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Annals
of the
Missouri Botanical Garden

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Annals of the Missouri Botanical Garden

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No. 1

HYDROGEN ION CONCENTRATION AND THE COM- POSITION OF NUTRIENT SOLUTIONS IN RE- LATION TO THE GROWTH OF SEED PLANTS

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INTRODUCTORY

By the use of the terms mineral nutrition or salt requirements of plants there is connoted a group of physiological processes and environmental conditions in which the mineral salts play an important rôle. Without entering into an elaborate discussion of these terms it may at least be pointed out that perhaps neither one is satisfactorily comprehensive. The last-mentioned is vague, and the other inadequate, due to the fact that when plants are grown in a so-called nutrient solution, as is well known, it is not merely the nutrient rôle the effects of which are followed. The concentration of the solute molecules and component ions of the culture solution directly affect the turgor, or osmotic surplus; the proportions of the ions—particularly of the cations—influence the permeability relations, which, operative through the protoplasts, seem to be the fundamental consideration in certain “antagonism” phenomena; the composition of the salts employed determines the acid-alkali equilibrium, that is, the hydrogen ion concentration, the influence of which is apparently most complex; and these and other possibilities affect ultimately growth, which, in part, of course, involves the incorporation into the living framework of the ions of the component salts.

For several years¹ the writer has given attention, as occasion permitted, to the reaction of the medium as affecting growth in soil solutions, also its effect upon toxic action; but it is only within the past two years that opportunity has been taken from time to time to examine this factor critically and so far as practicable in respect to physiologically balanced nutrient solutions.

The illuminating contributions of Clark and Lubs ('17) on the colorimetric determination of the hydrogen ion concentration of culture media for microorganisms, and of other biological fluids, effected so great an improvement in the simpler technique involving active acidity and alkalinity that there is now available a convenient, rapid, and sufficiently accurate method of investigating the hydrogen ion relations in connection with the salt requirements of higher plants. On the other hand, the extensive contributions of Schreiner and Skinner ('10, '10a, '11, '12), Tottingham ('14), Shive ('15), McCall ('16), and many others, on salt requirements and the constitution of the mineral nutrient solution have made it possible to select, within certain limits, well-balanced solutions as points of departure. In the work here reported, therefore, the writer has not concerned himself to any great extent with an investigation of the effects of variations in the proportions of the different salts involved in the nutrient solution. In this last-mentioned direction the recent literature represents a rapid advance both in technique and in result, and while, as will be pointed out later, the problem may not be finally solved, it has certainly been placed on a rational basis.

The triangle-diagram scheme was first rendered of biological significance by Schreiner and Skinner, referred to above, and it was effectively employed by them in studies of the relations of plants to certain toxic agents which might exist in the soil and in studies of the ameliorating action of the nutrient ions, K, NO₃, and PO₄, upon such deleterious compounds. They likewise investigated by this means the growth of wheat as affected by different ratios of phosphate, nitrate, and potassium. The same general diagram scheme has been perfected and advan-

¹ During the progress of these investigations the writer has had much assistance in the details of the culture work from various members of the graduate laboratory, to all of whom he is indebted, especially to Mrs. Emily Schroeder, Research Assistant, 1918-19, and Mr. R. W. Webb, Research Assistant, 1919-20.

tageously applied by Tottingham in his elaborate account of nutrient solutions, and by Shive, McCall, and others in intensive analyses of physiological balance. The effect of variation in H-ion concentration may be approached finally in the same way. In this rather general survey of certain aspects of the subject, however, it has seemed that the factors are for the most part too complicated for most economical treatment by this method alone.

TECHNIQUE AND MATERIALS

In the earlier work I selected for comparative studies on the influence of variation in H-ion concentration two solutions only: namely, a slight modification of Shive's R_5C_2 , considered his best solution of optimal concentration, and a much modified Crone solution developed in this laboratory. Later there was added the R_6C_1 solution of Livingston and Tottingham, and ultimately some other combinations which seemed worthy of consideration.

The partial volume-molecular proportions of the particular Shive solution employed are as follows: KH_2PO_4 , 0.0180; $Ca(NO_3)_2$, 0.0052; and $MgSO_4$, 0.0150. Ferric phosphate in small amount is added, the partial concentration being 0.0044 gm. per liter of solution. This insoluble salt is used at such a low concentration that its presence as a precipitate is scarcely perceptible. I have employed the same salts in the same proportions, except that "soluble ferric phosphate" has been substituted for the insoluble iron salt in all cases not otherwise indicated. This substance is described as consisting of scales of ferric phosphate with sodium citrate, possibly as a single salt. The exact molecular composition of this iron-furnishing substance is unknown. From the description in the National Standard Dispensatory (1905) it will be seen that it is commonly made by the addition of 50 gms. ferric citrate and 55 gms. sodium phosphate, unefloresced, to 100 cc. distilled water. It is barely possible that four salts are present, namely, sodium and ferric phosphate and sodium and ferric citrate. This salt combination possesses the advantage of solubility to a high degree, yielding what appears at first to be a true solution but seems in reality a colloidal solution of high dispersity. Used in such extreme dilution as

indicated in the Shive solution, there is no noticeable precipitation, even on standing. There is every reason to believe that this substance is an excellent source of iron. The Shive solution prepared in this way is designated solution A, and it is best to think of it as solution A, because, as developed later, Shive does not report the P_H for his solutions, and this three-salt solution may possess very different values in plant growth, depending upon the grade or reaction of the monobasic phosphate employed.

The original Crone solution is made up as follows: water, 1000 cc.; KNO_3 , 1 gm.; $CaSO_4$, .5 gm.; $MgSO_4$, .5 gm.; $Ca_3(PO_4)_2$, .25 gm.; and $Fe_3(PO_4)_2$.25 gm. In our solution we have halved the concentration of the first two salts, omitted the tricalcium phosphate, and substituted for the ferrous phosphate the "soluble iron phosphate" above mentioned. In fact, the solution as I have used it may no longer be called the Crone solution, but it was of interest in this work at the time, not because it was expected to compare favorably with solution A above, but rather because it differed widely in the combinations of the components and had afforded in my work very good, healthy growth. The partial volume-molecular proportions are as follows: KNO_3 , 0.00495; $CaSO_4$, 0.000726; $MgSO_4$, 0.000526; and "soluble iron phosphate," 0.125 gm. per 1000 cc. It will be noted that this is in reality a four-salt solution differing also notably from the earlier solutions of Sachs, Knop, Pfeffer, and Meyer. Inasmuch as the iron salt supplies also the phosphate, this B solution contains a higher concentration of Fe than the usual culture solution. There is more or less precipitation of a light or slowly settling iron salt, when the combined solution is prepared. However, by adding the soluble ferric phosphate last and at the greatest dilution possible under the conditions a light precipitate only is formed, and this develops slowly in the form of suspension films. It introduces no difficulties into the preparation of the solution, though perhaps renders its composition somewhat less definite. The films are so light that it is not difficult to remove uniform samples from the stock flasks. The osmotic value of this solution has not been determined, but it is obviously much less than that of the Shive solution, the latter being about 1.75 atmospheres.

The solution of Livingston and Tottingham, here designated solution C, possesses the following partial volume-molecular concentrations: KNO_3 , 0.0216; $\text{Ca}(\text{H}_2\text{PO}_4)_2$, 0.0026; and MgSO_4 , 0.0150. Iron is supplied as in the case of solution A, the modified Shive solution. It is assumed that this solution has approximately the osmotic value of solution A above described.

The methods of experimentation employed were in large measure those which I have described elsewhere ('11). "Well-seasoned" tumblers holding somewhat more than 250 cc. were used as culture vessels in all cases, the process of seasoning new tumblers consisting of filling them with a weak acid-dichromate cleaning solution and then steaming in the autoclave for one hour at 15 pounds pressure. Subsequently the tumblers were thoroughly washed and rinsed with distilled water. The distilled water used here and in preparing the solutions was in some series from a Stokes still and in other series double distilled from glass. After transferring, with pipette or burette, the required amounts of each constituent stock solution to the tumbler, the volume was made up to 240 cc. In those cases in which Canada field peas were used the tumblers were covered with heavy paraffined paper made fast by rubber bands. Small holes were punched in the paper and the radicles of the seedlings inserted. Additional support for the growing seedlings was afforded by means of wire supports. In the case of both wheat and corn the seedlings were inserted into notches or holes in a paraffined cork, the latter just fitting the mouth of the tumbler. All cultures contained ten plants, and duplicate tumblers were arranged in every case not otherwise indicated.

In most of the experiments here reported Merck's blue label chemicals have been employed, but under the conditions existing at the time it was not possible to be entirely uniform in this regard, and other standard reagents were used where necessary. No recrystallization or other purification method was applied to any salt employed in the culture solutions. Stock solutions of convenient concentration were prepared, and so far as practicable every factor and procedure was made uniform, or comparable, throughout. It soon became evident that the content of free phosphoric acid in the dihydrogen potassium phosphate

was not constant in the different makes and bottles of the reagent necessarily used, and a closer examination of this point as the work progressed indicated clearly that we were not securing the uniformity of P_H in the solution which we felt that we might reasonably expect. It was not anticipated that the standard as indicated by Sørensen ('09-'10) and others would be attained unless the reagent were guaranteed free from phosphoric or other acids. The variation in P_H is often too great to make it at all certain what is meant when this salt is designated merely as acid potassium phosphate. One manufacturer who was appealed to on account of the variability referred to, assured the writer that it was not possible to furnish the salt free of phosphoric acid under the existing conditions.

In this work the hydrogen ion concentration was invariably determined by the method of Clark and Lubs ('17), employing both their standard solutions and their indicators. The standard solutions in this connection, however, were prepared with salts recrystallized two or three times, and the greatest care was given to every detail of the method. They were not controlled by the electrode method but by close comparison with the established effective ranges of the different indicators, especially, also, indicators with overlapping ranges. When making comparisons there was arranged for each indicator a set of seasoned serological test-tubes each containing 5 cc. of any standard solution within the range of the particular indicator. The various sets were arranged on a rack with white paper background. From 3 to 5 drops of the indicator solutions were used. Inasmuch as many of the culture solutions employed were without color, sufficiently accurate determinations were readily made with the unaided eye. In the case of solution B, however, and likewise in certain cases referred to later, where a few algae appeared in the solutions, recourse was had to the method employing the colorimeter (Duggar and Dodge, '19) and later more especially to the micro-colorimeter (Duggar, '19).

The seedlings used in various phases of the work were wheat (*Triticum vulgare*), corn (*Zea Mays*), and field peas (*Pisum arvense*). In all the work reported in tables I-VI, also XI-XIX, the wheat was of the variety Fultz, and that reported in tables VII-X was with a new variety, the Pacific Coast Blue Stem,

supplied from the Plant Introduction Garden of the Bureau of Plant Industry at Chico, California. The latter had been found by Dr. H. S. Reed to be particularly good for solution culture work, and my experience is entirely confirmatory. The other seed were from selected but unnamed field varieties.

The seed were immersed over night in running water, and then the peas and corn placed for germination on paraffined wire netting over pans of well-washed, moist sphagnum. They were covered with moistened paper toweling, over which was inverted other pans, though ample ventilation was provided. The wheat was treated in much the same way except that it was germinated over water frequently changed. As soon as the plumules emerged light was admitted. After properly placing the seedlings, ten to each tumbler, they were left in diffuse light, in the room in which set up, for 12 to 24 hours in order to become better adjusted to the conditions before being installed in the greenhouse.

In some of the earlier experiments a complete series was arranged under a single set of conditions, and in such cases the tumblers were placed upon a rotating table. In much of the later work, however, more than one set of conditions was involved, so that the use of rotating tables was not practicable, and under the circumstances special care was taken with properly placing and spacing the tumblers on lattice tables, likewise shifting the order of the cultures so as to be wholly comparable.

In all cases as the plants were harvested, the remains of the seed, or cotyledons, were cut away. This was found necessary inasmuch as otherwise a considerable error would be introduced in the weights of those cultures in which relatively little growth occurred; for it was in such plants that the seed were incompletely exhausted. On removal from solutions containing precipitates the roots were thoroughly washed, and in all cases quickly and uniformly dried of surface water on absorbent gauze.

The criterion of growth on which stress is laid in this paper was total green weight. Other data included green weight of tops, average length of shoot (or leaf), dry weight, and general appearance—including root characteristics. Total green weight is, for the present purpose, entirely satisfactory and has the advantage in these relatively short-interval cultures of expressing

as truly as may be the growth and health of the plants. Dried leaves and withered tips count for little. Average length of leafy shoot is included in some of the tables, but this affords merely an index of stockiness or attenuation of the plants.

The purpose in this work was to get results not only in respect to growth relations with variations in the H-ion concentration, but also, especially in the later work, to secure data in respect to the extent of change in the P_H of the medium in which the plants had grown. The time interval which the plants were permitted to remain in the cultures between changes of solution was generally 6 to 7 days, but in certain cases referred to later this interval was diminished or increased for special reasons indicated in connection with the tabulated data. During any interval, however, distilled water was added as required. In general, it seemed to the writer that the practical value of a particular mineral nutrient solution should rest in part upon its capacity to furnish favorable growth conditions for a period not too limited, that is, the solution should possess among other favorable characteristics, if possible, the quality of resisting unfavorable change over a period of one week or even longer.

