Agricultural Experiment Station

OF THE

AGRICULTURAL AND MECHANICAL COLLEGE,

AUBURN, : : ALABAMA.

BULLETIN NO. 41, - - DECEMBER, 1892.

SOME DISEASES OF COTTON,*

GEO. F. ATKINSON.

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* This Bulletin was completed for publication by Prof. Atkinson in December, 1892.

THE BROWN PRINTING CO., STATE PRINTERS, MONTGOMERY, ALA.

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SOME DISEASES OF COTTON.

BY GEORGE F. ATKINSON.

I. General Nature of Cotton Diseases.

Two years study of the diseases of cotton have brought to light several well characterized maladies of this plant in the United States. Some of these are physiological in their nature, being due to disturbances of nutrition and assimilation, brought about by various causes, which will be discussed under the several topics.

Other diseases of the plant are due to the action of fungus organisms which live as parasites in various parts of the plant, penetrating the tissues, consuming the nutriment and living matter and setting up fermentations which act disastrously on the plant tissues.

To a trained observer the plants affected present certain symptoms and characteristics which would enable him to diagnose the disease.

Several diseases have been known to many planters and naturally names have been given to them in the absence of exact knowledge as to their nature. These names vary in different localities. Sometimes different names are applied to the same disease and frequently a single name is used for several very different troubles.

"Rust" is a term which is more widely used than any other and is frequently defined as "red rust," or "black rust." The term has become so general in its application as to be utterly valueless other than conveying the notion of *disease*. Quite likely that notion is all the planter intends to convey when he uses the term "cotton rust." To accept the term "cotton rust" as synonymous with cotton disease will tend to eliminate much of the confusion which must necessarily result should the term be accepted for any single disease. The great mystery which has clustered around this term as a name for a single disease is thus cleared away, and we are enabled to attach a true value to the reports and discussions of "rust" which appear from time to time in various publications.

The diseases of the cotton plant in general are increasing in severity and extent each year, especially those which are due to parasitic organisms and to impoverished and badly cultivated soils. Under conditions which exist largely throughout the cotton belt, this increase of disease is the natural outcome of years of continued cultivation of the crop without a wise rotation with other remunerative farm crops and a careful diagnosis of the needs of the soil.

The organisms which cause the more disastrous of the parasitic diseases rest in the soil during the winter season. With each successive crop they increase in numbers because their favorite pabulum is close at hand. The increase of the disease is comparable to what would occur among human beings were no sanitary measures taken to eradicate disease when once it gains foothold in a community. Varying conditions of temperature and humidity might cause temporary fluctuations in the rate of increase, but each year the trouble would become more deeply seated.

One of the most important features of cotton culture is the adaptability of fertilizers to different soil conditions and the requirements of the plant. For cotton growers, the fertilizer trade, so far as it relates to the various brands of ready mixed fertilizers is one of the greatest follies of the present day. The continued use of these fertilizer nostrums is as fatal to the cotton grower as it would be for an invalid with some dangerous disease who resorts to some of the medicinal nostrums, or cure alls, instead of at once consulting a competent physician. He grows steadily worse, but with reviving hope tries one after another of these ill-adapted mixtures, some of which actually do him injury.

Ready mixed fertilizers with attractive names, or those whose merits are pictured by the blandishments of the salesman or the seductive sentences of the advertising column find a too ready acceptance and use by the unsuspecting planter. Chance will sometimes bring about a happy coincidence, but more often the composition is unsuited to the particular soil, may lack the most needed constituent, or possess in excess several constituents, resulting in a loss to the user. One after another brand is used, while the crop grows smaller and the soil depreciates.

The trade in unmixed fertilizers, as kainite, acid phosphate, cotton seed meal, etc., is the more profitable for the planter to patronize if home production of manures will not meet his wants. They can be mixed by him at home more profitably during the winter season. The effect of the known ingredients can be observed in given soils and each year better adaptations can be made for the necessarily varying character of soils on a single plantation.

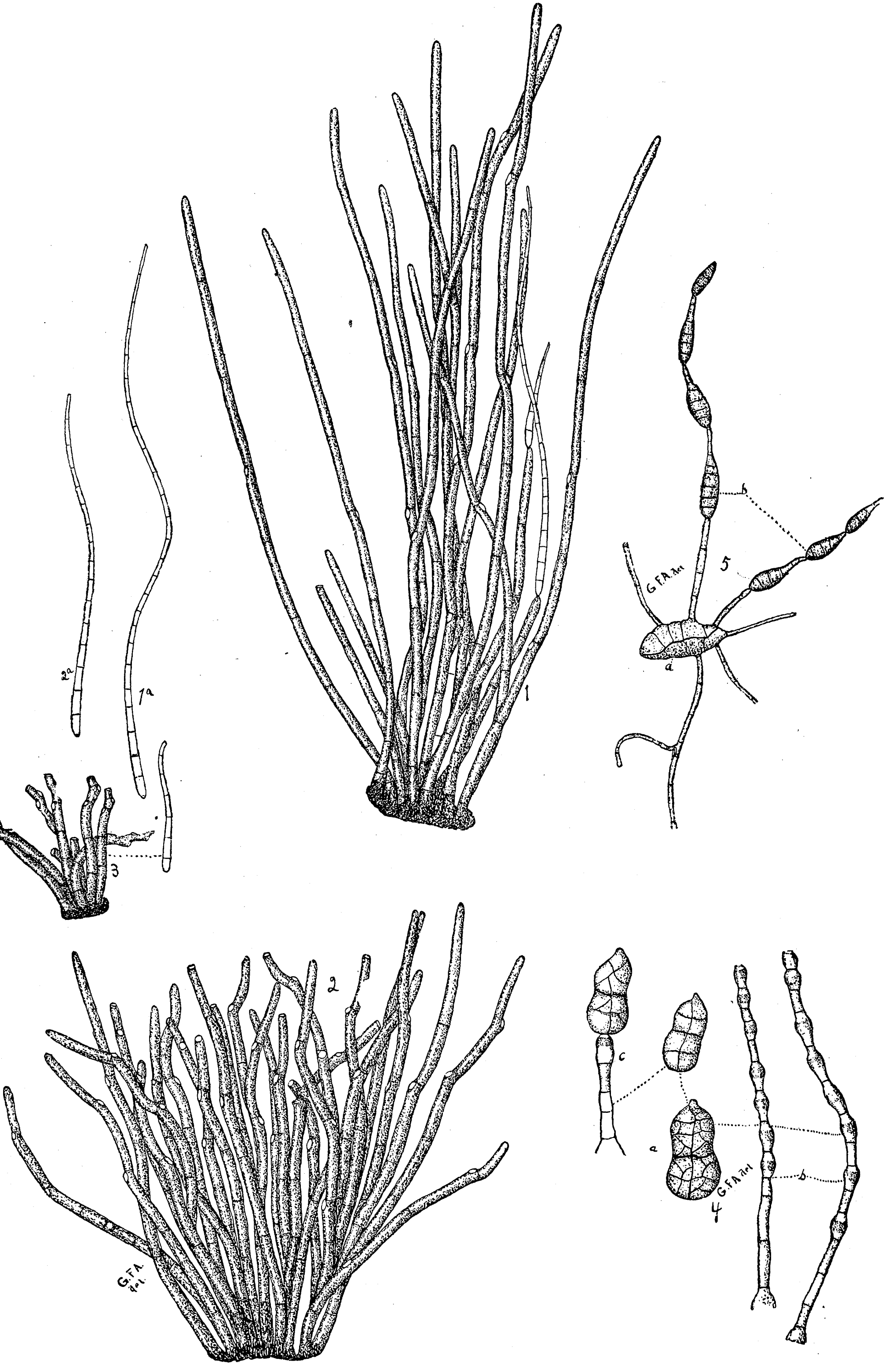
Much is yet to be learned by many planters concerning methods of cultivation and the proper distance which should be given the plants on different soils and with different degrees of fertilization. Very many probably err in hasty preparation of the soil before planting, in too much cultivation of the soil after planting, and in leaving too many plants on the ground.

There is a notion in some localities that "cotton will not begin to make fruit until the tap root strikes hard ground." The preparation of many fields for planting would lead one to believe that the motive was to have the hard ground so near the surface as possible in order that the tap root might readily and quickly "strike hard ground."

Thorough and deep preparation of the soil not too long before planting, followed by very shallow surface cultivation, just enough to cut off the weeds and leave a shallow surface layer of loose soil, is probably the best treatment which can be given so far as cultivation is concerned. The treatment of the soil bears a very important relation to the health of the plant. Too many in their haste to plant the crop do so on a shabbily prepared ground, probably thinking they will loosen the soil more deeply during cultivation. Experience shows, as is well known by those who have observed the effects of deep versus shallow cultivation, that the former is very injurious to the plant, since so many roots are severed by the plow.

Having discovered the nature of several of the most important diseases of the cotton plant, the next step to be taken is to put the knowledge in such form that cotton growers may be able to diagnose the diseases which appear. So long as the indefinite term "rust" is used for several diseases, we can make no progress in combatting them, and it would be useless to recommend a line of treatment for any particular disease, when the planter is liable to confuse several diseases and to apply the remedy for a different trouble from the one for which it is intended. The present bulletin is intended to present some of this matter in such a way that a few at least may more intelligently determine the trouble.

Oil paintings illustrating the various color effects produced upon the foliage by the different diseases have been made and should be published, that the planter might have such striking and visible characteristics of the disease at hand to compare with plants from any diseased area. The subject is of more than local or even State interest. It is a subject which concerns the entire cotton belt region of the United States and bears on the improvement of the condition of the most important agricultural product there grown. These paintings are too expensive to publish without Gov-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ernment aid, and the National Department of Agriculture could not do a better work for the cotton producing states than to put a copy of these illustrations, accompanied by popular descriptions of the disease, in the hands of several intelligent planters in each community.

II. Yellow Leaf Blight or Mosaic Disease.

The conclusions arrived at concerning the nature of this disease, as well as its treatment, published in bulletin No. 36, have been strengthened by farther study and experimentation during the summer of 1892. The reader is referred to that bulletin for the data concerning the disease as well as for the detailed description of the experiments for 1891.

It will be in place here, however, to give a brief description of the characteristic appearance of the disease, after noting the confirmatory experiments conducted during 1892.

Experiments for 1892.—A set of experiments to test the comparative merits of kainite, salt, and muriate of potash was arranged on the Experiment Station farm, the ingredients being worked in the soil during the month of February. As the disease did not appear at all on this plat, no comparisons could be made.

Another experiment was started on very poor sandy land which was designed to extend over a series of five years to test the value of "cow peas" (*Dolichos sinensis*) as nitrogen collectors for cotton under different conditions. The soil was heavily fertilized broadcast before plowing, with kainite and acid phosphate. No nitrogenous fertilizer was applied. A plat of nearly two acres was devoted to this experiment. Directly adjoining this plat on the south, the soil being the same, cotton was planted, having been quite heavily dressed with nitrate of soda in addition to some other fertilizer, but no kainite was used. North of one end of the first mentioned plat was one devoted to varieties of cotton treated with a complete fertilizer.

In July there began a perceptible yellowing of the plants in plat No. 1, while plats No's 2 and 3 bore a rich green foliage. Close observation showed that the yellow color in the plants of plat 1 was quite evenly diffused over the leaf. There was no indication of the checkered or mosaic arrangement of the yellow and green so characteristic of the disease. From this time on the yellowing of plat 1 became more and more marked until sometime in September the plants matured. Only a very few in this plat were at all badly diseased at this time, probably in places where the kainite was not well distributed.

Early in August plat No. 2 was very badly diseased, the leaves first presenting the checkered arrangement of the yellow and green color, then easily falling prey to such fungi as *Macrosporium nigricantium* and *Cercospora gossypina*, curling up, drying and falling away. The contrast between plats 1 and 2 was remarkable. In plat No. 3 a large area was also badly diseased.

A field of cotton of three or four acres, grown during the same season on a neighboring plantation, is worthy of mention. During May and June the plants grew vigorously and bore a healthy looking rich green foliage, and promised to surpass any cotton in that vicinity. But in July and August the disease appeared over the entire field and the destruction of the foliage was complete. The plant did not yield more than 50 per cent. of what it would if the foliage had not been destroyed by the disease. Judging from the experience of the past two years I inferred that no kainite or potash, or at least very little, was applied, though I knew the field was quite heavily fertilized at the time of planting. Upon inquiry I learned that the fertilizer was a compost of stable manure, cotton seed and acid phosphate. Had 200 lbs. to 300 lbs. per acre kainite been applied at time of planting the yield might have been nearly doubled.

Mr. A. H. Clark, of Hope Hull, Ala., continued experiments this year on the same plat of ground where they were conducted last year and reported in bulletin No. 36. The plat was laid off with the rows in the same place as last year, but different amounts of kainite etc., were used. The table presents the yield of seed cotton per acre in the different plats. The results of the experiment last year are introduced in a parallel column for easy comparison. As the disease appeared in the plat the effect of kainite on the yield is very marked.

TABLE I.

1891.

Basis fertilizer is 667 lbs. phosphate and 333 lbs. cotton seed meal per acre applied when bedded, other fertilizers as below stated applied June 9th, 1891, all on each side of drill.

1892.

Basis fertilizer 500 lbs. phosphate and 500 lbs. cotton seed meal per acre applied when bedded, all other fertilizers applied same date except when otherwise stated, all on each side of drill except where otherwise stated.

