difference in the physical or chemical composition of the soil. It was found, however, that the mountain pine (*Pinus montana*) acted as a nurse to spruce trees planted in its vicinity. In the same soil where spruce if planted alone would remain backward, it would if planted close to a mountain pine grow up vigorously. After some years of trial, it was found that the pine would hamper the growth of the spruce, and so it was cut down at an early age. It was discovered then that even if the mountain pine was cut down at an early age, it imparted to the adjacent spruce trees the ability to grow. The phenomenon is not understood, but it is supposed that the roots of the mountain pine are inhabited by some mycorhiza which produces the nitrogen necessary for the growth of trees and that this organism is transferred to roots of the surrounding spruce trees. Once this infection has taken place, the presence of the mountain pine is no longer necessary and it is usually cut down. Clearly this is a biological relationship.

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SPECIAL ARTICLES

OOSPORES OF POTATO BLIGHT

The potato blight fungus, *Phytophthora infestans,* has attracted more attention from botanists than almost any other fungus. The reasons for this are that under certain climatic conditions it causes sudden and widespread destruction of potato fields, and also that, though its life history has been carefully studied, the sexual or oospore stage has never been surely found. Berkeley, who was one of the earliest investigators to have a rational view of the cause of the epidemic of 1845, wrote at the time as follows:

> Few subjects have attracted more attention or have been more variously canvassed than the malady with which potatoes have been almost universally visited during the autumn of 1845. The press has teemed with notices the most contradictory; the attention of scientific men in every direction has been engaged by it; and three, at least, of the principal governments of Europe have issued commissions to examine into its etiology, and to discover, if possible, a remedy.

In 1875–76, at a time of considerable devastations of potato crops in Europe by the fungus, DeBary was employed by the Royal Agricultural Society of England to further investigate this fungus, while at about the same time Worthington G. Smith was engaged in similar work for the Royal Horticultural Society. As the result of their endeavors, considerable was learned concerning the life history of the fungus. Smith claimed to have found the oospores in the infested leaves and the old sets in great abundance, and was awarded a gold medal by the Royal Horticultural Society for his work. These bodies had been observed as early as 1845 by Rayer, Montagne and Berkeley. DeBary did not succeed in finding what he considered oospores of this fungus, and disputed Smith's claim with such good reasons that botanists generally believe that the oospores have never been discovered, though once or twice since investigators have claimed, without much conviction, to have found immature oogonia.

At the time of the controversy DeBary said:

> Ever since the oospores of a *Peronospora* were discovered, innumerable researches have been made for those of *Phytophthora.* I have myself looked for them for fifteen years, and on every opportunity have searched for them in the stalks, leaves, flowers, fruit and tubers of the potato. In July of the present year (1875), when the fungus appeared in this district in sad abundance, I obtained a very large amount of material for study, and at the same time secured the kindly assistance of two botanists experienced in researches of this kind, Dr. Rostafinski and Dr. Stahl. But again only negative results were arrived at. . . . That they will be regularly found somewhere or other is assured, for our knowledge of the habits of numerous allied fungi make this more than probable.

Smith deposited slides of his oospores with the British Museum. Concerning these Massee some time ago wrote me:

> I have very carefully examined W. G. Smith's type slide preparation, and am positively certain that the so-called oospores are nothing more than

the globose, thick-walled chlamydospores belonging to a Fusarium.

In a discussion following the Jones and Lutman paper at the American Association for the Advancement of Science meeting at Boston last year, Güssow said that he had seen these slides, and that the oospores much resembled the bodies that Jones and Lutman had obtained in their artificial cultures. The writer has not seen these slides, though he tried to obtain examples of the oospores from Smith a few years ago. Smith wrote at that time:

> No doubt you know that the oospores became a kind of political subject—oospores of *P. infestans* or not oospores of *P. infestans?*—and I had no wish to go on. Botanists and popular writers followed what they took to be the safer authority, just as Saccardo has done; this is right enough in a way.

While we have not seen these slides, on every possible occasion during the eight years that we have been studying this fungus, we have looked for oospores in the leaves and tubers under the conditions described by Smith. While we have never found spores that satisfied us that they were the potato blight oospores, we have found oospore-like bodies, both of animal and fungous origin, that might be mistaken for such, and possibly might be some of those bodies described by Smith. We have seen Smith's drawings, and his photomicrographs published in the *Quarterly Journal of Microscopical Science,* Vol. 15, in 1875, and the drawings of Montagne, published by Berkeley in the *Journal of the Horticultural Society,* Volume 1, in 1846, these latter being considered by Smith to represent the same thing he described as the oospores. None of these impress us as being the same as the true oospores that we have obtained in cultures. The only figures that at all show a resemblance are Figs. 134 to 136 in Smith's book on "Diseases of Field and Garden Crops," published in 1884. We are inclined to believe that these botanists had a variety of things under consideration, and while it is quite doubtful if any of them were the oospores of potato blight, we do not wish to make a positive assertion without seeing the original preparations.

