CRANBERRY DISEASES

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BY

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CRANBERRY SCALD.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 110.

B. T. GALLOWAY, *Chief of Bureau.*

CRANBERRY DISEASES.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 26, 1907.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 110 of the series of this Bureau, the accompanying technical paper entitled "Cranberry Diseases," by Dr. C. L. Shear, Pathologist in Charge of Investigations of Diseases of Small Fruits.

This paper contains the first full account of the fungous parasites of the cranberry and the diseases they produce. It also gives successful methods of preventing the diseases.

The illustrations which accompany this paper are considered essential to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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CRANBERRY DISEASES.

INTRODUCTION.

The American cranberry (*Vaccinium macrocarpum*) has been in cultivation for seventy-five years or more. The wild plant in its native habitat does not appear to be affected to any very noticeable degree by fungous parasites. Up to the present time only five species of fungi, according to the published host indices, have been reported as occurring upon this plant. It is generally the case, however, that the longer a plant is in cultivation and the greater the area covered by it the more numerous and serious are its parasites, since the conditions and opportunities for their development and distribution become much more favorable. This is true of the cranberry. At the same time, this plant by selection, cultivation, and growth under rather abnormal conditions has apparently become somewhat weakened and more susceptible to disease.

The cranberry is distributed from Newfoundland southward through the Alleghenies to North Carolina and westward into Wisconsin. It is also cultivated in a few localities on the Pacific coast, in Oregon and Washington. The native cranberry of that region is regarded by some botanists as a variety of *Vaccinium oxycoccus*.[1] ([a])

The diseases of the cranberry are most serious in the southern sections of its area of cultivation. The losses from the various maladies are heaviest in New Jersey and decrease as one proceeds northward through Long Island, Connecticut, and Massachusetts, being least of all in the bogs of Nova Scotia. There is also comparatively small loss from disease at present in Wisconsin and on the Pacific coast. The annual crop of the United States approximates 1,000,000 bushels, valued at about $2,000,000. The loss from disease is estimated to average about 10 per cent, or $200,000 each year. From a careful study of the matter is seems probable that the climatic conditions are chiefly responsible for the greater amount of loss in the southern localities. The long, hot summers of the southern region seem to be unfavorable to the production of the most hardy cranberry plants

[a] The serial numbers used in this paper refer to the bibliography which will be found on pages 55 to 57.

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and at the same time most favorable for the development of the various parasitic fungi which attack them.

Several serious diseases have been found to be prevalent. They have nearly all, however, been heretofore included under one name by cranberry growers. All softening of the fruit, accompanied by more or less discoloration, has been called "scald" or "rot." This was quite natural, as the differences in the appearance of fruit attacked by the different parasites are so slight that it is difficult to distinguish between them by external examination.

There is no accurate record, so far as we have been able to discover, as to when the cranberry diseases first became sufficiently serious to cause much loss. Mr. J. J. White read a letter before the Cranberry Growers' Association in 1873 showing that the scald was known twenty years earlier, i. e., 1853. The diseases have probably spread more or less gradually as the fruit has become more widely cultivated.

PREVIOUS INVESTIGATIONS.

Cranberry scald was a frequent subject of discussion at the early meetings of the New Jersey Cranberry Growers' Association,[2] which was organized in 1869 and is now called the American Cranberry Growers' Association.

In 1874 Dr. Thomas Taylor, Microscopist of the Department of Agriculture, was sent by the Commissioner of Agriculture, at the request of the American Cranberry Growers' Association, to investigate the so-called cranberry "scald," which had for some years caused a great amount of loss on some of the New Jersey cranberry bogs. Doctor Taylor [3] published several articles giving accounts of his observations and studies. He concluded, as a result of his work, that the primary cause of the trouble was an excess of acid in the soil and water. He also believed that excessive heat and drought were important factors, causing a fermentation to take place in the fruit. He observed fungous filaments in the rotten or scalded berries but did not consider this fact of much importance.

Taylor [5] says (Monthly Report, Dept. Agr., 1875, 446): "I am convinced that the scald and rot, so called, of the berry may arise from dissimilar causes, although chemically considered they are practically the same, viz, the conversion of their starch into grape sugar, a fermentable substance affording a nidus for the growth of fungi."

It will be seen from this quotation that the presence of a fungus was not considered the cause of the disease, but rather a secondary matter. Taylor believed that the trouble might be remedied by some application to the soil which would correct its acidity and prevent the fermentation in the fruit. In accordance with this suggestion a considerable variety of substances was tried by the cranberry growers, including lime, copperas, salt, and sulphur. Little or no benefit, however, seems to have been derived from these applications, and the diseases continued to cause serious loss, varying somewhat in different seasons as the climatic and other conditions chanced to be favorable to their development or otherwise.

Schroeter,[8] in 1879, in discussing a sclerotium disease of the fruit of *Vaccinium myrtillus*, mentions the American cranberry disease which had been described by Taylor and expressed his belief that the trouble was due to a parasitic fungus, either the same or one similar to that which he found in Europe. He had seen no specimens, however. Supposing the disease to be due to Sclerotinia, he recommended the application of lime and suggested flooding the vines just before the spores are formed.

Woronin [9] in 1888 in treating of *Sclerotinia oxycocci* refers to the cranberry disease of the eastern United States and suggests that it is caused by this fungus. This opinion was not based on an examination of specimens, however, but on Doctor Taylor's accounts of the disease. If the disease were caused by Sclerotinia he thought it could be eradicated by collecting and burning all the mummied berries.

No species of Sclerotinia has yet been found on cranberries in the East so far as known, but, as will be seen later, one has been found in Wisconsin.

In 1889, Dr. Byron D. Halsted,[10] of the New Jersey Experiment Station, undertook a study of the cranberry diseases, and as a result published a bulletin and several briefer reports on the subject. Doctor Halsted [8] recognized the parasitic nature of the disease, and described and illustrated, without name, the two stages of the fungus which produces cranberry scald. On account of his finding fungous hyphæ in the stems and roots of plants bearing rotten or scalded berries, he concluded that the parasite infested the soil and perhaps gained entrance to the plant, in part at least, by way of the roots. He consequently thought that remedies should be directed chiefly toward the improvement of soil conditions,[11] though later he recommended spraying with a solution of ammoniacal copper carbonate.[12] In his later publication [13] he says: "It seems well established that the fungus infests all parts of the plants and may enter the berry by means of the filaments which grow from the stem directly into the green berry, or by spores lodging upon the surface, the germ threads penetrating the fruit." Doctor Halsted [10] also investigated the cranberry gall disease, which will be referred to later.

Some work on cranberry diseases has also been done at the Wisconsin Agricultural Experiment Station. This will be referred to later in discussing the diseases.

In 1901, at the urgent request of the American Cranberry Growers' Association and in cooperation with the New Jersey Experiment Station, a study of cranberry diseases on behalf of the Bureau of Plant Industry was commenced by the writer. Both field and laboratory investigations have been continued since as the pressure of other duties would permit. Careful studies were first made of the field conditions, and laboratory and greenhouse studies have been made of the diseases found and the fungi producing them.

THE MOST SERIOUS DISEASES.

Cultures of the fungi found in diseased berries soon showed that, instead of a single disease, the term "scald" as used by cranberry growers includes at least three distinct diseases of the fruit—scald, rot, and anthracnose—caused by three different fungous parasites, *Guignardia vaccinii* Shear, *Acanthorhynchus vaccinii* Shear, and *Glomerella rufomaculans vaccinii* Shear. Besides the diseases which affect the more or less mature fruit there is another, commonly called "blast," or sometimes "blight," by the cranberry growers, which attacks the very young berries about the time the blossoms fall, causing them to turn black and shrivel up. There is also a disease which causes hypertrophy of the axillary leaf buds, and thus exhausting the vitality of the plant prevents the production of fruit. The most important diseases of the cranberry are those mentioned. Besides these there are a number of diseases of minor importance which will receive briefer consideration.

BLAST.

As already mentioned, the blast attacks the flowers and very young fruit, which shrivels up and becomes covered with the pycnidia of the parasite (Pl. II, figs. 1*a*, 1*b*). It frequently happens that as much as one-half of the crop on some bogs or portions of bogs is destroyed in this manner. The disease is caused by the pycnidial form of *Guignardia vaccinii* Shear.[24] The blasting of young fruit had been observed for many years by cranberry growers, but apparently the fungous nature of the disease was not known. There is, of course, some blast, or blight, of blossoms and of very young fruit due to other causes, as imperfect fertilization or injury by storms, frost, or insects, but by far the greater part of the blasted fruit on New Jersey cranberry bogs is due to the above-mentioned fungus.

Whitson, Haskins, and Malde[15] mention a cranberry "blight" which occurs in Wisconsin, killing the blossoms and very small fruit. This trouble, according to the writers mentioned, has been attributed by growers to hot weather. The results of their experiments were contrary to this theory. They concluded from their trials with several fertilizers that the blight depended largely upon the vitality of the vines. Plats treated with phosphates showed least blight. In conclusion they say: "The agent of destruction of these blossoms is probably a bacterial or fungus growth which takes place only under a devitalized or weakened condition." Having had no opportunity to make a study of the blight, or blast, in Wisconsin, we are unable to say how much of it may be due to *Guignardia vaccinii*, which produces the blast, or blight, in the East. From the fact that this fungus occurs in Wisconsin and destroys more or less of the fruit, it is highly probable that some of the blight, or blast, is also caused by it. The "blossom blight" is also mentioned by Whitson, Sandsten, Haskins, and Ramsey.[16] They state that a treatment for blight of three applications of Bordeaux mixture produced an increase of 30 per cent in the crop of fruit over that on adjacent vines not treated. This would seem to indicate that the disease is of a fungous nature.

SCALD.

The term "scald" is one which has been in general use among the New Jersey cranberry growers for a long time. It originated as a result of a view previously held by many growers that the softening of the diseased fruit was due to an actual scalding of the berry, caused by the hot sunshine when the berries were wet.

A condition somewhat resembling the effect of the fungus does sometimes occur when berries have been overflowed and covered with water for half a day or more during hot weather, but injury of this kind is infrequent and unimportant.

The first indication of the attack of the scald fungus upon the cranberry is the appearance of a minute, light-colored, watery spot upon its surface. This, under favorable conditions, rapidly spreads, usually in a concentric manner, until finally the whole berry becomes soft (Pl. I). Frequently the diseased area is marked by concentric dark-colored rings. This, however, is not always the case, and is not especially characteristic of this disease, as it sometimes occurs in the case of the cranberry rot. In very rare instances only a small, light-colored sunken spot is produced upon the berry, the fungus by some unknown cause having been retarded or entirely prevented from further development. In such cases we occasionally find the pycnidia of the scald fungus present, as illustrated by Doctor Halsted[10] in his work on cranberry scald. Ordinarily, however, there is no indication on the surface of the fruit of the presence of a fungus, except for occasional dark blotches or brownish zones, as mentioned above. Berries which are attacked before they are half grown usually shrivel up and become blackened and covered with the pycnidia of the scald fungus (Pl. II, fig. 1, *b*, and Pl. VI). This form of the disease is called blast, as already described.

The disease also affects the leaves, occasionally causing an irregular reddish brown spot, covering a portion of the leaf, and bearing pycnidia or perithecia of the fungus. These spots are of very infrequent occurrence. Where the disease has been severe for a number of years the plants are completely killed, and the dead, brown leaves still hanging to the vines are usually covered on the under surface with the minute fruiting bodies of the parasite (Pl. II, fig. 1).

Cuttings the first year or two after planting and before fruiting are sometimes seriously attacked by *Guignardia vaccinii*, which causes the leaves to turn yellow and fall and finally kills the plant. Some of the other cranberry fungi are also associated with this injury, but the greater part of the damage is apparently due to the scald fungus.

THE FUNGUS (GUIGNARDIA VACCINII, SHEAR) CAUSING BLAST AND SCALD.

Scalded or rotten berries so rarely show any fruiting forms of fungi that it is necessary to determine their presence and identity by careful microscopical examination and cultures. A microscopic study of the softened tissues of scalded berries at once reveals the presence of an abundance of fungous hyphæ. These hyphæ when transferred to culture media grow readily and frequently produce the fruiting forms of the fungus. This fungus, *Guignardia vaccinii* Shear,[24] which has been found upon blasted berries, upon the leaves of scalded vines, and isolated in numerous cases in pure cultures from scalded fruit, has been grown in the laboratory for several years.

Whitson, Sandsten, Haskins, and Ramsey[16] state that the cranberry scald in Wisconsin is caused by an unnamed species of Rosellinia. We have never found any fungus of this genus associated with cranberry scald or any other disease of the cranberry in Wisconsin or elsewhere. The only cranberry fungus which at all resembles Rosellinia is *Anthostomella destruens* Shear, which has been found only once in our investigations, and then in New Jersey. The true scald fungus (*Guignardia vaccinii*) has, however, been found in Wisconsin berries. There are two stages thus far known in the course of its development, a pycnidial and an ascogenous stage.

Pycnidial form.—The pycnidia are minute, black, membranous, globose receptacles, 100–120 μ in diameter, provided with a minute apical, sometimes slightly prominent ostiole, or mouth. When occurring on the leaves they are situated beneath the epidermis, usually on the under side, and are slightly erumpent, with the minute ostiole exposed. In most cases they are thickly and evenly distributed over the surface of the leaf, except for the infrequent occasions when only a portion of the leaf has been killed by the fungus (Pl. II, figs. 1 and 2). Mature pycnidia contain great numbers of pycnospores, bearing at their apexes a rather inconspicuous appendage consisting of granular matter, which appears to be embedded in a somewhat gelatinous substance. They are borne on short, simple sporophores 10–15 μ long. These pycnospores are hyaline, obovoid, with the apex frequently truncate, and measure from 10.5 to 13.5 by 5 to 6 μ. The appendage is usually about the length of the spore, or somewhat less, and curved (Pl. II, fig. 3, *a*, *b*, *c*). At maturity these pycnospores are expelled from the pycnidium in a small gelatinous tendril or threadlike mass, being held together by the gelatinous substance of the spore appendages as well as the free gelatinous matter which appears to be produced within the pycnidium and forms a thin layer about the pycnospore.

Ascogenous form.—The ascogenous perithecia are much less frequently found than the pycnidia. The perithecia resemble the pycnidia very closely in form, size, and other characteristics (Pl. II, fig. 10). In fact it is almost or quite impossible to determine, in the absence of asci or pycnospores, to which form a particular fruiting body may belong. The perithecia seem to have a denser, somewhat more opaque wall than the pycnidia, and they contain oblong, or somewhat clavate, short-stipitate, or sessile asci, the spore-bearing portion varying from 52 to 60 by 9 to 12 μ, the total length being 60 to 80 μ (Pl. II, fig. 11). The asci contain eight hyaline, or, when old, slightly yellowish brown, short elliptical or subrhomboid ascospores, having the contents rather coarsely granular (Pl. II, fig. 12). They vary in size from 13 to 16.5 by 6 to 7 μ. No paraphyses have been found. The characters of the ascogenous form of this fungus seem to agree most nearly with those of the genus Guignardia and correspond very closely to the black-rot fungus of the grape (*Guignardia bidwellii* (Ell.) V. & R.). The pycnidial stage of *Guignardia bidwellii*, as described and illustrated by Viala [18] and others, differs from the pycnidial stage of the cranberry scald fungus in scarcely any particular except in the absence of the spore appendage. A recent careful study of fresh pycnidia of *Guignardia bidwellii* shows that its pycnospores also bear a similar appendage. It is, however, shorter and less easily distinguished than that of *Guignardia vaccinii*, and soon disappears in mounted specimens. The appendage in the case of the cranberry fungus is very constant and characteristic.

The cranberry scald fungus is rather generally distributed throughout the cranberry-growing sections of this country. Pycnidia have been found on either leaves, flowers, or fruit in West Virginia, New

Jersey, Massachusetts, Nova Scotia, Wisconsin, and New York, and perithecia in New Jersey and New York.

CULTURES OF GUIGNARDIA VACCINII.