No. Plat.		PRODUCT SEED COTTON.	PRODUCT SEED COTTON.	
1	200 pounds kainite	1,088	1,720	400 pounds kainite.
2	400 " "	1,291	1,741	200 " "
3	Check	1,104	1,876	600 " "
4	"	1,048	1,143	Check.
5	200 pounds nitrate soda	959	1,655	600 pounds kainite June 20th.
6	400 " " "	1,040	1,151	600 " salt June 20th.
7	Check	711	1,403	200 " kainite in drill.
8	"	784	1,075	200 " salt in drill.
9	200 pounds salt	1,015	1,050	400 " salt.
10	400 " "	1,186	1,341	200 " "
11	Check	931	1,320	600 " "
12	"	997	1,115	Check.
13			1,570	200 pounds nitrate of soda.
14			1,260	400 " " "

Mr. Clark writes of the experiment as follows: "Plat 13 of 1892 with 200 pounds of nitrate of soda shows a benefit from it greater than does No. 14 from 400 pounds, which latter does not seem to be much benefitted, considering that it did not increase the crop to any extent last year, and that this year the larger application acted the same way. I am satisfied the product from No. 13 is an error. It is plain that kainite is a specific for the disease."

September 16 I visited Mr. Clark for the purpose of observing the result of the experiment as presented in the appearance of the foliage of the plant. The result was very marked and plainly indicated the value of kainite in checking the disease. The foliage of the salt and nitrate of soda plats was very little if any better than the checks, showing the characteristic workings of the disease far in excess of the kainite plats. Plat No. 13 presented no better appearance in this respect than any of the checks, and this fact corroborates Mr. Clark's belief that the yield as reported from that plat for 1892 is an error.

A preliminary account of this disease was published in 1891* and the results of a more extended study appeared in 1892.† The reader is referred to the latter for a full account of that study, but it will be in place here to briefly state the nature of the disease, especially since some figures have been prepared which make the description more intelligible.

Description of the Disease.—The disease‡ is a physiological one, the condition of the plant being one of imperfect nutrition or assimilation. To appreciate the peculiar appearance accompanying the first stages of the disease, when it can quite readily be recognized in comparison with other affections of the leaf, one must note the general form of the leaf, as well as the venation, the courses through which nutriment is distributed, and the final areas through which it is diffused in reaching the ultimate units or cells of the leaf. The leaf is palmate, the main ribs,or veins, radiating from a common point at the junction of the petiole to several points on the leaf's circumference, so that the leaf is either undivided, as in the case of the first few leaves developed after

*Botanical Gazette, Vol. XVI, March.
Bulletin No. 27, Alabama Agricultural Experiment Station, May.
†Bulletin No. 36, Alabama Agricultural Experiment Station, March.
‡ Portions of pages 5 and 6 of Bulletin No. 36 are quoted here.

the cotyledons and the young leaves in the axils of the branches; or three to four or five lobed or pointed, one of the main veins extending into the corresponding lobe of the leaf.

From these few main veins smaller ones branch in a monopodial fashion nearly at right angles, reaching out into the triangular area lying between. From these again still smaller branches extend, which themselves are branched, and so on until all parts of the leaf are at last intersected by the final smallest veinlets. This net work of veins is the medium through which the minute channels course that conduct water and nutritive solutions absorbed by the roots and transported through the circulatory passages of the stem to all parts of the leaf.

It will be seen that the ultimate ramifications of this network of veins divides the leaf tissue into quite small angular areas, and that the circulatory channels in the veinlets lie along the borders of these areas, Now it is clear that, as the nutritive substances pass by diffusion from the channels in the veinlets to the areas between them, the cells of these areas lying closest to the veinlets will be the first to obtain nourishment, and that the cells toward the centre of these small angular areas will be the last. When there is an abundance of the nutritive solution containing all of the necessary elements, all the cells of the areas will be well supplied, and, other things being equal, will remain healthy and green.

But if the supply is deficient either in quantity or quality the first cells to feel this deficiency will be those in the centre of these angular areas, while all the cells lying along the track of the distributing channels may be well supplied for a time. The effect of this deficiency, either in nutrition or assimilation, is shown in the partial disorganization of the chlorophyl, or green substance, which causes it to become yellow in color. At first this change in color is quite indistinct, but gradually becomes more marked until it is plainly seen. When this takes place it gives to the leaf a checkered or mosaic appearance, the cells along the channels in the veinlets which bound the yellowish areas remaining quite green for some time.

Figure 1 represents such a leaf in the early stage of the disease, the lighter colored spots representing the yellow areas.

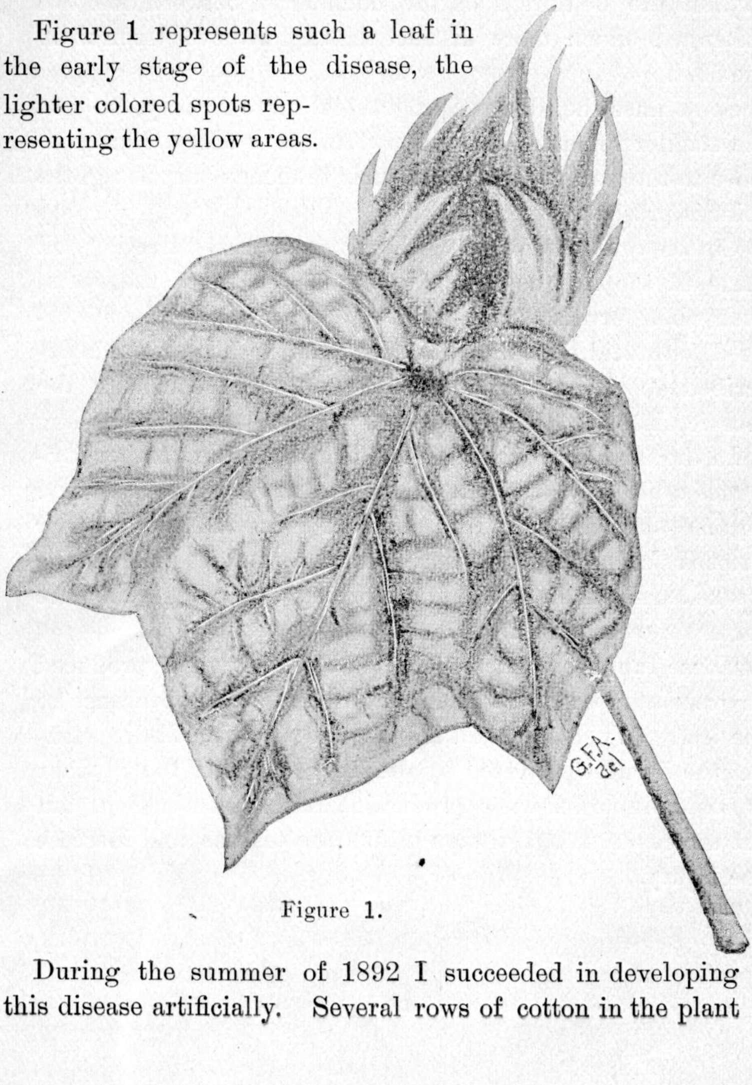

Figure 1.

During the summer of 1892 I succeeded in developing this disease artificially. Several rows of cotton in the plant laboratory were set apart for the experiment. When the plants were about one foot high the soil was flooded with water every day. In the course of two weeks the characteristic mosaic arrangement of the yellow and green color appeared in the leaves, and in a week more was very marked so that the definition of the boundaries between the two colors was much more distinct than I have ever seen it in the field.

Sometimes the disease progresses more rapidly, so that the smaller veins are also yellow, and it is only along quite close to the larger veins and their branches that the green color is present.

Cotton quite frequently has a yellow cast affecting all parts of the leaf as well as the tender parts of the stem, even when fertilized with kainite, and especially when fertilized with acid phosphate, as shown in the experiments described above, but it should not be confounded with the mosaic disease.

In the farther progress of the disease, if the weather continues quite dry, the leaf after awhile will gradually dry, become shrivelled and fall off. If rain and hot weather succeed each other, semi-parasitic fungi attack the weakened spots in the leaf, absorbing the living substance for their own growth.

These fungi are microscopic plants, but when produced in great numbers, give a dark brown or black appearance to the leaf. When the plant is badly diseased it will die without the injuries produced by these organisms if the weather is not suitable for their production and dissemination, but the attacks of fungi always hasten the disease and increase the injury.

In the latter stages of the disease the leaves assume different appearances according to the kind of fungus which grows in the diseased parts of the plant. Figure 2 repre-

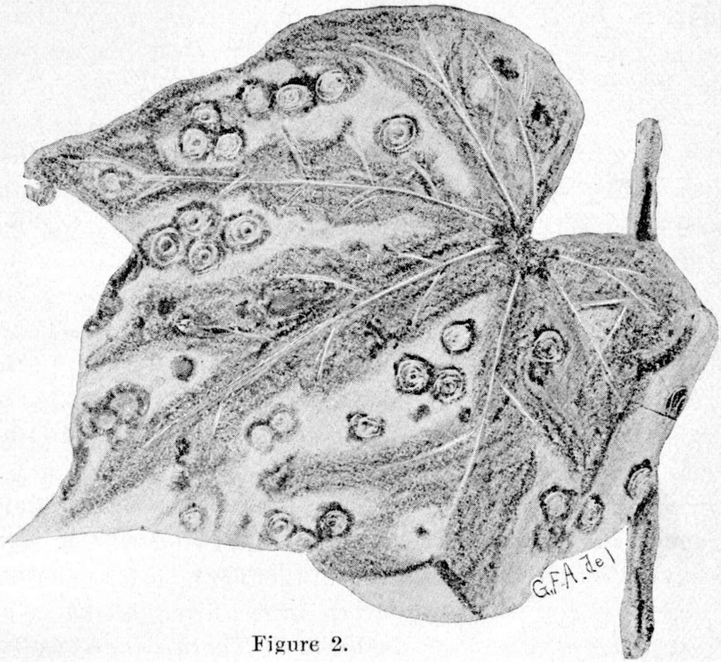

Figure 2.

sents one form when the leaf is attacked by *Macrosporium nigricantium.* This fungus causes circular spots, brown in appearance, and frequently marked by concentric rings of different colors. Fig. 4, Plate I, represents spores and fruiting threads of this fungus. The growing part of the fungus consists of minute thread-like bodies which grow inside the leaf and cause the spots. In a short time these fruiting threads shown at *b* in fig. 4 of the Plate, grow outside of the leaf and bear the spores on their ends. Frequently the leaf is covered with a fungus growth, the spores of which are shown at fig. 5 of the same Plate.

Figure 3 of the text represents another form the leaf may assume when the principal fungus growing on it is *Cercospora gossypina*. Tufts of the fruiting threads of this fungus as they stand out upon the surface of the leaf are shown in figures 1 and 3 of Plate I. Those being dark in color give the leaf a black or dark brown color. In figure 1 some of the long, slender, colorless spores are shown attached to the ends of the fruiting threads, and some free ones are shown at 1*a* and 2*a*. When these spores are developed in great profusion, being colorless, they give a whitish appearance to those places—some of these are shown in the white spots at the lower edge of the leaf in figure 3 of the text. This form of the fungus is the one which develops several successive crops of spores through the season. There is another form which is developed toward the close of the season, and is probably the form in which the fungus passes the winter. This is repesented in figure 4.

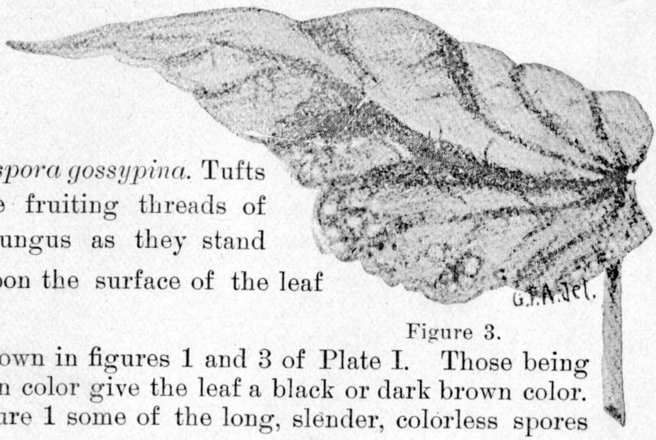

Figure 3.

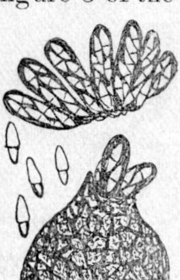

Fig. 4

A black ovate conceptacle is developed from the threads inside the leaf, which extends partly through the leaf surface. Inside this are several sacs, each of which contains eight spores. These are sometimes produced in great numbers upon leaves like the one in figure 3. The name of this fungus is *Sphærella gossypina*.*

*See Bulletin Torrey Botanical Club, Vol. XVIII, No. 10, 1891.

For description of the other fungi alluded to here see Bulletin No. 27, Ala. Agr. Exp. Station, and Botanical Gazette, Vol. XVI, No. 3, March, 1891.

III. Frenching.

This disease was first called to my attention June 16, 1891, but has for sometime been known to a number of planters. Why the name "frenching" was ever applied to this disease I have been thus far unable to determine, unless it be that, following the signification of the verb from the same root which means something *foreign*, and therefore later, *strange*, *unnatural*, etc., it is intended to denote a strange or unnatural appearance of the cotton plant.

I first collected specimens of the diseased plants at Matthew's Station and Hope Hull, Ala., on June 16th and 17th, and material has been sent me frem Allenton, Ala. July 9th I discovered it at Pike Roads, Ala. July 19th I collected specimens at Selma, Ala., in sandy land. September 4th I found it also in the sandy bottoms of the Alabama river, within two miles of Montgomery.

In August, 1892, I received it from Arkansas, the specimens being sent by Mr. C. L. Newman of Pine Bluff.

During the month of September, 1892, I was called to Athens, Ala., by Commissioner Lane to inspect some diseased cotton, and found the same disease there.

I am led to believe that its distribution is much wider, but these are the only places of which I have positive knowledge from personal examination of its presence.