In 1904 we first began to study the potato blight in artificial cultures. So far as we know, we were the first to make such cultures in this country, or at least to publish notes on them,[1] but in looking up the literature at the time, it was found that two French botanists, Matruchot and Molliard, had secured cultures even earlier. Their results, published in 1900 and 1903, were similar to those we had obtained; viz., the fungus was grown in certain media with fair success, but no oospores appeared, though we did very rarely find curious-shaped threads that might indicate futile attempts to form oogonia.

At the Baltimore meeting of the American Association for the Advancement of Science, in December, 1908, Jones and Giddings gave a paper[2] in which they described these curiously shaped threads which had appeared with more or less frequency in stab cultures of a specially prepared potato-gelatin medium that they used. Jones was inclined to believe that they were attempts at oogonial formation, though there were no indications of antheridia or oospores. At the same meeting the writer[3] described a special medium, Lima bean juice agar, on which the potato blight grew with far greater vigor than on any medium yet tried, so that its continued cultivation was as easy as that of any parasitic fungus. On this medium, however, no oospores appeared, and very rarely even the curious-shaped threads, though when *Phytophthora Phaseoli,* a near relative, was grown on it, oospores appeared in profusion.

At the Boston meeting of the American Association for the Advancement of Science, Jones and Lutman gave a second paper[4] in which they further discussed these curious bodies that appeared in their cultures. Though not stating positively that these bodies were of the nature of oogonia, they were inclined to consider them as resting spores. While much

[1] Conn. Agr. Expt. Sta. Rept., 1905.
[2] SCIENCE, XXIX., 271, February 12, 1909.
[3] Conn. Agr. Expt. Sta. Rept., 898, 1908.
[4] SCIENCE, XXX., 813, December 3, 1909.

more successful in producing these bodies than previously, due in part to the use of the lima bean medium in a modified form, and while these bodies showed a still greater modification toward the oogonial type, they did not succeed in producing in their cultures any bodies of the nature of antheridia.

During the past year the writer, with the aid of his assistant, Mr. E. M. Stoddard, has made still further tests with four strains of potato blight obtained from different sources, and with two of these (really one, as the other traces back to the same potatoes one season later) has obtained results far beyond anything yet reported. These results were primarily due to the use of a new medium, which gave us for the first time very definite attempts at oospore formation, and with a certain modification of this medium *absolutely perfect oogonia, antheridia and even oospores have been obtained.* We have not been successful, as yet, in producing the oogonia in cultures in anything like the abundance of those of *Phytophthora Phaseoli* and *Phytophthora cactorum* in the same medium, and very few of the oogonia produce even partially mature oospores, but of their nature there can be absolutely no doubt. Whether or not we can perfect their formation in greater abundance remains to be seen, but recently, from an unusually good culture, a temporary slide preparation showed over a hundred of these oogonia, mostly without oospores or with immature ones; whereas last March the most we could find in similar slides were half a dozen or less.

From the results of our recent investigation there is no doubt that the curious threads and bodies that Jones, and the writer to a much less extent, previously obtained, were attempts at the formation of oogonia. We should judge, however, that Jones's cultural media, except for one particular, were not suited to perfect these bodies further, and that the excretory markings he obtained on the cell walls were largely abnormal. From my investigations it can be stated that the oogonia of the potato blight are thick-walled, with a more or less roughened or ornamented external coat, due to excretory thickening of the original wall, and are tinted more or less a chestnut brown. The oospores are moderately thick-walled, smooth and colorless. The oogonia are of a quite different type from those of both *P. Phaseoli* and *P. cactorum,* which are similar. The oogonia and oospores of these two are somewhat smaller than those of *P. infestans,* but the chief difference is their smooth, hyaline, thin-walled oogonia.