Over 200 cultures from hyphæ, pycnospores, and ascospores have been made upon artificial media of various kinds. The first cultures of the fungus were made from hyphæ taken from the interior of scalded berries. The berries were first thoroughly washed and soaked in a 1 to 1,000 solution of corrosive sublimate ($HgCl_2$), and a portion of the pulp containing the fungous hyphæ was transferred with sterile needles to the culture medium.

The following culture media have been used: Cylinders of potatoes and of beets; steam-sterilized and dry-sterilized cranberry leaves and cranberry fruit; cranberry agar and cranberry gelatin, prepared by adding various proportions of cranberry juice to agar and gelatin; beef agar and sugar-beet agar; corn meal saturated with cranberry agar; corn meal saturated with cranberry gelatin; malta vita saturated with cranberry agar, and corn meal saturated with distilled water. It appears to grow equally well upon acid and neutral media.

We have had the greatest and most uniform success in the use of corn meal and water sterilized in an autoclave for about fifteen minutes. The fungus also grows readily on corn meal saturated with cranberry agar, corn meal saturated with cranberry gelatin, and on potatoes. It grows more slowly and less luxuriantly on most of the other media tried.

Pycnidial form.—Cultures producing the pycnidial form have been made from the pulp and skin of diseased fruits in thirty-eight different cases and from leaves in two instances. This form has also been grown from pycnospores. The mycelium in all cases is at first thin, floccose, and white. In a few days it becomes denser and takes on a bluish gray color. As the culture gets older the hyphæ spread concentrically and the mycelium loses its bluish tint and becomes grayish brown. Pycnidia begin to appear in four to eight days, and mature pycnospores can usually be found in twelve to eighteen days. The pycnidia form a more or less continuous layer on the surface of the somewhat felty subiculum formed by the mycelium. They are frequently inconspicuous on account of the velvety surface growth of hyphæ, with which the mycelial layer is covered. In the majority of cultures made from hyphæ taken from diseased berries only pycnidia are produced, and in many instances the culture has all the characteristics of growth and appearance of *Guignardia vaccinii*, but is either entirely sterile or produces sclerotia-like bodies resembling pycnidia externally but containing no spores.

Ascogenous form.—Cultures producing both pycnidia and asci have been obtained in five cases by transplanting the fungous hyphæ from diseased berries, and in three cases from affected leaves, to culture media.

The first successful culture was made from decaying fruit obtained in the Washington market. The source of the fruit is unknown, but it was probably from New Jersey. The culture was made on March 31, 1902. The berries used were softened; the skin was light colored and watery and showed small dark-colored blotches of fungous hyphæ on the inner surface. Two cultures were made from one of these berries by transferring portions of the pulp containing the hyphæ to flasks of cranberry agar and corn meal. The cultures were kept in the laboratory at the ordinary temperature, which varied from 16 to 25° C. The course of development and appearance of the fungus were the same as in the cultures producing pycnospores only, as previously described. Mature pycnidia were produced in about twelve to fifteen days, and at the end of twenty-two days a great abundance of ascogenous perithecia was found. There is nothing in the macroscopic appearance of a culture bearing ascogenous perithecia to distinguish it from one bearing only pycnidia. The ascogenous perithecia are practically identical in appearance with the pycnidia. In mature and old cultures the color of the mycelium becomes dark brown, or almost black, and the pycnidia or perithecia become more exposed on the surface of the subiculum or crustlike stroma.

The second successful culture of the ascogenous form was made January 20, 1903, by transferring a portion of the skin of a diseased berry showing darkened spots to a flask of water-saturated, autoclaved corn meal. The course of development was the same as in the culture just described. Many bodies resembling pycnidia were produced at first, but all examined were apparently sterile. Later, in addition to these sterile bodies, ascogenous perithecia of Guignardia were found.

The third successful culture of ascogenous perithecia was made December 23, 1903, from diseased New Jersey berries, which had been kept in ordinary storage in an unheated building in the Department. These berries showed the ordinary appearance of scalded fruit, and the cultures were made by transferring sections of diseased berries which had been washed and soaked in a solution of corrosive sublimate to flasks of sterilized corn meal. An abundance of fertile pycnidia was produced, and at the end of nineteen days perithecia containing mature asci were found.

The fourth successful culture was also made at the same time as the last mentioned, and from fruit from the same source, treated in the same manner.

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The fifth successful culture from diseased berries was made May 10, 1904. The berries were received from Cranmoor, Wis. They were softened and shriveled and showed definite black spots on the surface. After washing and soaking for three-fourths of an hour in corrosive-sublimate solution, sections of the diseased portion, including the skin, were transferred to large tubes of sterilized corn meal. About one month later ascogenous perithecia of Guignardia were found in this culture. Several other cultures made at the same time upon the same culture medium and from fruit having the same appearance produced only pycnidia. Transfers made from cultures producing asci to sterile potato cylinders have produced the ascogenous form as quickly and abundantly as when grown on corn meal.

Besides the successful cultures just described, which have been made from diseased berries, we have, in three instances, obtained from cranberry leaves pure cultures bearing both pycnidia and asci.

On March 23, 1905, cultures were made by placing in flasks of sterile corn meal leaves which had been first soaked for about one hour in a 1 to 500 solution of corrosive sublimate and then cut in two pieces. These leaves were taken from vines which had borne very badly scalded fruit during the previous season. The vines were collected on November 29, 1904, and kept in an ice box from that time until the cultures were made. The leaves were of 1903 growth and were to all external appearances healthy and free from fungi. Leaves taken from this collection in March, 1906, still produced plenty of good pycnidia and ascogenous perithecia. The course of development of the fungus in these cultures was identical with that described in the other cases. Pycnidia were produced in abundance in about fifteen days, and at the end of twenty-nine days ascogenous perithecia were found in three of the cultures.

From these original cultures many others have been made by transfer. Four generations have been grown in this way, producing both pycnospores and ascospores in each. After this the fungus appeared to have lost its vitality and did not grow well. In other cases it developed both spore forms for one or two generations only.

The fresh pycnospores of this fungus germinate and grow readily in water, in a dilute solution of sugar and water, and in ordinary culture media. Spores placed in a drop culture of sugar water in the laboratory began to show signs of germination at the end of two days. The germ tube usually arises from the side of the pycnospore, first forming a slight enlargement, which rapidly elongates into a germ tube and soon begins to branch (Pl. II, figs. 4 to 9). At the end of four days many of the germ tubes have attained considerable length. The tube occasionally arises from the basal end of the spore (Pl. II, fig. 6), but we have never seen it arise from the apical end, where the appendage is borne. The mycelium now grows more rapidly and soon assumes the color and other characteristics mentioned in the description of the macroscopic appearance of cultures of the fungus.

The appendage of the pycnospore, as seen upon immature spores, consists of a hazy, hyaline, finely granular, gelatinous mass, equaling the spore in diameter (Pl. II, fig. 3). A little later it becomes somewhat elongated, curved backward, and more or less appressed on the side of the spore. As the spore matures the appendage becomes still narrower and free from the side of the spore, but even at maturity it is usually somewhat curved. In old cultures which have passed maturity and in which all the spores have been set free, the appendage is frequently wanting and seems to have been dissolved or disintegrated.

No signs of a conidial form of the fungus have been found in any of the numerous cultures made, either from the mycelium or spores. No chlamydospores have been found in cultures, but what appear to be such are found in old berries destroyed by the fungus. Sterile pycnidia or perithecia are frequently found, especially in poorly developed cultures. These are sometimes solid and sclerotoid, with the interior cells lighter colored, and are about the same size as the pycnidia and perithecia.

CONDITIONS OR FACTORS DETERMINING THE PRODUCTION OF THE ASCOGENOUS FORM.

The reasons for the rare occurrence of ascus-bearing forms in cultures of what are undoubtedly ascomycetous fungi have always been obscure, and it has usually been found impossible to produce the ascogenous fructifications with much frequency or certainty.

The work of Klebs[19] and others upon the effect of various nutrient and other substances upon the production of sexual fructification, especially in the algæ, has suggested the possibility of such factors having a determining influence on the production of the ascogenous stage in this fungus. While our experiments in this direction have been comparatively few, there has been no indication that the composition of the culture medium is of particular importance in this respect. When once an ascus-producing race, strain, or generation of the fungus was obtained it grew almost equally well upon different culture media, such as steamed corn meal, cranberry gelatin and corn meal, cranberry agar and corn meal, and potatoes.

The effect of variations in temperature has also been tried upon a series of pycnospore-producing cultures made from the same original pure culture. Cultures in flasks on corn meal were kept in the laboratory, where the temperature varied from 20° to 26° C. Others were kept in a thermostat at a temperature of 30° C. Others have been kept in a refrigerator at a temperature of about 3° C. The cultures kept in the laboratory made the most rapid and vigorous growth of mycelium, those in the thermostat and refrigerator growing about one-half as fast. All these cultures finally produced pycnidia, but no signs of asci were ever found.

Experiments have also been tried to determine the effect of different quantities of moisture. The fungus was found to grow more rapidly on a rather wet medium, but there is no indication that this influences the production of the ascogenous stage of the fungus.

Other experiments were tried to determine the effect upon the growth and development of the fungus of varying the amount of available air and the evaporation by plugging the culture flasks more or less tightly. Little or no difference was noticeable in the growth in these flasks, and only pycnidia were produced.

The work of Blakeslee [20] on Mucor and the factors controlling the production of zygospores in that and related genera has suggested the possibility that the sexual or ascogenous fructification might arise from the union of different races or individuals. The few experiments we have made along this line, however, have been unsuccessful.

It has been thought by Brefeld [21] that ascus formation may depend upon the time of the year, or possibly the period of development of the fungus in its host. Our investigations, however, are not conclusive in regard to these points, so far as they concern *Guignardia vaccinii.* Cultures have been made from fruit and leaves taken almost every month during the year, and it will be noted that cultures which produced the ascogenous stage of the fungus were made in January, March, May, and December. Many other cultures, however, made during these same periods and from leaves and fruit in which the fungus had presumably passed through approximately the same period of development were either sterile or produced pycnidia only. While we have no cultures made from material taken during the summer which have produced ascospores, this may be due to the fact that comparatively few cultures have been made from leaves or fruit during that season.

In regard to the bearing of the duration of development of the fungus upon the production of asci, we have no means at hand of determining, except by mere conjecture, the age of the fungus which may be present at any particular time in the tissues of cranberry leaves or fruit, not knowing positively when the infection took place and the germ of the fungus entered the plant. All the evidence at hand, however, points toward June and July as the time.

As a result of our work, we are led to the belief that there is some inherent potentiality in the mycelium of the fungus in certain strains, races, or generations which causes it to produce the ascogenous stage whenever conditions for its growth are favorable, i. e., on favorable culture media without special reference to their exact composition or environment or on the leaves of its natural host. Whether this potentiality depends on some preceding union of nuclei from different or the same individuals, or some equivalent stimulus, we are, of course, unable to say. It appears possible, however, that there may be such a factor concerned.

DORMANT CONDITION OF THE FUNGUS.

Leaves and berries which, so far as can be discovered by external examination, are perfectly sound are very frequently found to contain the fungus. Leaves perfectly normal in appearance, taken from vines growing in diseased areas, have been thoroughly washed and soaked from fifteen minutes to two hours in a solution of corrosive sublimate, 1 part to 500 parts of water, in order to destroy any fungous spores which might possibly be present upon their surfaces. These leaves were then placed in sterile, moist chambers. After a period of eight to twelve days an abundance of the pycnidia of *Guignardia vaccinii* was found to have developed upon the leaves, and in some instances these were followed by the ascogenous form of the fungus. Berries apparently perfectly sound and healthy have also been treated in the same manner, and in many cases the characteristic decay of the fruit has followed. Cultures made from the pulp of these berries have produced the fruiting forms of the Guignardia.

So many experiments of this kind have been tried that we feel convinced that the fungus must be present within the tissues of the leaves and berries referred to in a dormant or more or less inactive condition. It does not seem possible that any spores could resist the action of the corrosive sublimate solution used. Tests which have been made show that the spores of *Guignardia vaccinii* are killed by being immersed in a 1 to 1,000 solution of corrosive sublimate for five minutes. A great number of microtome sections of leaves and fruit supposed to contain the dormant form of the fungus have been studied. It has been found very difficult to demonstrate the presence of the fungus and to determine its form, chiefly, perhaps, on account of unsatisfactory results in differential staining.

In case of the berries, carefully stained sections have shown what appear to be cells of fungous hyphæ just beneath the epidermis. In both leaves and fruit the fungus seems to be able to exist in the tissues in a more or less inactive or dormant condition while awaiting an opportunity for further development; such opportunity is apparently afforded by any conditions which weaken the cranberry plant and also by those which are favorable to the growth of the fungus, such as sufficient heat and moisture. If a similar condition of affairs should prove to obtain rather generally among similar parasitic fungi, as seems to be possible from observations and experiments made with other cranberry diseases and several anthracnoses on different hosts, it will have an important bearing upon the results and conclusions derived from ordinary infection experiments in which plants have been used which were not grown from uninfected seed under conditions which would preclude possible infection at any time previous to their use. It would also have an important bearing upon the value of inferences regarding the time of infection based upon the time of the outbreak of the disease.

It has been supposed that in the case of diseases such as the black-rot of the grape the time of its external destructive appearance followed within a short period after the germs of the disease had entered the tissues of the plant. In other words, it has been taken for granted that as soon as a germ tube gains entrance to the tissues of its host it proceeds to develop under normal conditions and soon produces its characteristic injuries. On the contrary, however, it seems much more probable that there is no regular period of incubation, but that the development of the parasite depends largely upon the conditions surrounding it and its host. If the host plant becomes weakened in any way or if the conditions of heat and moisture are especially favorable for the fungus its development may be rapid and continuous, but if these conditions do not obtain the fungus may remain in an inactive or dormant condition, or its development may be very slow or intermittent and in some cases perhaps entirely suppressed. Many illustrations of this condition can apparently be found among foliicolous pyrenomycetes which develop their fruits so abundantly during the winter on old fallen leaves. There is no evidence, so far as we know, that infection of these leaves takes place during the winter. The scanty observations which have been made indicate rather that the mycelium is present in the leaves when they fall, though there is no outward indication of its presence.

TIME AND MANNER OF INFECTION.

We have been unable thus far to discover exactly when and in what manner infection of the leaves and fruits takes place. The pycnidial form of the fungus may be found within from ten to fifteen days after the water with which the vines are usually flooded during the winter has been removed. This appears to be about the normal period required for the development of the pycnidia when the growth of the fungus is regular and continuous, as shown by its growth and development in pure cultures. The pycnidia appear first upon old leaves of vines which have apparently been weakened or killed by the disease. A great number of pycnospores are also produced about the 1st of July upon the very small blasted berries. These are probably the chief source of the infections which follow. The pycnospores may also be found more or less abundantly during the whole season upon old dead and dying leaves, especially of those vines which have been cut and broken.

The ascogenous form is apparently not of very frequent occurrence. It has been collected occasionally on old leaves from June to November, but, judging from the small quantity found, it does not seem probable that it is a very important factor in the general distribution and spread of the disease. Ascospores in most pyrenomycetous fungi appear to be produced normally in late winter and spring. The abnormal conditions under which the cultivated cranberry is grown—the plants being generally flooded with water from November until May—prevent the production of the fruiting forms of the fungus during that period. We have found by laboratory experiments that the fungus does not develop upon leaves when they are kept immersed in water. Twigs with leaves from vines bearing very badly scalded fruit have been kept in water in the laboratory for months without any external indication of the development of the fungus, while leaves from the same plants kept in moist chambers developed Guignardia in abundance. In the early stages of our investigation various inoculation experiments were tried, both in the field and in the greenhouse, using plants which were presumably free from disease, judging from the external appearance of the vines and berries. The results of these experiments have, however, since been shown to be valueless on account of the quite general occurrence of the fungus in leaves and fruit which appeared normal and healthy, as already pointed out. In order, therefore, to make conclusive infection experiments it is necessary to grow plants from seed in sterile soil under conditions which will prevent possible infection from any source except artificial inoculation. Thus far we have been unable to do this, owing to the fact that great difficulty has been experienced in germinating seeds and growing satisfactory plants in the greenhouse. From field observations made in connection with our spraying experiments it seems very probable that infection of the young leaves takes place very early in the season, soon after the water is removed from the bog and as soon as the first generation of pycnospores is produced upon the old dead and fallen leaves. There are also observations and facts which seem to indicate that infection of the berries generally takes place when they are rather young. This is self-evident of course in the case of the blasted fruit, which is destroyed when it is very small. Attempts to infect mature or nearly mature fruit in the laboratory have in all cases been unsuccessful.