Beginning with the lower leaves the first sign of the disease is a light yellowing of the leaf at the edge, or more commonly between the forks of the main ribs of the leaf. This yellow color is sometimes very pale and almost white. It is followed by a drying of the same parts of the leaf, and later, as these parts of the leaf die, they turn brown and become ragged and the leaf eventually falls to the ground. These different colors follow successively, and when the disease is well advanced all the colors are seen on the same leaf, the yellow color, of course, being nearer the still green portion of the leaf along either side of the main ribs. Figure 5 represents a leaf showing all the colors, the darker

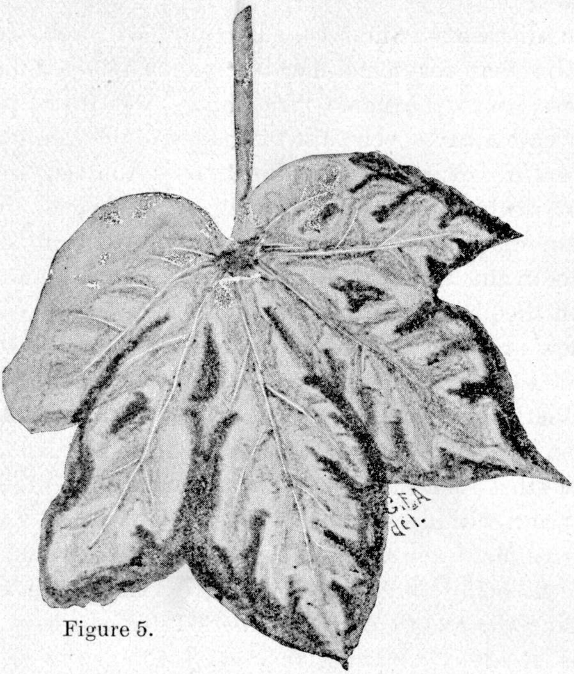

Figure 5.

color being the dead portions, the lighter color, the yellow, and the green color is along the veins.

Gradually the disease advances into the other leaves, until nearly all of the leaves are affected, when the lower ones begin to fall. At last the uppermost leaves are affected and fall away.

My first observations were made on plants about twelve inches in height, a short period before the first blooms appeared.

In May, 1892, at Mathews' Station, I observed the disease in very young plants, only a few days after they were up, and before the plumule was developed. The peculiar yellow color was easily noted in the cotyledons of the plant.

A few of these plants I took from the ground, conveyed them to Auburn and transplanted them. The transplanting checked their growth for a few days, then growth set in and all external signs of the disease disappeared, but in the latter part of June, when the plants were almost one foot high, they were severely attacked, and by the middle of July all of the leaves presented the peculiar striped appearance so characteristic of normal advanced stages of the disease. Some of the young plants collected in May were examined microscopically and found to be identical with the disease observed in the larger plants the previous year.

When the plant is old these progressive changes of color frequently are distributed over many more courses on the leaf, following not only between the main four or five veins of the leaf, but also the spaces between the primary branching of these veins. On plants possessing a mild type of the disease, some of the leaves may exhibit the yellow color in indefinite courses, now a few large yellow spots some distance from the edge, or a pale yellow occupying nearly one side of the leaf. But it is always sufficiently characterized either by the usual relation of the different colors, or by the peculiar shade of yellow, or both, for one who has once carefully observed the disease to easily detect it, except in some cases to be described later.

I am aware that other appearances of the cotton plant are termed "frenching," but I am lead to believe that the disease here characterized, and manifested by the specimens I have seen, is the one more generally known as frenching.

The leaves of a cotton plant are sometimes variegated with different colors, yellow, white, red and green. This is sometimes called "variegated cotton," or the "spotted cotton plant," "leprosy," etc. Some call this "frenching," and consider it the same as the disease I have described above. It is totally different, however. The leaves do not die from the trouble, but may remain alive and perform their functions.

The final and sure test of the disease is found upon breaking or cutting the stem of the plant. If it is "frenching" the tissues of the fibro-vascular system will appear light brown in color, the depth of the color depending upon the virulence, or stage, of the attack. Planters say the "heart" is black. A microscopic section of the stem reveals the presence of fungus threads which are interwoven in labyrinthian meshes, in some cases completely filling some of the vascular channels of the plant. The discoloration of the tissues is more apparent in those ducts infested with the fungus. With good illumination the color appears, when viewed in a microscopic section, to be a brilliant yellow, unless quite old, when it is much darker. The threads of the parasite when young are colorless, but as they age they assume a bright yellow color. They measure 2–4 micromillimeters in diameter. Very minute spores are developed from the ends of some of the threads and are found either

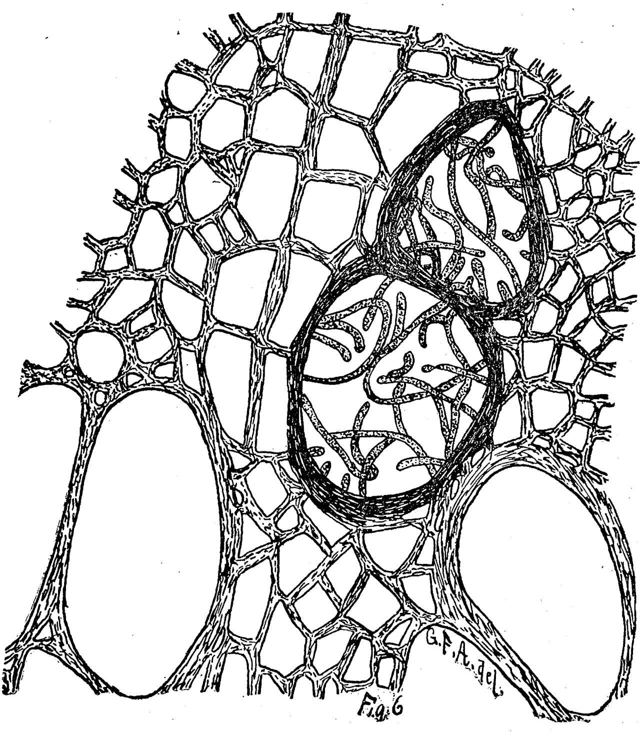

Fig. 6

attached to their places of growth or free within the ducts, and are 1–2 x 2–4 micromillimeters. In figure 6 is shown a portion of a thin section across a diseased stem, very highly magnified, the fungus threads are interwoven in two of the ducts.

Using proper precautions to prevent contamination of the culture media, pure cultures were obtained of the parasite from within the stem. In all such cases the fungus obtained proved to be a species of *Fusarium*.

The parasite enters the plant near the surface of the ground or in the upper parts of the roots. The threads then as they increase grow upwards and reaching the branches and petioles of the leaves grow out into their circulatory channels. This explains why the lower leaves are the first to be affected during the first period of the disease.

During the early stages the parasite is not in the leaves, the color changes and dying of the leaf being the result of a failure in nutrition due to the withdrawal of nourishment from the vascular channels of the stem by the parasite. The larger openings in figure 6 represent some of these cut across. It will be noticed that the failure of nutrition in the leaves is somewhat similar to that which occurs in the mosaic disease, but in frenching the interference with nutrition is so much greater than in the mosaic disease that the yellow color does not first appear in the smaller areas bounded by the smaller anastomosing veinlets, but extends rapidly up from the edge of the leaf between the larger veins.

The plants sometimes put out new growth and seem to recover to a certain degree from the disease. In many cases the upper part of the plant dies, the new growth coming from the latent buds and dwarfed branches near the ground. Many of the plants die outright.

Under favorable circumstances a new growth from the lower branches may entirely hide the dead top of the plant unless careful observation is made. In other cases the new growth may come from all parts of the plant. After a period of convalescence the plant may suffer a relapse. The second attack often differs materially from the first in external appearance, probably from the fact that the mycelium of the fungus is so well distributed throughout all parts of the plant that its effect in attacking the new growth and increasing in the old, is more rapid, thus not permitting the gradual sequence of color observed when the fungus has but one opening through which it can enter the growing parts of the plant.

A few leaves sometimes show the characteristic sequence of color, but the leaf soon wilts, thus checking the color changes. Plants may pass through several periods of convalescence and relapse during a season. The fruit even on plants that do not seem to be very badly effected may frequently decay when nearly ready to open.

The disease when not complicated with other diseases of the roots, does not advance with such rapidity into the roots, and this probably explains why so many plants sometimes recover, the roots in favorable weather sometimes supplying constantly the necessary moisture and nutrition, furnish material for the growth of the latent branches near the base. In sandy land the progress of the disease seems to be much more rapid, especially when the plant has attained considerable size and the fungus already is well distributed throughout the system. It then often happens that very few of the leaves show the gradual changes described above, but suddenly wilt on a hot or dry day; a few on one day, more on the following, or sometimes perhaps all on the same day. The plant then soon dies. This phenomenon of the disease in aged plants in sandy land is in external appearance very much like "root rot" of cotton in Texas, but caused by a different fungus. Occasionally the plants on the sandy land are also affected with nematodes and have large "knotty swellings" on the roots. These galls are caused by a nematode worm. Whenever cotton is frenching in soil affected by these worms, almost every plant effected by the worm is also affected with the organism of frenching. This is probably because the roots, being diseased by the worms, offer easy access to the parasitic fungus. However, many of the plants that are frenching are not affected by the nematodes even in sandy land. The two diseases are distinct, but when both attack a plant, the condition of the plant is much more serious. "Knotty swellings" are also found by some planters on roots of cotton in the prairie lands. These are probably caused by the same nematode. I have not observed them myself on cotton roots in the prairie lands, but have found them in such lands on the roots of tomatoes and lettuce. *

It is thought by most planters familiar with the disease, that it is confined to soils of a certain character. Some will say that it occurs only in gray soils of the prairie belt; others that it occurs only in the loose black, or gunpowder lands. This is due to the comparatively narrow area over which their observation extends. Thus, at Hope Hull, it is mainly in the gray lime lands, with a less per centage in the clay and very little in the bottom land adjoining the gray soil. At Mathew's Station, on the other hand, it seems to be confined mainly to the bottom land, some of the lands being known as "gunpowder land," a deep, black loam, which in dry weather becomes very finely powdered and loose. Considering also its occurrence in sandy soil, it will be seen that it is likely to infest any soil into which it may be carried and gain a foothold.

At Athens, Ala., I found okra affected by the same disease. No other plant is now known to be affected with the same disease that I am aware of. Corn seems to be entirely free from it, and perhaps more frequent rotation with corn would not only starve out the fungus, but benefit the plan-

*Agricultural Journal, Montgomery, Ala., August, 1891.

ter in another way also—that of providing grain for stock, instead of purchasing it at high prices, as many do.

CULTURES OF THE FUNGUS.—In starting the artificial cultures of the fungus, care was used to free them from contamination from any germs on the plant. With a knife heated to redness, the stem was cut and the bark carefully and quickly shaved off. Then with a flamed cool knife, portions of the diseased ducts were transferred to nutrient agar agar in test tubes. Cell cultures were made in which the sections were so thin that I could observe with the microscope that the growth obtained in the cultures originated from the young fungus threads in the tissues, or from the minute spores. Other cell and tube cultures were made by dropping the thin sections in liquified nutrient agar agar in the test tubes, and then pouring it upon thin glass to solidify. Frequently in such cases the spores were shown to be quite numerous from the number of centres of growth in the medium other than those where the sections were located.

The formation of spores takes place within fifteen or twenty hours from the time of starting culture from the stem or in sowings of the spores. The hyphae in artificial cultures remained hyaline in all the cultures made except in one culture in bouillon. In drawing specimens for examination from this culture, portions of the submerged mycelium were raised above the surface of the liquid. In a few days these possessed the same color as the older threads in the tissues. In bouillon and nutrient agar agar frequently enlarged cells appear in the hyphae, which resembles gemmae. Sometimes they occur at the end of a hypha, and in both cases often bear several flasked-shaped basidia.

The spores obtained in cultures vary from 2-4.5x4—40 micromillimetres. They are continuous, or one to four or five septate, according to their length. The very minute ones are narrowly oval. As they increase in length many are inequilateral and curved. They are colorless, faintly granular, and frequently possess one to several vacuoles, according to their size. The short ones have usually one rounded end, the opposite end being usually rather sharply pointed. Variations in this character occur. The longer spores have a tendency to be pointed at both ends when mature, though frequently one end is appreciably the stouter.

The fertile hyphae vary greatly. The earlier ones are short, flasked-shaped and supported on the main hypha by a narrow pedicel. As they age, they frequently increase in length, and branch producing dendritic forms. The formation of spores in cultures reminds one strongly of some species of *Glœosporium* and *Colletotrichum*, where they are clustered about the ends of the basidia. Frequently in this *Fusarium* the basidium elongates as the spores are being borne and leaves them distributed along its course.

Cultures in nutrient agar agar or bouillon produced shorter spores than on sterilized cotton bolls or Irish potatoes.

A saprophytic *Fusarium* is very common on decaying cotton bolls in autumn, and I have found it in various places during the past July, growing upon bolls which were probably first attacked by a bacterium. I have also found it on decaying bolls from plants badly affected by this vascular disease. Of this saprophytic species I made parallel cultures with the parasitic form, to determine if they were specifically distinct.

The cultures were made on sterilized cotton bolls and Irish potato. The two seem to be specifically distinct. In the saprophytic species the spores are more strongly curved and the ends very long and slender. This distinction was maintained throughout several cultures.

Some of the growths in artificial cultures are represented in figure 7, *a* from culture in agar, *b* from culture on cotton bolls, *c* from culture on potato.