Had the nutrient solutions used been merely solutions A and C, in which phosphate is supplied as the acid salts, it would have been simple to change the H-ion concentration towards neutrality by the use of various proportions of a dibasic salt. However, it was at the same time desired to increase the H-ion concentration, that is, to diminish the P_H exponent in order to determine approximately the favorable P_H limits. Moreover, changes in solution B could not be readily effected in the manner indicated without material changes in composition. It was therefore determined to use, in general, 0.1 n NaOH and approximately 0.1 molar H_3PO_4 in shifting the H-ion concentration. Actually, the concentrations employed were 0.1 n NaOH and 0.092 molar H_3PO_4 . The stock solutions were so arranged as to concentration that the amounts of alkali or of acid introduced might first be diluted considerably with distilled water. In this way there was less danger of precipitating out the calcium salt, as insoluble calcium phosphate, for example, in solution A, before the critical P_H was reached, also other possibilities of precipitation in the case of solution B.

The problem was then to shift the hydrogen ion concentration of the solutions used without disturbing any more than necessary the composition of the medium. From preliminary tests of solutions A and B it was inferred that the chief interest might attach to the addition of alkali to solution A and of acid to solution B. The P_H exponent of the former is low, but in the latter it more nearly approaches neutrality. It is seen that the active acidity of the Shive solution is due to dihydrogen potassium phosphate, and the relatively slight variation in the proportions of the other practically neutral salts may be assumed not to change materially the hydrogen ion concentration. In this sense, therefore, the 108 solutions tested by Shive are probably nearly identical and determine, in respect to growth, the values of the proportions of the nutrient ions present in the solutions only in relation to this one value of P_H . This value might, of course, be assumed to be most favorable under all environmental conditions, but it is equally possible that it is not. This is a factor which should be given most careful consideration in all mineral nutrient, or salt-balance, studies as well as in studies upon toxic action.

As a convenient index to the content of the various cultures a simple scheme of notation has been devised, which, with very slight call upon the memory, enables one to see at a glance the constitution of the culture medium. This involves a system of letters and numerals as explained below. The initial letter of a culture refers to the general constitution of the nutrient solution, and as stated above there are three such solutions. The modified Shive solution employed is designated A; the solution remotely based on the Crone formula is solution B; and the Livingston-Tottingham solution, C. The next letter is invariably a small letter and denotes the plant employed; thus w designates wheat; p, Canada field peas; and c, corn; while x is employed where more than a single kind of plant is designated, or where no particular plant is specified. A culture index such as ApO, BpO, or CpO, etc., refers to the use of peas with the solutions mentioned without the addition of acid, alkali, or other constituent. When acid or alkali is added an inclined line represents, in this case, neutrality, and when figures are given above the line mentioned they represent cc. of 0.092 molar phosphoric

acid; and when given below they represent cc. of 0.1 n sodium hydroxide. Thus Ap/10 indicates the addition of 10 cc. of 0.1 n NaOH to the A solution with peas. For the purpose of this paper we have considered molar phosphoric acid to be the sum of the values derived by titration against normal alkali, using as indicators both phenolphthalein and methyl orange.

I have attempted to control or counterbalance, in a measure, the addition of phosphorus when added as phosphoric acid by the introduction in one or two cultures of an amount of phosphorus in the form of the secondary salt equivalent to the acid added. At the same time, however, the addition of this salt necessarily shifts slightly the hydrogen ion concentration toward neutrality. The addition of sodium in the form of the alkali was in a measure controlled by adding as sodium sulphate an amount of this cation which is equal to that supplied in 10 cc. of alkali. As the work has progressed some other variations have been employed, notably the addition of solid calcium carbonate (1 gm. per culture, 240 cc.) to solution B, likewise of solid aluminium hydroxide, and of kaolin, the addition of phosphate in part as the primary salt and in part as the secondary salt, also variations in the form and amount of phosphate employed, and significant changes in the proportions of solution B. Modifications of the culture indices denoting such changes will be explained as these are introduced.

EXPERIMENTAL DATA

There are given in tables I, II, and III the results of the first tests conducted with wheat, corn, and peas respectively, using solutions A and B. In consulting these tables it is to be remembered that the "culture indices" are intended to afford briefly all necessary facts concerning the constitution of the solution, and an explanation of these has been made on p. 9, so far as the unmodified solutions and those containing additions of acid and alkali are concerned. In the tables referred to above, K/10 and K/20 represent respectively additions of K_2HPO_4 to balance the amounts of phosphoric acid added in cultures with similar numerals; and Na indicates the addition of sodium sulphate to equal the quantity of gram atoms of Na in 10 cc. of n/10 NaOH.

The wheat cultures were grown 17 days, the corn 21, and the

peas 18. The solutions were renewed and water loss was supplied as previously noted. The determination of the hydrogen ion concentration "after" growth in the case of corn furnishes an index of the change in the solution after the plants had grown in it for 10 to 12 days, representing the final interval. In this particular case the intervals between changes of solution were made rather long, with the idea of emphasizing conditions. The experiments were begun early in November under favorable growing conditions. The daily evaporation rate from a standardized spherical evaporimeter averaged 11 cc. per day.

TABLE I
(Series 1, Wheat)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH;
SOLUTIONS A AND B

No.	Culture indices	Total gr. wt. (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	Initial P _H of sol.
1	AwO	4.92	0.4077	24.32	4.0
2	Aw /5	4.62	0.3916	23.89	5.6
3	Aw /10	5.20	0.4135	23.69	5.9
4	Aw /15	3.94	0.3550	21.24	6.1
5	AwNa	4.72	0.3792	25.93	4.0
6	BwO	4.52	0.3545	24.19	7.0
7	Bw /5	4.94	0.3498	23.36	8.4
8	Bw /10	5.83	0.4090	22.27	9.0(+)
9	Bw 5/	2.53	0.2522	16.48	4.6
10	Bw 10/	0.69	0.1176	8.26	3.2
11	Bw 20/	0.67	0.1134	6.56	3.0(-)
12	BwK ₂ /10	6.38	0.4390	26.34	6.2
13	BwK ₂ /20	5.80	0.3996	25.94	6.2

From series 1, table 1, also fig. 1, it is seen that with wheat there is indication that the addition of a certain amount of alkali, shifting slightly the H-ion concentration, is beneficial, though Aw/5 is irregular. Wholly unexpected is the extent of the growth in certain of the B cultures. Introduced empirically, this solution has not only yielded well, but in their vigorous, green appearance these cultures rank highest. The addition of alkali to solution B is beneficial, possibly from the addition of the sodium ion or from the slight increase in the concentration

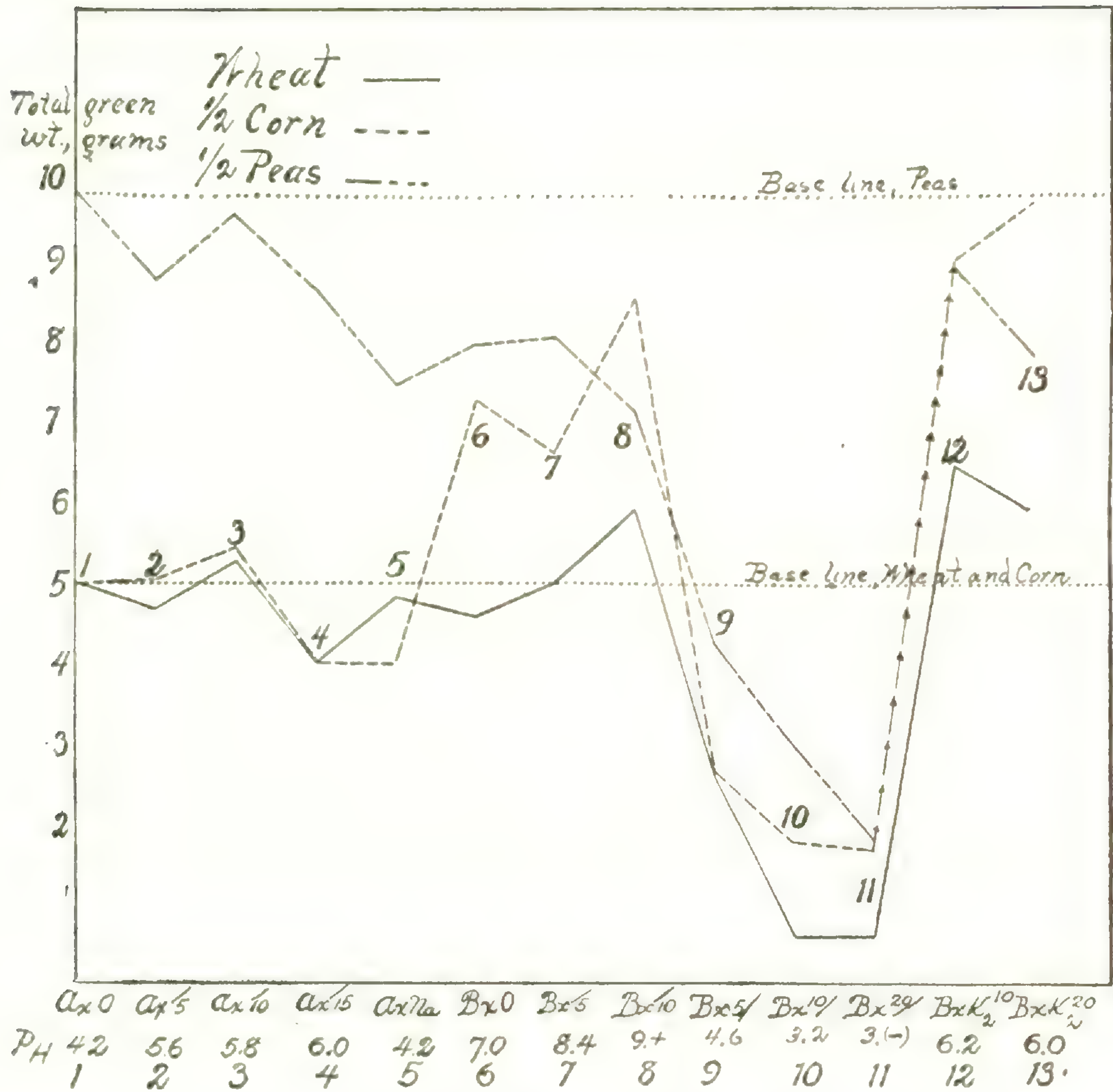


Fig. 1. Total green weight of wheat, corn ($\frac{1}{2}$), and Canada field peas ($\frac{1}{2}$), in solutions A and B, with variations—chiefly in H-ion concentration.

of the solution; and even more favorable is the addition of small amounts of secondary phosphate. With corn, table II, the shift towards alkalinity in the A solution affords slightly increased growth, but it is an important fact that there is a rapid falling off in the neighborhood of P_H 6. This is approximately the H-ion concentration at which precipitation begins. With this crop, the B solution alone, solution B plus small amounts of alkali, and solution B with the addition of dibasic phosphate yield strikingly heavier than solution A. On the other hand, peas, under the conditions of these experiments, made maximum growth in the relatively acid solution A.