Fresh pycnospores have been placed in drops of water upon fruit kept in sterile moist chambers, but without any noticeable result. The spores germinate, but are apparently unable to penetrate the epidermis of the fruit. That infection of the foliage and fruit instead of taking place in whole or in part by way of the roots and up through the stems, as supposed by Doctor Halsted, arises from external sources seems to be proved by the very satisfactory results of spraying experiments and by the observations already recorded. Several tips of vines bearing leaves, collected September 15, which had been thoroughly sprayed during the season, were carefully washed with corrosive sublimate and placed in sterile moist chambers. A few fungi developed in a very few of these leaves. Other leaves, collected at the same time from adjacent vines which had not been sprayed, were treated in the same manner. These were found to be completely infested with fungi, and the pycnidia of Guignardia developed in abundance on almost every leaf.

A considerable quantity of fruit which had been sprayed was treated in the same manner as the leaves already mentioned. As a result, 1,200 sprayed berries picked on September 18 showed on October 18 but 9.8 per cent of diseased fruit, while the same number of unsprayed berries from the same source kept under the same conditions in the laboratory for the same period showed 38.1 per cent of diseased fruit. The only explanation of these results in the light of our present knowledge of the effect of Bordeaux mixture is that most of the spores of the fungus had been destroyed by the spraying and therefore did not gain entrance to the leaves and fruit.

TREATMENT.

Applications to the soil.—Acting upon the supposition that the cranberry scald was primarily due to unfavorable soil conditions or to fungi attacking the plant by way of the root system, chemicals or fungicides to be applied to the soil were suggested as a remedy by Doctor Taylor,[4] and later they were tried by Doctor Halsted.[11] Lime, plaster, salt, sulphur, copper sulphate, and iron sulphate were tried in different quantities. No decided benefit is reported to have resulted from these applications.

Improving the condition of the plants.—It is a matter of general observation that the cranberry scald is much more serious on certain bogs or portions of bogs than on others. The conditions obtaining in the soil and water of these diseased areas no doubt have much to do with the prevalence of the disease. The factors concerned are so complex, however, that it is difficult to demonstrate satisfactorily exactly what they are and which are of greatest importance. The experience of various growers appears to show that the control of the water supply is an important factor. The cranberry plant is naturally water loving and grows in its wild condition in the sphagnum bogs of deep swamps. When it is cultivated in open meadows and without a constant and sufficient water supply it quite naturally becomes weakened and susceptible to disease. In order to keep the plants in a thrifty condition the water supply should not only be sufficient but well controlled, so that the moisture may be kept near the surface during the growing season. In many cases there are local soil conditions which interfere with the healthy growth of the plants.

The practice of applying a thin layer of sand to the surface of the bog every few years is quite general in Massachusetts and is believed to tend to keep the plants in a thrifty and vigorous condition. In New Jersey this practice is not so common and the beneficial results where it has been tried do not seem to have been so apparent as in Massachusetts. The practice of sanding, since the sand would cover all the fallen diseased leaves and many of the old dead vines, would tend to prevent the development and spread of the spores and might prove beneficial in this way, if in no other. It is also desirable as a sanitary measure to rake out and destroy all dead and dying plants. The fungus *Guignardia vaccinii* produces its spores in great abundance upon such plants, and these, therefore, serve as a source of distribution for the parasite. All such dead and diseased matter should be destroyed by burning, preferably in the fall of the year.

Selection of resistant varieties.—It has been frequently observed that even in the most diseased areas of cranberry plants there is an occasional vine bearing fruit which appears to be free from disease. It seems probable, therefore, that by the selection and propagation of such plants a variety might be produced which would show a very considerable degree of resistance to this disease. As the cranberry is generally reproduced by cuttings, the propagation of a resistant variety would be simpler and more likely to succeed than in the case of plants propagated by seed.

Application of fungicides.—As already stated, Doctor Halsted [11] recommended spraying with ammoniacal copper carbonate. He also reports [4] trying several fungicides, including Bordeaux mixture and potassium sulphid, making two applications of each. No benefit from these applications was observed.

After determining the parasitic nature of the cranberry scald, the relationship of the parasite, and the probable manner of infection, it seemed reasonable that the disease should be prevented by the proper use of fungicides. In our first experiments the ammoniacal copper carbonate solution, potassium sulphid solution, and Bordeaux mixture were used. As very little benefit was apparently derived from the use of the two fungicides first mentioned, later experiments were made with Bordeaux mixture only. In the spraying work of 1904 [25] the results showed an average of 21.7 per cent of diseased fruit on the sprayed plats, while on the unsprayed check plat there was an average of 76.8 per cent diseased. The circumstances under which this was done were such, however, that the applications could not be made at proper intervals. During the next season (1905 [26]) the work was done more thoroughly and the results were far more satisfactory. As a result of five applications the sprayed plats averaged 2.36 per cent of rotten berries, while the unsprayed check plats averaged 92.6 per cent of rotten fruit. The 6–6–50 formula for Bordeaux mixture was used and 4 pounds of resin-fishoil soap were added. It was found that the plain Bordeaux mixture did not spread properly over the surface of the fruit and foliage, and also did not adhere well. In order to correct these defects the soap was added and was found to give most satisfactory results. The cost of spraying as done in these experiments averaged from $15 to $20 per acre, the mixture being applied at the rate of 4 barrels, or 200 gallons, at each application. Success in preventing this disease by spraying depends largely upon the care and thoroughness with which the preparation is made and applied. In our last experiments the 5–5–50 formula was used, and with thorough work it has been found to give as satisfactory results as the 6–6–50 mixture.

ROT.

The term " rot " is here applied to a decay of the cranberry caused by a fungus which we have recently described as a new genus and species (*Acanthorhynchus vaccinii* Shear).[24] The appearance of the fruit attacked by this disease is not sufficiently peculiar or characteristic to satisfactorily distinguish it from scald or anthracnose by its external or internal appearance. The rot first appears as a small, light-colored, soft spot on the berry, finally softening and destroying the whole fruit. In the later stages of its development it very frequently produces small, dark-colored blotches on the inner surface of the skin. So far as has been observed, the fungus never produces spore-bearing fructifications upon the berries. The only way in which this disease can be positively diagnosed is by making a culture from the mycelium of the fungus taken from the interior of the affected fruit.

The disease attacks the leaves also, but the fungus is very rarely found in a fruiting condition except on those which have fallen to the ground. Judging from the frequency with which this fungus appears in cultures made by transplanting the fungous hyphæ from decaying berries, the injury caused by it is second only to that produced by the scald. Though this disease is most frequent and destructive in New Jersey, it has also been found in West Virginia, Massachusetts, Wisconsin, and Nova Scotia.

THE FUNGUS (ACANTHORHYNCHUS VACCINII, SHEAR) CAUSING THE ROT.

The fungus producing the rot differs in several respects from any species which we have been able to find described. The rarity of its occurrence in a fruiting condition in the field probably accounts for its not having been discovered before. It has been found occasionally in considerable quantity on fallen leaves of diseased vines, and frequently appears on apparently healthy leaves from diseased vines which are kept in a sterile moist chamber for a week or two. It grows readily on various culture media and produces an abundance of ascogenous perithecia.

Ascogenous form.—The perithecia are ordinarily sparsely scattered over the under surface of the leaf, being buried beneath the epidermis, which is very slightly elevated and punctured by the short neck and ostiole (Pl. III, fig. 12). They usually vary in diameter from 300 to 400 μ. The short neck of the perithecium is beset with black, nonseptate spines 50 to 70 μ long by 8 to 9 μ thick at the base. These black spines are a constant and characteristic feature of the fungus, occurring in all of our cultures, as well as under natural conditions (Pl. III, fig. 13). On leaves the perithecia are somewhat depressed globose, but in artificial cultures, where there is no pressure from above as there is in the tissue of the host, they are somewhat pyriform. The wall of the perithecium is membranous or submenbranous in texture and consists of a single layer of cells. The asci are clavate, short-stipitate, and range in size from 136 to 180 by 30 to 48 μ. They are accompanied by rather stout, sepate paraphyses, occasionally branched near the end and varying in dimensions from 200 to 340 by 5 to 8 μ. The ascospores are somewhat biseriate or irregularly uniseriate. They are hyaline until almost mature, but finally assume a pale yellowish brown color. In shape they are oblong elliptical, and the protoplasm is densely granular. They vary in size from 27 to 36 by 12 to 20 μ.

Fruiting specimens on leaves have been collected in May, July, August, September, and October, and have been found in Nova Scotia, Massachusetts, New Jersey, West Virginia, and Wisconsin.

No conidial or pycnidial form of this fungus has ever occurred in any of our numerous cultures, and no such form has been found associated with it in nature under such circumstances as to suggest a genetic relation.

Appressoria.—A rather remarkable body is produced by the germ tube of the germinating spore. This is a more or less disciform, dark-colored, rather opaque organ, with an irregular, rather deeply lobed margin (Pl. III, fig. 17). It has been found upon the surface of leaves which bore mature perithecia, but was first found on the smooth surface of the upper portion of culture flasks where spores of the fungus had germinated. It is produced at the end of a short germ tube, arising from the ascospore, and its primary function is evidently that of an apressorium or holdfast.

Appressoria were first described and so named by Fisch [37] in 1882, as found in Polystigma. A little later Frank [38] described the same thing and also the similar productions occurring in *Gloeosporium lindemuthianum*. These bodies have usually been called chlamydospores. Meyer,[39] De Bary,[40] Büsgen,[41] and, more recently, Hasselbring,[42] have discussed these organs and their formation and function. Their production has generally been regarded as due to chemical or contact stimuli and lack of nutriment. The organs which are produced by *Acanthorhynchus vaccinii* differ in form from any of those described by the authors just mentioned. They have been found, as already stated, on the sides of glass culture flasks and upon the surfaces of cranberry leaves. They are produced in a few hours from fresh spores discharged against and adhering to the cover of a petri dish. These appressoria when transferred to culture media soon germinate and produce an abundance of ascogenous perithecia. They have also germinated on the covers of petri dishes where they have formed. This would appear to indicate that they possess a reproductive function not depending necessarily upon their connection with the surface of the host plant. When produced upon the surface of a cranberry leaf, the small irregular projections about the margin of the disk appear to attach themselves firmly, apparently by dissolving and forming small shallow cavities in the surface of the epidermal wall. A germ tube arises near the center, or sometimes toward the margin of the appressorium, and penetrates the surface of the leaf, usually in the sections we have studied entering through a stoma (Pl. III, figs. 21, 22). Sometimes the germ tube does not appear to penetrate the leaf at once, but sends out several superficial brownish filaments upon the surface of the leaf, as shown in Plate III, figure 20. These appressoria have been frequently found upon fallen cranberry leaves during the summer. They are sufficiently large to be easily observed, and are so firmly attached to the leaves that they are not readily removed.

Relationship of the fungus.—Acanthorhynchus is evidently closely related to certain Sordariaceous fungi, especially such genera as Sordaria and Hypocopra. The perithecia and spores are somewhat similar, and the spores are forcibly discharged from the asci at maturity, as in those genera. In Acanthorhynchus the whole mass of eight spores is thrown in some cases as much as 10 centimeters or more, and, being embedded in a gelatinous matrix, they adhere to any object with which they come in contact. As the spores mature the protoplasm surrounding them becomes denser and forms a sort of secondary membrane (Pl. III, fig. 14, *c*). The ascus has a characteristic apex which suggests that of Hypocopra, as described by Zopf [43] and also by Griffiths,[44] though in Acanthorhynchus it does not turn blue upon the application of iodin and does not show the peculiar thickenings observed by Zopf. The mass of protoplasm surrounding the spores reaches to the apex of the ascus and is attached there. In the case of some asci from which the spores have been discharged a small caplike portion remains, which suggests that the ascus may rupture about the apex. In other cases, however, the spores seem to have been discharged through the apical pore or the ascus has been split longitudinally from the apical pore. It has been impossible to differentiate or to positively distinguish a secondary membrane about the mass of gelatinous protoplasm in which the spores are embedded, but the manner in which it holds together would signify that there may be an outer layer functioning as a secondary membrane.

Cultures of the fungus.—Cultures of this fungus were first obtained from mycelium found in the interior of rotten berries. These cultures were made by transplanting the mycelium as described in the case of *Guignardia vaccinii.* Perfect perithecia and asci have been produced in forty different cultures made from diseased berries. In a number of instances a mycelium apparently identical with that of Acanthorhynchus has appeared, but no perithecia were ever formed. The fungus grows and reproduces most readily on corn meal, corn meal agar, and cranberry agar and corn meal. A few mature perithecia have been formed on steamed sweet potato cylinders. The fresh ascospores sometimes germinate quickly in moist air and produce appressoria in a few hours. In most cases in which spores have been observed to germinate, appressoria have been formed. The spores very rarely germinate in culture media. They germinate in damp air or water on glass and also on cranberry leaves. In pure cultures the fungus first forms a branched white mycelium, which spreads concentrically from the point of origin, forming a rather close white layer, which continues to spread until the whole surface of the culture medium is covered. Soon the mycelium begins to assume a dirty, ochraceous color, which becomes quite uniform and is soon followed by the appearance of the dark perithecia of the fungus. These, when full grown, give a dark cast to the surface as they become uniformly distributed throughout the yellowish layer. As in case of other ascogenous forms whose natural mode of growth is within the tissues of their host, the perithecia in cultures are more or less covered with fungous hyphæ, with the exception of the short neck, which protrudes above the surface of the mycelial subiculum (Pl. III, fig. 13). The fungus grows best at ordinary laboratory temperatures, varying from 20° to 26° C., and the mature perithecia are produced in from fourteen to thirty days. As in the case of Guignardia, and for the same reasons, we have been unable to determine yet at what time infection of fruit and vines takes place. Appressoria have not been observed on diseased berries, but, as already stated, they have been found on leaves, with the germ tube penetrating the tissue. The fungus is found in a fruiting condition on the cranberry bogs soon after the water is removed from the vines in the spring. It is therefore probable that infection of the young leaves begins about this time.

This fungus also evidently has the power of remaining in a dormant or inactive condition in the leaves and fruits, as is shown by the development of the fungus in apparently normal and healthy leaves and fruits which have been disinfected and kept in moist chambers in the laboratory. That the original infection is from external sources is shown by the presence of appressoria on the leaves, the germ tubes of which have been found entering the tissue (Pl. III, fig. 22).

TREATMENT.

What has been said in regard to the treatment of cranberry scald applies equally well to the rot. The two diseases almost always occur together, and Bordeaux mixture applied in the same manner as for scald has given satisfactory results.

ANTHRACNOSE.

Anthracnose is a disease not heretofore reported as affecting the cranberry. As is the case in most other diseases to which this name is applied, it is due to one of the fungi which have been called Gloeosporium. The ascogenous stage of the fungus having been produced, it is found to belong to the genus Glomerella and has been named *Glomerella rufomaculans vaccinii* Shear.[24] Like the scald and rot, this disease is at all times difficult, and usually impossible, to diagnose by a macroscopic examination of the diseased berries. The berries from which we have isolated the fungus which causes this disease have not been uniform in appearance. In one case the berry was very soft and light colored, while in other cases the fungus did not seem to have developed so rapidly and the portion of the fruit affected by the disease was not so soft. Acervuli sometimes develop on the diseased berry, but usually they do not. Judging from the infrequency of occurrence of this fungus in cultures made from affected berries, the disease is much less injurious than the rot or scald. It appears, however, to be widely and generally distributed throughout the cranberry growing regions of the eastern United States.

THE FUNGUS (GLOMERELLA RUFOMACULANS VACCINII, SHEAR) CAUSING ANTHRACNOSE.

Two species of Gloeosporium have already been described as occurring upon species of Vaccinium, but their relation to the fungus causing this disease is doubtful. This parasite has been grown in pure cultures, producing both the conidial and ascogenous forms.