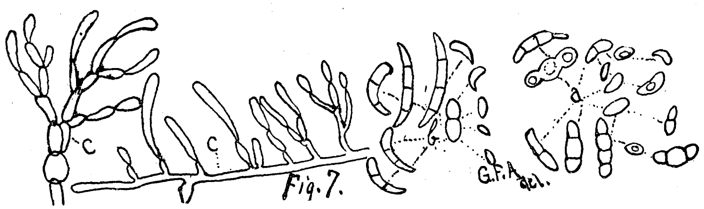

Fig. 7.

The fungus seems to be new and I propose for it the name *Fusarium vasinfectum.*

Inoculations.—Experiments were made in August, 1892, to determine if the disease could be obtained by inoculation with the fungus which I obtained in pure culture. The *Fusarium* was considered not to be a sufficiently aggressive parasite to be able to make its way into the ducts of the circulatory system unaided. Having found that the "damping off" fungus could disease the stems of the young cotton, and that many plants even when the ulcer reached the circulatory system, recovered from the effects of this external injury, it was suggested that possibly this fungus could open the way for the entrance of the *Fusarium.*

Accordingly several short rows of cotton were planted in the plant laboratory and just as the plants were issuing from the ground they were inoculated with the "damping off" fungus. When by examination it was shown that several plants were diseased so that an opening was made in as far as the vascular tissue, a portion of the earth was removed and pure cultures of the *Fusarium* were placed directly against the diseased portions of the plants. Some of the plants died from the effects of the "damping off" fungus, but loosening of the earth and partial drying of the soil saved others. In a few days the soil was kept well watered again. Aug. 24 one plant about 12 inches high died exhibiting signs of the disease in one leaf. Microscopic examination showed the Fusarium ducts near the ground, while for some greater distance up the stem the fibro-vascular tissue was brown in color. The discoloration and disease of the ducts is started by the injury from the "damping off" fungus. The diseased condition of the ducts affords an opportunity for the *Fusarium* to gain a foothold. As the plant recovers from the lesions produced by the "damping off" fungus it imprisons the *Fusarium* in a living condition. The *Fusarium* may for some time lurk in the circulatory passages making but slow growth. Its presence and growth upon the already partially diseased tissues extend the malady farther up the passages with the growth of the plant. Finally in many cases the *Fusarium* has such a strong foothold and is so wide spread through the system that the plant is overcome and dies outright, or sheds all its leaves. Favorable conditions may bring on a period of convalescence followed by a relapse as the *Fusarium* again gains the upper hand.

Some of the plants first diseased with the "damping off" fungus were inoculated by placing stems of a frenching plant against the diseased parts. In one case the result was beautiful, three of the leaves slowly passing through the yellow color changes and then wilting. The ducts of the stem also presented all the characteristics of the disease. The result was much more satisfactory than that obtained from the inoculation with the pure culture of the *Fusarium.* This suggested that possibly bacteria which are frequently obtained from the diseased tissues might be associated with the *Fusarium* in the etiology of the disease. While I do not wish to be understood as making any positive assertion in favor of the *Fusarium* being the cause instead of bacte ria, I do think the evidence thus far in hand gives greater support to the former view. The *Fusarium* is invariably found, both in cotton and in okra afflicted with the disease. Bacteria are not always found in the diseased tissues, forin quite a number of transplantings of diseased tissue to nutrient agar agar no bacteria were developed while the *Fusarium* always appeared. Again not always does the same species of bacteria appear, but now one species and then another.

IV. "Sore-Shin," "Damping off," "Seedling Rot."

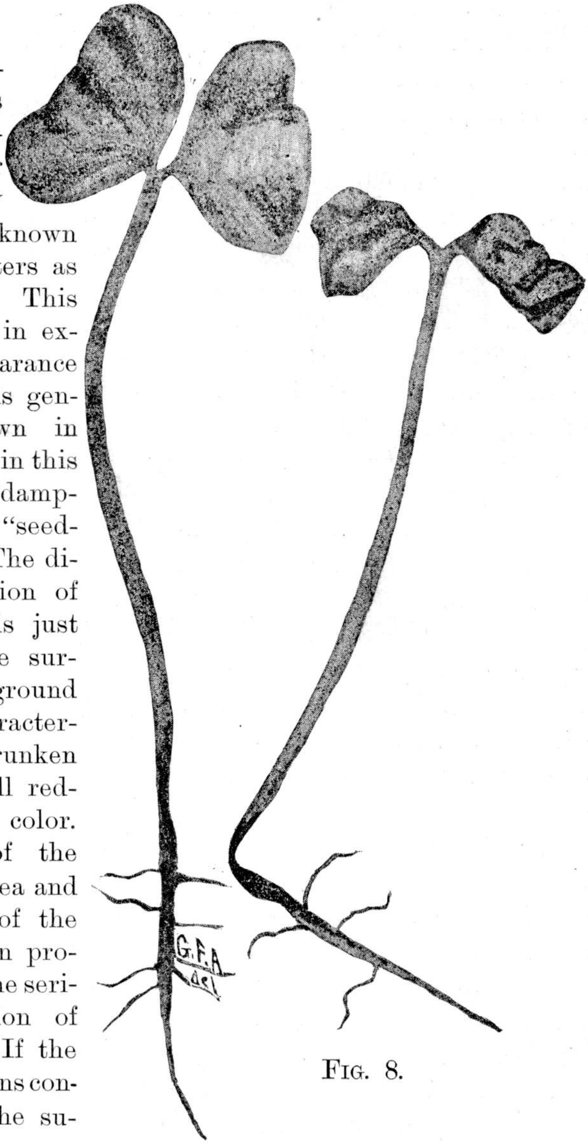

Fig. 8.

Young cotton plants are frequently injured or killed by what is known among planters as "sore-shin." This is identical in external appearance with what is generally known in Europe and in this country as "damping off," or "seedling rot." The diseased portion of the plant is just beneath the surface of the ground and is characterized by a shrunken area of a dull reddish brown color. The size of the shrunken area and the depth of the injury are in proportion to the serious condition of the ulcer. If the injury remains confined to the superficial tissues the plant may, and frequently does, recover. Such plants may show the disease for several weeks. Figure 8 represents two plants "damping off."

Damping off is so frequently attributed to the work of *Pythium DeBaryanum*, I supposed in this case that fungus was present, but numerous examinations failed to reveal it. Beside the frequent occurrence of threads of *Rhizopus nigricans*, and species of *Fusarium*, non-fruiting threads of some fungus were so generally observed I suspected their causal connection with the disease.

The threads are 9–11 micromillimeters in diameter and the cells 100–200 micromillimeters in length. At first they are colorless and possess numerous vacuoles of varying sizes in the nearly homogenous protoplasm. As they age they become brown in color. The branches extend obliquely from the parent thread, are somewhat narrower at their point of origin and possess a septum usually 15–20 micromillimeters from the parent thread, giving a clavate form to this part of the branch which is continuous with the parent cell. Frequently the hyphæ are associated in strands being woven and twisted together.

Pure cultures.—By placing effected seedlings on filter paper in a moist chamber there are developed in 24 to 48 hours numerous threads in a horizontal or procumbent position, which extend out for 1 c m to 3 c m over the paper, often not contaminated with other fungi. By transplanting a few of these threads, using a flamed platinum needle, into nutrient agar rendered acid by lactic acid (one drop concentrated lactic acid to about 10 c c of nutrient agar) a pure culture of the fungus was obtained.

A series of experiments was conducted to determine if the fungus found in the tissues of "sore-shin" cotton, could really produce that disease and "damp off" the young plants.

Experiment No. 1—Soil from the hill in the garden where young plants had just died from the disease was placed in two pots on June 27. Pot *a* was placed in the soil bed of the plant laboratory and watered. Pot *b* was steamed in the steam sterilizer for three hours and left in the sterilizer over night. June 28 it was placed in the soil bed beside pot *a*. Cotton seed after being scalded was planted in both pots. The plants began coming up July 1 and 2 and were well up July 3rd. In pot *a* the plants were damping off while in plot *b*, the soil of which had been steamed, the plants were perfectly healthy. I was now absent until July 16. On returning, my assistant reported that all the plants in pot *a* died in a few days. In pot *b* they were still perfectly healthy. This was very good evidence that the soil contained some parasite which caused the disease and the steaming killed that parasite.

Experiment No. 2.—This experiment was made in order to test the effect of kainite in the soil since it had been found in a few trials where the fungus was not very abundant in the soil that acid phosphate hastened the disease. Earth from soil in the garden which had been heavily fertilized with acid phosphate and in which plants died from "damping off" was placed in two pots. These were sunk in the soil bed in the plant laboratory June 27. Scalded cotton seed was planted in both. Pot *a* was watered with pure water while pot *b* was watered with a strong solution of kainite. The plants were well up July 3rd. Damping off began in both pots and in a few days all were dead. This indicates that while under ordinary circumstances acid soil conduces to the development of the disease, heavy application of kainite will not prevent it where the fungus is abundant in the soil.

Experiment No. 3.—Earth from the garden not known to be infected with the fungus, but quite likely containing it, was placed in a pot and steamed in the steam sterilizer for three hours. It was sunk in the soil in the plant laboratory July 16, and planted with scalded cotton seed. The plants were well up July 20. Three different groups of plants in the pot were inoculated with the fungus threads taken from a pure culture, grown on nutrient agar. The threads were placed against the lower part of the stem after removing the earth. The earth was then returned and the soil watered. Several groups of plants remained untreated in the pot to serve as checks.

July 22 one plant from group 1, and two plants from group 2, had fallen and were wilting. These were removed to a moist chamber on filter paper prepared in the same manner as described above. July 23 there was a profuse growth of the fungus threads extending out upon the filter paper. It was identified as the same as the one used in the inoculation. On the same day one plant in group 3 had fallen and was wilting. Others in groups 1 and 2 were diseased while the checks remained healthy.

This proves that the fungus used in the inoculation is the cause of the disease produceu at that season in the garden and fields which I examined.

July 28—Experiment No. 3—was photographed. Only one plant among the remaining number of the plants inoculated was erect, and examination showed that to be diseased. This was in group No. 1. In group No. 2 there were still three plants, one had fallen July 27 and was wilted; two fell during the night of July 27, and on the morning of July 28 were wilting. In group No. 3 were also three plants. Two had fallen July 25 and 26, and were nearly dry, while one had fallen during the night of July 27, and was wilting on the morning of July 28.

The group of plants not inoculated remained perfectly healthy.

Experiment No. 4.—July 22 water cultures were started in the following way. Two 4 oz. bottles were filled with distilled water to which a small quantity of acid phosphate, kainite and nitrate of soda was added. The cork was perforated to admit the radicle of the cotton plant seedling. The seed was previously scalded and germinated on filter paper in a moist chamber. The seedlings were placed in position and the experiment photographed. No. 1 was inoculated by placing a tuft of fungus threads against the stem where they would keep moist, while No. 2 served as a check.

July 23 the fungus had taken hold of the plant in No. 1, as shown by the discoloration and shrinkage of the tissues. July 25 the plant in No. 1 was dead while the check plant in No. 2 was perfectly healthy, and had grown as shown in the photograph taken on the same date.

Experiment No. 5.—This experiment was designed to test the fungus of "root rot" of alfalfa sent by Prof. George W. Curtis, Director of the Texas Agricultural Experiment Station, which appears to be identical with root rot of cotton in Texas.

A pot of soil from the garden was steamed in the steam sterilizer for two hours, cotton seed previously scalded was planted July 20th, along with refuse earth and particles of alfalfa roots from the Texas material. The plants were coming up July 23 to 25. July 26 one plant had "damped off." July 27 several plants were badly diseased so that the least pull caused them to break off at the diseased area. The "damping off" fungus was found, and also numerous threads of *Rhizopus nigricans*, which was abundant on the alfalfa roots.

Experiment No. 6.—This experiment was designed to test the effect of the *Rhizopus nigricans*, which developed so abundantly in experiment No. 5. Two pots of soil from the garden were steamed for two hours, the soil being previously wetted. Scalded cotton seed was planted July 27. A culture of the *Rhizopus* was added to the seed planted in pot *a*. Pot *b* was retained as a check. Plants remained healthy in both.

Experiment No. 7.—This experiment was designed to test a preparation chiefly recommended as an insecticide, but claimed also to possess fungicidal properties. The preparation is known as "par oidium," or "black sulphur." The experiment was conducted in pots *a* and *b* of experiment No. 2, where all the plants had died from damping off. The "par oidium" was mixed with three inches of the surface soil, and seed not scalded was planted in both pots July 16. July 20 when seed planted in other places on July 16 was up, I examined the seed in pots *a* and *b* and found it dead. Fresh seed was then obtained and after being scalded was planted in pots *a* and *b*, while check plantings were made in other places to determine the quality of the seed. The check plantings germinated while not a seed in pots *a* and *b* germinated. July 25 some of the seed in pot *a* were opened and placed on filter paper in a moist chamber, when in 24 hours a profuse growth of the characteristic fungus appeared. This showed that the "par oidium" had not prevented the growth of the fungus.

Experiment No. 8.—This was conducted to determine whether or not seed would germinate in the soil used in experiment No. 7 after being steamed. July 25 the soil in pot *b* was removed. That in a pot *a* was divided perpendicularly, one half being placed in pot *b*. First, soil was placed underneath this soil in both pots to raise the surface nearly level with the rim of the pots. Pot *a* was steamed for two hours, and when cooled, scalded seed was planted in both pots. July 28, 29 and 30, the seed in pot *a* had germinated, the plants were coming up and were perfectly healthy. In pot *b* not a seed had germinated. The fungus had multiplied to such an extent in the soil that it killed the seed before germination could take place.