TABLE II
(Series 1, Corn)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH;
SOLUTIONS A AND B

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	AcO	9.84	2.91	0.5452	22.02	4.0	5.4
2	Ac /5	9.94	2.74	0.6139	22.64	5.6	5.6
3	Ac /10	10.71	2.43	0.7642	22.97	5.9	5.9
4	Ac /15	7.90	2.25		20.36	6.1	6.0
5	AcNa	7.92	2.56	0.4652	14.49	4.0	5.2
6	BcO	14.35	4.22	1.0198	25.79	7.0	5.0
7	Bc /5	13.12	2.70	0.8102	26.28	8.4	8.0
8	Bc /10	16.90	3.95	1.0271	29.24	9.0(+)	8.4
9	Bc 5/	5.23	1.17	0.4606	14.67	4.6	4.0
10	Bc 10/	3.43	0.70	0.5387	10.54	3.2	4.0
11	Bc 20/	3.32	0.41	0.5617	8.42	3.0(-)	4.0
12	BcK ₂ /10	17.75	3.94	1.0170	31.84	6.2	7.2
13	BcK ₂ /20	19.22	4.51	1.1881	30.09	6.2	6.6

TABLE III
(Series 1, Peas)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH;
SOLUTIONS A AND B

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	Initial P _H of sol.
1	ApO	19.47	6.44	1.1014	27.84	4.0
2	Ap /5	17.37	5.31	0.9368	27.92	5.6
3	Ap /10	17.71	5.51	1.0155	29.42	5.9
4	Ap /15	17.10	5.42	1.0140	26.76	6.1
5	ApNa	14.77	5.57	0.8786	25.60	4.0
6	BpO	15.72	5.76	0.9200	25.10	7.0
7	Bp /5	15.86	5.10	0.8559	27.40	8.4
8	Bp /10	14.10	4.56	0.7822	25.59	9.0(+)
9	Bp 5/	8.27	2.70	0.6558	15.83	4.6
10	Bp 10/	5.85	1.78	0.5184	12.98	3.2
11	Bp 20/	3.47	0.93	0.3770	7.59	3.0(-)
12	BpK ₂ /10	17.69	5.17	0.9770	29.19	6.2
13	BpK ₂ /20	15.39	4.79	0.8660	27.18	6.2

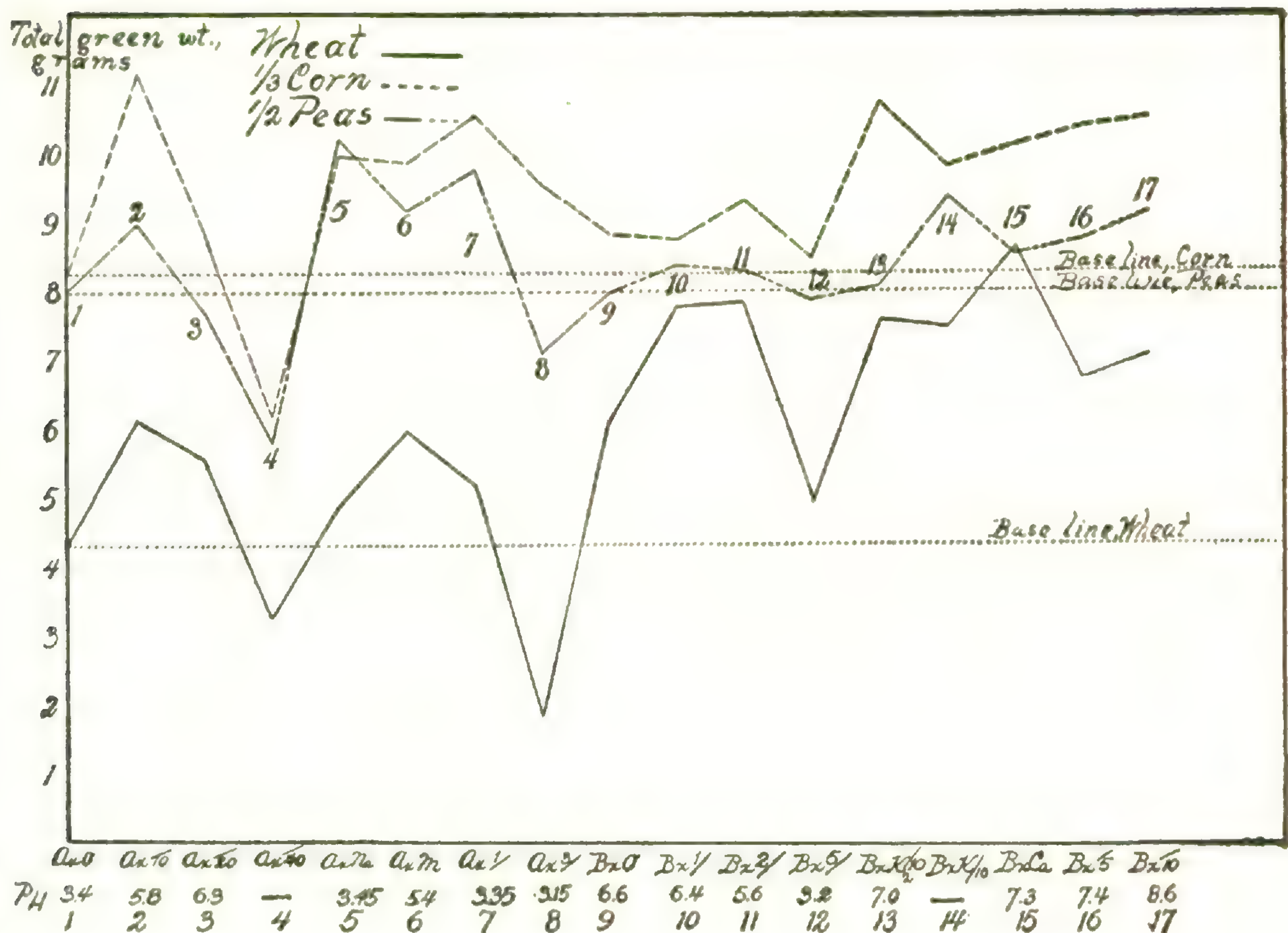


Fig. 2. Total green weight of wheat, corn ($\frac{1}{3}$), and Canada field peas ($\frac{1}{2}$), in solutions A and B, with variations—chiefly in H-ion concentration. The base lines are drawn through cultures strongly acid, P_H 3.4.

A point of considerable interest, emphasized particularly by the results with peas, is that the range of most favorable growth with respect to hydrogen ion concentration differs materially with the constitution of the nutrient solution; thus the addition of acid to the B solution, although shifting the H-ion concentration towards that of the A solution, exhibits a corresponding rapid diminution of the growth quantities. From these data alone it is not possible to formulate an explanation of the fact last mentioned, but it is probably related in part to ionic conditions, in part to the composition and state of aggregation of the iron and calcium particles, or to other, indetermined factors.

It should be pointed out, that in examining the curve, fig. 1, and all subsequent curves, a horizontal, or base line, is drawn through the growth quantity representing generally the unmodified solution A, so that all cultures may be compared with this,

TABLE IV
(Series 2, Wheat)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	Initial P _H of sol.
1	AwO	4.39	.545	24.37	3.4
2	Aw /10	5.30	.611	24.75	5.8
3	Aw /20	4.56	.533	22.74	6.3
4	Aw /40	3.21	.431	19.80	*
5	AwNa	4.86	.556	25.01	3.45
6	AwM	5.93	.542	23.04	5.4
7	Aw 1/	5.21	.569	24.63	3.35
8	Aw 3/	1.79	.306	16.38	3.15
9	BwO	6.07	.503	21.86	6.6
10	Bw 1/	7.76	.625	23.96	6.4
11	Bw 2/	7.82	.657	24.40	5.6
12	Bw 5/	4.96	.500	21.81	3.2
13	BwK ₂ /10	7.60	.623	26.18	7.0
14	BwK /10	7.51	.602	25.45	
15	BwCa	8.67	.810	25.32	7.3
16	Bw /5	6.75	.570	23.24	7.4
17	Bw /10	7.08	.606	24.49	8.6

* Heavy precipitate.

and the number of points in the curves above or below the base lines indicates for each crop, under the conditions reported, the relative increase or decrease in green weight.

The change in the P_H of the solutions occurring as a result of contact with the roots was followed only in the case of corn. As a rule, in the more acid solutions the reaction is shifted somewhat towards neutrality, but irregularities occur in solution B, some of which may be related to changes not due to the interchange of ions between roots and solution.

The second series of experiments, the results of which are included in tables IV, V, and VI, also plotted in fig. 2, was carried through during late November and early December. The conditions were much the same in general as those prevailing during the earlier work. There was this difference, however, that while the first series was placed on latticed tables in greenhouses with proper spacing to provide for favorable and uniform condi-

TABLE V
(Series 2, Corn)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	Initial P _H of sol.
1	AcO	25.44	7.63	2.325	32.33	3.4
2	Ac /10	33.52	7.96	2.567	32.91	5.8
3	Ac /20	26.14	6.36	2.170	30.71	6.3
4	Ac /40	18.28	5.10	1.642	22.26	*
5	AcNa	29.94	7.89	2.001	32.49	3.45
6	AcM	29.48	8.10	2.139	27.57	5.4
7	Ac 1/	31.56	8.18	2.337	32.56	3.35
8	Ac 3/	28.60	6.06	1.888	32.06	3.15
9	BcO	26.46	8.60	2.515	33.71	6.6
10	Bc 1/	26.19	9.34	2.232	33.31	6.4
11	Bc 2/	27.86	10.29	2.151	33.03	5.6
12	Bc 5/	25.35	7.75	2.108	30.50	3.2
13	BcK ₂ /10	32.25	11.48	2.476	33.51	7.0
14	BcK /10	29.48	9.96	2.453	29.46	
15	BcCa	30.42	11.80	2.852	34.55	7.3
16	Bc /5	31.20	10.68	2.530	34.65	7.4
17	Bc /10	31.55	9.90	2.767	33.98	8.6

* Heavy precipitate.

tions, the second series was placed upon the rotating table and rotated throughout the period of culture. The rotating table employed was that previously described (Duggar and Bonns, '18) except that there was substituted for the special pot platforms a continuous platform constructed above the radiating arms and the secondary motion was, of course, eliminated. The wheat was grown 21 days, while the corn and peas were grown 24 days. One change of solution was made after about 12 days of growth. It is, therefore, a rather severe test of growth quantities when infrequent renewals of solutions are made. The water loss from transpiration was supplied about every second day.

In determining the hydrogen ion concentration of the solutions employed at the beginning of the experiment it was found that the active acidity of solution A was 3.4, consequently much greater than the theoretical. This was found to be due to the

TABLE VI
(Series 2, Peas)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	ApO	16.01	5.29	1.351	24.02	3.4	4.6
2	Ap /10	17.89	6.21	1.473	22.72	5.8	5.8
3	Ap /20	15.34	5.30	1.332	19.93	6.3	6.0
4	Ap /40	11.55	4.68	1.124	12.49	*	6.8
5	ApNa	20.30	7.20	1.603	26.03	3.45	4.4
6	ApM	18.28	6.15	1.418	24.19	5.4	6.4
7	Ap 1/	19.39	6.60	1.505	24.50	3.35	4.6
8	Ap 3/	14.17	5.22	1.262	21.13	3.15	4.2
9	BpO	15.91	5.70	1.326	19.59	6.6	6.2
10	Bp 1/	16.69	6.13	1.410	22.16	6.4	6.0
11	Bp 2/	16.58	5.82	1.391	22.48	5.6	6.0
12	Bp 5/	15.78	5.33	1.316	20.24	3.2	4.6
13	BpK ₂ /10	16.12	5.91	1.413	19.01	7.0	6.6
14	BpK /10	18.75	6.87	1.501	21.33		5.2
15	BpCa	17.15	6.18	1.393	23.44	7.3	8.0
16	Bp /5	17.49	6.32	1.389	19.21	7.4	7.4
17	Bp /10	18.38	6.29	1.413	21.65	8.6	8.0

* Heavy precipitate.

use of a new supply of monobasic potassium phosphate. This was a high-grade reagent, but was not guaranteed free of phosphoric acid, and no such guaranteed salt was then obtainable. The determinations indicate very clearly that attention must be paid to the determinations of the P_H value whenever such experiments on nutrition are conducted. This series of experiments must be examined and interpreted in the light of the P_H value referred to. Nevertheless, it should be pointed out here, though emphasized later, that the P_H exponent of the more acid solutions is rapidly increased with the growth of the crop. The increased acidity is doubtless due to an excess of acid in the preparation of the salt. This relatively high acidity affected, of course, to a degree the P_H of other solutions to which alkali was added.

In general, this series is an extension and continuation of the previous work, modified particularly by the addition of certain

cultures not included in the previous series. Attention may be drawn to the inclusion of cultures in which the hydrogen ion concentration of the A series was increased by slight additions of phosphoric acid, as in Ax 1/, Ax 3/, likewise in solution A the substitution for one-half the quantity of the monobasic salt by an equivalent of the dibasic potassium phosphate, this being designated AxM. In the B solution there were also introduced cultures to which relatively small amounts of phosphoric acid were added, Bx 1/, Bx 2/, and Bx 5/, also one culture in which was included 1 gm. of solid calcium carbonate, BxCa. A fresh quantity of the salt in the case last mentioned was introduced with each change of solution. A general examination of the total green weight quantities in the case of wheat indicates that under the conditions of this experiment the maximum growth quantities were obtained with the B solution. Small amounts of phosphoric acid or of either phosphate (BxK₂/10 and BxK/10) gave an increase in growth over the unmodified solution, and within the range of hydrogen ion concentration which prevailed in this culture solution relatively little influence was exerted by changes in P_H except in the case of one culture, Bw 5/, where the hydrogen ion concentration was increased to P_H 3.2. On the other hand, with the A solution it is clear that the addition of alkali to the unmodified solution is generally beneficial, at least at concentrations up to and including Aw /10, in which culture the P_H exponent is raised to 5.8. Further addition of alkali gives a falling off in the growth quantities. In the culture Aw /20 where the hydrogen ion concentration is P_H 6.3, precipitation occurred and a marked decline in growth is apparent, although the reaction of the medium is the same as that which in the B series promoted an amount of growth approaching the maximum. This is one of the many indications pointing clearly to the probability that the most favorable hydrogen ion concentration, or range of concentration, for a particular nutrient solution does not necessarily correspond to that which is most favorable with the solution of entirely different constitution. The growth quantity recorded for Aw 1/ is not strictly in line with the discussion above. The duplicates differed considerably. We have here, of course, two factors involved: (1) increase in acidity, and (2) slightly increased PO₄ concentration.

With respect to corn it will be seen that the maximum yield occurs in culture Ac /10, although maximum root growth occurs in several B cultures. As between the different cultures in the A series the results are much the same as in the case of wheat except that the AcM culture with a combination of mono- and dibasic phosphate does not exhibit the benefit reported in the previous case. On the other hand, when one examines the data for dry weight quantities it will be found that maximum growth, as before, occurs in the B solution and in the culture to which solid calcium carbonate was added. Moreover, the next best growth is found in the addition of a slight amount of alkali to the B solution.