Conidial form.—The acervuli are rather small, scattered over the under or upper surface of the leaf and sometimes occurring upon old berries which have been destroyed by the fungus. The epidermis is usually somewhat dark colored immediately above and about the mass of conidia. At maturity the epidermis ruptures and the conidia form a light, flesh-colored, waxy mass upon the surface. They are hyaline or subhyaline, as observed under the microscope, and oblong elliptical, or sometimes slightly smaller at one end, varying in dimensions from 12 to 18 by 4.5 to 6 μ (Pl. III, fig. 2). The conidiophores are simple, tapering upward, and from 15 to 20 μ long. The conidia germinate readily in water or ordinary culture media. The mode of germination and growth agrees with that of other species of Gloeosporium, as described by Stoneman,[45] Clinton,[46] and others, except that no septum is formed in the conidia so far as observed. This conidial form has been found on berries from several localities in Massachusetts, and also on leaves from New Jersey which were soaked in corrosive sublimate 1–1,000 and kept in a moist chamber for from one to two weeks. It has also been obtained in cultures made from diseased fruit from Wisconsin, Massachusetts, and New Jersey.

Ascogenous form.—This stage of the fungus has not been found on the cranberry plant either in the field or in moist chambers, but has been grown in cultures from leaves bearing the fungus, and also from ascospores. The perithecia are membranous, subglobose or slightly pear shaped, usually somewhat buried in a felty subiculum or pseudo-stroma when growing on corn meal and forming a continuous layer over its surface (Pl. III, fig. 6). In old cultures they frequently become closely packed and form a more or less opaque stratum. The asci are clavate, sessile, or short stipitate, and measure 60 to 72 by 10 to 12 μ (Pl. III, fig. 7, *a*, *b*, *c*), and are sometimes accompanied by what seem to be evanescent paraphyses (Pl. III, fig. 9). The ascospores are somewhat irregularly biseriate, oblong elliptical, and occasionally slightly inequilateral or curved. They are hyaline at first, but when fully mature become pale greenish yellow. They vary in size from 9 to 18 by 5 to 7.5 μ (Pl. III, fig. 8).

Appressoria, or chlamydospores.—In badly decayed berries and in old pure cultures the irregular dark-colored bodies have been found which have been called chlamydospores by some authors and appressoria by others (Pl. III, figs. 4 and 5). The work of Fisch,[37] Frank,[38] Hasselbring,[42] and others seems to show that the primary function of these organs is that of an appressorium. In the case of the cranberry anthracnose, at least, they may also function as reproductive bodies. Some of those found in the interior of a decayed berry (Pl. III, fig. 4) were carefully transferred to culture media and were found to germinate and produce a luxuriant growth of mycelium and conidia. It has been urged that they show no provision for distribution, as spores or reproductive bodies should. When produced in the interior of berries, however, they appear to show even less possibility of functioning as appressoria. The bodies as found in fruit and old cultures are somewhat variable in form and appearance, but agree in general with those produced upon the germ tubes arising from conidia. The light-colored spot frequently observed and regarded by some as a germ pore is quite as frequently wanting in the cases we have observed. Though probably primarily functioning as appressoria, these bodies under certain conditions appear to serve the purpose of a resting spore or chlamydospore.

Cultures of Glomerella rufomaculans vaccinii.—Cultures made from berries affected with anthracnose and from leaves have in most cases produced conidia only, but in four instances the ascogenous stage was also produced. The berries were from Massachusetts, New Jersey, and Wisconsin.

Cultures have also been made from leaves containing mycelium as well as from conidia and ascospores. The growth in all cases is essentially the same in appearance. The conidia germinate readily, sending forth one or more germ tubes, which soon begin to branch and then form a rather dense pure white mycelium. This on sterilized corn meal spreads rapidly until the surface of the medium is covered with a compact layer of the fungus. On poured plates of beef agar the growth of the mycelium is much less luxuriant. Acervuli of conidia begin to appear in three or four days, and these are frequently followed by the formation of dark-colored bodies resembling the fundaments of perithecia. These bodies, however, have never produced mature asci on agar cultures.

The germination of the ascospores and the subsequent growth and development of the mycelium are essentially the same as in the case of the conidia. Cultures from ascospores on poured plates of beef agar only produced conidia and what appeared to be young perithecia, but no asci were ever found. Transfers made of germinating ascospores from such poured plates to flasks of sterilized corn meal produced ascogenous perithecia in abundance in about ten to twelve days. In the case of one culture made from a diseased berry, very few conidia were ever formed, but an abundance of the ascogenous form was present after eighteen days. We have not as yet succeeded in growing the ascogenous form in pure cultures from single conidia. Little opportunity, however, has been given for making such cultures from the ascus-bearing form, on account of the few conidia produced by it. Besides beef agar and corn meal, the fungus has been grown upon cranberry agar and corn meal, and also upon potato cylinders. Although the fungus appears to grow best on corn meal or cranberry agar and corn meal, there is nothing to indicate that the culture medium is the determining factor in the production of the ascogenous stage of the fungus. As in the case of the scald fungus, *Guignardia vaccinii*, the important factor seems to be some particular potentiality of the mycelium or spore from which the culture is made.

Factors determining the production of the ascogenous fructification.—Previous successful attempts of the writer and others to produce asci in various forms of Gloeosporium have indicated that there is a much more important factor involved than the culture medium or conditions of light, temperature, and moisture. Whether the nearness or remoteness of origin of the conidia from an ascogenous form is of importance has not yet been satisfactorily determined. The successful cultures made by Miss Stoneman [45] were from conidia taken from acervuli produced upon the different hosts of the species studied. In such cases, of course, there is no means of determining the ancestry of the conidia used.

Relationship of the fungus.—The ascogenous forms of the numerous anthracnoses known have very rarely been recognized or reported as occurring under natural conditions. It is probable, however, that some of the pyrenomycetous fungi which have been described under the genera Physalospora or Phomatospora, or perhaps under other closely related genera, are really the ascogenous forms of species of Gloeosporium. The very close relationship of many of the species described under these genera and the want of any very striking or peculiar characteristics of the known ascogenous forms of Gloeosporium make it difficult to determine with certainty from purely morphological characters the generic identity of these organisms. The name Glomerella has been proposed for these fungi by Spaulding and von Schrenk.[47] This name, however, may have to be abandoned if it can be demonstrated that ascogenous forms heretofore described under an older valid generic name are really stages in the development of congeneric species. The question of specific distinctions in this genus is very perplexing. The differences in the morphological characters of the ascogenous fructifications are quite as slight and unsatisfactory for separating species as the differences which occur in the conidial forms. This has been clearly shown by the studies of Shear and Woods.[35] Various inoculation experiments made with the conidial forms occurring on different hosts have seemed to indicate that they will pass readily from one host to another. Most such inoculation experiments appear to us inconclusive, particularly in such cases as those given by Halsted[14] and others, in which transfers of conidia were made from one mature fruit to another by inserting the conidia in the fruit. These experiments may perhaps be more correctly interpreted as indicating that the fruit upon which the fungus grows successfully in such an inoculation experiment is simply a satisfactory nutrient medium for the fungus. In order to demonstrate the possibility of the various forms being passed from one host to another as actual parasites, it would be necessary to make the inoculations on the living and actively growing parts of the plants. This has been done in one case, at least, by Sheldon,[48] in which he successfully inoculated stems and leaves of growing sweet peas by applying conidia from the bitter-rot (*Glomerella rufomaculans* (Berk.) Spauld. & von Schrenk) of the apple. Whether other forms will show equal ability to pass from one host to another as active parasites remains to be determined.

Dormant condition of the fungus.—We have found by experiments similar to those described in connection with the account of the scald fungus, *Guignardia vaccinii* (p. 21), that the mycelium of the cranberry Glomerella may remain in an inactive or dormant condition in the tissues of the living fruit of the cranberry for a considerable time. Whether the fungus is really inactive or not it is difficult to say. It at least does not give the slightest local external evidence of its presence. Berries which were, so far as could be determined by external examination, perfectly sound and free from fungi, were very thoroughly soaked and washed in a 1–500 solution of corrosive sublimate. Such leaves and berries when placed in warm, sterile, moist chambers developed typical cases of anthracnose. On the leaves treated in the same manner numerous acervuli have appeared, and cultures made from the mycelium found in the decayed fruits mentioned above have produced the conidia in pure cultures. Inoculation experiments, made by applying fresh conidia to the surface of cranberries and apples placed in warm moist chambers, have been without definite results. It seems that in the case of this fungus, as well as Acanthorhynchus and Guignardia, the spores do not possess the power of penetrating the epidermis of the fruit after it has reached maturity. Infection apparently occurs earlier in the season, but the exact time and manner has not yet been determined for want of plants known to be entirely free from disease.

TREATMENT.

From the beneficial results of spraying cranberries where this disease was known to be present and also from the success obtained in preventing other diseases caused by similar fungi, such as the bitter-rot fungus of the apple,[49] it appears probable that thorough spraying with Bordeaux mixture will prove a satisfactory treatment. The disease so far as now known is always associated with scald or rot, and the treatment recommended for those diseases will be sufficient for this.

HYPERTROPHY.

The fungus (*Exobasidium oxycocci* Rostr.) causing hypertrophy is only known at present from Massachusetts. In 1906 it destroyed a considerable part of the crop on several cranberry meadows in that State and caused considerable alarm. It is apparently somewhat erratic in its behavior. On one meadow it attacked almost every plant on a part of the bog, while some other portions were almost free from it. The variety known as Matthews seemed to be especially susceptible to the disease.

The disease first makes its appearance on flooded bogs soon after the water has been removed in the spring, which is usually about the middle of May or a little later. The axillary leaf buds, which usually remain dormant, are attacked by the disease and produce short shoots with rather close, enlarged, swollen, and distorted leaves which are pink or light rose colored (Pl. VII, *C* and *D*). The colored hypertrophied leaves, being close together, bear a slight superficial resemblance to a flower of some sort. This appearance has led some persons to call these diseased shoots " false blossoms." This is misleading, as it suggests some reference to the flowers of the cranberry, which are not included in this peculiar malformation.

Most of the affected plants are attacked before the blossoms have developed, thus preventing the production of fruit. Shoots whose buds are attacked later in the season after the blossoms have opened or fallen (Pl. VII, *D*) also usually fail to develop fruit, as the vitality of the shoot is apparently exhausted by the fungus. Besides the fruit-bearing shoots, ordinary vegetative shoots or runners are also affected in the same manner (Pl. VII, *C*).

No opportunity has been afforded to examine plants which had suffered from this disease the previous year, but the injury to the affected plants and the lowering of their vitality are so evident that the production of fruit the succeeding season would probably be far below normal even though the disease did not recur upon the plants.

THE FUNGUS (EXOBASIDIUM OXYCOCCI, ROSTR.) CAUSING HYPERTROPHY.

In this, like all Exobasidii, the mycelium of the fungus infests the tissue of the leaves and stems, producing the hypertrophied condition described above. The basidia are elongate clavate, and are produced at the extremities of the hyphæ. They emerge on the surface of the affected part of the host and produce usually four basidiospores at the ends of short, slender sterigmata. The spores are usually somewhat fusiform, slightly curved, and hyaline, measuring 14 by 3.5 μ. They proceed to grow soon after falling and may be seen in old specimens in different stages of germination. From one to three transverse septa are usually formed, after which a germ tube arises from either or both ends, which produces conidia somewhat resembling the basidiospores, but smaller. The fungus, when mature, gives a fine, gray, powdery appearance to the surface of the distorted parts of the host.

Relationship to other Exobasidii.—This species, so far as it has been studied, agrees in morphological characters with *Exobasidium vaccinii* (Fckl.) Wor. The spores of *Exobasidium vaccinii* are, according to Saccardo, 5 to 8 by 1 to 2 μ. This, according to Woronin,[9] Richards,[59] and others, is an error, as the basidiospores usually range from 14 to 17 by 3 μ. The error possibly arose from the confusion of basidiospores with conidia, which are frequently present, especially in specimens which are getting old.

The typical form of *Exobasidium vaccinii* occurs on *Vaccinium vitis-idaea*, producing hypertrophied spots on the leaves. No record has been found of the occurrence of hypertrophied shoots on this host similar to those found on cranberry plants. Rostrup[51] seems to have been the first to describe this form. In 1883 he reported it as occurring on *Oxycoccus palustris* in Denmark. His description accords exactly with the specimens we have found on the cranberry plant. He says he could not find the two forms, i. e., the one producing spots on the leaves, typical *Exobasidium vaccinii*, and the one producing hypertrophied shoots, *Exobasidium oxycocci*, on the same plant, but the two were found in the same locality in one instance.

An Exobasidium also occurs on cranberry plants in Massachusetts, which produces spots on the leaves like those produced on *Vaccinium vitis-idaea*, and agrees also in all microscopical characters with *Exobasidium vaccinii* (Fckl.) Wor. (Pl. VII, *A* and *B*). No specimens of the two forms could be found on the same plant or in the same vicinity. No cross-infection experiments with these two forms have been tried on these hosts so far as known, and as the observations already made seem to indicate the probability of their being separate species, we shall retain for the present the two names as already used.

Richards [59] reports infection experiments with the Exobasidium producing spots on leaves of Andromeda and the one forming large inflated galls on the same host. He succeeded in producing the leaf-spot form by using spores from the gall-producing form which was named *Exobasidium andromedae* by Peck.[53] This suggests the possibility of the interchange of other forms, and it is hoped that further work may be done in this direction.

Exobasidium oxycocci occurs in greatest abundance in May and June. It has also been collected as late as September, when occasional fresh specimens were found at Brewster and Pleasant Lake, Mass.

TREATMENT.

Little, if anything, so far as can be learned, has been attempted in the way of controlling diseases caused by Exobasidii, as they have rarely assumed economic importance. As definite knowledge in regard to time and manner of infection is lacking, it is difficult to recommend treatment. It is possible that spraying with Bordeaux mixture may be beneficial, and experiments in this direction are planned for the coming season, when it is also hoped to secure more knowledge of this fungus.

LESS IMPORTANT DISEASES.

FUNGI ATTACKING THE FRUIT.

Synchytrium vaccinii Thomas.—This fungus was first described from New Jersey specimens by Dr. Fr. Thomas,[55] of Germany, in March, 1889, under the above name. When first discovered it threatened to do serious injury to the New Jersey cranberry bogs. It was first found in 1886 upon a bog near Browns Mills, N. J. Doctor Halsted,[10] of the New Jersey Experiment Station, gave an account of the disease in 1889, and called the parasite the cranberry gall fungus. The fungus attacks the leaves and young stems as well as the flowers and fruit, forming great numbers of small, reddish, gall-like swellings upon their surface (Pl. IV, figs. 15 and 16). Sections of these galls show the fructification of the fungus embedded near their center (Pl. IV, fig. 17). The fungus consists of a scanty vegetative mycelium producing globose sporangia, which finally develop a mass of swarm spores within. The sporangia rupture and the spores are then set free. These swarm spores are motile and well adapted to distribution through the water. At the time this fungus was found at the place mentioned a considerable portion of the plants on one side of the cranberry meadow was affected and the complete destruction of the vines was threatened. So far as known the only measure taken to prevent the disease was the withholding of the water during the winter, as it was believed that the disease was distributed chiefly by the water. This plan seems to have proved successful, as the disease disappeared entirely within a few years. When the affected bog was recently visited it was impossible to find a trace of the fungus present on the vines or to learn of its occurrence anywhere in the region since. It seems to have entirely disappeared.[a] Similar sudden appearances of new parasites have been observed. No entirely satisfactory explanation of such phenomena has yet been given. Their sudden disappearance is less common. This fungus is not restricted to the cranberry plant, but has been found on several other ericaceous plants. Specimens on the following hosts collected by Doctor Halsted in New Jersey are preserved in the pathological collections of the Department: *Gaultheria procumbens*, *Cassandra calyculata*, *Kalmia angustifolia*, *Azalea viscosa*, *Clethra alnifolia*, and *Gaylussacia* sp. It may be expected to appear again if the conditions for its development and spread should happen to be favorable. Since its discovery in New Jersey it has been found as far north as Newfoundland, but has not been reported as doing harm to the cranberry, except in the case mentioned.