DESCRIPTION OF THE CULTURES.—It was difficult in the culture in moist chambers from the roots of diseased plants to prevent bacteria from accompanying the threads. The acidulated medium prevented the growth of the bacteria while it did not interfere with the growth of the fungus. Five different cultures were started in this manner. Four test tubes containing sterilized corn stalk pith saturated with acidulated nutrient agar agar were inoculated with the threads. One failed to grow, two were contaminated with *Rhizopus nigricans*, and two developed pure cultures of the desired fungus. The fifth inoculation was made into acidulated nutrient agar agar in a liquid condition, which was allowed to partially cool, and then was poured out upon a sterilized glass plate, the partial cooling of the agar permitted it to remain in a heap about 1 c m high and 4 c m in diameter. A pure culture of the desired fungus was obtained in this also.

In the plate culture a profuse growth followed, the hyphæ emerging in all directions from the substratum, extended all over the glass plate to the edge, and there, in the course of a week, hung down in broad, brown mantles or veils of exceedingly delicate texture, reaching to the water in the bottom of the vessel.

In a like manner by this time the threads grown from the diseased plants in the moist chamber had extended over the filter paper for four or five inches, forming in many cases distinct strands, of a dark brown color, from the association and intertwining of several hyphæ, resembling the strands of some Hymenomycetes. These strands also occurred in the plate culture.

In the test tube culture the hyphæ first appeared, springing in a radial direction from the point of inoculation on the corn-stalk pith as a white, fluffy mass which soon spread over the surface of the pith and leaped by strands across the space intervening between the pith and walls of the tube, where in many cases, compact masses of hyphæ developed, composed of short cells very much constricted at the septa and broader than the normal ones. These were white at first but became brown with age, and suggested the development of sclerotia. This culture was started June 21st, and by July 21st, as growth seemed to have ceased, more nutrient agar was poured into the tube, partly immersing the pith. In twenty-four hours a profuse growth had appeared over the surface of the agar.

July 18th additional cultures were started from the plate culture by transplanting portions of the agar containing the threads, as well as the threads alone taken from near the edge of the glass plate, into test tubes of acidulated nutrient agar. Growth appears first as a loose, abrupt convex tuft of radiating white threads. In a few days this tuft increases greatly in the periphery, but little in height. At the same time minute, powdery-looking masses appear which are seated on the mycelium, near the surface of the medium, in the meshes of the tuft or near the extremity of the loose threads. Some of these are young sclerotia, as noted above,—white at first, but gradually changing to a brown color. These occurred in all the cultures.

Cultures on Irish Potatoes.—July 23rd several Irish potatoes were halved, placed in covered glass vessels and steamed two hours each day for two successive days. Being in closed vessels the steam did not reach the potatoes readily, and numbers of bacteria developed. Observing this, July 25th the covers of the glass vessels were partially removed during the process of steaming which continued for two hours, killing the bacteria, since no farther development took place. After cooling, July 25th, p. m., two of the halves of the potatoes were inoculated with the fungus threads from a test tube culture. July 26th, a. m., the fungus had grown rapidly, spreading in a radial direction over the cut surface of the potato for about 2 *c m.** July 27th, a. m., it had reached and passed the edge of the potato, extending over the edge about 1½ *c m*, the growth for the twenty four hours being about 3 *c m.*

On the surface of the potato the threads form a stout pellicle lying quite close to the surface, while at the edge they tend to separate into strands and diverge outward and downward.

July 28th, a. m., the two cultures in vessels of different size presented some differences. In the glass jar, 6 *c m* in diameter, the infusion from the steamed potato was more plentiful in proximity to the potato and of greater depth on the bottom of the vessel than in the shallow and broader vessel. This increased moisture and richness of pabulum conduced to a much more rapid and profuse growth of the fungus. The threads for a short distance down the perpendicular surface of the potato stood out loosely, while lower down, as the moisture and nutriment increases, they cling more closely to the side of the potato, forming a pellicle with a few loose threads or strands. Upon reaching the infusion they again grow into a very compact pellicle, the strands of which extend radially to the side of the vessel.

* Two and one-half centimeters are nearly equal to one inch.

The pellicle is thrown into radiating and dichotomously forked folds.

Upon the surface of the pellicle in both cultures there are later developed many procumbent free strands and threads. At the ends of the free threads, and over the surface of the pellicle, numerous powdery-looking tufts, alluded to above, are developed. Those close to the surface of the pellicle form the sclerotia. The pellicle is 400 micromillimeters or more in thickness.

On Irish potato in test tubes the fungus develops a loose weft of threads and strands. Many strands extend across to the walls of the tube where numerous sclerotia are developed. The sclerotia also are developed on the strands in the intervening space between the potato and walls of the tube, as well as on the surface of the potato.

In one of the potato cultures, where the potato was first boiled, then halved and steamed, the pellicle as it advanced over the surface of the potato caused a depression parallel with and a little behind the advancing border of the weft. The pellicle later became strongly and irregularly folded.

Cultures on Cotton Stalks.—A cotton stalk, from 1 *c m* to 2 *c m* in diameter was cut into sections about 5 *c m* long, boiled and then placed in a glass jar where they were steam sterilized for two hours each day on two successive days.

July 30 they were inoculated with threads of the fungus. August 2, from the point of inoculation, which was at one end of the small pile of stems near the lower portion, the fungus had spread radially for a distance of 3 *c m* to 5 *c m* in a rather compact but moderately thin pellicle nearly obscuring the bark of the stems. On the side of the glass jar it also extended radially from the same point for a distance of 3 *c m*. Upon the infusion in the lower part of the vessel the pellicle was much thicker, showing much more vigorous growth, and here the brown color appeared. The powdery tufts and sclerotia were also developed.

Culture on Oak Wood.—From an oak limb which had been

*One micromillimeter, equals 1-25,000 part of an inch.

dead about one year, still possessing the bark, about 3 *c m* in diameter, a section 5 *c m* long was taken, boiled, and split in halves. These were placed in a small glass jar, a little distilled water, and a small quantity of cotton stem infusion, added, and then steam sterilized two hours each day for two successive days. July 28 this was inoculated with threads of the fungus. August 2 the fungus had spread radially from the point of inoculation, a distance of about 3 *c m*, forming a very thin gauze like pellicle through which the wood could be distinctly seen. The growth was somewhat more vigorous on the weak infusion. August 4th the gauze like pellicle had not increased in density, while the growth on the infusion was much more compact and sclerotia were developing on the sides of the glass jar as well as on the surface of the wood.

Culture on Cotton Seed.—July 25th some cotton seed killed by the fungus was opened and placed on filter paper in a moist chamber. July 26th a profuse growth of the fungus had begun. August 2 sclerotia were observed on the filter paper several centimeters distant from the seed varying in size up to the size of a bird shot. Connecting these with the seed are strands of the fungus.

Culture on Horse Dung.—July 28 a small quantity of horse dung was placed in a small glass jar and steam sterilized for two hours each day on four successive days. Steaming was then omitted one day and then the material again steamed for two hours. August 3 the horse dung was inoculated with the fungus. August 4, very little perceptible growth had taken place, the threads from the point of inoculation radiating for a short distance, about 1 *c m*. August 5 this growth had extended making in all about 2 *c m*. There was no infusion whatever in the vessel, and the slow growth was found to be due to a lack of moisture, for on the addition of sterilized water, the growth was accelerated and numerous sclerotia were afterward formed.

V. Anthracnose.

Colletotrichum Gossypii Southworth.

During the summer of 1890 this then new disease of cotton was studied independently by both Miss Southworth* and the author.† While it seems to be quite widely distributed serious injury seems to be confined to localities. While I have observed it in quite a number of places in Alabama, only at Brundidge have I noted any very serious injury to the fruit. At that place in September, 1891, fully ten to fifty per centum of the crop was destroyed on some plantations. In the vicinity of Auburn while it occurs on the bolls its greatest injury seems to be confined to young cotton plants.

Affecting the Bolls.—The disease on the bolls originates in minute spots. These spots when very small are of a dull reddish brown color, and present minute shallow depressions of the surface tissue. As these spots enlarge the tissue blackens until the development of the spores begins. These are developed in pustules, usually confluent, in the center of the nearly circular spot. Their development changes the color of the spot, which becomes a dirty grey, if there are few spores or a bright pink, if the spores are numerous. Where the spores are few in number, many of them stand out upon the surface on threads which have grown up through the tissue. The spores being colorless give a greyish cast to the dark back ground of diseased tissue. When the spores are developed in great quantities they are piled up into a considerable heap and form a large confluent mass occupying the central portion of the spot. A pink pigment, given off by the spores, is produced here in such quantity by the mass of spores that it can be readily seen. It is this pigment which gives the pink color to the spots.

*Journal Mycology, Vol. VI, No. 3.
†Journal Mycology, Vol. VI, No. 4.

While the disease is progressing and the spots are increasing in size the bands of color in the tissue move out centrifugally. The outer band which is the border of the spot is dull reddish brown in color and its outer limits are frequently ill-defined. Inside of this border is a blackish band of tissue which borders the pink center. As the spots increase in size they coalesce and frequently unite in forming a large diseased irregular area covering sometimes one-half the surface of the boll.

FIG. 9.

Figures *9* and *10* show different stages in the progress of the disease.

FIG. 10.

Such fruit cannot mature good lint. The fungus brings about a premature ripening of the tissues, so that they deaden and dry into fixed forms. The normal process of maturity being thus interfered with the natural separation of the carpels of the boll is arrested. The boll either remains closed or as is more usually the case the carpels separate at the apex only, the boll appears as in Figure 11, to crack partially open, and in this condition firmly holds the lint within. It is not infrequent then to find the fungus even on the lint.

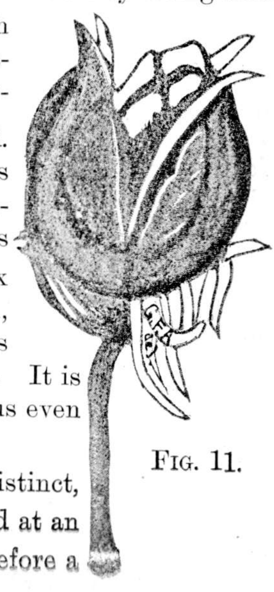

FIG. 11.

Sometimes the spots are not distinct, nearly the entire tissue being involved at an early period so that the boll dies before a profuse development of the spores at any given point takes place. In such cases the boll appears nearly black partly from the dead tissue and partly from the numerous black hyphæ and sclerotia of the fungus.

Affecting the stem.—So far as I have observed the fungus does not produce any characteristic injury of the stem which is noticeable, but it is frequently found in injured parts of the stem, and on the scars left by falling leaves, where the dying tissue of the scar, especially in humid weather, invites its development.

In my early studies of cotton anthracnose* I thought the fungus attacked the upper part of the stems in September occasioning a scalded appearance of the stems and leaves. Since I have become more familiar with the yellow leaf blight or mosaic disease, I am convinced the trouble was caused primarily by that disease and afforded a good opportunity for the fungus of anthracnose to develop.

The fungus sometimes effects seriously the stems of seedling cotton, attacking the stem at the surface of the ground or just below causing the plant to wither and die much as if it damped off. The tissues redden, and shrink frequently in longitudinal lines. The macroscopic appearances of the injury are usually quite different from those occasioned by the "damping off" fungus. The stem is not apt to present the well-defined ulcer, or diseased depression, which is so characteristic of the injury from the "damping off" fungus.

Seedlings are probably frequently diseased in this way from the spores which are lodged in the lint of the seed at time of planting. In some cultures of young plants in sterilized soil I have sometimes been annoyed by the development of the fungus in the stems under circumstances such that they were diseased in no other way than from spores which remained attached to the seed.

Affecting the leaves.—The anthracnose is frequently found upon the leaves but it is more apt to develop in sickly leaves, or injured places, than to attack healthy leaves. Indeed, there does not seem to be any characteristic affection

* Journal Mycology, Vol. VI, No. 4, p. 174. Washington, D. C., 1891.

of the leaves but from the partial saprophytic habit of the fungus otherwise diseased or injured leaves, as well as the stems, provide a nidus for the propagation and transport of the spores through the growing season, to the bolls.

The seed leaves, or cotyledons, however, suffer frequently from a characteristic injury. While the cotton seed is germinating the spores, caught in the tangle of lint still adhering to the seed coats, germinate also and attack the fleshy cotyledons as they are slipping from the coats. The fungus attacks the edges of the cotyledons and destroys an irregular area bordering the middle portion. The cotyledons being quite fleshy and succulent form a suitable place for the profuse development of spores and the diseased area is marked by the bright pink or roseate tint so characteristic of its profuse development on the fruit.

The degree of success which attends the throwing off of the seed coat by the cotyledons during germination probably bears a very close relation to their susceptibility of disease. After the young root has emerged from the seed coat, or hull, if the temperature conditions are such as to cause the hull to dry and remain so, or provide it with little moisture, it is cast off by the cotyledons with difficulty, and sometimes not at all. Frequently the hull clings to the extremities of the cotyledons, holding them firmly, while their bases are exposed to the light, and consequently take on a healthy green color. The edges of the cotyledons, held firmly bound, acquire a sickly yellow color, and frequently the effort to extricate themselves, results in some abrasion of the tissue. In either case the edges of the cotyledons, so held under extremely unnatural conditions, are an easy prey to the anthracnose spores which fall on them from the tangle of lint still on the seed coat. Such cotyledons are sometimes attacked by a *Fusarium*, the spores of which also produce a pink pigment, and the fungus can then only be differentiated from anthracnose by a microscopic examination.