Throughout this work it will be noticed that the variation in total growth amounts between the various cultures of peas, differing mainly in P_H , is not so marked as that shown by the other two plants used in these experiments. Again, there were considerable differences between different plants in the same culture (more marked, however, in the case of wheat), and this indicates beyond any doubt that the variability of the seed is a factor which may affect to a slight extent the regularity of the results. In any event, the maximum growth with peas in this series occurred when a small amount of sodium sulphate was added. The amount of growth in the unmodified A solution is considerable in spite of the high acidity, yet there appears to be a slight advantage in the addition of a small quantity of alkali, although the latter is rendered doubtful by a comparison of cultures ApO, Ap 1/, and Ap 3/. In solution A Canada field peas are apparently only slightly affected by changes in hydrogen ion concentration up to the point of precipitation of the phosphate as the insoluble calcium salt. The curve, fig. 2, exhibits all the necessary data for growth comparison. Since these experiments were made it has been found that a frequent laboratory grade of acid potassium phosphate will give a P_H anywhere from 3.5 to 4.5, but more frequently less than 4.0.

Change in P_H after plants had grown in the solution was followed in the case of peas, with a result much like that of the first series. The more acid solutions are shifted towards neutrality, but solutions with exponents greater than 5.8 or 6.0 may vary scarcely at all, while the more alkaline solutions are generally shifted toward neutrality.

TABLE VII
(Series 3, Wheat)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH;
SOLUTIONS A, B, AND C; RENEWAL EVERY FOUR DAYS

No.	Culture indices	Total gr. wt. (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H		
					Initial	End 2nd per.	End 4th per.
1	AwO	1.92	0.325	12.02	4.8	4.8	4.8
2	Aw 9/10 K	7.92	1.054	18.04	5.3	5.6	6.0
3	Aw 4/5 K	6.27	0.776	17.08	5.5	5.5	5.5
4	Aw 3/5 K	6.36	0.814	14.82	6.0	5.8	5.8
5	Aw 1/2 K	10.18	1.211	20.52	6.1	5.7	6.1
6	Aw 3/10 K	6.55	0.789	17.12	6.4	6.1	6.1
7	Aw h/Al	5.21	0.862	17.26	3.6	3.6	5.3
8	AwAl	6.39	0.893	17.60	5.3	5.4	5.8
9	BwO	8.24	1.124	19.96	5.9	7.1	7.1
10	2(BwO)	7.65	1.010	19.27	5.8	7.3	8.0
11	BwK ₂	3.22	0.500	15.00	7.1	7.4	7.8
12	BwCa	6.47	0.950	21.34	7.6	7.6	7.8
13	BwAl	13.85	1.954	25.33	7.1	7.4	7.7
14	CwO	5.60	0.683	14.89	4.8	5.6	6.5
15	CwNH	3.71	0.603	14.87	4.3	4.6	4.8
16	CwGC	5.29	0.796	16.21	6.7	7.0	7.8
17	CwGP	4.37	0.640	14.10	7.1	7.0	7.4
18	Cw /1	8.44	1.045	18.54	5.3	5.8	7.2
19	Cw /2	7.72	1.022	16.96	5.8	6.0	6.6
20	Cw /5	6.15	0.928	16.23	6.4	6.4	7.3
21	CwAl	8.20	1.178	20.74	5.4	5.8	7.0

Series 3 was arranged with a view to repeating some of the work previously conducted and likewise to an extension of it. Two plants, wheat and corn, were employed, and the subdivisions of the series may be appropriately designated 3w4, 3w10, 3c4, and 3c10, indicating respectively (3w4) cultures with wheat, solutions renewed every 4 days; (3w10) cultures with wheat, solutions changed every 10 days; (3c4) cultures with corn, solutions changed every 4 days; and (3c10) cultures with corn, solutions changed every 10 days. In this case, therefore, a culture of any plant in a particular solution with a change of solution every 4 days, was duplicated by a similar culture in which the solution was renewed every 10 days.

Sections 3w4 and 3c4 of this series were grown on the rotating table, while sections 3w10 and 3c10 were grown in another green-

TABLE VIII
(Series 3, Wheat)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH;
SOLUTIONS A, B, AND C; RENEWAL AFTER A TEN-DAY INTERVAL

No.	Culture indices	Total gr. wt. (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H		
					Initial	End 1st per.	End 2nd per.
1	AwO	2.55	0.482	12.40	4.8	4.6	4.8
2	Aw 9/10 K	5.04	0.765	15.29	5.3	5.6	6.3
3	Aw 4/5 K	5.50	0.812	14.07	5.5	5.2	5.9
4	Aw 3/5 K	5.52	0.748	13.76	6.0	5.6	6.1
5	Aw 1/2 K	5.53	0.849	12.23	6.1	5.5	6.4
6	Aw 3/10 K	1.06	0.262	10.64	6.4	6.0	6.1
7	Aw h/Al	2.52	0.506	13.61	3.6	3.8	4.9
8	AwAl	4.40	0.668	13.52	5.3	5.5	6.1
9	BwO	7.62	1.079	20.12	5.9	7.6	7.4
10	2(BwO)	7.90	1.094	19.11	5.8	7.6	8.0
11	BwK ₂	2.82	0.470	14.42	7.1	8.2	8.5
12	BwCa	5.12	0.789	17.14	7.6	7.8	8.8
13	BwAl	10.30	1.622	26.65	7.1	7.6	8.0
14	CwO	4.95	0.707	14.10	4.8	5.9	6.7
15	CwNH	5.57	0.858	16.15	4.3	4.6	5.3
16	CwGC	5.50	0.846	16.91	6.7	7.6	8.8
17	CwGP	1.70	0.308	10.77	7.1	7.4	7.6
18	Cw /1	7.10	0.995	16.24	5.3	6.2	7.7
19	Cw /2	6.42	0.887	16.62	5.8	6.4	7.6
20	Cw /5	5.50	0.778	16.28	6.4	6.8	7.4
21	CwAl	6.45	0.971	14.67	5.4	6.4	7.4

house, and the cultures were distantly spaced on a lattice table, or bench, constructed with the idea of providing for all cultures uniform circulation, or conditions favoring uniform water loss. The light relations were perhaps somewhat more favorable for the group of cultures renewed at four-day intervals. This series was begun on May 14. During the first two weeks the weather was moderate and cloudy, while during the last week it was bright and warm, perhaps too warm for the best growth of wheat. While the evaporation from a standardized spherical atmometer was low, seldom exceeding 12 gms. per day, during the first two weeks it rose to a maximum of 27.8 and 25.4 as a record for the two houses on May 31.

The modification in the A group of cultures in this series consisted chiefly in the introduction of K₂HPO₄ as a source of part

TABLE IX
(Series 3, Corn)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH;
SOLUTIONS A, B, AND C; RENEWAL EVERY FOUR DAYS

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Great-est length (cm.)	P _H		
						Initial	End 2nd per.	End 4th per.
1	Ac h/1	9.55	1.70	1.422	16.78	3.4	3.4	5.2
2	Ac h/2	32.10	7.08	3.301	27.92	3.7	4.1	5.6
3	AcO	50.61	12.94	4.716	35.74	4.8	4.8	5.6
4	Ac 9/10 K	33.08	10.24	3.015	26.58	5.3	5.6	5.8
5	Ac 4/5 K	41.12	10.13	3.898	30.50	5.5	5.3	6.2
6	Ac 3/5 K	40.90	9.76	3.820	29.60	6.0	5.6	6.3
7	Ac 1/2 K	40.80	12.98	3.434	29.98	6.1	5.6	6.9
8	Ac 3/10 K	47.20	15.24	3.915	31.75	6.4	6.0	6.9
9	Ac h/Al	16.57	3.82	2.117	19.93	3.6	4.6	5.3
10	AcAl	27.78	7.85	3.288	23.05	5.3	5.2	6.3
11	BcO	36.06	9.65	4.107	29.32	5.9	6.8	6.8
12	2BcO	49.72	13.75	5.159	34.11	5.8	7.1	7.0
13	BcK ₂	43.23	12.12	4.290	30.94	7.1	7.0	7.0
14	BcCa	36.41	11.01	4.305	29.78	7.6	7.2	7.2
15	BcAl	37.90	12.45	4.597	32.46	7.1	7.1	5.7
16	CcO	29.02	8.58	2.920	23.95	4.8	5.2	7.2
17	CcNH	20.44	4.68	2.307	22.44	4.3	4.6	4.6
18	CcGC	33.33	9.86	3.210	25.82	6.7	6.8	7.7
19	CcGP	32.82	8.83	3.061	26.57	7.1	6.6	7.8
20	Cc /1	35.83	10.82	3.437	29.01	5.3	5.6	7.8
21	Cc /2	35.32	8.80	3.306	27.84	5.8	6.1	7.6
22	Cc /5	35.70	10.25	3.271	28.18	6.4	6.4	8.0
23	CcAl	41.83	12.33	4.201	29.98	5.4	5.7	7.6

of the potassium and phosphate ions. The stock solution of this salt was made to contain the same number of gram atoms of PO₄ as the stock solution of KH₂PO₄. These solutions were then combined so that the ratios of monobasic to dibasic phosphate were respectively 9: 1, 4: 1, 3: 2, 1: 1, and 3: 7, the culture indices being Ax 9/10 K, Ax 4/5 K, Ax 3/5 K, Ax 1/2 K, and Ax 3/10 K, with the P_H of the solutions affected as indicated in the tables. In culture AxO, another high grade of KH₂PO₄ was employed, and the P_H exponent is higher than the theoretical; while in the Ax h/1 cultures, used especially in the case of corn, the more acid grade is employed. Ac h/2 is intermediate in

TABLE X
(Series 3, Corn)

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH;
SOLUTIONS A, B, AND C; RENEWAL AFTER A TEN-DAY INTERVAL

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Great-est length (cm.)	P _H		
						Initial	End 1st per.	End 2nd per.
1	Ac h/1	13.70	3.15	2.080	22.42	3.4	5.1	6.4
2	Ac h/2	18.13	3.83	2.268	23.77	3.7	5.4	6.3
3	AcO	34.42	7.75	3.922	31.65	4.8	4.0	5.2
4	Ac 9/10 K	34.82	9.10	3.282	29.64	5.3	5.6	5.3
5	Ac 4/5 K	34.12	7.72	3.298	27.17	5.5	5.1	5.3
6	Ac 3/5 K	37.62	9.70	3.589	28.07	6.0	5.6	5.4
7	Ac 1/2 K	41.80	11.30	3.784	28.76	6.1	5.6	5.4
8	Ac 3/10 K	37.50	12.56	3.397	27.25	6.4	5.8	6.4
9	Ac h/Al	19.67	4.34	2.491	23.23	3.6	5.2	6.1
10	AcAl	32.29	9.22	3.389	25.70	5.3	5.8	5.3
11	BcO	28.26	8.78	3.366	24.36	5.9	7.2	5.5
12	2BcO	38.04	7.77	4.525	30.22	5.8	7.7	5.3
13	BcK ₂	43.00	12.63	4.172	31.83	7.1	8.0	5.8
14	BcCa	29.85	9.20	3.617	26.59	7.6	8.4	7.3
15	BcAl	27.80	7.70	3.271	27.75	7.1	7.0	5.6
16	CcO	30.65	8.40	2.923	24.84	4.8	5.6	7.6
17	CcNH	14.44	3.80	1.994	23.85	4.3	4.6	5.8
18	CcGC	27.50	6.97	2.788	23.94	6.7	7.6	8.4
19	CcGP	32.37	8.90	3.145	23.83	7.1	7.3	8.2
20	Cc /1	31.85	7.20	3.060	26.95	5.3	6.2	7.5
21	Cc /2	34.50	9.35	3.005	29.65	5.8	6.4	7.4
22	Cc /5	38.90	9.25	3.487	29.43	6.4	7.0	7.1
23	CcAl	25.06	5.89	2.699	24.74	5.4	6.4	7.7

acidity between AcO and Ac h/1, with salt proportions the same. Again, to other cultures containing these two grades of phosphates there were added to each culture vessel (and with each renewal) 1 gm. of solid aluminium hydroxide of the highest purity procurable. The latter are designated AxAl and Ax h/1 Al respectively.

In the B group cultures were prepared with the addition of solid aluminium hydroxide (BxAl), as above, also with solid calcium carbonate BxCa, with the addition of a small amount of K₂HPO₄ (BxK₂), and the unmodified solution of double strength [2(BxO)].

The C group of cultures (Livingston-Tottingham medium) is here introduced for the first time. Explanations already given explain the culture indices in this group, except in the following cases: CxNH, CxGC, and CxGP. In the first mentioned one-half the atomic proportion of nitrogen is supplied as $(\text{NH}_4)_2\text{SO}_4$, and in the last two calcium glycono-phosphate is added to replace monobasic calcium phosphate. In CxGC the atomic proportion of Ca is kept the same as in CxO, while in CxGP it is the phosphorus which is equivalent.