Pestalozzia guepini vaccinii Shear.[22]—This fungus has been isolated in eight instances from diseased cranberries. It is also frequently found on the leaves of the cranberry plant. The effect of this fungus upon the berries, like that of some other parasites, is not sufficiently characteristic to enable one to recognize it by an examination of the fruit. Hence we are unable to determine how much injury is caused by it. The indications are, however, that it does not do nearly as much damage as the other parasites already described. It is much more frequent upon the leaves than upon the berries and may be found upon the recently fallen leaves during the summer. It also develops very frequently on leaves apparently free from disease when they are placed in a sterile moist chamber.

The acervuli of the fungus are formed beneath the epidermis and are sparsely scattered over the leaf (Pl. II, fig. 15). As the fungus matures the epidermis ruptures and the spores collect in dark masses or spread out and form a thin layer upon the surface about the acervuli. The conidia are elliptical and somewhat inequilateral and usually four-septate (Pl. II, fig. 15, *a*, *b*). The three central cells are dark colored and usually guttulate. The septum below the upper cell is usually darker than the others. The two terminal cells are hyaline, and the apical one is furnished with three to four filiform setæ,

[a] Since this was written the disease has again been reported as occurring this season in New Jersey.

varying from 22 to 35 μ in length. The basal cell also has a short hyaline appendage 6 to 12 μ long.

This fungus is quite generally distributed in the cranberry-growing regions. Specimens have been obtained from West Virginia, New Jersey, Wisconsin, Massachusetts, and New York.

Pestalozzia guepini Desm. is given by Farlow and Seymour[60] as occurring on the cranberry, but a study of that species indicates that our plant is a variety at least, as indicated, and may perhaps be found to be a distinct species.

The spores of this fungus germinate readily under ordinary laboratory conditions in water or culture media. The germ tube almost invariably arises from the basal cell of the spore (Pl. II, fig. 15, *c*, *d*). Occasionally two germ tubes arise, one from each side of the basal cell (Pl. II, fig. 15, *d*). The germ tube grows rapidly and soon begins to branch, forming a nearly white mycelium. This covers the culture medium with a thin, rather compact layer. About the time acervuli begin to form, a faint pinkish tinge appears. Acervuli and spores are produced in about ten to twelve days. The acervuli first appear as dark-colored dots. Spores are produced in enormous numbers and spread about the acervuli in irregular black masses.

This fungus has been grown from leaves and fruit from different sources on different media and under different conditions for several years, but no other spore form has ever been found. Where the growth of the fungus is very luxuriant, abnormal spores are produced, which bear four or five and rarely six appendages, sometimes much longer than usual, and branched.

This fungus is common and widely distributed, but so far as our knowledge goes does not attack the fruit with sufficient frequency to cause much loss. It is much more common on the foliage and may thus injure the plants affected. It has been found to be present in leaves which showed no external signs of disease, as has already been noted in the case of *Guignardia vaccinii* and some of the other cranberry fungi.

There is reason to believe that where the disease is present it can be controlled by the usual treatment with Bordeaux mixture.

Helminthosporium inaequalis Shear[24].—This fungus has been obtained in cultures made from diseased cranberries from New Jersey. These cultures were made November 8, 1905, by carefully transferring the fungous hyphæ from the pulp of affected berries to flasks containing sterilized corn meal. There was nothing in the external appearance of these berries to indicate that the injury was due to other than the usual rot or scald fungi. The first growth of the mycelium was nearly white, but very soon assumed a light, smoky color, and finally became a dark, smoky brown. The whole surface of the medium was covered with a thick, loose layer of much-branched hyphæ. The vegetative hyphæ frequently form strands of several filaments closely united (Pl. V, fig. 8).

The fertile hyphæ were distributed over the surface and bore conidia at the apex as well as at the sides (Pl. V, fig. 4). These conidia are somewhat elliptical and usually conspicuously inequilateral (Pl. V, figs. 5, 6, 7). They are thick walled and from three to five celled at maturity, all but the terminal cells, which are hyaline, being of a deep-brown color. The conidia measure from 18 to 36 by 8 to 14 μ. In old cultures tufts or clusters of erect, slender, irregular, somewhat branched, hard, black bodies 5 to 15 millimeters in length are formed in great abundance, covering the surface of the culture (Pl. V, fig. 9). These appear to be of a sclerotoid nature. They have never been found to bear fructifications of any sort. When broken up and pieces are transferred to culture media, the mycelium grows and soon produces conidia. So far as known this fungus is of infrequent occurrence and probably causes very little injury. It has not been found in a fruiting condition upon fruit or vines in the field.

Gloeosporium minus Shear.[24]—Besides the Gloeosporium (*Glomerella rufomaculans vaccinii*), already described as causing the cranberry anthracnose, another has been found which has been published under the above name. Only the conidial stage is known. All efforts to produce an ascogenous form have thus far failed.

The acervuli are amphigenous, small, and scattered, and do not form a definite discolored spot on the leaf so far as observed. They sometimes occur upon the berries. In such cases the epidermis is dark colored above and about the acervulus. The conidia are discharged through a rupture in the epidermis and form a pale pinkish, glutinous mass. They are oblong-elliptical or subcylindric and sometimes inequilateral or somewhat clavate (Pl. III, fig. 11), and are usually guttulate when fresh. They vary in size from 6 to 9 by 3 to 4 μ and are borne on simple, slightly tapering sporophores one and a half to two times the length of the conidia. No setæ have been observed in any of the acervuli.

The conidia of this species are only about one-half as large as those of *Glomerella rufomaculans vaccinii* and show no great amount of variation, either under natural conditions or in cultures. This species is perhaps closely related to *Gloeosporium myrtilli* Allesch., which has conidia 6 to 10 by 1.5 to 3 μ, and occurs on *Vaccinium myrtillum* in Germany.

This fungus was first found on cranberries offered for sale in the Washington market in April, 1902. It has also been found on cranberry leaves from New Jersey and has been isolated from other leaves from the same State. It is apparently of comparatively rare occurrence and perhaps of little importance as a disease producer.

Sporonema oxycocci Shear.[24]—This excipulaceous fungus has been found on cranberry leaves from various localities. The pycnidia are imperfectly developed, the upper portion being thin and disappearing toward the center of the disk (Pl. V, fig. 18). They are dark brown, scattered or gregarious, pulvinate, covered by the epidermis, and measure about 50 to 100 μ in diameter. They rupture by a longitudinal or irregularly triangular slit (Pl. V, fig. 17). The spores are continuous, hyaline, cylindrical, obtuse, borne on very short ovoid sporophores, and measure 17 to 19 by 3 to 4 μ (Pl. V, figs. 19 and 20). In cultures the range of variation in spore measurement was somewhat greater, being 15 to 20 by 3 to 4 μ.

Specimens have been obtained from Carver and on Cape Cod, Mass., and Martinsville, Me.; also from near Belleplain and Whitesville, N. J., the dates ranging from June to September.

This fungus has usually been found on dead or dying cranberry leaves, but in one instance it was found in a diseased berry which was obtained in the Washington market. The berry had a soft, slightly discolored spot. After thoroughly washing and soaking the berry in corrosive sublimate solution, a portion of the diseased pulp and skin of the fruit was carefully transferred to a flask of sterilized corn meal. Normal pycnidia of the fungus developed upon the portion of the skin of the berry in the culture. The mycelium spread to the culture medium and formed a rather compact thin layer, at first whitish, then dark grayish green, and finally dark grayish brown and somewhat mouse colored. In about a month mature pycnidia were formed about the sides of the flask. The so-called pycnidia are incomplete and consist in the culture of dense, dark, pulvinate masses depressed at the center where the pycnospores are borne and somewhat overgrown by loose hyphæ from about the margin. Frequently instead of normal spore development the sporophores became lengthened and formed irregular stout hyaline filaments about twice the length of the spore. The single instance in which this fungus has been found in the fruit shows that while it is capable of injuring the fruit, it perhaps does very little damage at present.

Arachniotus trachyspermus Shear.[23]—This fungus was first isolated from a very badly diseased berry from New Jersey which had been kept from September until April 11. The berry was very soft and light colored. The same fungus has also occurred twice on the surface of decayed fruit which had been kept in a moist chamber for a considerable period.

In pure cultures the fungus first forms a fine, thin, white mycelium, which is soon followed by the development of minute arachnoid snowy-white perithecia (Pl. IV, figs. 18 and 19), which are 325 to

425 μ in diameter and consist of slender, thin-walled, unarmed hyphæ, forming an anastomosing arachnoid layer about the mass of asci. The asci are globose or subglobose, very thin walled, and 7 to 8 μ in diameter (Pl. IV, figs. 20 and 21). The ascospores are ovoid, light lemon yellow in mass, echinulate-roughened, and measure from 3.25 to 4 by 2 to 2.5 μ (Pl. IV, fig. 22). The asci are very closely packed together and borne upon the tips of the very slender and scantily branched filaments of the ascogenous hyphæ. It is not until the ascospores are fully mature that the color and rough surface are readily recognized.

The species is closely related to *A. candidus* (Eid.) Schroet., but differs in having rough, faintly colored spores. A minute, greenish, conidial form resembling Penicillium occurred in all the old cultures of this fungus. These cultures were apparently pure and free from contamination, and it seems quite probable that this represents the conidial stage of this Arachniotus. We have, however, been unable as yet to satisfactorily demonstrate this by other cultures made from ascospores and conidia. This fungus has not been found fruiting in the field, and is probably of no great pathological importance.

Septoria longispora Shear.[24]—This fungus has been collected three times in New Jersey—twice upon cranberry leaves and once upon a fruit. It has also been grown in ten cases in cultures from cranberry leaves. The pycnidia are scattered over the surface of the leaf or fruit and seated beneath the epidermis. They vary in size from 120 to 250 μ in diameter (Pl. IV, figs. 12 and 13). No definite spot or discolored area seems to be formed. The pycnospores are very long and slender and curved, varying from 150 to 240 μ by 3 to 4 μ (Pl. IV, fig. 14). When straightened they reach 300 μ long. They are borne on simple slender sporophores 6 to 9 μ long. The length of the spores seems to separate this species from any other Septoria described, as they are twice as long as those of any species heretofore known. This fungus appears to attack the fruit but rarely. It has been found only in New Jersey, and is apparently of infrequent occurrence.

Sphaeronema pomorum Shear.[24]—This fungus has been found but once. It was obtained in a culture made by the transfer of hyphæ from the interior of a diseased berry taken from a lot of sprayed fruit from New Jersey. It has been kept growing on culture media for a long time. The fungus first formed a thin white layer upon the culture medium, and this was soon followed by the development of numerous pycnidia quite evenly scattered over the surface of the mycelial layer, giving it a dark appearance. The pycnidia are membranous or subcoriaceous, globose or subglobose, 120 to 200 μ in diameter, and provided with a slender neck about 80 μ long (Pl. V, fig. 1). The pycnospores are hyaline or pale greenish yellow in mass, oblong or subcylindric, and measure from 5 to 10 by 3 to 6 μ (Pl. V, fig. 1, *a*). This fungus has not been found upon either leaves or fruit in the field, and appears to be of rather rare occurrence.

Phyllosticta putrefaciens Shear.[24]—This fungus has been obtained in two cases in cultures made from the hyphæ taken from the interior of decayed berries. The berries were picked from the sprayed plats at Whitesville, N. J., and kept in the laboratory about a month. The berries showed no external appearances which would indicate that the disease was different from that produced by rot or scald fungi.

The pycnidia are gregarious, membranous, globose, or subglobose, and vary from 75 to 150 μ in diameter (Pl. V, fig. 10). The spores are faintly yellowish in mass, ovoid or oblong-ovoid, and measure from 4 to 6 by 2 to 3 μ (Pl. V, fig. 10, *a*). In the cultures the fungus first produced a thin, white, floccose mycelial layer over the surface of the medium. This gradually became thicker and then produced a layer of black pycnidia. What appears to be the same fungus has been found on leaves from Massachusetts. A fungus closely resembling this one has also been collected in Massachusetts on cranberries which had been destroyed by the berry worm. The spores were slightly larger and the ostiole different. This fungus presumably is the pycnidial stage of some ascogenous fungus, but no such form has appeared in any of the numerous cultures which have been made.

Anthostomella destruens Shear.[24]—This fungus has only been found in one instance, when it was obtained from a diseased berry grown in New Jersey. The culture was made November 2 by transferring the fungous hyphæ from the interior of the berry, as in the other cases mentioned. A white mycelial layer was first formed, and this was soon followed by the development of black perithecia more or less overgrown by the white filaments of the mycelium. The perithecia are membranous or submembranous, globose, and 350 to 450 μ in diameter (Pl. IV, fig. 8). The asci are cylindric or cylindric-clavate and vary from 150 to 225 by 14 to 18 μ (Pl. IV, fig. 9). No paraphyses have been found. The ascospores are dark brown, elliptic, uniseriate, and 16 to 24 by 10.5 to 12 μ (Pl. IV, fig. 10). This fungus has not been found fruiting in the field and is apparently of rare occurrence. None of the cultures made from ascospores has shown any other spore form. The plant is perhaps rather closely related to *Anthostomella picacea* (C. & E.) Sacc., which has been found on Vaccinium, but it is easily separated by the size of the asci and spores.

Penicillium glaucum Link.—This fungus occurs frequently on old diseased fruit when it is kept in a sterile moist chamber. It grows especially upon the old calyx of the flower and the apex of the fruit and has been isolated from the pulp of decayed fruit. In cultures and on decaying fruit it occasionally produces the coremium form. The fungus probably does not cause decay of the fruit, except where the skin has been injured to permit its entrance.

Leptothyrium pomi (Mont.) Sacc.?—Occasionally about picking time there appear on cranberries minute black fungous specks or spots having an appearance identical with that of the "flyspeck" or fruit speck of the apple. Microscopical examination shows that these spots consist of thin, dense, superficial, dark-colored, short-celled, rather thick-walled hyphæ. When old the spots are slightly convex, and when examined in cross section show a somewhat lighter colored compact cellular mass closely attached to the epidermis of the fruit (Pl. V, fig. 15). Specimens kept for a long time in a moist chamber have never shown any indication of spore formation. A study of these specks in different stages of formation shows that they arise from a germinating spore. An anastomosing, dark-colored, thick-walled mycelium is formed (Pl. V, figs. 13 and 14), which continues for some time to increase in size and thickness until it reaches the condition shown in Plate V, figure 15. A careful examination of the surface of berries bearing these specks revealed the presence of three different kinds of fungous spores (Pl. V, fig. 16, *a*, *b*, and *c*). Those shown at *b* and *c* were rather frequent. The form shown at *a* is the only one which was found germinating, and as remains of similar spores were found connected with the very young specks we are led to think that they are produced by these spores. We have no means of knowing to what genus of fungi any of these spores belong. Those shown at *c* bear a strong resemblance to Cladosporium.

So far as we have been able to learn, no one in this country has found any spores produced by this fungus. We have attempted to grow the plant in culture media, but without success. *Labrella pomi* Montagne[56] was described as follows: "Macula nulla, peritheciis ellipticis minimis rugosis nitidis, sporidiis globosis." In view of the mention of globose spores in the description and our scanty knowledge of the original plant, it is rather doubtful whether the plant we are dealing with is that described by Montagne.

This fungus has only been seen from one locality, Parkdale, N. J. It does not seem to injure the fruit except that it renders it unsightly. Thorough spraying will probably prevent its appearance.

FUNGI OCCURRING ON THE LEAVES OR STEMS.

Several of the species of fungi already described as attacking the fruit are also found on leaves or stems. The following species have been found only on the leaves or stems of the cranberry. So far as our present knowledge of these goes, they do not cause sufficient injury to be of great economic importance. Their future behavior can not be foreseen, however, and they may bear some direct relation to each other or to the other parasites which may prove important.

Venturia compacta Peck.[54]—This fungus has been before reported upon the cranberry by Professor Peck, who found it in New York. It has also been collected, according to Ellis, in Maine, and by Halsted in northern New Jersey. We have found it on cranberry leaves from Nova Scotia, and also from Massachusetts, New Jersey, and Wisconsin. Fusicladium has been demonstrated to be the conidial stage of certain species of Venturia, but no such conidial form has been found in connection with this species. *Cladosporium oxycocci* Shear has been found associated with it, but nothing is known as to the relation between the two forms.