I have succeeded also in inoculating young plants through their seed leaves.* A portion of a boll containing a profuse

*Journal of Mycology, vol. vi, no. 4, p. 177, Washington, D. C., 1891.

development of spores was immersed in water, which was then shaken thoroughly to scatter the spores in the water. The cotyledons of the young plant were well wetted with this, and a bell jar placed over the plant for a day. Natural conditions of temperature and humidity were then imitated as nearly as possible. The plants being in a frame artificial heat could be produced, temperature ranging from 20° C at night to 35° C at midday were produced. The humidity of the air in the frame was kept above that outside by closing the frame and wetting the soil. After four days the humidity was reduced while the temperature was maintained.

A week later an examination was made of a cotyledon which was dying, the distal end being half dead and shrivelled while the base was still green. It was well infected, and there were numerous clusters of setæ at the edge, also clusters of spores, and in the interior of the cotyledon spores borne on scattered basidia. Ten days from the time of inoculation another plantlet was diseased, both cotyledons being affected. When the distal half was pretty well dead and shrivelled the examination was made. Very few external signs of the fungus were present, but in a few places at the edge the setæ were just piercing through, and sections showed numerous spores and clusters of gemmæ within. The base of each cotyledon was apparently healthy, and each was still firmly attached to the stem. In no case were the spores developed in such numbers as to show the roseate tint. In this respect the result of the inoculations differed from what we observe in a natural appearance of the disease on the cotyledons probably due to artificial conditions.

Since the plant is thus shown to be vulnerable to the attack of the fungus at the cotyledons and young stem from spores resting on the seed, the suggestion is called forth that possibly we have here a case similar to the well known cases of *Cystopus candidus* and certain of the *Ustilagineæ*. The researches of DeBary showed that members of the *Cruciferæ* were open to the attack of *Cystopus candidus* only through their cotyledons. The fungus having thus found an entrance to its host traveled through the stem to other parts of the plant.

Brefeld and others have shown that wheat, oats and barley are only attacked by their specific Ustilago at the time of germination when the germ tube of the sporid enters the young stem and the parasite grows along with its host, doing no apparent injury until just prior to harvest time. In this case soaking the grains in blue stone water, or immersing them for a short period in hot water, destroys the spores of the smut while the grain is not injured.

If the analogy of cotton anthracnose with *Cystopus*, and the smuts is such as these facts would suggest, then, since the inoculating spores are now shown by my investigations to be in considerable numbers on some cotton seed, why can the analogy not be farther carried out and we be able to prevent anthracnose, in a large measure at least, by scalding the seed prior to planting?

We have no positive evidence that the anthracnose fungus does travel along through the plant from the young stem or cotyledons to the bolls and leaves. But circumstantial evidence indicates that such is not its course. In the first place the fungus reproduces spores again, very soon comparatively, after germination takes place, so that crops of spores are produced in rapid succession where conditions for growth are present. In the second place, the fungus is not in any appreciable degree an obligate parasite, but is markedly saprophytic at times.

There is a reasonable possibility that the crop of spores produced on the diseased young stem or cotyledons will soon find an opportunity for growth and production of another crop of spores at some injured point in a leaf, or upon the partly dying tissue at old leaf scars, where I have found the fungus in fruit. Furthermore, when the fungus obtains a good hold in the tissue of the stem it does serious injury, which is not the case with the smuts in the stem of the cereals. It is therefore exceedingly improbable that the analogy at first suggested really does exist. Nevertheless, it is quite probable that one common source of infection of young plants, and the production of numerous spores at an early season, might be remedied by scalding the seed. When cotton is planted on ground not cultivated in cotton the previous year, if the seed were scalded there is reason to believe that the disease might be prevented in that field. It is not yet known whether or not spores live over the winter in any appreciable numbers in soil where cotton is grown. It is possible that the same treatment of the seed might be efficacious in soils where cotton is continuously planted. The method is worth a careful trial.

Characters of the Fungus.—The spores are oblong, usually rather sharply pointed at the base, often rounded at both ends, with a broad, shallow constriction in the middle, nearly cylindrical or distinctly curved, usually vacuolate with one or more vacuoles.

They vary greatly in size from 4.5 to 9 micromillimeters in diameter by 15 to 20 micromillimeters in length. Where they are produced on green or decaying bolls, or other softened parts of the plant, they are frequently associated in distinct acervuli or heaps, which are 100 to 150 micromillimeters in

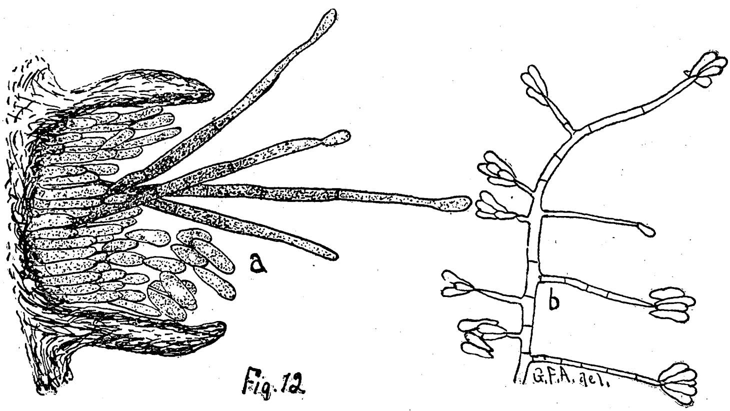

Fig. 12.

diameter. One of these pustules is shown at figure 12 *a*. They are composed of numerous spores developed from the ends of fertile threads which arise from a stroma of mycelial threads within the tissues of the plant, and lie in groups closely parallel. The fertile threads are of two kinds, short colorless basidia, which are first developed and the more numerous, and rather long, dark, olive septate setæ. The setæ are straight, curved, flexuous, simple, or rarely branched, and measure 100 to 150 micromillimeters in length. Their ends are nearly hyaline, and the spores borne upon them are often obovate, the base being rather sharply pointed. They seem to arise later in the development of the pustule, when parts of the stroma are becoming dark in color, either from dark parts of the stroma or from rudimentary sclerotia.

Artificial Cultures.—Several artificial cultures were made to trace the development of the fungus. In some cases the nutrient medium used was agar-agar peptone broth and an infusion of cotton leaves, but it was found that it grew about as well without the addition of the infusion. Pure cultures were obtained in several ways. Bolls on which the spores were just being produced, were placed in a moist chamber. When the cluster of spores was well elevated and distinct, not so old as to be contaminated with bacteria, with a flamed needle a few spores could easily be taken not accompanied by other germs.

Some of the cultures were made in cells so that germination and growth could be directly observed under the microscope at short intervals. The spores germinate quite freely under favorable circumstances in four to ten hours. At the time of germination, or prior to it, frequently one or two transverse septæ are observed in the spore, dividing it into

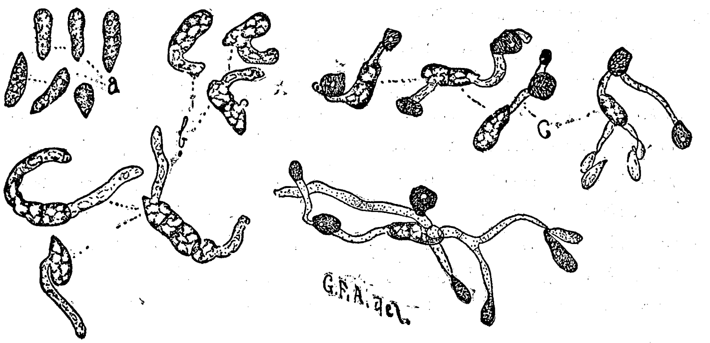

Fig. 13.

two or three cells. Several germ tubes may be produced from a single spore. Figure 13, *a* represents spores when when sown, and *b*, some just after the beginning of germination. The mycelial threads begin to branch immediately, and are somewhat flexuous in their course. From all parts of the mycelium short fertile branches soon arise of 1, 2, or 3 cells' length, which resemble the basidia and produce spores. Sometimes these fertile branches or basidia arise directly from the spore. In the solid medium the spores form a single basidium, when not crowded by the basidia and other spores, are clustered around the end, each succeeding spore pushing the one which has just become free to one side. The sharply pointed basal end of the spore favors this. After several days there is a beautiful crown cluster of spores about the end of the basidium, all lying parallel to each other. Figure 12, *b* shows a few of such clusters in an artificial culture. Spores are sometimes produced in less than twenty-four hours from the time of sowing.

Besides the production of spores certain branches, either near or remote from the center of the growth, produce at their ends peculiar enlarged cells, olive brown in color varying in their outline but always of greater diameter than the hyphæ which produce them. These bodies frequently produce immediately a normal hypha resembling the others of the mycelium. This in turn may soon produce another bud, or may grow to considerable length, produce basidia and spores, or produce spores soon after its origin from the bud as an ordinary basidium. These buds, or gemmæ, as they might be properly called, are shown in Figure 13, *c*. In many cases the gemma immediately begins to bud in an irregular manner, producing cells similar in color but very closely compacted into an irregularly oval or elongated or flattened, imperfect sclerotium. After one or two weeks' growth a large number of these gemmæ and imperfect sclerotia are developed near the center of growth, *i. e.*, the original spore. At the same time the basidia have become very numerous at this point, arising from the mycelium or by the branching of the older ones, and the mass of spores assumes the roseate tint. Cultures were also started in pure water and in a weak nutrient medium. In water the germ tubes almost invariably, when once or twice the length of the spore, produced the gemmæ. If these developed another tube it was only to give rise to another gemma. In no case at that time were spores produced nor any appreciable length of mycelium. In the weak nutrient medium the gemmæ were produced freely. Also, a number of hyphæ produced one to four or five spores. While the vegetive growth exceeded that of the spores sown in pure water, there was but little compared with the growth in a rich nutrient medium, and the spores did not live so long.

These gemmæ produced soon after germination, more freely in weak nutrient media, are spoken of by some as secondary spores.* They are not secondary spores in the usual acceptance of that term. They do not become freed from the mycelium except by accident, or by the dying of the thread to which they are attached, in which case they are more properly gemmæ. Their frequent later development into compound gemmæ by budding would strengthen this view, and indicate that they are rudimentary sclerotia, or perhaps presage the development of pycnidial or ascigerous stages as yet unknown in this genus.

I have also obtained pure cultures of the fungus when contaminated with bacteria by the usual method of separation by dilution in liquid nutrient agar, both by plate cultures and by Esmarch rolls.

In cultures on nutrient agar, I have never observed the setæ to develop in such numbers as they do naturally on the cotton plant, but by pouring a small quantity of liquid agar on scorched cotton in a culture tube and then inoculating this medium with spores the setæ developed profusely.

*Southworth, Journal of Mycology, vol. vi, Nos. 3 and 4. Halsted, Botanical Gazette, vol. xvii, No. 9.

VI. Shedding of Bolls.

The "shedding" of bolls or "forms," or their death and drying while still attached to the plant is very frequently a source of great loss to the cotton crop. The trouble has long been known, but perhaps the most widely prevalent and disastrous form has been misunderstood. It is variously attributed to the work of the boll worm, to a puncture made by some Hemipterous insect, etc. That some of the shedding is due to the work of the boll worm can not be denied, but many planters are now coming to believe, as is quite true, that usually comparatively little of this trouble is caused by that worm. The shedding referred to here is a purely physiological trouble not due to the work of insects, nor to the action of a fungus.

During three years observation in Alabama, I have found this physiological form of shedding to be by far more serious than that produced by other causes combined. It occurs most frequently in extremes of either dry or wet weather, or during the change from one extreme to the opposite extreme. It may occur to some extent under normal climatic conditions, especially if the cotton plants are too numerous on the ground, or the variety of cotton is one which develops a very large amount of fruit forms in proportion to the leaf surface.

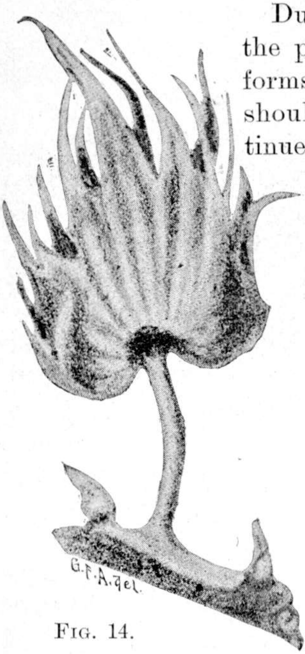

FIG. 14.

During a normal period for growth the plants put out a number of fruit forms, say so many as could be matured should the favorable conditions continue. If a very dry period succeeds this so that it interferes with the supply of nutrient materials or moisture from the soil there will occur a partial withholding of the customary daily supply of tissue forming material just at a very critical period in the life of the younger "forms." This may be sufficient not only to stop the growth of the tissue in the form, but also to deprive it of much of its accustomed moisture. The tissues of the young fruit are thus forced into an unnaturally matured condition. The fruit, including the pedicel and often more or less of the surface tissue of the stem at its point of attachment becomes first of a paler green color than the adjacent parts of the plant, so that a well marked color line delimits the healthy from the unhealthy portion. This is well shown in figure *14*, where a part of the surface tissue of the stem participates in this unnatural maturity. In many cases the tissue is separated at this line so that the fruit falls off completely or hangs by a few fibres to the stem, hence the term shedding.

The more or less complete separation of the tissues at the line of division between the healthy and dying portion depends upon the point of attachment of the fruit to the stem, and also to some extent upon the variety of cotton.

In figure *15*, *a* represents a scar, the point of attachment of the pedicel of a fallen boll. In this case the boll was situated near the angle formed by the branch, and also nearly perpendicular to it. In such cases the line of separation is apt to be clean cut, resembling the scar left by a falling leaf. If the point of attachment is at a somewhat greater distance from the angle and the pedicel much more inclined obliquely, the line of separation is apt to include from one half to one inch of the surface tissue of the stem below the pedicel, and very frequently then the lower part of the dead surface tissue does not entirely separate and the boll remains clinging to the plant. In some varieties, especially the so-called "cluster" varieties of cotton the separation of the tissues does not take place so frequently, and the boll usually remains firmly fixed in position, but the dead part readily indicate the tissues involved. Figure *15*, *b* represents such a case.

