Peck) Kuntze

This species is the only member of either the dwarf or leafy mistletoes that grows in northeastern United States. It occurs on black, red and white spruce and has been found once causing a witches'-broom on eastern larch in Vermont. It is only seen occasionally on the red and white spruce but is more or less common on black spruce. When the parasite occurs, the spruce is frequently killed or at least dwarfed to half its normal size and makes very irregular growth.

Symptoms.

Two types of symptoms are noticeable on black spruce. The weaker and more shaded branches when attacked make an abnormal growth in length and the branches are more spreading. The foliage of these branches is yellowish and the leaves much smaller than normal. The usual symptom, however, is the production of upright clumps of branches, known as witches'-brooms (Fig. 62). A lateral branch near the infected part assumes an upright growth. Around the base of this branch many upright laterals arise and in time large brooms are formed. The foliage of the brooms is yellowish and the leaves smaller than normal. The ultimate effect of the production of

Fig. 62. — Witches'-broom on black spruce caused by a dwarf mistletoe.

several brooms, even on an older tree, is slow starvation of the remainder of the tree. As shown in the illustration (Fig. 63), the tree finally dies, the brooms being the last part to succumb.

stimulus which the parasite causes in the tissues. For a further discussion of the mistletoes which grow parasitic on trees, see page 54.

References

Schrenk, Hermann von. Notes on Arceuthobium pusillum. Rhodora **2**: 2–5, pl. 12. 1900.

Jack, J. G. Arceuthobium pusillum in Massachusetts. Rhodora **2**: 6–8, pl. 13. 1900.

Jones, L. R. Arceuthobium pusillum on a new host in Vermont. Rhodora **2**: 8–9, pl. 14. 1900.

Pecky Wood-Rot

Caused by *Trametes pini* Fries

Spruce is commonly affected by pecky wood-rot or ring-shake. This disease is the most destructive wood-rot of conifers in the United States. It has been reported in larch, pine, spruce, hemlock, fir and arbor-vitæ. Practically all conifers seem to be susceptible except the junipers. In Europe, pine, larch, fir and spruce are attacked. The usual common name for this disease is ring-shake, because a few annual rings are often destroyed, a part of the distance or entirely around the trunk, causing a shake in the timber. This symptom is not so common in those conifers with a low resin-content, however, and the name pecky wood-rot seems more appropriate. It is by far the most destructive disease of conifers in the forest and by some is believed to equal in importance all other wood-rots. The sapwood and bark as well as the heartwood are invaded and decayed.

Symptoms.

The appearance of spruce heartwood when decayed by this fungus is characteristic and the rot may be identified without the accompanying sporophores. Around the decayed area, the spruce wood is stained a purplish tinge. In cross-section when smoothed with a knife or plane, the wood inside the purple zone is found to be full of small holes or pockets with white linings (Fig. 64). Narrow black lines are sometimes present between the pockets. The partially decayed wood between the pockets is reddish in color. If the affected wood is split, the pockets are found to be longer than wide and the white fibers contained and the black lines between the pockets can

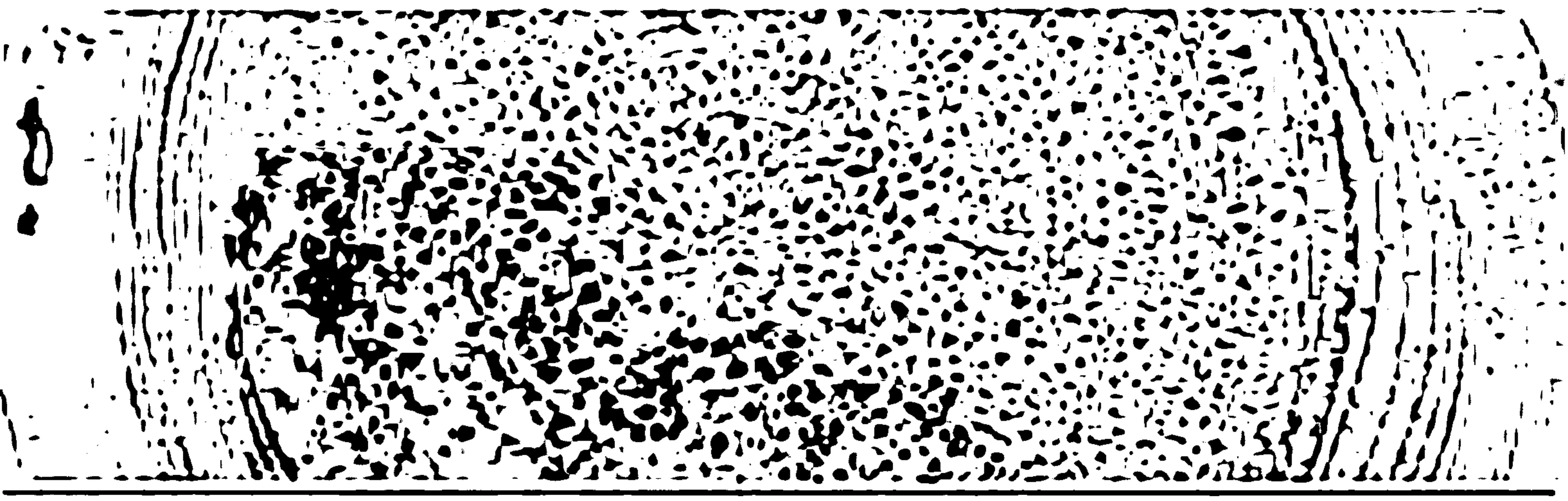

FIG. 64. — Pecky wood-rot in spruce.

be more clearly seen (Fig. 65). The decay extends eventually into the sapwood and bark.

Trees affected by this disease, as is the case with other wood-rots, do not show any external symptoms until the sporophores appear and limbs or the top of the tree die due to the girdling action when the sapwood is destroyed. The sporophores are of two types, depending on the place from which the mycelium emerges in its formation. A triangular-shaped shelving form is produced at old branch wounds, where the food materials gathered from an extensive region are furnished for the formation of a single fruiting-body. At other places where the mycelium has reached the sapwood and bark, a large number of small fruiting-bodies are formed which lie closely appressed to the bark and only project slightly at the upper edge. The larger sporophores from branch wounds add a new layer of tubes each year. The upper surface is hard, black and roughened by many irregular concentric folds. The under surface is light brown and covered with minute holes which are the open ends of the tubes in which the spores are borne.

Cause.