This fungus shows considerable variability, especially in the grouping of the perithecia and the production of spines, the size and shape of the asci, the presence or absence of paraphyses, and the arrangement of the spores. The perithecia are usually aggregated in rather dense clusters, but are occasionally solitary (Pl. IV, fig. 1). The spines may be few and arranged about the ostiole or more numerous and scattered over the upper half of the perithecium (Pl. IV, figs. 3 and 5). They vary in size from 30 to 60 by 6 μ. The asci are usually swollen at the lower end (Pl. IV, fig. 6), but are frequently cylindrical (Pl. IV, fig. 4). They vary in size from 48 to 66 by 9 to 12 μ. The spores are very constant in size and shape, measuring 14 to 18 by 4 to 6 μ. It was at first thought that the extreme forms might be separate species, but a study of more material shows all sorts of intermediate conditions. Schweinitz [57] has reported *Venturia cincinnata* Fr. on *Vaccinium macrocarpum* from Pennsylvania. An examination of Schweinitz's specimen indicates that it is *Venturia compacta* Pk. Fries's [58] species was found on *Vaccinium oxycoccus*, and so far as the description goes scarcely differs from our plant, except that the perithecia are said to be solitary. We have been unable to find a specimen of Fries's species in his herbarium, and it is perhaps doubtful whether the two species are the same. It seems rather probable, however, that such is the case.

This fungus seems to be comparatively rare except in Massachusetts, and though a parasite it evidently does little damage. It is not known to attack anything but the leaves. However, from the habits of its near relatives, which cause the serious scab diseases of other fruits, it may perhaps sometimes attack the fruit of the cranberry.

Sclerotinia oxycocci Wor ?[9]—The Monilia form of a fungus closely resembling this was found upon the young leaves and tips of cranberry plants sent from Wisconsin in July, 1905. This fungus has not been reported heretofore upon the American cranberry, though different species of the genus attack various species of Vaccinium in Europe and do considerable damage to the fruit. Under favorable conditions for its reproduction and distribution this fungus might prove a very serious enemy of the cranberry, and it is quite important that steps should be immediately taken to eradicate it whenever and wherever it is found.

The ascogenous stage of this fungus has not yet been found here, though it probably occurs in the locality from which the conidia were obtained. The conidia are borne in chains and measure 12 to 20 by 10 to 12 μ (Pl. IV, fig. 23). They agree in all particulars with Woronin's description and figures, except in the size of the spores. In his description Woronin gives 25 to 28 by 16 to 22 μ as the measurements.

Discosia artocreas (Tode) Fr.—This fungus has been found on cranberry leaves from Cranmoor, Wis., which had been kept in the laboratory in a moist chamber. Other specimens have been obtained on leaves from near Whitesville and Jamesburg, N. J., from Wareham and Brewster, Mass., and from West Virginia. The specimens collected in the field were found in September and November. This fungus has usually been regarded as a saprophyte and probably does no particular injury to the cranberry plant.

Plagiorhabdus oxycocci Shear.[24]—This interesting fungus, which it has been necessary to refer to a new genus and species, was found on cranberry leaves collected near Carver, Mass., in May, 1906. The pycnidia are scattered, slightly erumpent, covered by the epidermis, 125 to 190 μ in diameter. The wall is not regular and well developed, but is thicker and denser above. The interior is either simple or somewhat chambered, but opens through a single ostiole (Pl. V, fig. 2). The pycnospores are hyaline or faintly colored in mass, and are borne on slender, simple sporophores (Pl. V, fig. 3). They measure 8 to 11 by 3 μ and are borne obliquely on the sporophore, which is abstricted at its base and remains as an appendage (Pl. V, fig. 3, *a*), which is 10 to 15 by 0.75 μ. This species is closely related to *Plagiorhabdus crataegi* Shear,[24] which is found on the fruit of Crataegus. It would therefore not be surprising if the species occurring on the cranberry should also be found upon the fruit.

Sporonema pulvinatum Shear.[24]—This fungus has been found upon cranberry leaves in three instances—once on leaves collected in New Jersey in November, 1905, and once on leaves from Olympia, Wash., collected in October; also upon leaves from West Virginia collected in June and kept in a sterile moist chamber. The pycnidia are simple, dark brown, pulvinate, formed within the epidermis, the outer wall of which adheres to their surface. They are 300 to 420 μ

in diameter by 100 to 150 μ thick, and sometimes collapse from above (Pl. V, fig. 25). No signs of an ostiole have been seen, and the manner in which the pycnidium ruptures is not known. The spores are pale greenish yellow in mass, continuous, subelliptical, and somewhat curved, 6 to 8 by 2 to 2.5 μ. They are borne on simple, tapering sporophores about twice the length of the spores (Pl. V, figs. 27 and 28). The pycnidia bear a close resemblance to immature specimens of *Lophodermium melaleucum* (Fr.) De Not., and it may be the pycnidial stage of this or the closely related *Lophodermium oxycocci* (Fr.) Karst. This fungus is closely related to *Sporonema epiphyllum* (Fr.) Shear[24], but has larger pycnidia and smaller spores, which are less curved and without a pseudoseptum.

Rhabdospora oxycocci Shear.[24]—This fungus has been found on leaves still adhering to old cut vines collected in September and November near Whitesville, N. J. The pycnidia are formed beneath the epidermis on the under side of the leaf and are quite evenly distributed over its surface. They are depressed-globose, slightly erumpent, and somewhat cushion shaped, 150 to 225 μ in diameter. The wall consists of two layers, which sometimes separate, the inner collapsing and expelling the spores (Pl. V, figs. 21 and 22). The ostiole is plain or slightly depressed and the epidermis above the pycnidia is blackened and transformed by the fungus. The pycnospores are hyaline, narrow cylindric-fusiform, and slightly curved. They show one or two septa or pseudosepta at maturity and measure 20 to 26 by 2 to 3 μ. The sporophores are slender and branched (Pl. V, figs. 23 and 24). This fungus has not yet been found attacking the berries.

Leptothyrium oxycocci Shear.[24]—This fungus has been collected several times on living and dead leaves.[a] It was first sent from Pierceville, Mass., by Mr. H. J. Franklin, May 22, 1906. The pycnidia are dimidiate, scattered, irregular, black, erumpent, subsuperficial, collapsing and rupturing irregularly, or breaking free about the base, 160 to 250 μ in diameter (Pl. V, figs. 29 and 30). The wall of the pycnidium shows a more or less parallel series of cells in its structure (Pl. V, fig. 31). The spores are hyaline, fusiform-elliptic, uniseptate, 10 to 15 by 2.5 to 3 μ and borne on slender, tapering sporophores (Pl. V, figs. 32 and 33).

Ceuthospora (?) *lunata* Shear.[24]—This fungus has been collected several times on dead and dying cranberry leaves. It was first found by the writer near Wareham, Mass., in September, 1902. It has also been collected at Carver and Onset, Mass., and near Whitesville, N. J. The pycnidia are scattered, depressed-pulvinate, slightly erumpent,

[a] Since the above paragraph was written, this fungus has been found on old mummied fruit at the same place where the other specimens were collected.

200 to 375 μ in diameter, irregularly chambered within and bearing a single prominent ostiole, through which all the chambers empty (Pl. V, fig. 11). The walls are subcoriaceous and irregular in thickness. The sporogenous hyphæ form a dense, compact, intricate layer, the ultimate divisions of which are somewhat dichotomous and bear the short, elliptic, inequilateral, or slightly curved, simple, hyaline spores, which are 7 to 9 by 3 to 3.5 μ (Pl. V, figs. 12 and 12, *a*).

The generic relationship of this fungus is rather uncertain, and we have referred it for the present to Ceuthospora, though it does not well agree with the description of the genus.

Valsa delicatula C. & E.—This fungus has been collected at Whitesville, N. J., on old cranberry stems which had been piled at the edge of a bog. It also occurs on other ericaceous plants in New Jersey, but has not heretofore been reported upon the cranberry. Associated with the ascogenous perithecia on the same stems was found a Cytospora, which is perhaps the pycnidial condition of this species.

Cladosporium oxycocci Shear.[24]—There are occasionally found in the spring on leaves of the previous year small, brownish, diseased spots bearing a Cladosporium, to which the above name has been given. The fertile hyphæ are brown, septate, more or less flexuous, and erect or spreading. They vary from 50 to 100 μ in length and arise from a small, black, sclerotoid base (Pl. IV, fig. 24). The conidia are acrogenous, varying from ovoid to cylindric-clavate, pale yellowish brown, continuous or uniseptate, and 15 to 24 by 3 to 4 μ (Pl. IV, fig. 24, *a*). We have specimens from Arichat, Nova Scotia, from Cape Cod, Massachusetts, and from Belleplain, N. J.

Another Cladosporium which has not been identified specifically has also been found on dead tips of young shoots of the cranberry from Massachusetts.

Plectrothrix globosa Shear.—This fungus was described by the writer in 1902.[22] It occurred on cranberry leaves which were kept in a sterile moist chamber in the laboratory and was quite regularly associated with *Pestalozzia guepini vaccinii*, making its appearance soon after the maturity of that fungus. It probably has no genetic relation to Pestalozzia, however. The plant has not been collected in the field and is perhaps a simple saprophyte.

Chondrioderma simplex Schroet.—This myxomycetous fungus was found at Hampton, N. J., covering living cranberry vines and other plants. It apparently did no injury, however, except such as might be caused by temporarily covering the surface of the leaves and vines. The sporangia and spore masses soon rupture and disappear after maturity and are not likely to do any permanent damage to the plants.

Epicoccum.—An undetermined species of this genus was obtained in three different cultures made from diseased cranberry vines from Olympia, Wash. Whether this was the cause of the diseased condition of the vine is not known.

Diplodia.—Dead cranberry vines collected at Wareham, Mass., and near Belleplain, N. J., bear a Diplodia not yet satisfactorily identified. The spores are brown, uniseptate. and measure 14 to 18 by 8 μ.

Chaetomium.—One or two species of this genus have occurred on leaves kept in a moist chamber and also in cultures made from cranberry stems and berries. In some cases they may have been due to contamination and in any event are probably not of pathological importance.

Oospora.—A fungus apparently belonging to this genus has occurred on leaves kept in a moist chamber.

Macrosporium.—An undetermined species of this genus has also been found in cultures and on leaves kept in a moist chamber.

PREVENTIVE AND REMEDIAL MEASURES.

REGULATION OF THE WATER SUPPLY.

Careful field studies have indicated beyond doubt that the physiological condition of the plants, as well as their environment, has much to do with their susceptibility to disease; therefore, anything which promotes the production of vigorous and hardy plants serves as a means of preventing the diseases to a certain extent. It is difficult, or impossible, on account of the very complex factors involved in the conditions of soil, moisture, and the plants themselves, to tell which are of most importance in their relation to the occurrence of diseases. Certain cranberry bogs, or portions of bogs, frequently show much more loss from diseases than others. From the experience of various growers, as well as from our own observations, it appears that the control of the water supply is a very important factor. The quantity of water necessary to keep the plants in the most vigorous condition depends largely upon the nature of the soil and subsoil, as well as the contour and natural drainage conditions of the land. The supply of water should be constant and capable of complete control, so as to avoid any great fluctuations during the growing season. In order to accomplish this, the water supply should be obtained from a reservoir rather than directly from a running stream. Some very successful growers find that keeping the water at such a level in the ditches that the surface of the bog will be continually moist, but not wet, keeps the plants in the most healthy condition.

DESTRUCTION OF DISEASED VINES.

It is also important that steps should be taken so far as practicable to prevent the distribution and reproduction of the diseases by destroying all dead vines and leaves before the fungi have had opportunity to mature and set free their spores. Small areas of vines frequently die from the attacks of fungi and from other causes. All such vines should be pulled or cut and collected early in the season, at least within a week after the water has been drawn from the vines, and burned. Vines which have been cut in raking bogs to prepare them for scooping should also be destroyed in the same manner; otherwise the spores of the cranberry fungi develop in great numbers upon them and are a fertile source of infection for the young leaves and fruit. Little is to be feared from full-grown rotten berries, as the fungi very rarely produce any spores upon them.

SELECTION AND BREEDING OF RESISTANT PLANTS.

The selection of individual plants showing ability to resist the diseases is also an important means of avoiding them. It is a matter of common observation that some of the varieties are much more subject to disease than others. It may also be noticed that in any badly diseased area of vines there is occasionally one which bears sound fruit. By selecting and propagating these apparently resistant plants a variety much less subject to injury could probably soon be produced.

APPLICATION OF FUNGICIDES.

After determining the life histories of the most serious parasites causing the diseases it seemed very probable, judging from their relationships and the manner in which closely related species attack other fruits, that they could be successfully combated by the application of fungicides, the same as their relatives were. Experiments and tests of fungicides have been conducted for the past four years. Several kinds were used the first season, as already mentioned. Bordeaux mixture applied in the form of a spray proved much more satisfactory than any of the others. Besides these a dust Bordeaux mixture has been used quite thoroughly by one of the cranberry growers, but without any decided benefit.

BORDEAUX MIXTURE.

In the spraying experiments plats were selected where from 75 to 100 per cent of the crop had been lost by disease in former years. In the experiments of 1904 four applications of Bordeaux mixture were made during the season. In order to determine accurately the results, alternate plats were left unsprayed, as a check. According to actual counts of the sound and diseased berries made at picking time, from September 8 to 13, on 35-yard-square plats, representing the average condition of the sprayed and unsprayed areas, it was found that the greatest percentage of diseased fruit on any of the sprayed plats was 27.5, as against 100 per cent on the unsprayed plats. The minimum amount of disease on any of the sprayed plats was 13 per cent, as against 89 per cent on the check plats. The average number of diseased berries on all the sprayed plats was 21.7 per cent and on the unsprayed plats 76.8 per cent, and in addition to the protection of the fruit from diseases the general vigor and appearance of the sprayed plants was noticeably improved.

These experiments, owing to circumstances beyond our control, were not entirely satisfactory, as the applications of the fungicide were not made with sufficient frequency and at the most desirable time. In 1905 a more thorough and satisfactory series of experiments was conducted upon the same plats. The water was removed from the bog May 10 to 12. It is the usual practice of cranberry growers to flood the bogs from twenty-four to thirty-six hours during the first week in June, in order to destroy insects. It had been planned to spray part of the experimental plats before this second flooding. The water supply of the bog was, however, insufficient for a second flooding, and the relation of spraying to this operation was therefore not determined. Two of the plats were sprayed five times—May 19, June 22, July 14, July 31, and August 15. At picking time, September 8, accurate counts were made of all the diseased and sound berries on small areas which showed the average condition of the fruit on the sprayed plats. Counts were also made on equal areas showing the average condition of the fruit on the check plats. As a result of these counts it was found that there was an average of only 6 per cent of rotten fruit on the sprayed plats, while there was a little more than 91 per cent rotten on the unsprayed plats. Two other plats sprayed five times, but beginning June 2 instead of May 19, showed as a result of the counts made as in the experiment just mentioned an average of 2.36 per cent of diseased berries on the sprayed plats and 92.06 per cent of diseased fruit on the unsprayed plats. This appears to indicate that the application made on June 2 was more beneficial than that made at the earlier date, May 19.

Another plat was sprayed but four times, as follows: July 14, July 31, August 1, and August 15. Estimates of the amount of diseased fruit on the sprayed and unsprayed plats, made as in the previous cases, showed 18.3 per cent of rotten berries on the sprayed plat and 91.53 per cent on the unsprayed plat. This indicated what had already been anticipated, from our knowledge of the time of maturity of the parasites causing the diseases, that the earlier applications are exceedingly important, most of the infection apparently occurring before the fruit is half grown.

A portion consisting of 1,048 square feet of one of the plats which was sprayed five times was carefully hand picked and produced 3 bushels of sound fruit, this being at the rate of about 125 bushels per acre. The same area from the adjoining check plat gave a scanty peck of sound fruit, or 10.42 bushels per acre. In other words, there was twelve times as much sound fruit on the sprayed plat as on the unsprayed plat, or a saving of over 100 bushels per acre.