Under the conditions of these experiments the Aw cultures, particularly, were less satisfactory than usual, possibly in large part due to the high temperature prevailing towards the end of the period. The series was discontinued earlier than planned owing to the drying of the leaf tips of wheat and even of some entire plants. On the whole the wheat cultures show many inconsistencies, but despite this also some strikingly interesting results.

Increasing the P_H exponent by means of the dibasic phosphate may under these extreme conditions more than treble or quadruple the growth quantities. It is probably a matter of shifting the sum of conditions from the side of toxicity to that of growth maintenance. Even in the case of the C solution, increasing the P_H exponent is here a factor in promoting growth increase. Under other conditions I have not found this to be true, as will be indicated later.

The addition of aluminium hydroxide is under these conditions distinctly favorable, as seen by comparing the following pairs, AwO and AwAl (also AwO and Aw h/Al), BwO and BwAl, CwO and CwAl. The value of this reagent is doubtless in part due to its action as a buffer.

The temperature was most favorable for the corn cultures, and they exhibited, on the whole, an unusually vigorous growth. The green weight determinations are an accurate indication of growth extent but not of appearance. The B group was dark green in color, with heavy purplish stems; while both the A and C groups were strongly chlorotic. Chlorosis was much intensified during the last week of growth, and it seemed probable that if these cultures were longer maintained, a considerable reduction in the growth rate would occur. It is assumed, how-

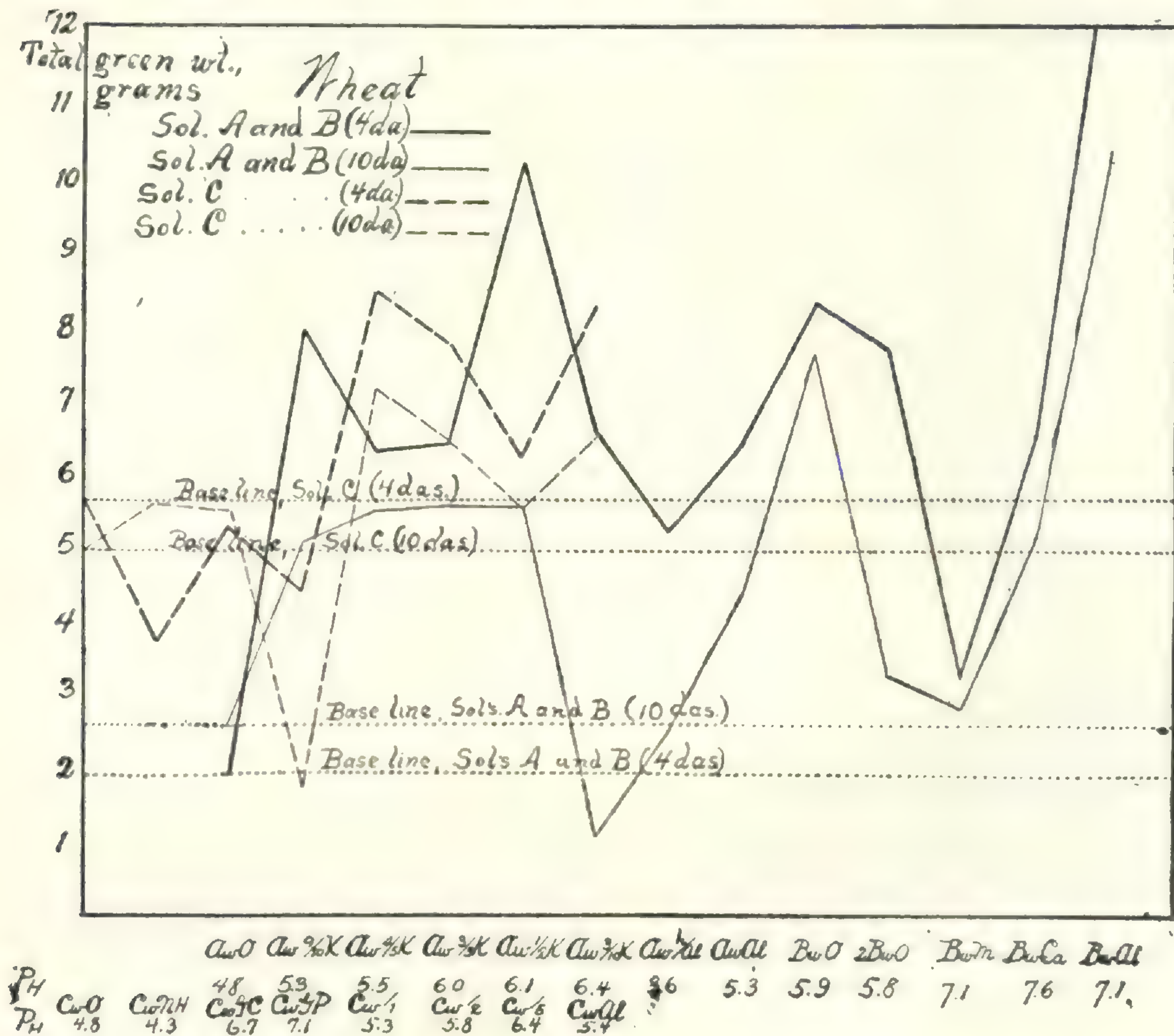


Fig. 3. Total green weight of wheat in solutions A, B, and C, with modifications effected largely by combinations of phosphates or by the introduction of "insoluble" buffers. Intervals between the renewal of solutions were 4 and 10 days.

ever, that in these cases the chlorosis may be related to inadequate iron supply, and not to faulty proportions of the main salt constituents.

The *Ac h/1*, *Ac h/2* and *Ac h/Al* cultures all show the injurious effect of high acidity; but with the initial value of P_H 4.8 the best growth in the one lot is in the A solution, though practically approached in the double strength of the B solution [$2(BcO)$]. Aside from the considerable variation in cultures differing only slightly in composition or in P_H , the chief point of interest is the depressing action of the ammonium salt in both lots (*BcNH*).

The curves, figs. 3 (wheat) and 4 (corn), exhibit diagrammatically the data above discussed, and require no explanation, further than to point out that the results with solution C appear

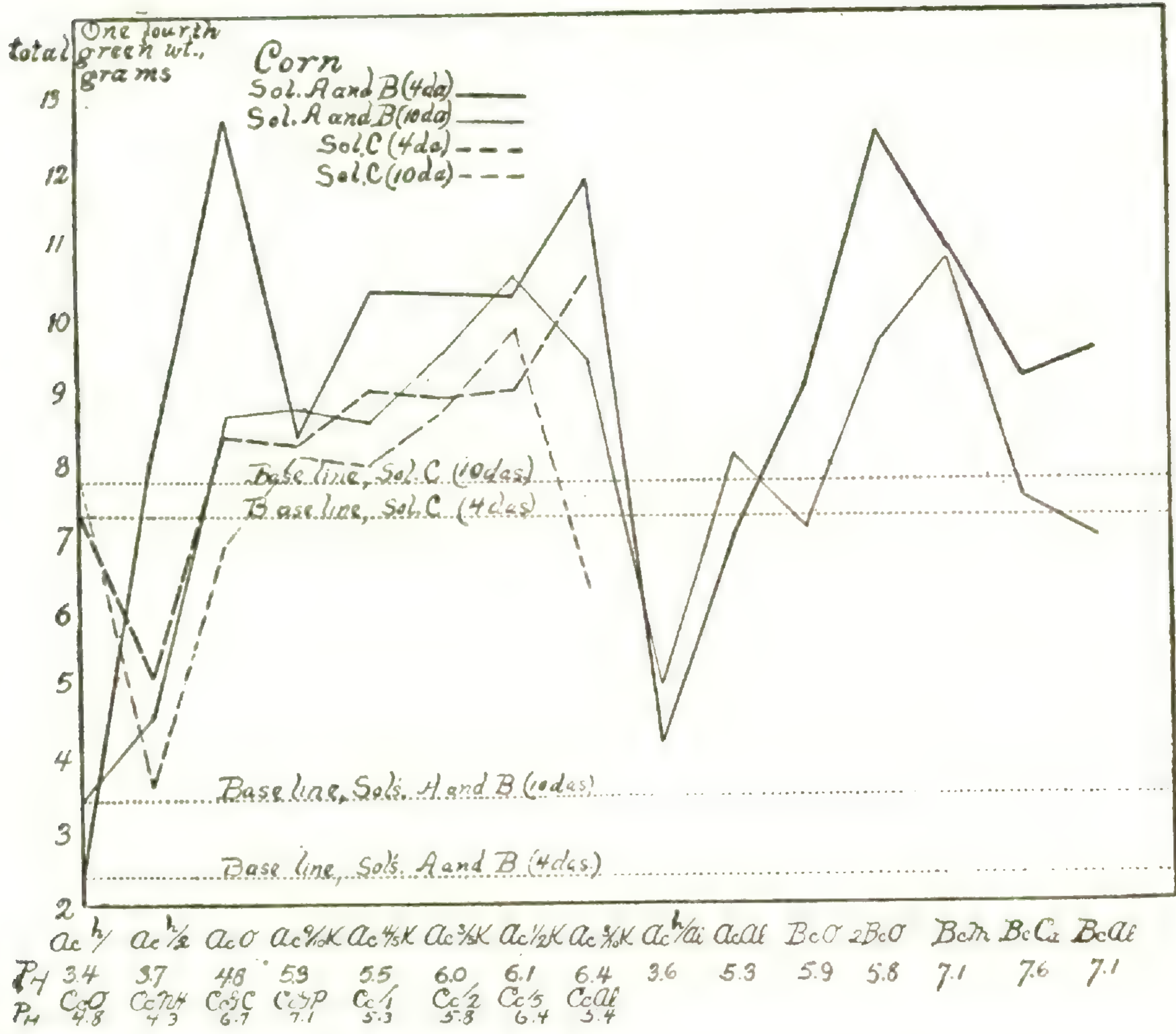


Fig. 4. One-fourth total green weight of corn in solutions A, B, and C. See further explanation under fig. 3.

in the same region of fig. 3 as solution A merely because it was necessary to do this in order to present all the data in a single figure.

In order to include solution C again in the tests, and at the same time to change somewhat the range of hydrogen ion concentrations in the A and B solutions, as well as to repeat the former work, a more extensive series of experiments was arranged with wheat, corn, and peas as indicated by the results in tables XI-XIX. Meanwhile, it had been determined from preliminary experiments that nutrient solutions of diverse constitution seem to be considerably influenced by the conditions under which the cultures were grown. There was, therefore, introduced into this series three sets of conditions. On account of the fact that other experiments were under way in the green-

TABLE XI
(Series 4, I—Wheat [moist, high temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
					Initial	After gr.
1	AwO	4.19	.491	30.71	3.4	4.0
2	Aw /5	4.10	.400	26.77	4.6	5.3
3	Aw /10	3.78	.399	27.00	5.8	4.4
4	Aw 1/	2.60	.338	24.63	3.35	4.4
5	Aw 3/	2.22	.328	22.08	3.15	3.6
6	AwNa	3.83	.468	30.10	3.45	3.8
7	AwM	4.65	.485	29.23	5.4	4.0
8	BwO	5.22	.469	32.96	6.6	7.2
9	Bw /5	4.90	.466	32.84	7.4	7.6
10	Bw /10	4.65	.424	32.04	8.6	8.2
11	Bw 1/	5.38	.491	32.06	6.4	7.2
12	Bw 5/	5.35	.472	31.33	3.2	6.8
13	Bw 10/	.95	.177	12.26	2.8	3.8
14	BwK ₂ /10	5.13	.466	35.55	7.0	7.2
15	BwCa	5.70	.539	34.23	7.3	6.6
16	CwO	4.82	.465	29.12	4.2	6.4
17	Cw /5	4.17	.401	24.78	6.4	7.0
18	Cw /20	2.25	.301	18.85	7.6	7.2
19	Cw 1/	4.05	.403	26.50	3.6	6.4
20	Cw 5/	2.47	.296	20.85	3.2	5.2
21	CwNa	4.50	.441	28.72	4.2	6.6

houses at the same time no particular effort was made to control accurately the conditions of growth. The following general conditions were decided upon: (I) Moist high temperature, (II) moist low temperature, and (III) dry high temperature. These conditions are relative, of course, and all supported good growth. "Moist" in the sense here used simply means that by frequent sprinkling of walls and floors the humidity was raised above that of the usual greenhouse compartment. However, in the case of those cultures placed under conditions of high moisture and high temperature there was also necessary a slight degree of shade. This caused the plants to grow up rather quickly. As a result of this rapid growth in this section of the series it was determined to take down all cultures after about 15 days except those placed under the conditions referred to as moist, low

TABLE XII
(Series 4, II—Wheat [moist, low temperature])
SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
					Initial	After gr.
1	AwO	3.72	.681	16.81	3.4	4.0
2	Aw /5	10.87	1.373	22.90	4.6	6.0
3	Aw /10	8.85	1.087	21.40	5.8	6.4
4	Aw 1/	4.42	.736	16.75	3.35	4.0
5	Aw 3/	3.27	.579	16.23	3.15	3.4-3.5
6	AwNa	6.80	.862	19.28	3.45	5.8
7	AwM	11.24	1.323	24.20	5.4	6.6
8	BwO	10.92	1.035	20.75	6.6	7.0
9	Bw /5	8.40	.912	19.27	7.4	7.6
10	Bw /10	9.02	.924	22.12	8.6	8.1
11	Bw 1/	7.37	.908	20.69	6.4	7.1
12	Bw 5/	9.17	.910	20.06	3.2	7.2
13	Bw 10/	.90	.209	8.80	2.8	3.6
14	BwK ₂ /10	8.82	.984	19.46	7.0	7.5
15	BwCa	11.64	1.354	20.51	7.3	7.4
16	CwO	6.75	.870	18.54	4.2	7.7
17	Cw /5	6.77	.826	16.93	6.4	7.8
18	Cw /10	5.60	.681	12.85	7.6	8.6
19	Cw 1/	7.22	.915	18.90	3.6	7.7
20	Cw 5/	7.55	.916	18.17	3.2	7.5
21	CwNa	7.75	.853	18.78	4.2	7.8

temperature. On account of conditions prevailing at the time, sections I and III were actually maintained from 16 to 18 days. The plants in section II were permitted to run from 25 to 27 days. This was an extreme test of the tolerance of these solutions, and no change of the nutrient medium was made in any culture throughout the entire period of growth. The water lost by transpiration was, however, replaced from day to day.