Pecky wood-rot of conifers is caused by the bracket-fungus *Trametes pini*. This name was first applied to the shelving form of sporophore and later the smaller resupinate form was

Fig. 65.—Advanced stage of pecky wood-rot in longitudinal section.

named *Trametes pini abietis*. This latter name is no longer used, since the identity of the two forms has been established. Like other fungi of the same group, the spores are formed in perpendicular tubes on the under side of the sporophore. The spores drop out of the tubes and are disseminated by the wind. Infection may occur when these spores lodge on exposed heartwood, at broken branches or when the top of the tree is

Stringy Red-Brown Heartwood-Rot

Caused by *Echinodontium tinctorium* Ellis and Everhart

In western United States Engelmann spruce is destructively attacked by this heartwood-rot. Fir and western hemlock are affected by the same disease. When this heartwood-rot is present in the tree, it may be identified from the exterior by the rusty knots. The heartwood of the branch stubs is colored a bright red. Three distinct stages in this decay are recognizable when the trees are cut. As the rot advances, the wood becomes discolored, spongy and occasionally contains light brown spots. Later the wood becomes red-brown and the spring-wood is dissolved, leaving the summer-wood of the annual rings in separated layers. These sheets of summer-wood are then destroyed and the tree is hollow. The fruiting-bodies of the causal fungus are large woody bodies with pendent teeth on the lower surface. Further details concerning this heartwood-rot will be found under fir diseases, on page 166.

Brown Pocket Heartwood-Rot

Caused by *Fomes roseus* Fries

Spruces are often affected by the brown pocket heartwood-rot. The same rot is also found in juniper, fir, larch, pine and hemlock. When the decay has advanced to its final stage in spruce, it may be confused with the red-brown root- and butt-rot caused by *Polyporus Schweinitzii* (see page 331). At first long cylindrical pockets of brown charcoal-like wood are formed in the heartwood. The pockets, however, increase in size until they coalesce and then the wood is uniformly brownish and splits into cubes. The fruiting-bodies of the causal fungus are either small, thin, shelf-like bodies or large and hoof-shaped. The under surface is rose-colored. For further details concerning this disease, see under juniper diseases, on page 204.

Cuboidal Wood-Rot

Caused by *Polyporus borealis* Fries

This wood-rot occurs in spruce and hemlock. No definite statements are found in literature concerning its importance and distribution in this country. The first evidence of the decay in the wood is the appearance of fine parallel strands of mycelium which burrow holes in the radial and tangential direction. Later these strands of mycelium become larger and appear as white cords in the wood (Fig. 28, page 186). Finally the mycelium disappears, leaving numerous empty channels, and the wood splits into minute cubes. For further details concerning this wood-rot, see under hemlock diseases, on page 185.

Brown Root- and Butt-Rot

Caused by *Fomes annosus* Fries

Practically all conifers are occasionally affected by the brown root- and butt-rot. In Europe this disease is recognized as one of the most destructive to conifers in the forest. In this country it is found to some extent both in the eastern and western forests, but it is not nearly so important as many other root and trunk diseases. It occasionally occurs in pine, spruce and fir, and may be expected in other conifers, including juniper. The fungus causing this root-rot is sometimes found on deciduous trees, but is considered both in Europe and North America to be of negligible importance and probably never parasitic on hardwood trees. The characteristics of the rot seem to differ somewhat with the kind of tree affected, but since these variations have not been described it is impossible to treat them in detail. In the conifers with a low resin-content, the decay extends upward in the trunk for several feet. This is especially true in the firs of the western forests. In resinous conifers, the rot is confined to the roots and butt of the tree.

Symptoms.

The general symptoms of this root- and butt-rot are as follows. The mycelium invades the heartwood, sapwood and bark of the roots. The most rapid progress is made in the heartwood. The first sign of the rot is a bluish discoloration of the wood. The wood then becomes dirty yellow and finally brownish or red-brown. While this color change is progressing, black spots appear in the spring-wood of the annual rings. Rapid decomposition of the fibers around the black spots results in white areas with black centers. The white areas then coalesce and result in the complete destruction of the spring-wood. This leaves the layers of brown and brittle summer-wood as separate sheets of tissue. These sheets shrink and, falling apart, cause the root to become more or less hollow. While this process of destruction is going on in the wood, white sheets of mycelium are formed in the bark, which is killed. The same general changes are shown in the heartwood of the trunk where the amount of resin present does not interfere with the development of the mycelium.

The sporophores of the causal fungus are formed on the roots and base of affected trees. They appear as perennial, shelving bodies with a light brown upper surface and white or yellowish under surface. The inner structure of the bodies is white. Small pores are apparent on the under surface. The sporophores are also often found under the surface of the soil as incrusting bodies on the roots and base of the trunk.

Cause.

The brown root- and butt-rot of conifers is caused by *Fomes annosus*. The spores from the tubes on the under sides of the fruiting-bodies may cause infection through wounds in exposed roots or possibly in fire scars and other wounds at the base of the tree. The most efficient means of spreading from tree to tree is by way of the roots which come in contact with each

rays destroyed. Later the heartwood is decayed and becomes brownish. The fruiting-bodies of the causal fungus are large, white, fleshy structures formed on the ground. They are attached to the diseased roots by long tuber-like stalks. Further details concerning this root-rot will be found under fir diseases, on page 170.

CHAPTER XXX

SYCAMORE OR PLANE-TREE DISEASES

The species of sycamore or plane-tree are large trees growing abundantly throughout their range in bottom-lands. Although not making a part of the forest lands of the country, the wood of sycamore is utilized for many specialized products. Three species of Platanas are recognized as native to the United States. Others are Mexican. A common street tree is *P. acerifolia*, thought to be a hybrid and often passing as *P. orientalis*, which latter is native in Europe and Asia.

The sycamore is apparently subject to but few important diseases. The leaf- and twig-blight, however, causes serious damage to the tree wherever it grows. The trees are deformed and although defoliated frequently, are not often killed. Several other fungi cause leaf-spots of sycamore. No other diseases of importance have been recorded on this tree. This may be due partially, however, to a lack of attention to the tree, since it is not associated with the principal timber-trees and is of little economic importance.

Leaf- and Twig-Blight

Caused by *Gnomonia veneta* (Sacc. and Speg.) Klebahn

The most common and destructive disease of the sycamore is the leaf- and twig-blight or anthracnose. Some species of oak, especially those belonging to the white and red groups, suffer to some extent from the same disease. The disease is generally prevalent throughout eastern and central United

States and in California. The most severe damage occurs where the twig-blight and canker types of the disease seriously deform the trees. Although certain trees are more or less affected every year, this blight occurs in epiphytotic form in seasons when weather conditions are favorable in early spring for the development of the causal pathogene. The Oriental plane and oaks in Europe, where they are extensively used as shade and ornamental trees, are attacked by the same fungus. It is probable that the range of this fungus is coexistent with the distribution of the sycamore and it may be expected to cause damage wherever the tree is grown. Owing to repeated defoliation, several years in succession, and the twigs being killed back, the ultimate damage is considerable. Cases have been reported in which trees were killed outright. Generally, however, repeatedly affected trees show great recuperative powers, and produce a second crop of leaves year after year.

FIG. 66. — Leaf-blight of sycamore.

Symptoms.