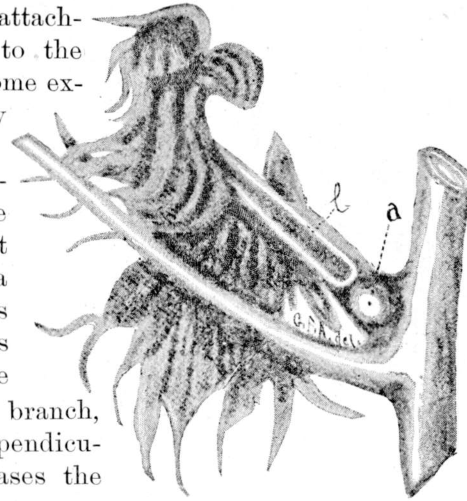

Fig. 15.

The matured bolls do not form a separative layer of tissue when the tissue dies, but they remain fixed to the plant. This is a provision of nature not only for the opening of the boll, but also for the preservation of the lint until it can be gathered in good condition. In like manner the falling away, of the dead immature bolls and forms is a useful provision of nature, since the plant is left in a better condition for gathering the fruit which does mature. One great objection held by some to the cluster varieties of cotton is their tendency to hold the dead immature fruit. It is interesting to note here the factors of selection which in time may cause only the fittest of the varieties to survive; the fact that cluster varieties are more subject to this physiological trouble, and the objection held by many to the strong tendency of the immatured boll to cling to the plant when dead. Another objectionable tendency in some of the cluster varieties, is that so marked in "Welborn's pet," where several bolls in a cluster may fuse into an abnormal one, which readily cracks open when immature and subjects the internal parts to the action of bacteria and fungi.

VII. Angular Spot of Cotton.

This disease is named from the dark angular spots which appear in the leaf as shown in figure 16. It is very wide spread but seldom appears to such an extent as to attract attention, though I have observed it in every cotton field I ever visited during the growing season. The disease is first manifested* by a watery appearance in definite areolate spots, which are bounded by the veinlets of the leaf. The spots are sometimes very numerous and frequently conjoined; often the disease follows one or more of the main ribs of the leaf, being bounded on each side by an irregularly zigzag line. As the disease ages the spots become blackish and then light brown, frequently then bordered by a blackish color where the disease has extended somewhat centrifugally. The dead spots in the leaves sometimes break out, leaving many perfo-

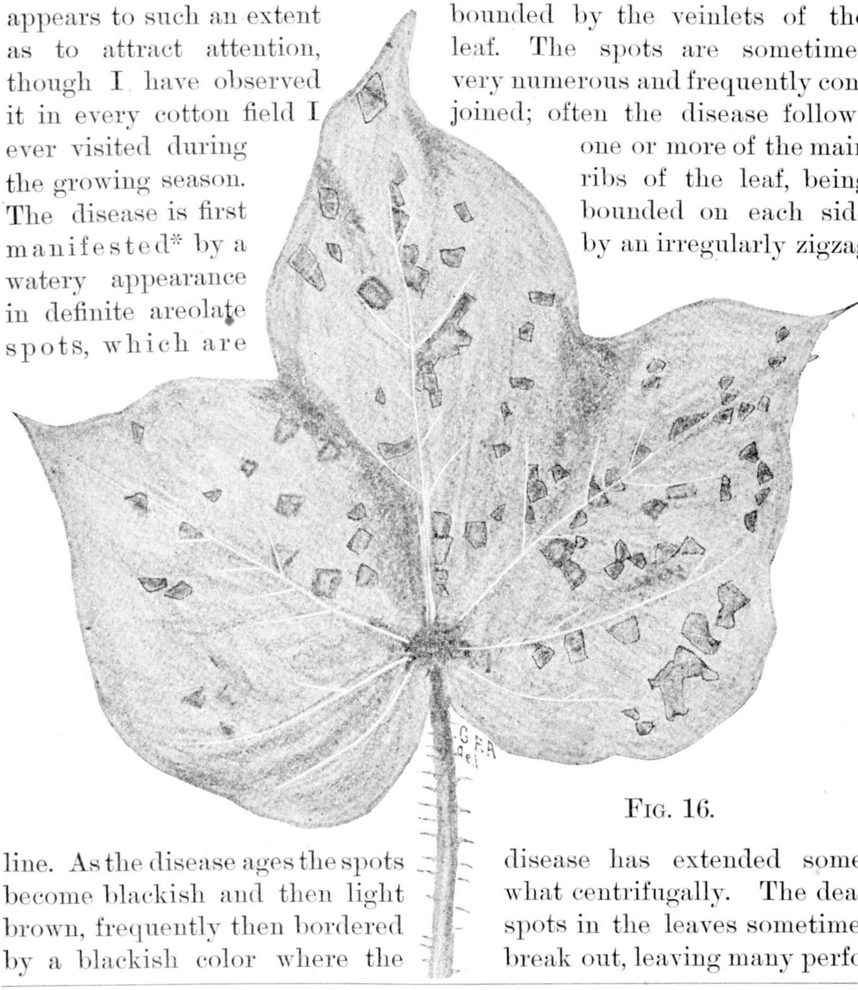

Fig. 16.

* Bulletin No. 27, Ala. Agr. Exp. Station. Botanical Gazette, vol. xvi, No. 3, March, 1891.

rations in the leaves with ragged edges, somewhat as results in cotton leaf blight. The disease hastens the falling off of the leaves. In the very earliest appearance of the spots, when the watery condition is coming on, these spots swarm with bacteria. This suggested that it might be a bacterial disease. Cultures of the organism present were obtained, and inoculations of healthy leaves have been made at several different times, but I have never been able to produce the disease as a result. The disease usually appears only on the older leaves, those which have passed the prime of their existence. It is quite likely that the bacteria present may easily start the trouble in such leaves, but that they might be unable to enter and disease the younger healthy leaves. This might account for the failure of the inoculations. Sometimes it attacks nearly all the leaves in the plant, but rarely. This suggests that such plants may be constitutionally weak from some unfavorable condition, either frost or the weather, which renders them susceptible of attack.

VIII. Areolate Mildew of Cotton.

(Ramularia areola Atkinson.)

The areolate mildew of cotton is so called because it occurs in definite small areas of the leaf which are limited by the small veins and gives a mildewed, or frosty appearance to the affected places, as shown in figure 17.

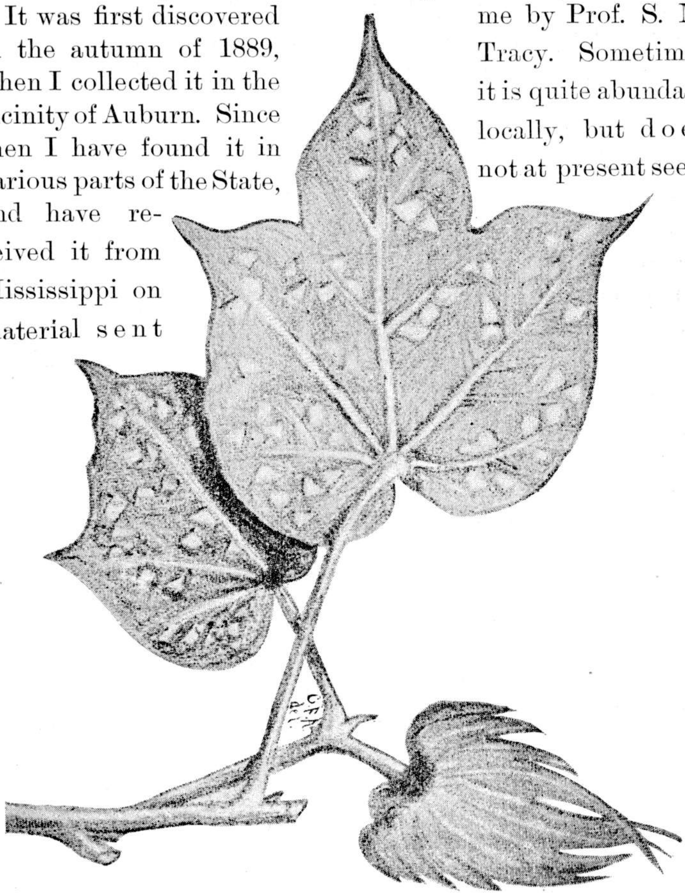

FIG. 17.

It was first discovered in the autumn of 1889, when I collected it in the vicinity of Auburn. Since then I have found it in various parts of the State, and have received it from Mississippi on material sent me by Prof. S. M. Tracy. Sometimes it is quite abundant locally, but does not at present seem to occasion any serious injury. I have found it as early as August, and from that time it may be met with until the close of the season.

The mildew is caused by a fungus, a member of the genus *Ramularia*. The mycelium, or vegetive part of the fungus, grows inside the leaf. It reproduces by the growth of a cluster of short fungus threads through the leaf epidermis

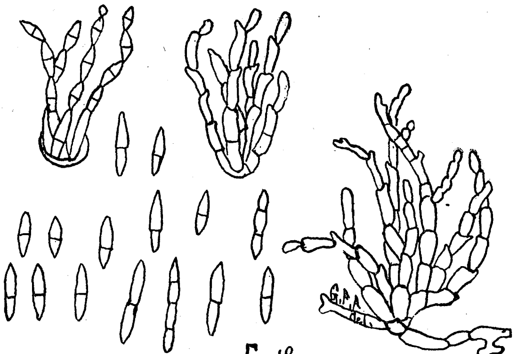

Fig. 18

to the outside. Clusters of these fertile threads are shown in figure 18. In figure 18 are also represented some of the spores, or reproductive bodies, which are borne on the wind to other leaves and spread the mildew. These spores grow at the end of the fertile fungus threads and become separated by a constriction forming, which eventually cuts the spore free. The hypha, or fertile thread, then elongates at one side of the scar left by the abjointed spore and produces another. Sometimes, in the early development of the spores, they are produced in series or chains, as shown in one of the figures.

All parts of the fungus are colorless, or rather, hyaline, so that the mass of hyphæ and spores on the surface of the diseased area give it a frosted appearance.

The fungus was first described in the Botanical Gazette, Vol. xv, No. 7. Following is a technical description of the fungus.

Ramularia areola, spots amphigenous, pale at first, becoming darker in age, 1 m m to 10 m m (mostly 3 m m to 4 m m), angular, irregular in shape, limited by the veins of the leaf, conidia in profusion giving a frosted appearance to the spots. Hyphæ amphigenous, fasciculate, in small clusters distributed over the spots, subnodose, older ones frequently branched below, more rarely above. Where they are toothed, the teeth are frequently unilateral when the hyphæ are curved instead of zigzag, several times septate, stouter below, hyaline, 25–75 micromillimeters x 45–7 micromillimeters. Conidia oblong, usually abruptly pointed at the ends, sometimes concatenate in the early development of the hyphæ, hyaline, 14–30 micromillimeters x 4–5 micromillimeters.

IX. Cotton Leaf Blight.

(*Sphærella gossypina* Atkinson.)

Cotton leaf blight is a disease of the leaves caused by the *Cercospora* stage of a fungus, *Sphærella gossypina*. It usually attacks the older leaves of the plant, or all of the leaves when the plant is not very vigorous, or in rather wet soil, in unfavorable weather, or when the vitality of the plant is weakened from other causes. The same fungus attacks plants effected with the yellow leaf blight, or mosaic disease, but plants first affected by that trouble and afterward attacked by the *Cercospora* do not present the characters of the cotton leaf blight. The beginning of the disease is indicated by small reddish spots on the leaf which increase in size centrifugally, the outline being rather irregular. Later the central portion of the spots becomes light brown, or even a dirty greyish white, the border only presenting the red color. By this time the tissues in the center of the spot are dead and dry and frequently break and fall away. These stages of dissolution are brought about by the threads of the fungus growing within the tissues of the leaf and absorbing the liquid substance of the leaf for their own growth. As the nutriment in these spots is being exhausted the fungus threads give rise to tufts of fertile hyphæ, as

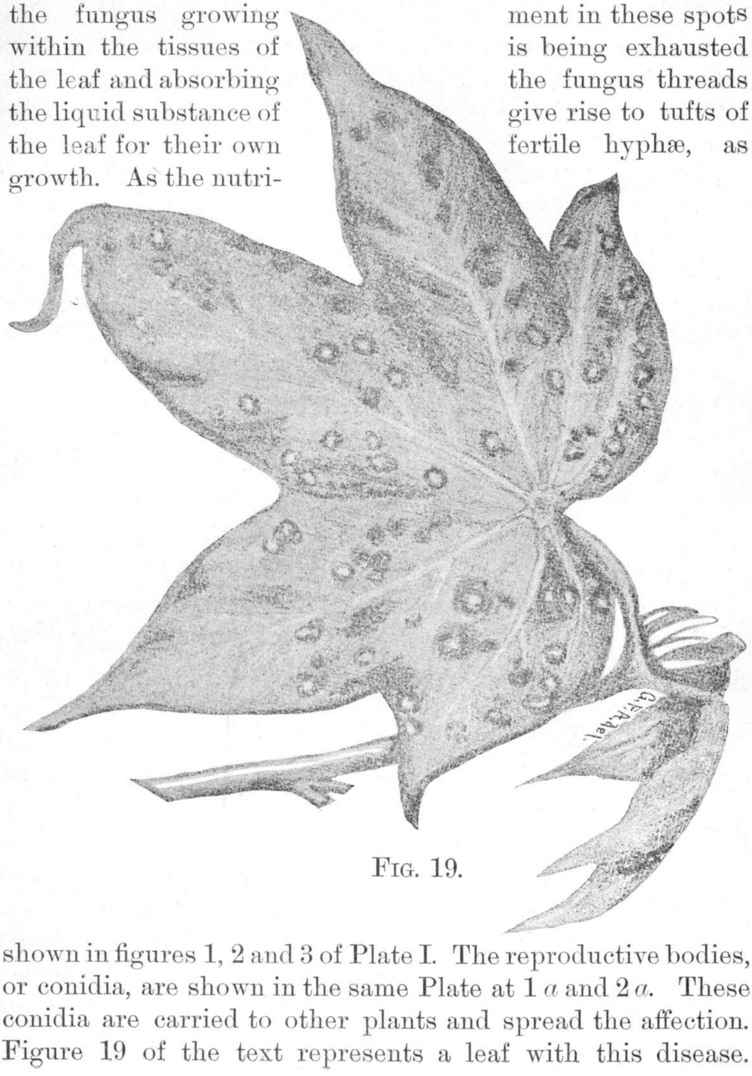

FIG. 19.

shown in figures 1, 2 and 3 of Plate I. The reproductive bodies, or conidia, are shown in the same Plate at 1 *a* and 2 *a*. These conidia are carried to other plants and spread the affection. Figure 19 of the text represents a leaf with this disease.