A general survey of the blocks of cultures represented by solutions A, B, and C gives evidence that under conditions of rather moist air and high temperature (table XI) wheat grown without change of solution for 18 days exhibits less striking differences in the maximum growth quantities than may be seen in the earlier series of cultures. Nevertheless, the highest value, whether of total green weight or of dry weight, is found in culture

TABLE XIII
(Series 4, III—Wheat [dry, high temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
					Initial	After gr.
1	AwO	2.77	.395	19.70	3.4	4.8
2	Aw /5	5.50	.582	26.23	4.6	5.8
3	Aw /10	5.61	.601	24.90	5.8	6.1
4	Aw 1/	1.78	.287	17.14	3.35	3.4
5	Aw 3/	1.55	.248	16.33	3.15	3.4
6	AwNa	3.66	.441	23.70	3.45	3.6
7	AwM	3.35	.390	21.89	5.4	5.0
8	BwO	7.43	.658	26.54	6.6	7.2
9	Bw /5	7.25	.733	30.97	7.4	7.6
10	Bw /10	5.64	.493	22.37	8.6	8.6
11	Bw 1/	4.72	.554	24.38	6.4	8.6
12	Bw 5/	5.42	.566	25.19	3.2	7.3
13	Bw 10/	.17	.092	6.67	2.8	2.9
14	BwK ₂ /10	6.40	.615	26.58	7.0	7.9
15	BwCa	7.39	.765	28.62	7.3	8.2
16	CwO	4.49	.510	21.60	4.2	7.2
17	Cw /5	4.97	.576	23.43	6.4	7.6
18	Cw /20	3.32	.450	20.20	7.6	8.2
19	Cw 1/	4.80	.491	23.66	3.6	7.0
20	Cw 5/	2.00	.298	19.02	3.2	5.0
21	CwNa	4.50	.522	24.00	4.2	7.4

BwCa. Several other cultures in the B block, notably Bw 1/ and Bw 3/, exceed slightly all those of the C block by either of the 2 important criteria, that is, green weight or dry weight. Under these conditions the tolerance of high hydrogen ion concentration is generally marked, as shown in cultures AwO, AwNa, Bw 5/, and Cw 1/. Likewise the range of tolerance and of strong growth is considerable.

In section II of this series with wheat (table XII) it is the inference from the data that when grown for a longer period (25 days) under cooler conditions wheat is less resistant to high hydrogen ion concentration. This is shown in part by the fact that the 4 cultures yielding highest in green weight are BwCa, AwM, BwO, and Aw /5. There is, however, no striking falling off, on the whole, as hydrogen ion concentration increases to

TABLE XIV
(Series 4, I—Corn [moist, high temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	AcO	19.05	4.42	.593	34.72	3.4	4.2
2	Ac /5	27.32	6.80	1.786	40.20	4.6	4.6
3	Ac /10	18.85	3.87	.305	38.58	5.8	6.0
4	Ac 1/	14.83	4.01	1.136	30.48	3.35	6.3
5	Ac 3/	9.45	3.28	1.129	29.23	3.15	6.4
6	AcNa	6.44	3.09	.973	22.77	3.45	6.6
7	AcM	24.02	4.80	1.615	38.24	5.4	6.5
8	BcO	22.31	4.93	1.781	38.63	6.6	5.2
9	Bc /5	19.77	2.44	1.452	39.65	7.4	6.4
10	Bc /10	21.12	4.97	1.538	39.64	8.6	6.1
11	Bc 1/	20.93	3.81	1.726	40.85	6.4	5.6
12	Bc 5/	21.55	4.33	1.724	41.25	3.2	4.4
13	Bc 10/	9.02	2.38	.936	22.71	2.8	7.1
14	BcK ₂ /10	25.56	4.44	1.770	43.46	7.0	5.2
15	BcCa	19.02	2.70	1.572	43.40	7.3	7.2
16	CcO	20.02	4.70	1.396	27.26	4.2	7.7
17	Cc /5	16.11	3.28	1.105	26.72	6.4	7.4
18	Cc /20	15.81	4.81	1.207	22.18	7.6	7.9
19	Cc 1/	19.81	4.88	1.341	33.56	3.6	7.6
20	Cc 5/	26.72	6.67	1.780	31.02	3.2	7.6
21	CcNa	18.81	3.94	1.165	30.62	4.2	7.7

about P_H 3.2, although there is not the consistency which might be expected between cultures AwO, Cw 1/, Cw 5/, and Bw 5/.

Where the conditions involved a relatively dry atmosphere and a high greenhouse temperature the response of the organism to the different culture solutions is of special interest. The three cultures with highest green weight yields are all in the B block, namely, BwO, BwCa, and Bw /5. These are so far ahead of the cultures in the A and C blocks, irrespective of hydrogen ion concentration within the usual range, as to leave no doubt whatever that for continued cultivation in the same solution for a period of 18 days the B solution is decidedly the most favorable culture medium. In this case too we have as definite an indication as has been afforded as to the limitation imposed by hydrogen ion concentrations. With an exponent

TABLE XV
(Series 4, II—Corn [moist, low temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	AcO	8.77	3.25	1.007	15.83	3.4	5.6
2	Ac /5	22.81	8.44	1.703	22.98	4.6	6.0
3	Ac /10	23.10	8.94	1.521	22.78	5.8	6.2
4	Ac 1/	21.97	6.94	1.933	21.75	3.35	5.8
5	Ac 3/	11.28	2.82	1.303	15.65	3.15	6.0
6	AcNa	19.30	7.91	1.744	20.56	3.45	6.0
7	AcM	27.56	10.69	2.078	22.72	5.4	6.0
8	BcO	18.90	7.50	1.828	20.64	6.6	6.4
9	Bc /5	31.99	14.50	2.508	23.51	7.4	5.9
10	Bc /10	28.63	14.54	2.213	21.84	8.6	7.0
11	Bc 1/	23.61	7.74	2.423	24.14	6.4	4.8
12	Bc 5/	27.80	10.60	2.464	23.44	3.2	6.0
13	Bc 10/	15.50	6.20	1.366	16.19	2.8	5.6
14	BcK ₂ /10	36.30	6.44	2.950	23.50	7.0	5.7
15	BcCa	26.03	10.11	2.699	23.57	7.3	7.4
16	CcO	34.60	11.02	2.763	24.66	4.2	7.6
17	Cc /5	28.47	9.72	2.350	23.59	6.4	7.6
18	Cc /20	20.90	6.75	1.868	20.10	7.6	8.6
19	Cc 1/	23.52	7.55	1.966	23.40	3.6	7.6
20	Cc 5/	21.22	6.70	1.687	22.15	3.2	7.6
21	CcNa	24.60	9.07	2.090	19.74	4.2	7.6

below P_H 4 there is definite diminution of growth in every instance, except Bw 5/. AwM seems to be distinctly out of harmony in this group. The suggestion from culture Bw /10 is that under these climatic conditions a relatively low degree of alkalinity, probably about P_H 8, would represent the limit for most favorable growth in a solution thus constituted.

The results with corn grown in a moist atmosphere at a high temperature are perhaps more erratic than in any other section of the work. At least with the data at hand it is extremely difficult to interpret these results. It would appear that the best growth is in culture Ac /5, and it is closely followed by Cc 5/, the last solution being close to the usual limit of growth in respect to hydrogen ion concentration. In both these cases the increase in the growth over that in BcK₂/10, AcM, and BcO is

TABLE XVI
(Series 4, III—Corn [dry, high temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	AcO	24.43	8.59	1.812	24.35	3.4	5.9
2	Ac /5	25.90	7.94	1.751	22.81	4.6	6.0
3	Ac /10	17.22	5.28	1.360	27.64	5.8	6.2
4	Ac 1/	21.80	5.60	1.667	31.24	3.35	4.0
5	Ac 3/	17.49	4.61	1.405	23.65	3.15	4.6
6	AcNa	16.00	4.70	1.231	27.17	3.45	5.6
7	AcM	30.41	9.61	2.014	32.26	5.4	6.2
8	BcO	19.89	6.30	1.604	27.07	6.6	4.0
9	Bc /5	20.89	7.11	1.756	29.80	7.4	6.8
10	Bc /10	20.90	5.85	1.810	30.41	8.6	6.8
11	Bc 1/	23.00	9.25	1.637	27.75	6.4	5.0
12	Bc 5/	20.02	7.70	1.442	29.59	3.2	4.2
13	Bc 10/	1.64	.43	.285	5.11	2.8	3.4
14	BcK ₂ /10	24.52	9.89	1.665	31.33	7.0	5.2
15	BcCa	23.44	8.81	1.867	32.53	7.3	7.8
16	CcO	16.62	4.97	1.125	25.67	4.2	7.8
17	Cc /5	18.52	5.20	1.180	32.71	6.4	8.0
18	Cc /20	11.28	4.06	.835	14.88	7.6	8.0
19	Cc 1/	20.56	5.65	1.407	29.97	3.6	7.9
20	Cc 5/	8.63	1.61	.856	20.75	3.2	7.6
21	CcNa	15.54	5.57	1.122	25.31	4.2	7.8

largely an increase in the growth of roots. It is perhaps possible that the partial shade of this series referred to above has been a factor in the irregularities which prevail throughout. There is no basis on which to explain the growth in AcNa. Turning, however, to table xv, indicating the results with corn grown at low temperature and higher humidity the data are notably different from the preceding. In this case the most favorable medium is culture BcK₂/10, rather closely followed by CcO and less closely by Bc5/. In this section it is also notable that the maximum root growth occurs over a range of hydrogen ion concentration from 4.2 to 8.6. Exclusive of culture CcO the higher growth quantities are obtained for the different solutions at relatively low hydrogen ion concentration, that is, with media approaching neutrality more or less. This is particularly ob-

TABLE XVII
(Series 4, I—Peas [moist, high temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	ApO	12.53	4.15	1.010	28.46	3.4	3.5
2	Ap /5	13.82	4.15	1.059	31.05	4.6	4.2
3	Ap /10	13.92	3.87	1.062	13.25	5.8	5.8
4	Ap 1/	11.55	3.42	.937	28.00	3.35	4.7
5	Ap 3/	11.93	3.17	.990	29.68	3.15	5.8
6	ApNa	12.56	3.93	1.024	31.42	3.45	4.6
7	ApM	12.81	3.93	.966	30.00	5.4	4.6
8	BpO	10.60	3.02	.839	25.87	6.6	6.4
9	Bp /5	13.17	3.64	.957	31.97	7.4	7.5
10	Bp /10	9.80	3.11	.746	32.47	8.6	7.6
11	Bp 1/	11.17	3.47	.809	23.37	6.4	7.0
12	Bp 5/	11.12	2.89	.842	26.22	3.2	5.8
13	Bp 10/	7.59	2.21	.623	23.29	2.8	4.8
14	BpK ₂ /10	12.30	3.61	.936	26.62	7.0	7.3
15	BpCa	12.55	3.50	.937	29.57	7.3	7.6
16	CpO	12.44	3.39	.974	25.34	4.2	5.2
17	Cp /5	8.19	2.16	.657	21.66	6.4	6.2
18	Cp /20	10.52	2.93	.928	22.37	7.6	7.5
19	Cp 1/	12.50	3.50	.982	26.02	3.6	5.0
20	Cp 5/	6.93	2.01	.605	21.36	3.2	4.2
21	CpNa	10.72	3.06	.923	22.35	4.2	5.4

servable in cultures Ac /10, Bc /5, Bc /10, BcCa, and Cc /5. Corn grown under conditions of high temperature and low humidity exhibits a maximum in AcM followed respectively by BcK₂/10, Ac /5, BcCa, and Bc 1/. An examination of block A would seem to indicate that P_H 3.4 to 4.6 is entirely favorable in this medium, but there is a striking difference between Ac/10 and AcM, which is not readily explainable.