Leaf-blight becomes noticeable soon after or while the leaves are expanding in the spring. Often some leaves and the growing tip of the twig are affected, turn brown and die as they emerge from the bud. This symptom is often confused with

slightly raised margin. Small black fruiting-bodies break through the dead bark the spring following infection. After a year or two the dead bark falls away, leaving the wood bare and surrounded by a callus (Fig. 69). The wounds are then often healed over and no great damage results. On the small twigs which are killed back, minute pimples cover the yellow bark. The repeated killing of the twigs causes abnormal branching and gnarled growths which many times produce witches'-brooms. This causes the tree to have a general irregular and scraggly appearance. In the northeastern states, in some localities, it is often hard to find trees that are not thus affected.

Fig. 68. — Cankers on small sycamore twigs.

Cause.

Leaf- and twig-blight of sycamore and oak is caused by the fungus *Gnomonia veneta*. The perithecial stage occurs on the fallen leaves and matures in the spring. The stage which develops as the small cream-colored pustules, along the veins of the blighted leaves while they hang on the tree, is known as *Glæosporium nervisequum*. Other names were given to the spore stages developed on the twigs and cankers before their identity as one fungus was proved. There are still many facts about this disease to be learned. It is not known which spore stage causes the first infection of new leaves in the spring. The ascospores from the dead leaves on the ground or conidia from the fruiting-bodies on dead twigs or cankers may cause the primary infection. Internal over-wintering mycelium may also grow out into the newly developing twigs and leaves from the infected twigs of the previous year. After a few leaves are infected, the spores from the fruiting-structures along the veins are thought to be largely responsible for the general infection of the remaining leaves of the tree. Frequent rains and a humid atmosphere are conducive to epiphytotics of this disease when these conditions occur in proper correlation with the development of the leaves and the first fruiting-bodies resulting from primary infection. The twigs and branches are infected by the spores produced on the leaf-lesions or by the mycelium growing down through the petioles into the twigs. Twigs infected the season before are often girdled and killed just after the leaves expand the next spring. After the leaves fall to the ground, the mycelium lives saprophytically and produces perithecia which mature in the spring just as the buds are bursting. It is probable that the spores are shot out of the perithecium, as is the case with similar fungi.

Fig. 69. — Cankers on limbs of sycamore.

Control.

Since this disease is universally present on sycamore and common on oak as well, the first steps in controlling it must begin with the elimination of the spore-producing material in the vicinity of the tree. All the leaves from affected trees should be carefully raked together and burned. Following this, all dead or cankered twigs and branches should be pruned from the tree and burned. This is a tedious operation and unless care is taken many infected twigs will be missed. The twigs that are overlooked become apparent as soon as the leaves are out in the spring and should be removed at that time. The twigs left until that time, however, have had a chance to disseminate spores and start the primary infection of the leaves. If these sanitation precautions are thoroughly carried out for all the sycamores and oaks in the vicinity, the amount of primary infection may be considerably reduced, or under adverse weather conditions entirely eliminated. However, since the greatest damage probably comes from secondary infection, spraying with bordeaux mixture is advised to protect the leaves. When spraying has been tried, this disease has been successfully controlled. Bordeaux mixture (4–4–50 or 5–5–50) applied thoroughly with a power sprayer, so that all the leaves are covered, will prevent the spores that may be present from infecting the leaves. The number and time of the applications depend on the weather conditions. The first application should be made after the buds burst and before the leaves are half grown. A second application should be given about one week later and the third and fourth if the season is rainy, at intervals of two weeks. For fuller directions on spraying trees, see page 357.

References

Southworth, E. A. A disease of the sycamore. U. S. Dept. Agr. Rept. Com. Agr. **1888**: 387–389, pl. 15. 1889.

Southworth, E. A. Glœosporium nervisequum (Fckl.) Sacc. Jour. Mycology **5**: 51–52. 1889.

Edgerton, C. W. The physiology and development of some anthracnoses. Bot. Gaz. **45**: 367–408, pl. 11, figs. 1–17. 1908.

Duggar, B. M. Anthracnose of sycamore. *In* Fungous diseases of plants, pp. 278–280. 1909.

Brown Checked Wood-Rot

Caused by *Polyporus sulphureus* Fries

The black walnut is at times affected by the brown checked wood-rot caused by the sulfur fungus. Oak, chestnut, maple, butternut, locust and alder are often affected by the same disease. The wood is changed to a reddish charcoal-like substance which is split into cubes. These cubes are separated from each other by sheets of mycelium. The sporophores of the causal fungus are orange and sulfur-yellow and appear in late summer. The symptoms are more fully described under oak diseases, on page 247.

CHAPTER XXXII

WILLOW DISEASES

THE many species of willow (Salix), which are the common trees and bushes in lowlands and along stream banks, are not subject, so far as known, to many important diseases. A few leaf diseases are known which may cause defoliation. The leaf-rusts are very common. Wood-rots are often found in willow but no studies have been made of them. In general, but little attention has been paid to willow diseases because of the slight economic importance of the trees.

POWDERY MILDEWS

Caused by *Uncinula salicis* (D.C.) Winter, and *Phyllactinia corylea* (Pers.) Karst.

Two powdery mildew fungi attack the leaves of willows in the United States. Both species are found throughout the country. They are of little importance so far as damage to the trees is concerned. Without the aid of the microscope, the two cannot be distinguished from one another. The one, *Uncinula salicis*, however, may occur on both sides of the leaf, while *Phyllactinia corylea* is usually confined to the under side (Fig. 70). The black fruiting-bodies of the former are smaller than those of the latter. The life history and methods of control of the powdery mildew fungi are discussed on page 37.

LEAF-RUSTS

Caused by fungi of the genus Melampsora

Three species of rust-fungi are known to affect the leaves of various willows in the United States. One of these is very common and is found generally distributed throughout the northern states. The other two are apparently rare and are known only in Colorado and Utah. The leaf-rusts are important on young trees because defoliation often results.

Fig. 70. — Powdery mildew on willow leaves.

Symptoms.

The three rust-diseases are very similar in appearance. In early summer the affected leaves show yellowish areas on which are borne small orange-yellow pustules. These pustules appear powdery, due to the mass of spores they contain. Later in the season on the same areas, small dark brown raised spots are formed. The heavily infected leaves may drop from the tree.

Cause.

The common willow rust is caused by *Melampsora Bigelowii* Thüm. This fungus also causes a rust of the leaves of larch (see page 212). The spores (æciospores) borne in the pustules on the larch leaves infect the willow leaves. The orange-

White Wood-Rot

Caused by *Trametes suaveolens* Fries

Willows in eastern and central United States are commonly affected by this white wood-rot. The disease seems to be most destructive when willows are badly wounded by the breaking of branches or by injudicious pruning. The actual importance and symptoms of this wood-rot have apparently not been studied as but little has been published on the disease. The sporophores of the causal fungus are easily recognized. They are sessile, annual, shelf-like bodies, usually four or five inches broad, and project three or four inches from the trunk. The upper surface is convex, smooth, whitish or gray and velvety to the touch. The under surface is flat, white or grayish and has a chamois-skin texture. The pores on the under surface are large. This fungus occurs only on willow and produces fruiting-bodies abundantly. For a general discussion of the life history and control of wood-rot fungi in living trees, see page 64.