Preparation and application.—The method of preparation, as well as the dates and manner of application, is of exceeding importance in securing satisfactory results. The Bordeaux mixture should be freshly made. Good stone lime should be used, and from 3 to 5 pounds of commercial resin-fishoil soap should be added to it. In our first experiments, in which the plain Bordeaux mixture was used, it was found that the spray either collected in drops upon the surface of the leaves and fruit or ran off entirely, the surface of the cranberry leaves and fruit being so glossy that the mixture did not spread and adhere properly. It was found that by adding the resin-fishoil soap the mixture not only formed a film and spread over the surface of the leaves and fruit, but also adhered for a much longer time than the plain Bordeaux mixture.

The comparison of sprayed and unsprayed fruit at the time of picking does not show the full amount of profit to be derived from the treatment, as there is usually a considerable loss from the development of the diseases during the period between the time of picking and the time of marketing the berries. In order to compare the keeping qualities of the sprayed and unsprayed fruit, 2,400 perfectly sound berries, so far as could be determined by external appearance, were selected. Twelve hundred berries were from a sprayed plat and 1,200 from a check plat. They were all kept in the laboratory under similar conditions in order to determine the amount of disease which would develop in each case before the time for marketing the fruit. On October 18, the date upon which most of the fruit from the bog was marketed, and exactly one month from the date of picking, a careful examination of the 2,400 berries showed only 9.8 per cent of the sprayed fruit diseased, while 38.1 per cent of the unsprayed fruit was diseased. In other words, four times as much of the unsprayed fruit as of the sprayed fruit decayed between the time of picking and marketing. The decay which developed was apparently caused by the dormant infection.

Cost of spraying.—The cost of spraying as it was done in these experiments averaged from \$15 to \$20 per acre, the Bordeaux mixture being applied at the rate of 4 barrels, or 200 gallons, per acre at each application, making for five applications a total of 1,000 gallons per acre. The cost would probably vary somewhat under different conditions and different methods, but in no instance should it exceed \$20 per acre.

SUMMARY.

There are four serious fungous diseases of the cranberry—scald, caused by *Guignardia vaccinii;* rot, caused by *Acanthorhynchus vaccinii;* anthracnose, caused by *Glomerella rufomaculans vaccinii*, and hypertrophy, due to *Exobasidium oxycocci.* The first three diseases mentioned have heretofore been confused and considered as one.

Life history studies have shown that *Guignardia vaccinii* produces two forms of fructification—pycnidial and ascogenous—and is closely related to *Guignardia bidwellii*, which causes the black-rot of the grape.

Similar studies of *Acanthorhynchus vaccinii* reveal only ascogenous fructifications, but very striking and characteristic appressoria, which perhaps fill in part the place of a pycnidial form, are produced.

Glomerella rufomaculans vaccinii is also found to produce both conidial and ascogenous forms.

The production of ascogenous fructifications appears to depend in both *Guignardia vaccinii* and *Glomerella rufomaculans vaccinii* chiefly upon some inherent potentiality of the race, strain, or generation from which the hyphæ or spore used in the culture are derived. The composition of the culture medium and the conditions of temperature, moisture, and light are relatively unimportant factors.

The fungi producing scald, rot, and anthracnose, as well as *Pestalozzia guepini vaccinii*, are able to live in the tissues of cranberry leaves and fruit in a more or less dormant or noninjurious condition for a considerable period and may apparently at any time develop rapidly and destroy the tissues when conditions are favorable.

Thirteen other fungi have been found affecting cranberry fruit, most of which have, however, not shown indication of particular pathological importance. Sixteen different species have been found on either stems or leaves. Most of these do not seem to cause serious injury to the plant.

Preventive measures should include renovation of the cranberry bog, careful control of the water supply, and the cultivation of hardy and disease-resistant varieties.

Thorough treatment with Bordeaux mixture has proved successful in controlling the diseases. The addition of resin-fishoil soap is essential in order to make the mixture properly cover and adhere to the plants. As a result of five applications in 1905, only 2.36 per cent of the sprayed fruit was found to be destroyed at picking time, whereas 92 per cent of the unsprayed fruit on the plat adjoining was destroyed.

The cost of five applications, each of 200 gallons per acre, varies, according to the conditions and methods employed, from $15 to $20 per acre.

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DESCRIPTION OF PLATES.

PLATE 1.—*Frontispiece.* Cranberry scald, showing different stages in the progress of the disease. A.—Early stage. B.—Later stage, showing dark zones. C.—Berry completely destroyed.

PLATE II.—Fig. 1.—A cranberry leaf, showing pycnidia of *Guignardia vaccinii* thickly scattered over the under surface; *a*, a cranberry blossom blasted by *Guignardia vaccinii*, showing pycnidia on calyx, corolla, and pedicel; *b*, a blasted fruit, showing pycnidia. Fig. 2.—A vertical section of a single pycnidium of *Guignardia vaccinii* from a cranberry leaf, showing pycnospores in various stages of development. Fig. 3.—An immature pycnospore of the same fungus, showing the partially formed appendage; *a*, the same, showing a little later stage of development; *b* and *c*, fully developed pycnospores and appendages. Figs. 4, 5, 6, 7, 8, and 9.—Various stages in the germination and growth of pycnospores of *Guignardia vaccinii* grown in weak sugar solution; 4, 5, 6, and 7, seventy-two hours after sowing; 8 and 9, eighty-six hours after sowing. Fig. 10.—A vertical section of a perithecium of *Guignardia vaccinii*, showing asci, from a cranberry leaf collected in New Jersey. Fig. 11.—Three asci, with ascospores showing variations in length of the stipe and the arrangement of the spores; *a* and *b*, from perithecia on a leaf; *c*, from a pure culture. Fig. 12.—A fresh, mature ascospore, showing the usual condition, in which the protoplasm is very coarsely granular. Fig. 13.—An old ascospore from a dried specimen, having its contents homogeneous. Fig. 14.—*a*, A portion of the coarse brown mycelium from the interior of a scalded berry, from which a culture was made December 23, producing pycnidia and ascogenous perithecia of *Guignardia vaccinii; b*, a portion of younger, lighter colored hyphæ from the same berry. Fig. 15.—*Pestalozzia guepini vaccinii; a*, a conidium having an apical appendage with three branches; *b*, a conidium having an apical appendage with four branches; *c*, a germinating conidium; *d*, a germinating conidium sending out two germ tubes.

PLATE III.—Fig. 1.—Vertical section through an acervulus of *Glomerella rufomaculans vaccinii* from the under surface of a cranberry leaf. Fig. 2.—Four conidia from the same, showing some of the variations in form and size. Fig. 3.—A portion of an acervulus of *Glomerella rufomaculans vaccinii* from a pure culture on corn meal, showing the dark-colored setæ which are occasionally found; *a* and *b*, conidiophores and conidia from another pure culture on corn meal. The conidiophores arise from a dark stromatic layer consisting of cells resembling appressoria, as shown in 3, *a*. No large acervuli, forming dense masses, occurred in this culture. Fig. 4.—Appressoria or chlamydospores from pulp of a cranberry from Massachusetts destroyed by *Glomerella rufomaculans vaccinii.* Fig. 5.—Portion of mycelium from corn-meal culture No. 736, forty-two days old. Conidia and appressoria found, fifteenth day; matured asci appeared the twenty-third day—no light spots seen in these. Where they appear they are probably due to the presence of vacuoles or oil globules. Fig. 6.—An ascogenous perithecium of the same fungus grown in a pure culture. Fig 7.—Asci from the same; *a*, cylindrical form, with overlapping uniseriate spores; *b*, shorter subclavate form; *c*, ascus from older culture, showing shorter stipe. Fig. 8.—Fresh, mature ascospores from the same. Fig. 9.—Asci and fugaceous paraphyses from culture of *Glomerella rufomaculans vaccinii.* Fig. 10.—Portion of an acervulus of *Gloeosporium minus*, from a pure culture from a diseased New Jersey berry. Fig. 11.—Conidia from the same. Fig. 12.—A portion of a cranberry leaf, showing the slightly elevated epidermis and the protruding neck of *Acanthorhynchus vaccinii.* Fig. 13.—A single perithecium of the same fungus, taken from a pure culture on corn meal, showing portions of the hyphæ which form the thin, loose mycelial layer with which the perithecia are overgrown in artificial cultures. Fig. 14.—Asci and paraphyses from the same pure culture; *a*, a young ascus, in which the mature ascospores are surrounded by granular gelatinous matter; *b*, a slightly older stage; *c*, a nearly mature ascus, in which the granular protoplasm is shrunken about the spores and attached to the apex of the ascus. A portion of it remains as a thin gelatinous envelope about the spores after they are expelled from the ascus. Fig. 15.—Two ascospores of the same. Fig. 16.—A germinating ascospore, bearing the peculiar appressorium. Fig. 17.—An appressorium viewed from above. Fig. 18.—A group of appressoria attached to the surface of a cranberry leaf. Fig. 19.—A germinating appressorium grown in a poured plate. Fig. 20.—A germinating appressorium from the midrib of a leaf, showing superficial branching hyphæ. Fig. 21.—A section of a germinating appressorium on a leaf; *a*, a germ tube which has entered the leaf through a stoma. Fig. 22.—Another germinating appressorium; *a*, the germ tube entering the leaf through a stoma.

PLATE IV.—Fig. 1.—*Venturia compacta.* Massachusetts specimens on the under surface of a leaf showing various aggregations of perithecia. (Natural size.) Fig. 2.—Group of perithecia magnified 24 diameters. Fig. 3.—Single perithecium, showing spines distributed over the upper half. Fig. 4.—Two asci, showing variability in shape and length. Fig. 5.—A perithecium of the same fungus from a Wisconsin specimen, showing fewer spines arranged about the apex. Fig. 6.—Three asci from the same, showing variations in shape and arrangement of the spores. Fig. 7.—A single ascospore from the same. Fig. 8.—A perithecium of *Anthostomella destruens* from a pure culture of the fungus. Fig. 9.—An ascus from the same. Fig. 10.—Two ascospores of the same. Fig. 11.—A germinating ascospore of *Anthostomella destruens.* Fig. 12.—Pycnidia of *Septoria longispora* on under surface of a cranberry leaf. Fig. 13.—Section of a pycnidium of *Septoria longispora* on a cranberry leaf. Fig. 14.—Three spores of *Septoria longispora* from a cranberry leaf. Fig. 15.—*Synchytrium vaccinii* on pedicel, bracts, and flower of a cranberry. (Natural size.) Fig. 16.—*Synchytrium vaccinii.* A single gall enlarged. Fig. 17.—*Synchytrium vaccinii.* A section through a gall showing the hypertrophied tissue and the sporocarp. Fig. 18.—*Arachniotus trachyspermus* on a decayed and shriveled cranberry. Fig. 19.—*Arachniotus trachyspermus* on the side of a culture flask. Fig. 20.—Ascogenous hyphæ and asci of the same from a pure culture. Fig. 21.—A single ascus of the same from a pure culture. Fig. 22.—A single ascospore of the same. Fig. 23.—*Sclerotinia oxycocci* Wor? Branching chain of conidia, inverted; *a*, a single conidium. Fig. 24.—*Cladosporium oxycocci.* Conidiophores bearing conidia from a cranberry leaf; *a*, a single septate conidium from the same.