In table xvii it may be noted again that slight variations in the culture medium do not materially affect the growth of peas when grown under the conditions there indicated. The A solution with the addition of alkali yields, it is true, the maximum growth quantities, but these quantities are only slightly in excess of those obtained with the same solution unmodified or of several cultures in the B block, notably Bp /5, BpK₂/10, and

TABLE XVIII
(Series 4, II—Peas [moist, low temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	ApO	17.72	6.55	1.772	19.07	3.4	5.5-5.6
2	Ap /5	25.71	12.17	2.290	18.06	4.6	6.0
3	Ap /10	24.26	9.72	2.299	20.00	5.8	5.9-6.0
4	Ap 1/	21.05	9.00	1.980	17.77	3.35	5.9
5	Ap 3/	22.52	9.44	2.183	19.18	3.15	5.6
6	ApNa	20.69	8.52	.889	17.61	3.45	5.7
7	ApM	25.65	11.20	2.310	19.87	5.4	
8	BpO	13.87	8.26	1.400	15.82	6.6	6.1-6.2
9	Bp /5	13.65	5.18	1.308	14.74	7.4	7.1
10	Bp /10	18.57	7.54	1.704	15.63	8.6	7.6
11	Bp 1/	16.93	6.61	1.590	17.38	6.4	6.0
12	Bp 5/	16.14	7.59	1.378	13.30	3.2	6.0
13	Bp 10/	9.55	3.88	.881	10.98	2.8	5.5
14	BpK ₂ /10	18.11	8.90	1.455	16.26	7.0	6.2
15	BpCa	20.17	8.23	1.944	19.28	7.3	7.4
16	CpO	16.44	6.44	1.650	13.85	4.2	7.2
17	Cp /5	16.31	6.10	1.762	13.62	6.4	7.8
18	Cp /20	12.32	4.54	1.406	10.82	7.6	7.7
19	Cp 1/	16.36	6.95	1.599	13.61	3.6	7.2
20	Cp 5/	17.62	7.06	1.760	13.22	3.2	6.4
21	CpNa	16.54	5.62	1.711	17.38	4.2	7.0

BpCa, as also by two cultures in the C block, namely CpO and Cp 1/.

Wider differences are found in the case of peas grown at lower temperature in more humid air, but the maximum growth occurs in the A block, especially with the addition of a small amount of alkali (Ap /5) and in the ApM culture, containing both mono-basic and dibasic phosphates. No culture in the B block approaches the values referred to, and the same is true of the C cultures. Grown 16 days under dry conditions at a high temperature the yield of the various cultures is much reduced, and the relative values of the culture media do not remain the same as before. In this instance the B block exhibits the highest yields, especially cultures BpCa and BpK₂/10. The next higher yield is found in Ap /10. In the A block the effect of high

TABLE XIX
(Series 4, III—Peas [dry, high temperature])

SALT REQUIREMENTS AND H-ION CONCENTRATION IN RELATION TO GROWTH

No.	Culture indices	Total gr. wt. (gms.)	Gr. wt. of roots (gms.)	Total dry wt. (gms.)	Greatest length (cm.)	P _H	
						Initial	After gr.
1	ApO	7.42	3.05	.952	23.68	3.4	4.6
2	Ap /5	10.62	3.55	1.026	24.63	4.6	5.0
3	Ap /10	13.95	4.49	1.161	27.63	5.8	5.4
4	Ap 1/	3.20	1.10	.642	11.82	3.35	5.3
5	Ap 3/	6.78	2.47	.796	18.84	3.15	5.0
6	ApNa	11.22	3.60	.945	25.33	3.45	4.4
7	ApM	10.00	3.89	1.095	23.57	5.4	5.6
8	BpO	12.79	4.37	1.023	24.06	6.6	4.5
9	Bp /5	12.97	4.15	1.059	25.96	7.4	7.3
10	Bp /10	12.90	4.12	1.027	26.05	8.6	7.4
11	Bp 1/	8.64	2.15	.877	21.11	6.4	7.0
12	Bp 5/	11.95	4.27	.948	24.23	3.2	6.1
13	Bp 10/	2.97	0.75	.432	9.95	2.8	3.0
14	BpK ₂ /10	14.32	4.90	1.130	27.37	7.0	7.3
15	BpCa	14.44	4.92	1.233	26.33	7.3	7.8
16	CpO	6.60	2.10	.929	16.91	4.2	6.0
17	Cp /5	11.65	3.50	1.046	21.43	6.4	6.6
18	Cp /20	5.11	1.22	.760	15.40	7.6	7.6
19	Cp 1/	10.97	3.45	.977	21.28	3.6	5.4
20	Cp 5/	5.40	1.25	.636	15.54	3.2	5.8
21	CpNa	8.75	2.45	.966	18.99	4.2	6.0

hydrogen ion concentration is marked. In general, as the conditions of evaporation are intensified it would appear that somewhat more favorable results are obtained with this plant when the hydrogen ion concentration does not approach too closely the acid limit.

It is clear, however, that the preparation of nutrient solutions with acid phosphate—even though of high grade—may mean, and often does mean, a hydrogen ion concentration either perilously near the critical region for growth, or actually inhibiting growth. This is particularly true for wheat, and it may be true for corn and other crops under any conditions which may accentuate acid injury. Pronounced diminution in growth may occur as the P_H exponent is progressively diminished from about 4.5.

For each plant in the preceding series a separate set of curves (figs. 5, 6, and 7) has been prepared; and in each figure there are

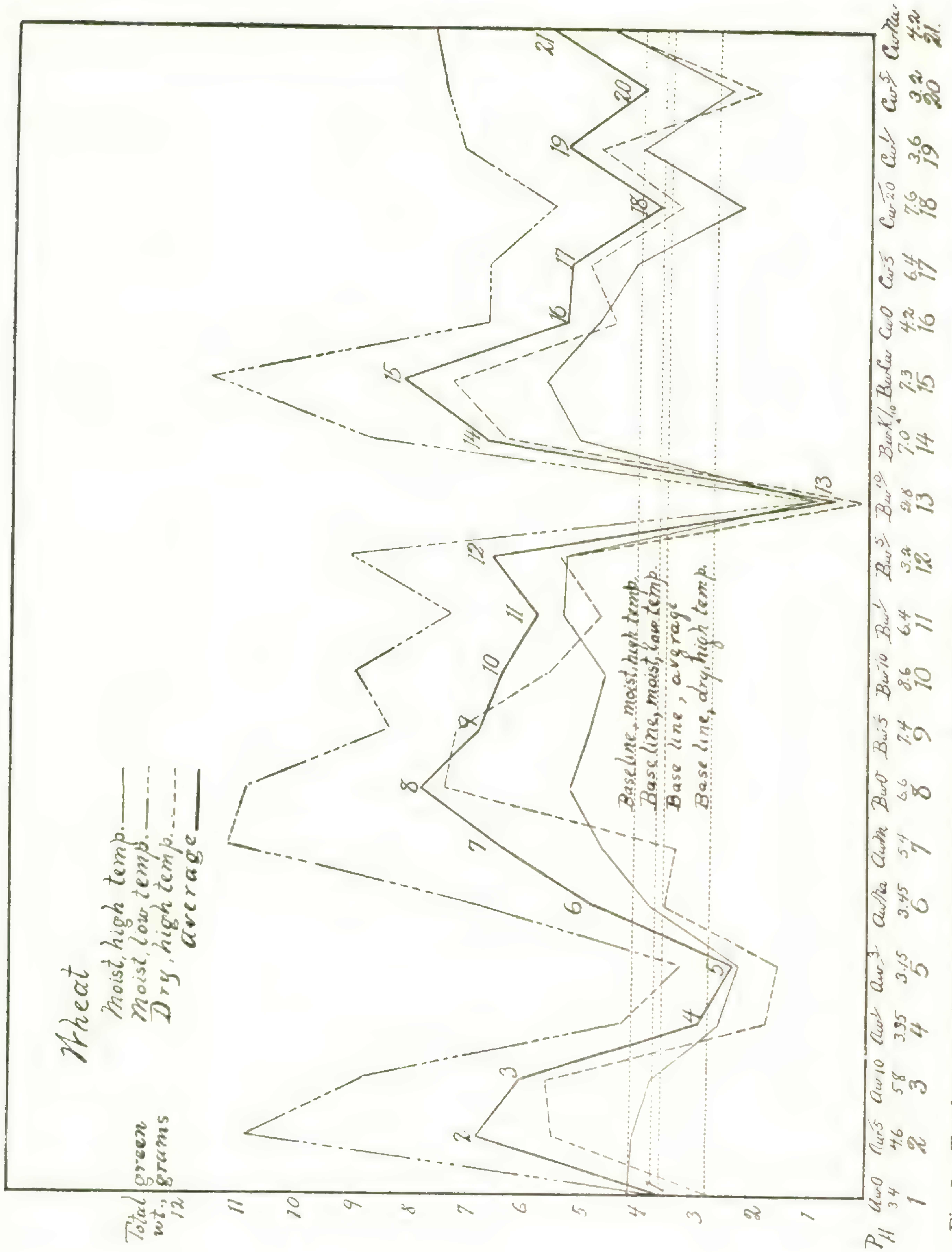


Fig. 5. Total green weight of wheat in solutions A, B, and C, with variations and under somewhat diverse external conditions, as indicated in connection with the curves.

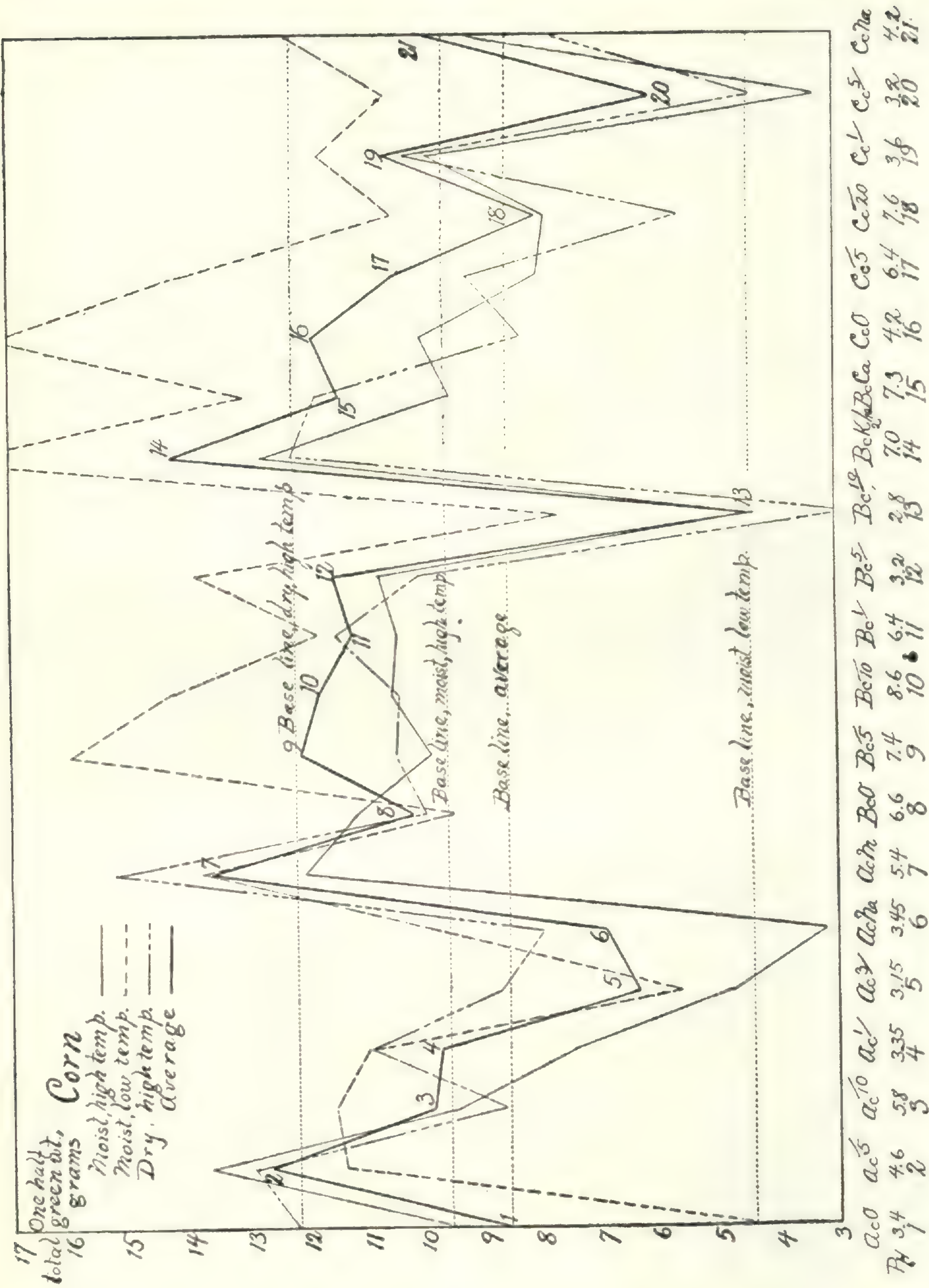


Fig. 6. One-half total green weight of corn in solutions A, B, and C, with variations and under somewhat diverse external conditions, as indicated in connection with the curves.