CHAPTER XXXIII

TREE SURGERY

Many of the diseases and injuries of the bark and wood of valuable shade and ornamental trees may be controlled by removing the affected parts. Two factors determine whether surgical methods are advisable; the value of the tree should justify the expense and the men who do the work should be capable. As to the expense that is justified, the owner alone can judge after estimating the cost of the work. The capabilities of the workmen largely determine whether or not the expense involved will be wasted. The surgical work done by many individuals and companies is both worthless and injurious to the tree. For this reason the public has become skeptical regarding the value of tree surgery. There is nothing mysterious nor difficult about the practice and it can be done by any one who understands the structure and physiology of trees and the general nature of the diseased conditions of wood and bark. Ability to work in all parts of the tree and handle the necessary tools greatly facilitate the operations. The following discussion is written primarily as a guide in surgical methods. At the same time it will aid the reader in critically examining work done by others.

The heartwood of the tree may be removed without in any way interfering with its life processes. The removal of a large area of heartwood may, however, weaken the tree and some bracing or bolting may be necessary. The sapwood and bark must be carefully conserved. This is easily appreciated when one considers that these tissues are the communicative channels for the upward movement of water and raw food materials from the roots to the leaves and for the downward movement of the manufactured foods from the leaves to all parts of the twigs, branches, trunk and roots. If the bark and sapwood are injured at any place to the extent that the tree is partially girdled, the water and food materials pass with difficulty around the injured area. Under some conditions, the limbs and roots directly above and below the injury will suffer and may die. It is, therefore, necessary in all tree surgery work to conserve as much of the living bark and sapwood as possible. Whenever these tissues are exposed in the process, they must be immediately protected by a coating of shellac or they will soon dry out to such an extent that the living cells will die. This precaution is especially necessary to protect the delicate cambium tissue which lies between the bark and sapwood and is the formative region in which these tissues are being constantly generated.

Two results are accomplished by surgical methods; first, the unsightly diseased parts of the tree are removed; and secondly, the enlargement of the diseased area is prevented, and in the case of diseases caused by living organisms, the source of further infection is removed. Tree surgery may be divided into two distinct types: by pruning, the affected limbs or roots are cut off; and by lesion excision, only the affected area of bark or wood is removed.

Pruning

There are certain fundamental principles which must be observed, if pruning is to be a successful eradication measure. The work of pruning should begin at the top of the tree and the greatest care must be taken to avoid injury to the bark during the operation. Rubber-soled shoes should be worn by the workmen. Iron-climbers, such as are worn to climb poles, should never be used in trees. Ladders are the most effective and least injurious means of reaching all parts of the tree. The

condition that it will not afford entrance to decay-producing organisms. If the wound bleeds profusely, it may be necessary to wait a few days until the surface dries, otherwise the operations described below should follow in a day or so, or better immediately.

Disinfecting Wounds

The woody portion of the cut should be disinfected. Three methods may be used:

1. Swabbing the wound with a water solution of a disinfectant. Mercuric chloride or copper sulfate are advised. Mercuric chloride may be bought in tablet form. One or two tablets to a quart of water is sufficient. If copper sulfate is used, a solution should be made by dissolving one ounce of copper sulfate in three quarts of water.

2. The surface of the wound may be seared with a gasoline torch. This method should be employed especially when the wound continues to bleed.

3. The wound may be painted with a wood preservative, ordinary creosote being satisfactory. It penetrates into the wood much further than a water solution of an antiseptic substance. It should not be used, however, on bark.

Wound Dressings

The next important operation is the application of a durable wound dressing. Two difficulties must be overcome in applying this: first, the wound is usually moist and it is difficult to make some dressings adhere tenaciously; and second, the surface will check on drying and no dressing will prevent this. These difficulties may be somewhat overcome by applying a temporary dressing followed, after the surface begins to check, by the permanent dressing.

Tar, asphaltum, lead paint, slater's cement and many "tree paints" are available as wound dressings. Ordinary coal-tar is most generally used and is recommended. Asphaltum, both melted and dissolved, is also a desirable substance to use.

Crude tars are obtained largely from bituminous coal, petroleum and wood, when these substances are burned in closed retorts. The temperature at which the distillation is carried out determines largely the chemical character of the crude tar. The products are named according to their source, coal-tar, oil-tar and wood-tar. The larger part of the coal-tar is produced in coke- and coal-gas manufactories. Bituminous coal is distilled at temperatures varying from 1500° to 3000° Fahr. until the charge has been reduced to coke. The tar, resulting as a by-product, varies in its nature according to the character of the coal and the temperature used. The tar contains mainly hydrocarbons of the aromatic series, such as phenols, naphthalenes and anthracenes. Coal distilled at relatively lower temperatures contains less of the aromatic hydrocarbons and a greater or less quantity of paraffin hydrocarbons. Oil-tar is largely produced as a by-product of water-gas production. This tar is characterized by an absence of the phenols (tar-acids) and a greater or less quantity of the different hydrocarbons. Wood-tars are quite different and contain, in particular, less of the aromatic hydrocarbons. Thus it is seen that crude tars may vary greatly and while some make suitable wound dressings because of their consistency and chemical nature, others do not.

In the further distillation of crude tars, three general classes of substances are obtained, — oils lighter than water, oils heavier than water and pitch or refined tar. The oils heavier than water are known as creosotes. Carbolineum is a trade name for a coal-tar creosote distilled at a high temperature. Creosote or carbolineum are not recommended for wound dressings, since neither is of a satisfactory consistency for making a permanent coating. In addition, they penetrate deeply and are said to injure, in many cases, the living tissues around the wound. The crude tars (usually coal-tar) are most generally used and are the best all-round dressings. It should be remembered that coal-tar contains a large percentage of the more toxic substances (phenols, and the like) than does oil-tar, which contains no phenols. The refined tars (pitch) are in all cases less toxic and less fluid. The tars must be chosen with regard to their physical as well as chemical properties, since they must be durable in hot, as well as in cold weather.

Another pitch-like compound, asphaltum, is highly recommended. This is the residuum of the distillation of western petroleum. Its toxicity has been little investigated but it appears to be a desirable wound dressing. It is durable and the distillations running to high temperatures (200°–285° Fahr.) leaves an asphaltum which remains solid at the temperatures to which it will be exposed as a wound dressing. It must be applied heated to the melted condition, or dissolved in benzene or other liquid petroleum products (varnolene is recommended). Many "tree paints" are solutions of asphaltum. The solvent used in some of these paints often kills the living tissues around the wound. Pure white lead paint makes a good dressing which prevents checking to some extent. It must be renewed frequently.

Slater's cement, although not much used, is said to make a suitable dressing. The wound should first be painted with a disinfectant since this cement has no fungicidal properties. The cement remains plastic and does not crack. Before recommending, it should be determined whether or not it actually prevents infection.