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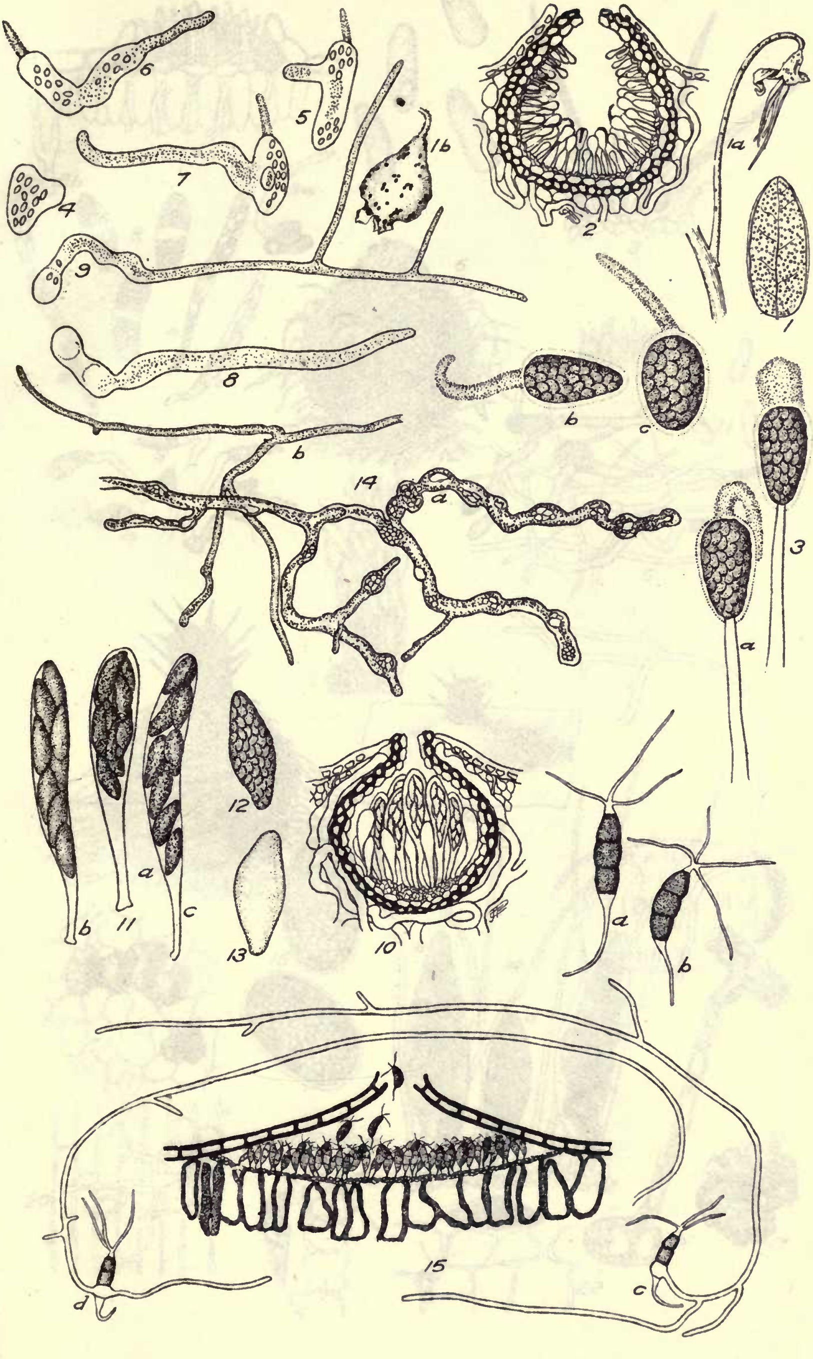
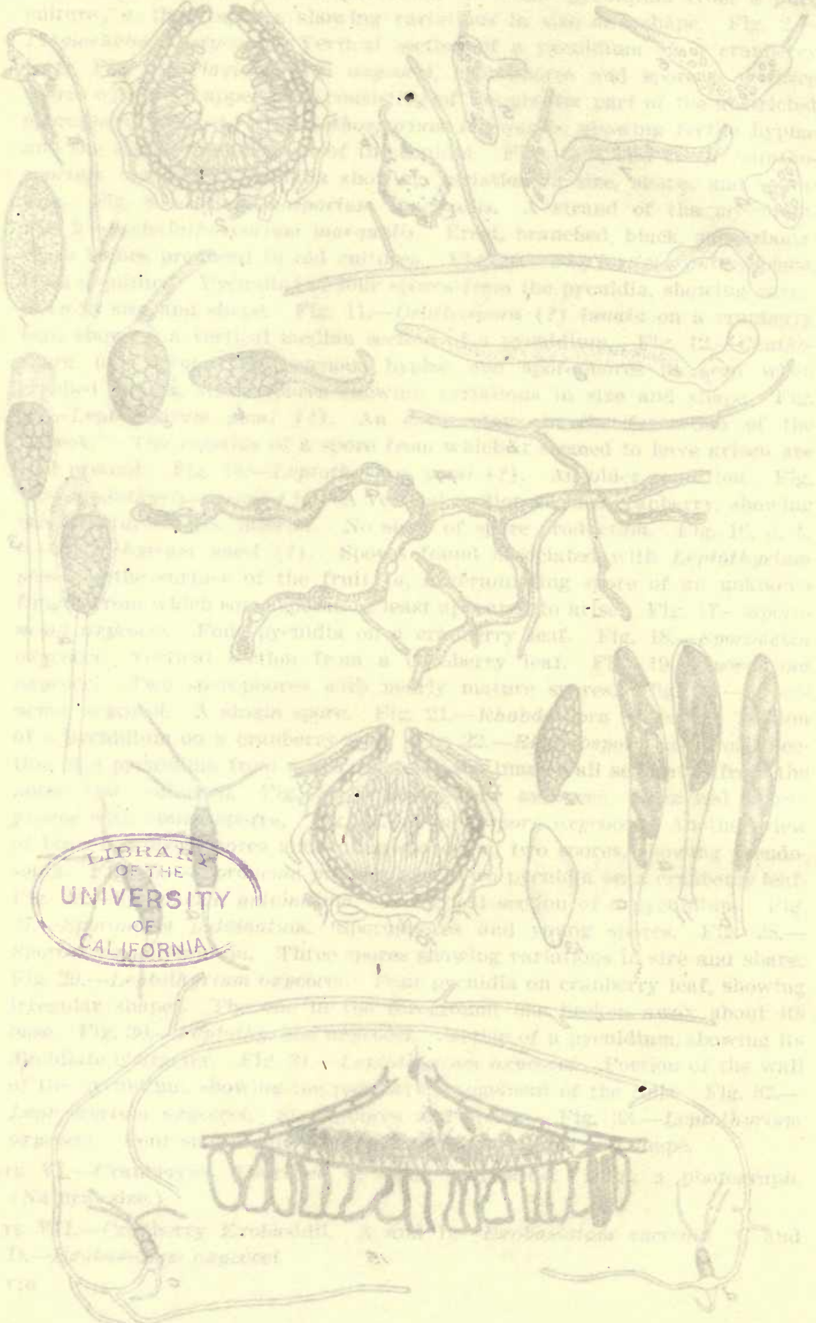
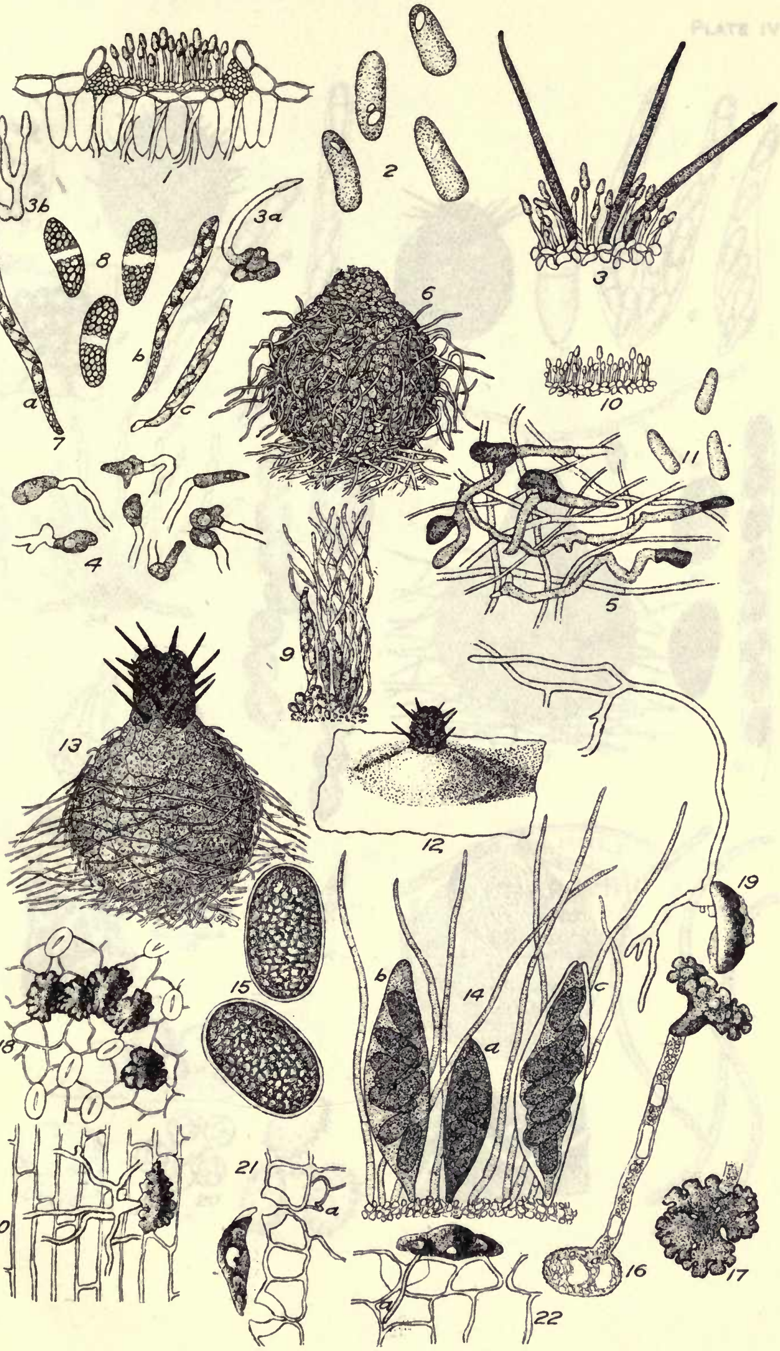
PLATE VI.—Cranberries destroyed by blast and scald. From a photograph. (Natural size.)

PLATE VII.—Cranberry Exobasidii. A and B.—*Exobasidium vaccinii.* C and D.—*Exobasidium oxycocci.*



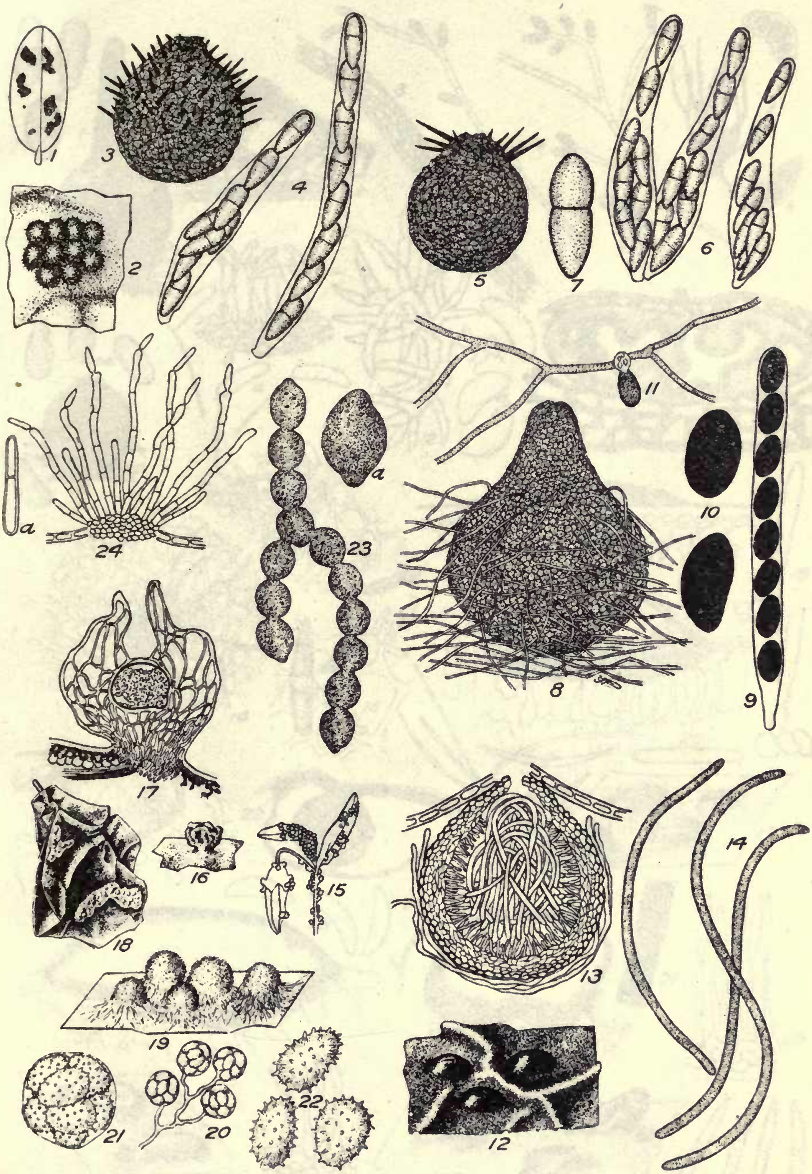
FUNGOUS PARASITES OF THE CRANBERRY.





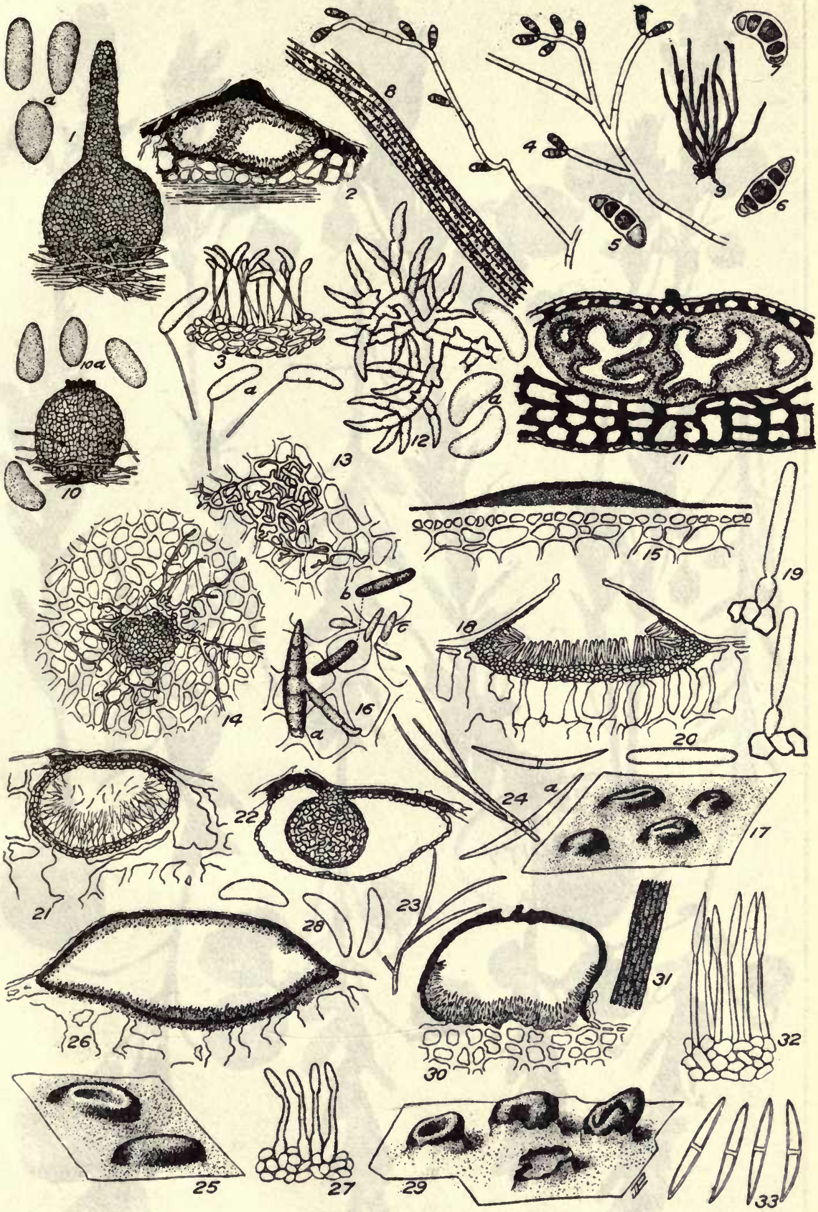
FUNGOUS PARASITES OF THE CRANBERRY.

PLATE IV.

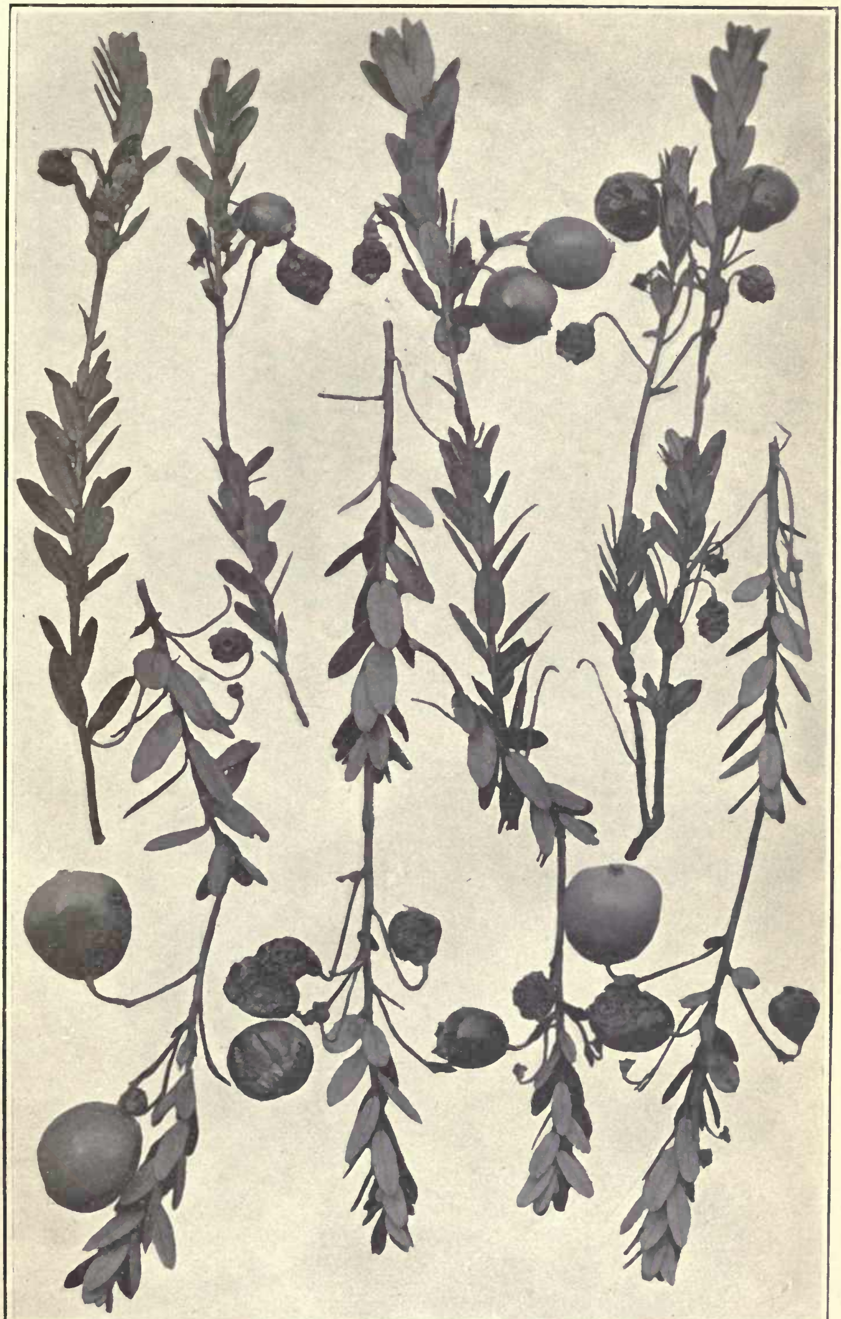


FUNGOUS PARASITES OF THE CRANBERRY.

PLATE V.



LESS IMPORTANT CRANBERRY FUNGI.



CRANBERRIES DESTROYED BY BLAST AND SCALD.

(Natural size.)

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CRANBERRY EXOBASIDII.

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