Not only has the writer obtained the oospores of *P. infestans* in pure cultures, but he has also succeeded in raising what he considers crosses of this fungus with both *P. Phaseoli* and *P. cactorum* by inoculating a test-tube of the special medium with *P. infestans* at the top and one or the other of these two species below. With the growth of the two colonies together there appear in the vicinity of the *P. infestans* colony not only the oospores of the other fungus but also oospores of the *P. infestans* type. These oospores of the *P. infestans* type so far appear only rarely in the crosses with *P. cactorum,* which, however, have only recently been made. In the crosses with *P. Phaseoli* the oospores of the *P. infestans* type are more abundant than they have ever yet appeared under the most favorable conditions in pure cultures of *P. infestans,* and many of them produced perfect oospores. On the whole the oogonia and oospores appear to be somewhat larger and less deeply tinted than those from the pure cultures of *P. infestans.* Crosses between *P. infestans* and *P. Phaseoli* made last March still continue to produce oospores of the *infestans* type, not usually as abundant as those of the *Phaseoli* type, however, though these cultures have been renewed six times since their original crossing. These descendants are not from the oospores, since they never germinate in the cultures.

From the data at hand it looks as though there were not two strains (male and female) of the potato blight, as we suggested some time ago, but that the potato fungus had largely lost its power to reproduce itself sexually. This loss may have come about by propagating it year after year asexually

through its hibernating mycelium in the potato tubers, just as the potato itself has largely lost its power to reproduce sexually through the formation of seeds. This loss of sexual power is shown in different degrees by the different strains of the fungus in artificial cultures. The fungus seems to lose first its power of producing antheridia and then of producing oogonia. Under favorable conditions attempts to form oogonia first appear, and under still more favorable conditions the antheridia are produced, and with the formation of these the oospores also appear in more or less perfect form.

A further discussion of this subject, with photomicrographs of the sexual stages as we have gradually developed them, will appear in the next report of the Connecticut Agricultural Experiment Station.

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NEW HAVEN, CONN.,
December 20, 1910

A POSSIBLE LINE OF DESCENT OF THE GOBIOID FISHES

Indicating the doubt existing as to the relationship of the gobies are the several different positions assigned to them in the schemes of classification suggested from time to time by different authors. Without attempting anything like an exhaustive survey of the disposition of the group by different authorities its treatment by a few of them may form an introduction to the suggestions of relationship in the following lines.

Dr. Gill, in his "Arrangement of the Families of Fishes,"[1] places the superfamilies Gobioidea and Cottoidea in adjoining groups. But in his later arrangement[2] he has several families interposed between the Gobiidæ and Cottidæ, as the Batrachidæ, the Uranoscopidæ, the Trachinidæ, the Malacanthidæ and others.

Dr. Jordan, in his "Guide to the Study of Fishes,"[3] has placed the gobies near the cottoid fishes with the following remark: "The great family of Gobiidæ, having no near relations among the spiny-rayed fishes, may be here treated as forming a distinct suborder."

Dr. Boulenger, in the Cambridge Natural History,[4] places the Gobiidæ between the Kurtidæ and Echeneididæ, and expresses the opinion that the gobies "are not very remote from the Perciformes, and may have evolved out of a type not very different from the Percidæ."

Mr. Regan, in his classification of the teleostean fishes,[5] has placed the suborder Gobioidea between the Blennoidea and the Kurtoidei.

Recently while examining the skeleton of *Dormitator maculatus*, a large goby from the warm waters of the American Pacific and Atlantic, I was impressed with the similarity of its shoulder girdle with that of the family Cottidæ and certain other cottoid or mail-cheeked fishes. In light of the fact that there is otherwise very little in the anatomy of the gobies that might show their line of descent, I wondered that the line from some ancestor of the Cottidæ had not been long ago suggested, more especially as there seems to be little reason why such relationship should not exist.

The similarity of the shoulder girdles of these families has long been known. As early as 1865 Dr. Gagenbaur published a picture of the shoulder girdles of a gobioid and a cottoid fish side by side in the second part of his "Untersuchungen zur Vergleichenden Anatomie der Wirbelthiere."[6]

The condition of the shoulder girdle in the Cottidæ and Gobiidæ is as follows: The coracoid elements and the actinosts are arranged in a continuous row on the posterior edge of the clavicle; the hypercoracoid above, next the actinosts, and ending below with the hypocoracoid—the actinosts attached directly with the clavicle, and separating the coracoid elements widely from each other. In the typical condition—the condition in the great majority of fishes—the coracoid elements are broadly attached to each other, and the actinosts are attached to their posterior edges remote from the clavicle.

[1] "Smith. Miss. Col.," 1872.
[2] *Mem. Nat. Acad. Sci.*, Vol. VI., pp. 127–138.
[3] Henry Holt and Co., 1905.
[4] Macmillan and Co., 1904.
[5] *Ann. Mag. Nat. Hist.*, Ser. 8, Vol. III., 1909.
[6] *Hemitripterus acadianus* and *Gobius guttatus*, Taf. VII., figs. 8 and 9.