The capping of pruning wounds and the covering of exposed surfaces with sheet metal is sometimes advised. There are many reasons why such a practice is unscientific. In nailing on the sheet metal, many small cracks are made in the wood. Those which extend back under the cover cannot be reached by a fresh coat of any dressing. The cap cannot form a permanent or absolute covering and moisture will in time accumulate be-

care must be taken to cut back into the healthy bark beyond the advance of any parasite which may be present. The bark should be cut at right angles to the surface and the edges should be clean and smooth. The wood beneath the cankered area should in most cases be removed to the depth of a half inch or more. Then the ends of the wound must be shaped to a point. All of this work can be done with a draw-shave, chisel, gouge, mallet and heavy sharp knife. The diseased tissue which is removed should be burned, since it may serve as a source of infectious material. The Endothia canker of chestnut (see page 140) affords a good example of the care necessary to remove all affected tissues. The early failures to prevent the extension of the cankers by incision of the bark only was later explained by the discovery that the mycelium penetrated into the wood, even to the fifth annual ring at times. With this fact in mind, successful treatment of the cankers is effected by the removal of all diseased wood beneath the cankered area. The tendency of certain parasites to spread up and down the limb or trunk in the cambium region or sapwood, without causing apparent injury to the overlying bark, presents another difficulty in canker excision. This habit of growth is common for many parasitic fungi and bacteria. The mycelium of a fungus may spread in this way for many inches above and below the cankered area. Its presence is usually evident as dark colored streaks in the sapwood.

When the lesions extend deeply and extensively into the wood as in the case of heartwood- and sapwood-rots, the complete removal of all the affected tissue is very difficult. Large cavities must be excavated, which is a tedious and an expensive operation. Tissues in the advanced stages of decay are easily detected and removed. Such wood is usually soft and crumbly. But if the excavating stops with the removal of the punky wood only, no benefit will result from the work, for many of the fungi which cause wood-rots advance a considerable distance into the wood beyond the limits of evident decay and discoloration. A layer of apparently healthy wood outside the discolored area must be removed from all sides of the cavity to make sure that all of the mycelium is eradicated.

The size of the opening of the cavity should be no greater than is absolutely necessary, as healthy sapwood and bark must be conserved. The form of the opening will depend on conditions, except that it must be pointed below and above, as in the case of canker excision, to insure rapid healing at these places. The edges of the cavity must be clean cut and should be shaped with a chisel or gouge. The bark may be finally shaped with a strong knife. Shellac should be applied to the bark and sapwood as this is done.

For cavity work, gouges of various sizes, chisels, a mallet and a heavy knife are needed. In opening a diseased area, it is often necessary to cut away healthy sapwood and bark in order to get at the decayed wood with the gouge. Often the diseased wood must be followed for some distance above and below the original opening. Instead of making other small holes in the bark and sapwood, a narrow continuous opening is much better. The bridges of healthy bark and sapwood left, when holes are made, are bad practice for two reasons: the decayed wood is not as effectively removed and the bridges are likely to die and may be the source of future difficulty.

CAVITY TREATMENTS

At this point it must be decided whether or not the cavity is to be filled. Cavities may be treated in one of three ways: (1) left open; (2) closed by sheet metal conforming to the position of the original bark; and (3) filled with solid substances. The last method is the most commonly practiced and is the most expensive and, in the main, least scientific.

If the cavity is not to be filled, no further shaping is necessary except that it should be left so that it will not hold water. The bottom should slope outward at a sharp angle from all directions. After the removal of all the diseased wood, the surface of the cavity should be covered with a good wound dressing (see page 348). In the case of cavities in which a large amount of heartwood is exposed, the wood can very advantageously be painted with creosote or carbolineum. This will serve excellently as a penetrating and permanent disinfectant. Then one or more coats of a dressing such as asphaltum (heated to liquid condition) or coal-tar should be applied. After such treatment the work is finished so far as remedying the diseased condition is concerned. The diseased part of the tree has been eradicated and the wounded surface protected. There are several additional steps often taken which are non-essential and even harmful to the success of the work. In other words, cavities are better left open. The orchardist, especially, should never spend money filling cavities or even tinning them. If the cavity is left open, it can be inspected yearly and any necessary renewals of the dressings made. The only advantage claimed for tinning cavities is that the holes are closed up, the tree appears normal in shape and the metal furnishes a support for the developing callus. In the case of narrow slit-like cavities, this may eventually result in complete healing over.

Tinning is not to be advised on large cavities. It is mainly advantageous for those which may be expected to heal ultimately. The main benefit derived from the tinning is the support of the callus which would otherwise roll inside the cavity. The disadvantage of tinning is mainly that the surface of the cavity is no longer visible. The opening of the cavity must be so shaped that the metal will lie without wrinkling. Also a band of bark, about one-half to three-quarters of an inch wide, must be removed so that the metal may be seated on the wood and nailed fast. The metal should be placed even a little below the inner surface of the bark. Zinc and copper are the best

of the concrete must project no further than the sapwood. The callus will then roll over the edge and be supported by the concrete. The outer surface should be left rough and tar or cement paint used to waterproof the surface of the filling.

When asphaltum is employed, it is generally mixed with sand, sawdust or excelsior. A system of briquettes made of asphalt and sawdust is often used to build up a wall, making the face of the filling. This is laid up as a brick wall is made, each briquette being first dipped in hot asphalt. The briquettes next the edges of the cavity are nailed to the wood. Reinforcing may be adopted as in concrete fillings, and the space behind the briquette wall is filled with asphalt mixed with sawdust or sand. Sheet metal may be used instead of the briquettes but it is liable to tear loose with the bending of the tree.

In all tree surgery work, the ingenuity of the worker is called on to figure out what is best under the existing circumstances. The book, "Practical Tree Repair" by Peets, and an article in the 1913 Yearbook of the Department of Agriculture by Collins, give many details of this kind of work which are not included here.

The fact to be kept in mind, however, is that most tree surgery becomes necessary only because small injuries were not cared for. Proper pruning, wound dressings, bracing, bolting, chaining, guying and all such operations are necessary to prevent injuries. If such points are given attention, very little surgical work need be done.

References

Collins, J. F. Practical tree surgery. U. S. Dept. Agr. Yearbook **1913**: 163–190, pls. 16–22. 1914.

Peets, Elbert. Practical tree repair, pp. 1–265. (Illustrated.) 1913.

Selby, A. D. Dressings for pruning wounds of trees. Ohio Agr. Exp. Sta. Circ. 126: 163–170. 1912.

Selby, A. D. Tree fillings and wound dressings for orchard and shade trees. Ohio Agr. Exp. Sta. Circ. 150: 61–63. 1915.

Gaskill, Alfred. The planting and care of shade trees. Forest Park Reservation Commission of New Jersey, pp. 1–128, pls. 1–5, figs. 1–43. 1912.

CHAPTER XXXIV

SPRAYING AND DUSTING FOR LEAF DISEASES

In the absence of experimental data on the spraying or dusting of shade and ornamental trees for the control of leaf diseases, only very general recommendations can be made. The various leaf-spots, powdery mildews and sooty molds that often affect trees doubtless can be controlled by fungicides applied to the leaves. General directions will be found under the discussion on the powdery mildews for the control of these fungi (see page 37). These recommendations are based largely on the results obtained in controlling powdery mildews on fruits and small ornamentals. In order to control the many leaf-spot diseases, data should be available on the life history of the pathogenes (so that the time of applications might be determined), the strength and type of fungicide to use and the number of applications that are necessary. Without a definite knowledge of these facts, spraying can only be advised as an experimental practice.