By comparing this with figure 3 of the text some notion can be gained how great the difference is when complicated with a physiological disease. The *Cercospora* stage of this fungus was first described by Cooke as *Cercospora gossypina**. A short notice of the disease was published by Scribner in 1887.† He notes that it is probably the *Cercospora* stage of some *Sphærella*, since it agrees in many respects with other fungi known then to be but the conidial stage of *Sphærella*. This suggestion the present writer found to be correct, when in 1890 he found the perfect stage of the *Cercospora*, and named it *Sphærella gossypina*.‡ The *Sphærella* is illustrated in figure 4.

I found this *Sphærella* at Auburn several times during the autumn of 1890 on leaves of *Gossypium herbaceum* in the spots earlier occupied by the *Cercospora*. During the following winter, in looking over a quantity of cotton leaves sent me by correspondents, I found the same *Sphærella* on leaves from Eutaw and Alberta Station. These leaves were remarkable for being almost covered with a profuse growth of the *Cercospora* on both sides. The *Sphærella* was also very abundant, and since we would, from the analogy of other forms, expect the perfect stage of the *Cercospora* to be a *Sphærella*, there was practically no doubt of the genetic connection of the two forms. Since then, the perfect stage of a fungus is the one which bears the name, *Cercospora gossypina* Cke. becomes a synonym of *Sphærella gossypina*.

The perithecia are ovate, and nearly black, as shown in figure 4. They are partly immersed in the tissue of the leaf, the ostiolum and the upper surface projecting through the epidermis. They measure 60–70 x 65–90 micromilli-

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*Grevillea, Vol. XII, P. 31, 1883.

†Dept. Agr. Report for 1887, P. 355.

‡Bulletin Torrey Bot. Club, vol. xviii, No. 10, 1891.

meters. These perithecia contain several subcylindrical asci, varying from clavate to lanceolate, and measure 8–10 x 40–45 micromillimeters. Two of these can be seen partly escaped from the perithecium, and a group is shown just above the perithecium in figure 4. Each ascus contains eight spores. These are ellipitcal, or nearly fusoid, and when mature constricted at the septum, one cell being usually somewhat smaller than the other. They are obliquely uniseriate, or partly biseriate, and measure 3–4 x 15–18 micromillimeters.

The illustrations of the fungus accompany the first article in this bulletin, because the fungus is so frequently an accompaniment of the disease described there, in its later stages.

X. Root Gall of Cotton.

Root gall is a disease of the roots caused by minute parasitic worms. These worms live in the roots where they cause abnormal thickenings, resulting in what is known as galls, which give the roots a knotty appearance. There are several places in the State where it occurs with unusual severity. I have seen it at Saville, Ala., on the farm of G. W. Rhodes; at Selma, and also at Montgomery.

Figure 20 on next page represents one of the plants from the farm of S. F. Houston, at Selma. The injuries produced by the worms upon entering the roots, as well as the injuries following the breaking down of the tissues of the galls, forms a suitable opening for the organism of "frenching," when that is also present in the soil. Cotton is frequently affected by these nematode worms at Auburn and in other places, but I have only seen serious results when "frenching" was complicated with it. It is possible in such cases to find plants badly diseased by the nematode which are not at all affected with "frenching," but the majority are. This goes to show that the nematodes do not produce the "frenching" in those places, but that they may open the way for the entrance of that organism, just as the "damping off" fungus, or any other injury to the root will do, provided the organism of "frenching" is in the soil. These worms are nematodes, and belong to the family *Anguillulidæ*, the eel worms. A common example of eel worms is the vinegar eel, as it is called, because it is so frequently found in the mother of old vinegar. The worms are usually shaped like an eel,

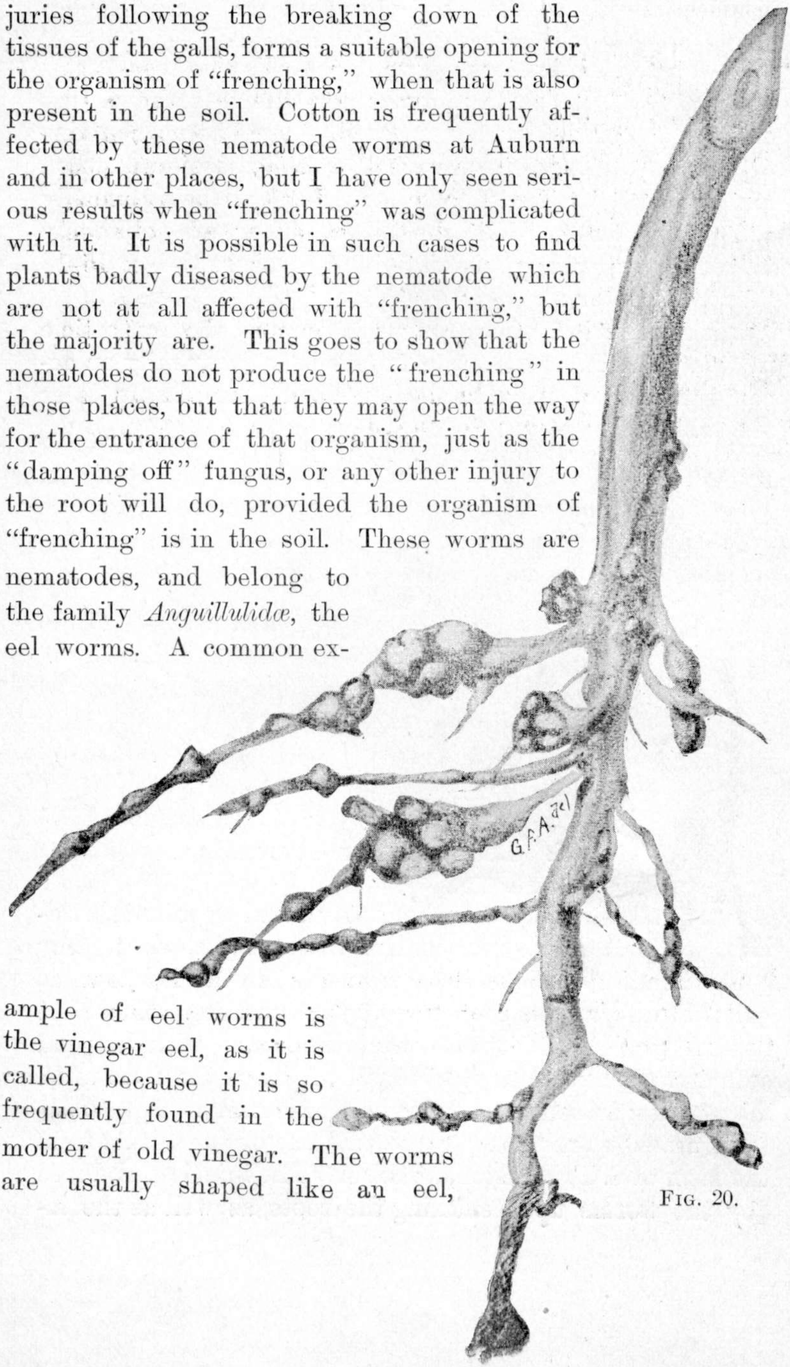


FIG. 20.

whence the name, but of course they are much smaller, being microscopic, or only so that they can just be seen with the eye when full grown.

The eggs of the nematode are bean-shaped and about 100 micromillimeters long. Figure 21 represents the egg in all stages of development, from the single cell to the mature larva, which is coile several times in the egg membrane. From the time that the embryo begins to take on the form of a larva, as shown in 11 and 12 of figure 21, it now and then moves around in the egg membrane by twisting and coiling its body. When mature these writhings and contortions become more violent, and finally cause the rupture of the membrane and the larva is set free.

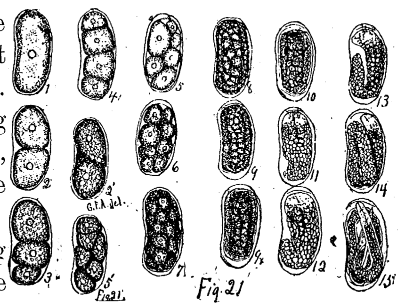


Fig. 21

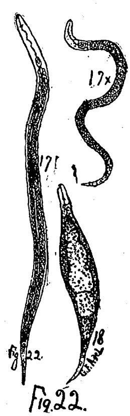
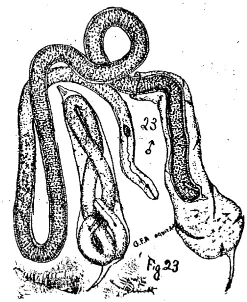
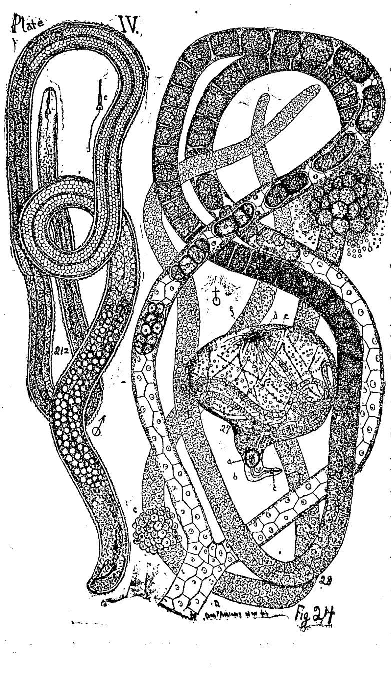


Fig. 22.

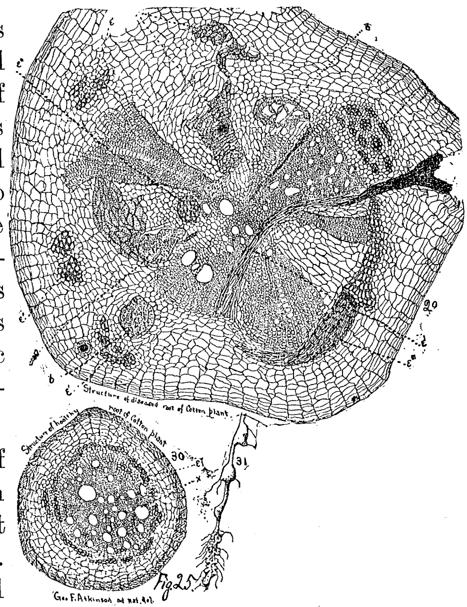
It can now be seen to possess the form of an eel, but its structure is quite different. The blunt end is the head. In 17 of figure 22 there can be seen a minute slender spear, which projects a little out of the mouth of the head end. The nematode has the power of thrusting this spear forward and backward. By this means it punctures a hole in the root and enters, and by similar operations makes a passage for itself through the tissues. Once in the tissues it sucks up the juices, and by its presence stimulates the tissues of the root to abnormal growth by attracting liquid nutriment to those parts, In this way galls are formed. The worm soon becomes stationary in the tissues of the gall, moults its skin for the second time, having moulted once just about the time of hatching. Its body now begins to distend, as shown in 18 of figure 22, and continues until it forms a vesicular body resembling a small gourd. Before it is fully grown important differences appear in the males and females. The males, instead of distending farther, begin to pass through another transformation. Their cyst wall, or the distended skin, remains unchanged, but the worm inside begins to elongate and at the same time to become more slender, so that it separates from the cyst wall and eventually lies within, coiled two to four times, as shown in figure 23. Casting this distended skin makes the third moult, and while they are elongating they cast their skin for the fourth time. By this transformation the male has returned to the eel form of the worm, but they are much longer and stouter than the larva, and their tails are blunt instead of pointed, and are about 1 *mm* long. They now break through their cyst wall and seek the female to fertilize her.





The female continues to distend so that she closely resembles a stout gourd, the head being the small end, and when mature contains 200 to 300 eggs. Figure 24 (27) represents a female much enlarged, and (28) are the ovaries much more magnified. (21*z*) represents a male. The paired testes can be seen. The larvæ hatch while still in the body of the parent, unless accident ruptures the gall and frees them. Under favorable conditions the worm will develop from the egg to the mature female with more eggs in about one month. Several generations can therefore be developed in a single season.

Figure 25 represents a section through a gall on cotton roots.



A full account of this worm was published in Bulletin No. 9 of this Station. This should be consulted by those who wish to obtain more accurate information concerning the worm and its injuries to various plants. Its scientific name is *Heterodera radicicola*.

Bulletin No. 21 of this Station gives an account of a new root rot disease of cotton. I have since found that the organism of frenching was associated with the nematodes in producing that disease, or rather in making it much more serious.