The source of primary infection in the spring for most leaf-spot diseases is in the old dead leaves on the ground. These should be raked together and burned in the late autumn. Some of the leaf-spot fungi also attack the twigs and when this is the case the diseased twigs should be pruned off. Unless these eradication measures are taken, spraying will be less successful in controlling the disease.

The three common fungicides are bordeaux mixture, lime-sulfur solution and sulfur dust. The toxic agent in the first is copper and in the latter two, sulfur. These substances are applied to the foliage in a finely divided form in order to cover the leaves as completely as possible. Then when the fungous spores lodge on the leaf, they are either killed outright or soon after germination by contact with the copper or sulfur. Thus it is seen that the use of spray and dust mixtures will prevent leaf-spot diseases only when the mixture is applied before infection has taken place. In addition it should be remembered that while the leaves are growing, the increase in leaf surface exposes unprotected tissue and therefore applications must be renewed frequently. Applications should be made before rain periods, since the spores are disseminated and produce infection while the leaves are wet. The fungicides will not wash off materially. After a time they weather and are no longer efficient. In general, applications should be made at intervals of ten or fourteen days.

So far as is known, bordeaux mixture, lime-sulfur or sulfur dust may be used at the ordinary concentrations without injury to trees. The first two are liquid mixtures and the latter is applied dry. For large trees the spraying machines for liquid fungicides must develop a high pressure. Such machines are expensive. Blowers to apply sulfur dust are less expensive. Lime-sulfur is obtained on the market in concentrated form. It usually may be used with safety at a dilution of one part of the concentrate to fifty parts of water. Dry sulfur for dusting must be finely ground. Ten parts of dry arsenate of lead to ninety parts of sulfur-flour is recommended. The arsenate of lead makes the distribution of the sulfur more uniform and gives it greater adhesive qualities. Bordeaux mixture in various forms and strengths may be bought ready for diluting. Home-made bordeaux mixture, however, is more efficient and is not difficult to prepare. It is generally used at the strength designated as 5–5–50, that is, 5 pounds of quick-lime, 5 pounds of copper sulfate and 50 gallons of water.

Bordeaux mixture is made as follows: Prepare a stock solu-

APPENDIX

Common Names of Trees

A list of the common names of trees used in this manual is given below with the scientific name opposite cach. In most cases, the common name recommended by Sudworth[1] is adopted.

Alder (general)	*Alnus* sp.
Alpine fir	*Abies lasiocarpa* Nutt.
Alpine larch	*Larix Lyallii* Parl.
Arbor-vitæ (general)	*Thuja* sp.
Arbor-vitæ (specific)	*Thuja occidentalis* Linn.
Ash (general)	*Fraxinus* sp.
Aspen	*Populus tremuloides* Michx.
Bald cypress	*Taxodium distichum* Rich.
Balm of Gilead	*Populus balsamifera* Linn.
Balsam fir	*Abies balsamea* Mill.
Basswood (general)	*Tilia* sp.
Basswood (specific)	*Tilia americana* Linn.
Beech	*Fagus grandifolia* Ehrh.
Birch (general)	*Betula* sp.
Black ash	*Fraxinus nigra* Marsh.
Black gum	*Nyssa sylvatica* Marsh.
Black jack oak	*Quercus marilandica* Muench.
Black poplar	*Populus nigra* Linn.
Black spruce	*Picea mariana* B. S. P.
Black walnut	*Juglans nigra* Linn.
Box-elder	*Acer Negundo* Linn.
Buckeye (general)	*Æsculus* sp.
Bur oak	*Quercus macrocarpa* Michx.
Butternut	*Juglans cinerea* Linn.
California buckeye	*Æsculus californica* Nutt.
Carolina hemlock	*Tsuga caroliniana* Engelm.

[1] Sudworth, G. B. Check list of the forest trees of the United States, their names and ranges. U. S. Dept. Agr. Div. Forestry Bul. 17 : 1–144. 1898.

Catalpa (general)	*Catalpa* sp.
Cedar (general)	*Chamæcyparis* sp. and *Libocedrus* sp.
Chestnut	*Castanea dentata* Borkh.
Chestnut oak	*Quercus Prinus* Linn.
Chinquapin	*Castanea pumila* Linn.
Colorado blue spruce	*Picea Parryana* Parry
Cottonwood	*Populus deltoides* Marsh.
Coulter pine	*Pinus Coulteri* Lamb
Cuban pine	*Pinus heterophylla* Sudw.
Dogwood	*Cornus florida* Linn.
Douglas fir	*Pseudotsuga taxifolia* Brit.
Dwarf juniper	*Juniperus communis* Linn.
Eastern hemlock	*Tsuga canadensis* Carr.
Eastern larch	*Larix laricina* (Du Roi) Koch.
Elm (general)	*Ulmus* sp.
Engelmann spruce	*Picea Engelmanni* Engelm.
European chestnut	*Castanea sativa* Mill.
Fir (general)	*Abies* sp. and *Pseudotsuga* sp.
Fraser fir	*Abies Fraseri* Poir.
Grand fir	*Abies grandis* Lindl.
Gray pine	*Pinus Sabiniana* Dougl.
Green ash	*Fraxinus lanceolata* Borkh.
Hackberry (general)	*Celtis* sp.
Hardy catalpa	*Catalpa speciosa* Warder
Haw (general)	*Cratægus* sp.
Hemlock (general)	*Tsuga* sp.
Hickory (general)	*Carya* or *Hicoria* sp.
Horse-chestnut	*Æsculus Hippocastanum* Linn.
Incense cedar	*Libocedrus decurrens* Torr.
Jack pine	*Pinus Banksiana* Lamb.
Japanese chestnut	*Castanea crenata* Sieb. and Zucc.
Jeffrey pine	*Pinus Jeffreyi*
Juniper (general)	*Juniperus* sp.
Knob-cone pine	*Pinus attenuata* Lemmon
Larch (general)	*Larix* sp.
Large-tooth aspen	*Populus grandidentata* Michx.
Limber pine	*Pinus flexilis* James
Loblolly pine	*Pinus Tæda* Linn.
Locust (general)	*Robinia* sp.
Locust (specific)	*Robinia Pseudacacia* Linn.
Lodge-pole pine	*Pinus contorta* Loud.
Lombardy poplar	*Populus nigra italica* Du Roi
Long-leaf pine	*Pinus palustris* Mill.
Maple (general)	*Acer* sp.

White ash	*Fraxinus americana* Linn.
White birch	*Betula populifolia* Marsh.
White cedar	*Chamæcyparis thyoides* B. S. P.
White elm	*Ulmus americana* Linn.
White fir	*Abies concolor* Parry
White oak	*Quercus alba* Linn.
White pine	*Pinus Strobus* Linn.
White spruce	*Picea canadensis* B. S. P.
Yellow birch	*Betula lutea* Michx. f.
Yellow buckeye	*Æsculus octandra* Marsh.
Yellow cedar	*Chamæcyparis nootkatensis* Spach.
Yellow oak	*Quercus velutina* Lam.
Yellow poplar	*Liriodendron Tulipifera* Linn.

Synonymy of Polypore Names

Following is a list of the polypore names used in this manual. Opposite each is the name applied to the same fungus by Murrill[1] in the North American Flora.

Fomes annosus Fries	*Fomes annosus* (Fries) Cooke
Fomes applanatus Fries	*Elfvingia megaloma* (Lev.) Murr.
Fomes Earlei (Murr.) Sacc.	*Pyropolyporus Earlei* Murr.
Fomes Everhartii (Ellis and Gall.) Schrenk	*Pyropolyporus Everhartii* (Ell. and Gall.) Murr.
Fomes fomentarius Fries	*Elfvingia fomentaria* (L.) Murr.
Fomes fraxinophilus Peck	*Fomes fraxinophilus* (Peck) Sacc.
Fomes fulvus Fries	*Pyropolyporus fulvus* (Scop.) Murr.
Fomes geotropus Cooke	
Fomes igniarius Fries	*Pyropolyporus igniarius* (L.) Murr.
Fomes juniperinus Schrenk	*Pyropolyporus juniperinus* (Schrenk) Murr.
Fomes officinalis Fries	*Fomes laricis* (Jacq.) Murr.
Fomes pinicola Fries	*Fomes ungulatus* (Schaeff.) Sacc.
Fomes rimosus Berkeley	*Pyropolyporus Robiniæ* Murr.
Fomes roseus Fries	*Fomes roseus* (Alb. and Schw.) Cooke
Fomes texanus (Murr.) Hedg. and Long	*Pyropolyporus texanus* Murr.
Polyporus amarus Hedgcock	

[1] Murrill, W. A., North American Flora, 9: 1–131. 1907.

Polyporus Berkeleyi Fries	*Grifola Berkeleyi* (Fries) Murr.
Polyporus borealis Fries	*Spongipellis borealis* (Fries) Pat.
Polyporus betulinus Fries	*Piptoporus suberosus* (L.) Murr.
Polyporus croceus Fries	*Aurantiporus Pilotæ* (Schw.) Murr.
Polyporus dryadeus Fries	*Ionotus dryadeus* (Fr.) Murr.
Polyporus Ellisianus (Murr.) Long	*Tryomyces Ellisianus* Murr.
Polyporus frondosus Fries	*Grifola frondosa* (Dicks.) S. F. Gray
Polyporus obtusus Berkeley	*Spongipellis unicolor* (Schw.) Murr.
Polyporus Rheades Fries	*Ionotus dryophilus* (Berk.) Murr.
Polyporus Schweinitzii Fries	*Phæolus sistotremoides* (Alb. and Schw.) Murr.
Polyporus squamosus Fries	*Polyporus caudicinus* (Scop.) Murr.
Polyporus sulphureus Fries	*Lætiporus speciosus* (Batarr.) Murr.
Trametes pini Fries	*Porodædalia pini* (Thore) Murr.
Trametes suaveolens Fries	*Trametes suaveolens* Fries

GLOSSARY

Acervulus (acervuli). Open, saucer-shaped, asexual fruiting-body.

Æciospore. One of the types of spores formed by the rust-fungi. Æciospores are produced in the blisters on conifers in the case of the blister-rusts. The juniper and cedar rust-fungi form æciospores on the pomaceous host.

Ascospore. Sexually formed spores which are borne within a sac called an ascus. The asci are in turn borne on or in various types of fruiting-bodies.

Ascus (asci). Sac-like structures containing ascospores. Asci are borne in open or closed fruiting-bodies. Perithecia contain asci.

Bacterium (bacteria). Small, microscopic plants. Plants consist of single cells, which may be motile. Parasitic forms cause infectious diseases of plants and animals.

Basidiospore. Short lived spores borne on germ-tubes of teliospores in the rust-fungi. They are forcibly discharged and are carried by the wind.

Cambium. Region of growth in a woody stem or root, at which wood is formed on the inside and bark on the outside.

Canker. A dead area of bark.

Chlorophyl. The green coloring material produced in the leaves of the higher plants. Chlorophyl is instrumental in making starch from carbon dioxide gas and water.

Enzyme. A complex chemical compound capable of causing the transformation of certain organic substances into substances of greater or less complexity without itself entering into the product.

Epiphytotic. A plant disease which assumes an unusual and generally destructive nature in a locality. Usually called an epidemic, which term refers only to human diseases.

Fruiting-body. Large or small, open or closed structures made of mycelium in which the spores of fungi are formed.

Fungus. Simple plants lacking chlorophyl. Consisting of mycelium which may be massed to form large fruiting-bodies. Fungi obtain food by decomposing living or dead plant and animal tissue.

Fusiform. Spindle-shaped.

Germ-tube. A short tube which grows from a viable spore. The germ-tube then branches and a new mycelium is formed if growth-conditions are suitable.

Gill. The pendent plates or lamellæ found on the under side of toadstools. The spores of the fungus are borne on the sides of the gills.

Haustorium (haustoria). Special branch of the mycelium which is pushed into a cell to obtain food-materials.

Heartwood. The wood at the center of a tree, which contains no living cells and serves only for support.

Heterœcious. Said of a parasitic fungus which requires more than one kind of host for the completion of its life history.

Host. Any plant in which a parasite grows.

Hypertrophy. Enlargement of a portion of a plant, as galls on limbs.

Hypha (hyphæ). Individual branches of the mycelium of a fungus.

Infect. Said of a parasitic organism when it succeeds in establishing parasitic relations with a host-plant.

Infection. The act of infecting, see above.

Infection court. Any place or area of a host-plant where infection occurs. Also said of any place where infection is possible.

Lesion. Any definitely diseased area in which the primary cause of the disease is present.

Mycelium (mycelia). The vegetative body of a fungus, made up of long threads containing protoplasm.

Parasite. An organism which lives in or on another living organism for the purpose of obtaining food-materials.

Parenchymatous. Tissue composed of thin walled cells which are capable of further differentiation.

Pathogene. Any factor which causes disease, usually restricted to living organisms which live parasitically.

Perithecium (perithecia). A closed globose or flask-shaped fruiting-body containing asci and ascospores. Spores usually forcibly discharged.

Cook, M. T. The diseases of tropical plants, pp. 1–317, figs. 1–85. 1913.

Duggar, B. M. Fungous diseases of plants, pp. 1–508, figs. 1–240. 1909.

Freeman, E. M. Minnesota plant diseases, pp. 1–432, figs. 1–211. 1905.

Galloway, B. T., and Woods, A. F. Diseases of shade and ornamental trees. U. S. Dept. Agr. Yearbook **1896**: 237–254, figs. 53–57. 1897.

Harshberger, J. W. A text-book of mycology and plant pathology, pp. 1–779, figs. 1–271. 1917.

Heald, F. D., and Wolf, F. A. A plant-disease survey in the vicinity of San Antonio, Texas. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 226: 1–129, pls. 1–19, figs. 1–2. 1912.

Meinecke, E. P. Forest tree diseases common in California and Nevada. U. S. Dept. Agr. Forest Service, pp. 1–67, pls. 1–24. 1914.

Metcalf, H. Diseases of ornamental trees. U. S. Dept. Agr. Yearbook **1907**: 483–494, pls. 58–60, fig. 52. 1908.

Peets, Elbert. Practical tree repair, pp. 1–265. Illustrated. 1913.

Schrenk, Hermann von. Some diseases of New England conifers. U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 25: 1–56, pls. 1–15, figs. 1–3. 1900.

Schrenk, Hermann von. Fungous diseases of forest trees. U. S. Dept. Agr. Yearbook **1900**: 199–210, pls. 21–25. 1901.

Schrenk, Hermann von, and Spaulding, P. Diseases of deciduous forest trees. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 149: 1–85, pls. 1–10, figs. 1–11. 1909. (Bibliography given.)

Selby, A. D. A brief handbook of the diseases of cultivated plants in Ohio. Ohio Agr. Exp. Sta. Bul. 214: 307–456, figs. 1–106. 1910.

Stevens, F. L., and Hall, J. G. Diseases of economic plants, pp. 1–513, figs. 1–214. 1913.

Stone, G. E. Shade trees, characteristics, adaptation, diseases and care. Mass. Agr. Exp. Sta. Bul. 170: 123–264, figs. 1–109. 1916.

European Publications

Bourcart, E. Les maladies des plantes — leur traitement, pp. 1–655, figs. 1–14. 1910.

Canevari, A. Malattie e Parassiti delle Principali Piante Coltivate, pp. 1–374, figs. 1–101. 1913.

Cooke, M. C. Fungoid pests of cultivated plants, pp. 1–278, pls. 1–24, figs. 1–23. 1906.

Delacroix, G. Maladies des plantes cultivées, pp. 1–431, figs. 1–108. 1908.

Ferraris, T. I Parassiti Vegetali delle piante coltivate od utili, pp. 1–1032, figs. 1–184. 1913.
Hartig, R. Wichtige Krankheiten der Waldbäume, pp. 1–127, pls. 1–6. 1874.
Hartig, R. Die durch Pilze erzeugten Krankheiten der Waldbäume, pp. 1–24. 1875.
Hartig, R. Die Zersetzungserscheinungen des Holzes der Nadelholzbäume und der Eiche in forstlicher, botanischer und chemischer Richtung, pp. 1–151, pls. 1–21. 1878.
Hartig, R. Untersuchungen aus dem forstbotanischen Institut zu München. **1**: 1–165, pls. 1–9, figs. 1–2. 1880. **3**: 1–151, pls. 1–11, figs. 1–13. 1883.
Hartig, R. Text-book of the diseases of trees, pp. 1–331, figs. 1–159. 1894. (English translation of the second German edition, by Somerville and Ward.)
Massee, G. Diseases of cultivated plants and trees, pp. 1–602, figs. 1–171. 1910.
Peglion, Vittorio. Le Malattie Crittogamiche delle piante coltivate, pp. 1–554. 1912.
Prillieux, E. Maladies des plantes agricoles. **1**: 1–421, figs. 1–190; **2**: 1–592, figs. 191–484. 1895.
Savastano, L. Patologia arborea applicata, pp. 1–666. 1910.
Sorauer, P. Handbuch der Pflanzenkrankheiten **2**: 1–550, figs. 1–62. 1908.
Sorauer, P. Manual of plant diseases, pp. 1–891, figs. 1–208. (Translation of Handbuch der Pflanzenkrankheiten, volume one, by Frances Dorrance. Issued in ten parts; not completed.)
Tubeuf, K. F. von. Beitrage zur Kenntniss der Baumkrankheiten, pp. 1–58, pls. 1–5. 1888.
Tubeuf, K. F. von. Diseases of plants induced by cryptogamic parasites, pp. 1–598, figs. 1–330. 1897. (Translated from the German by W. G. Smith.)
Voglino, P. Patologia vegetale, pp. 1–287, pls. 1–6, figs. 1–303. 1905.
Ward, H. M. Timber and some of its diseases, pp. 1–295, figs. 1–45. 1909.

Publications on Tree Surgery and the Care of Trees

Bailey, L. H. The pruning-manual, pp. 88–106.
Des Cars, A. A treatise on pruning forest and ornamental trees, pp. 1–65, figs. 1–53. 1894.
Fernow, B. E. Care of trees, pp. 1–392, figs. 1–115. 1910.
Gaskill, A. The planting and care of shade trees. Forest Park Reservation Commission of New Jersey, pp. 1–128, figs. 1–43. 1912.
Lodeman, E. G. The spraying of plants, pp. 1–399. 1896.

Mulford, F. L. Pruning and tree-doctoring. *In* Bailey, Standard Cyclopedia of Horticulture, Vol. I, pp. 354–356. 1914.
Murrill, W. A. Shade trees. Cornell Univ. Agr. Exp. Sta. Bul. 205 : 73–120. 1902.
Peets, Elbert. Practical tree repair, pp. 1–265. Illustrated. 1913.
Solotaroff, W. Shade-trees in towns and cities, pp. 1–287, pls. 1–45, figs. 1–35. 1911.
Taylor, A. D. Shade trees, their care and preservation. Cornell Univ. Agr. Exp. Sta. Bul. 256 : 305–345, figs. 223–259. 1908.
Webster, A. D. Tree wounds and diseases, pp. 1–215. Illustrated. 1916.

B

C

F

N

O

P

S

Printed in the United States of America.

Three Acres and Liberty

By BOLTON HALL

$1.75

"Three Acres and Liberty" as revised is no dream book of success falling into one's lap. It shows the care and pains that must go into successful cropping of land. According to the library reports the earlier edition was for many months the most called for volume in the public libraries all over the Union and the well-worn copies now available show how deeply it was studied.

What use to make of your back yard, of your window sills, of your schoolrooms, of your cellar, and your roof for raising food or for learning how to raise food is set out with great detail and with unimpeachable authorities, but in an entertaining manner in the revised "Three Acres and Liberty."

The Fat of the Land

By JOHN WILLIAMS STREETER

Revised edition, $1.50

At the turn of the season each year there is always an interest in farm books. The appeal of country life is a very real one to thousands of city dwellers, and even if they cannot ever realize their dream, and know that they cannot, they still like to read about those who have turned their faces countryward.

Mr. Streeter, in "The Fat of the Land," tells of the development of a splendid factory farm, and of a well-paying investment out of some land that had been allowed to run down. He puts into concrete form with elaborate detail and abundant figures the practices of the most progressive farmers of to-day, and sets forth the methods of modern scientific agriculture.

THE MACMILLAN COMPANY

Publishers 64-66 Fifth Avenue New York