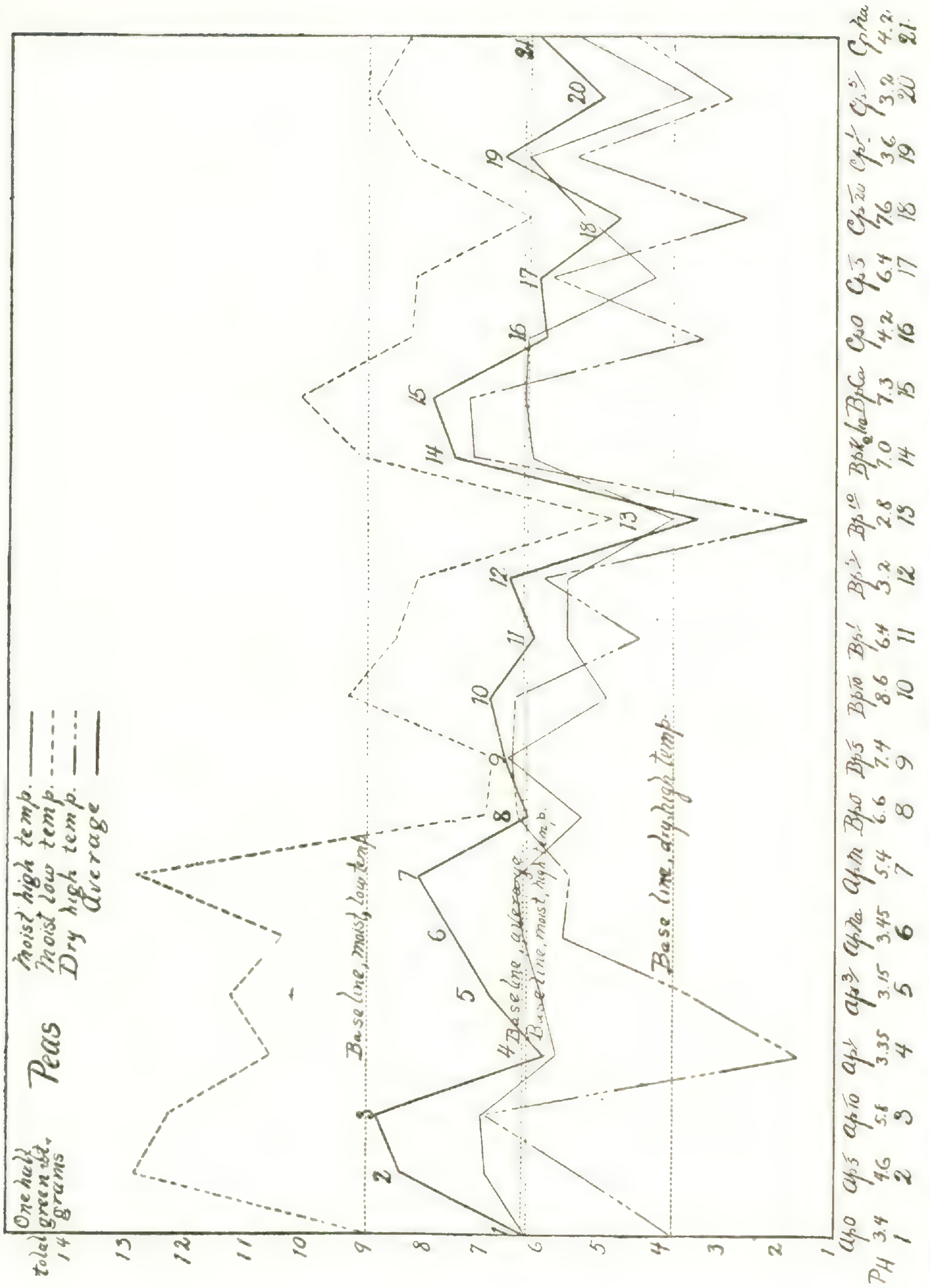


Fig. 7. One-half total green weight of Canada field peas in solutions A, B, and C, with variations and under somewhat diverse external conditions, as indicated in connection with the curves.

3 curves representing the results under the 3 combinations of conditions, as well as a fourth curve exhibiting the average of the 3 others.

GENERAL DISCUSSION

Hoagland ('17) determined the effect of H- and OH-ion concentration on the growth of barley seedlings in an incomplete nutrient solution, omitting calcium, magnesium, and iron,—employing therefore only phosphates of potassium in some series and in others adding to these small proportions of sodium salts, including nitrate. The H-ion adjustments were made on the alkaline side with K_3PO_4 and K_2HPO_4 ; on the acid side there was used KH_2PO_4 , supplemented in one case by H_3PO_4 and by the dibasic salt. As a result of numerous experiments he finds that a concentration of OH-ion greater than 1.8×10^{-6} was injurious, and it was extremely toxic when the concentration reached 2.5×10^{-5} . A concentration of H-ion of $.7 \times 10^{-5}$ was favorable to growth while $.3 \times 10^{-3}$ was very toxic. In these solutions there was, of course, opportunity for antagonistic effects, and since the solutions were unbalanced, the injurious effect of the potassium or sodium ions or both would require consideration.

Some of the complicated effects resulting from the addition of salts to toxic acid and alkaline solutions, especially in respect to the water relations of plants, have been dealt with by Dachnowski ('14); but inasmuch as the constituents of nutrient solutions were not involved either in control experiments or otherwise the data are scarcely applicable here.

It is difficult, if not impossible, to attempt a comparison of the toxic action of H-ions and OH-ions from the dissociation respectively of mineral acids and such hydroxides as those of sodium and potassium in distilled water with the toxic effects produced by the same ions in a culture solution containing diverse other ions, especially the cations of the salts usually employed. In the latter solutions antagonistic effects, dependent in part upon specific relations of the plant employed, must to a certain degree obscure the magnitude of the effects. It is of interest to note, however, that Kahlenberg and True ('96) found that roots of *Lupinus albus* just lived in $n/6400$ HCl. Nevertheless, after 5

days in $n/25,600$ HCl the growth rate was but little more than one-half that of similar roots in distilled water. Thus we may assume that a hydrogen ion concentration approximately $P_H 4$ depressed the root growth of this plant. The same seedlings survived $n/400$ potassium hydroxide during 24 hours, but with this reagent no growth measurements after an interval of several days, comparable to those with HCl, were made. The results of Heald ('96) also show that while roots of *Pisum sativum* survived $n/6400$ HCl, and those of *Zea Mays* $n/1600$, still in the former the growth rate was low in $n/12,800$ and for corn in $n/3200$, during an interval of 48 hours. No comparisons with distilled water were included.

Loew ('03), working with the seedlings of *Zea Mays*, and Miyake ('14), using *Oryza sativa*, have both shown a relatively greater resistance of these plants to alkali than to acid, all of which emphasizes the importance of devoting special consideration to the initial acidity of the culture solution.

Respecting the reaction of soils, there is considerable evidence indicating that acidity alone is not necessarily a limiting factor in the growth of many crops. With a method considered adequately accurate as applied to field conditions, Gillespie ('16) has examined air-dried samples of 22 crop soils and found the P_H exponent to vary from 4.55 to 7.1 in the case of 18 soils from Maine, Maryland, and Virginia, and a variation of from 8.1 to 8.7 with 4 soils from Utah and Montana. It is also reported by Gillespie and Hurst ('18) that the highest acidity ($P_H 4.5$) was not in the least injurious to potato culture in Caribou and Washburn loams, the two main potato-soil types in the region in which they worked.

Plummer ('18), employing the soil-suspension method, examined 68 samples of a variety of soil types of humid regions, especially of the southern states. Untreated sandy loam or clay soils exhibited a range of acidity $.1 \times 10^{-3}$ to 1×10^{-6} , while peat gave in one instance a hydrogen ion concentration $.2 \times 10^{-1}$. Evidence was gained to the effect that the surface film emphasizes the direction of the reaction, that is, in acid soils the surface film is more acid and in alkaline soils it is more alkaline. This is scarcely in corroboration of certain work of Sharp and Hoagland ('16).

In general, when the reactions of the culture solutions (such as have been employed in this work) are strongly acid, the contact with plant roots effects a change towards neutrality. The extent and rapidity of this change, however, depend somewhat upon the crop, and especially upon the composition of the culture solution. It may be noted, for instance, from tables XI-XIX that solution A never became neutral, while solution C was changed, in the extreme case, to P_H 8.6. On the other hand, it is not necessarily true that alkaline culture solutions tend to become acid, as may be seen in the case of solution C. Solution B, normally near the neutral point, may be shifted slightly in either direction.

Impelled in part by the general experience of others in field work, indicating a general tendency of cultivated soils to become acid, Breazeale and Le Clerc ('12) undertook solution-culture experiments to determine "the effect of the reaction of the culture medium on the growth of wheat seedlings and particularly on the development of the root," with a view to a possible explanation of the results obtained in practical agriculture. They regard the acid tendency as due primarily to the decay of organic matter and secondarily to the selective action of the root; the last mentioned only they proposed to investigate. Their experiments were chiefly with certain salts, particularly KCl, K_2SO_4 , and $NaNO_3$, used singly and each in combination with solid $CaCO_3$. According to their results greater absorption of the K ion, when the potassium salts are used, caused the solution to become acid; while in the case of the sodium salt, the greater absorption of the NO_3 ion tended to produce alkalinity. The addition of calcium carbonate precludes the development of acid with the potassium salts. In the toxic action reported no account is taken of the lack of physiological balance in the solutions lacking Ca, and no experiments were made with KNO_3 . Moreover, only a titration method (consistent with the general usage at that time) was employed in determining acidity and alkalinity.

Some time previous to this Hartwell and Pember ('07) emphasized the "marked property of the seedlings [wheat, rye, barley, and oats] of rendering the nutrient solutions alkaline—," insufficient, however, to cause precipitation. Similar observations are numerous in the literature.

Hoagland and his associates ('17, '18, '19) in a series of articles have pointed out some misinterpretations and discrepancies in the earlier work, and among other things have shown that with certain proportions of salts in solution cultures and in sand cultures having an initial acid reaction, this reaction was changed with the growth of the crops until it was approximately neutral. In certain cultures with an initial reaction approximately neutral, plants were grown to maturity without change of solution, and with the reaction remaining constant throughout. A nutrient solution strongly alkaline from the presence of K_3PO_4 became approximately neutral. Hoagland has also emphasized an important point appreciated likewise by some earlier investigators, namely, that the equivalence of positive and negative ions in the solutions is maintained, and the state of equilibrium, the recognition of which is often too vague, is of necessity kept in mind in any discussion of the absorption of ions.

In this paper it has been pointed out that there is generally a decline in growth in solutions A and C when the H-ion concentration is approximately $P_H 6$. This may be due to the relative insolubility of the phosphates. On the other hand, the generally more favorable growth in the B solution at or approaching neutrality may be related in part to the better distribution of phosphate ions or particles, due to the presence of certain substances in a state of greater dispersity. In this connection it will be recalled that Bonazzi ('19) and Allen ('19) have contributed interesting data on the favorable effects of shaking or agitation, on the growth of *Azotobacter chroococcum*, an organism necessarily grown in alkaline solutions.

Toole and Tottingham's ('18) results, showing increased yield with the addition of ferric hydroxide to Knop's solution, are also of particular interest in considering the data obtained in this work with solution B. At present there seems to be no basis for a final opinion on the rôle of aluminium in promoting growth in these experiments. The high adsorptive property of the compound used, together with its buffer action, may be concerned in the explanation. The maximum effect of this compound occurred with wheat, but in view of the complication of factors involved this may not be significant.

In the various series of experiments here reported there is

considerable diversity in the intervals between the renewal of solutions. These intervals have varied from four days to a time interval covering the entire culture period. The results have been as consistent as might be expected, and it is believed that the value of lengthening the interval in this way is important from the standpoint of reducing the labor in the maintenance of such cultures. Trelease and Free ('17) have, however, shown that frequent changes of solution are more favorable for growth; but it also appears from their data that renewals during the first two weeks are not so important as those made later. They suggest that a continuous flow of solution through the culture is more beneficial than a daily change.

The work of Pantanelli ('15) and others has shown that after plants have been for a few hours in contact with salt solutions it may be demonstrated that there has been a different rate of absorption of the various ions. The solution, therefore, changes rapidly in the presence of abundant absorbing surfaces. Hoagland has also emphasized this point, and within a certain range of osmotic concentration he regards the initial concentration of any particular ion as practically immaterial. Nevertheless, it would be admitted by all that there must be on the one hand a true physiological balance, and that on the other hand, the concentration of no necessary ion or molecule shall become a limiting factor in growth. It is not, however, proposed to discuss in this paper the significance and final results of the interchange of ions or molecules between roots and solutions.

Discussing limiting factors in water cultures Stiles ('16) has drawn attention to the limited application of the water-culture method in physiological problems. He regards this as related to "(1) the difficulty in analyzing results due to the complex of factors not under control; (2) the difficulty of controlling in some cases even the factor whose action is being investigated; and (3) the excess of labor required to produce results which are only of a low degree of accuracy."

In a previous paper Stiles ('15) has in a measure crystallized the feeling of many investigators working with water cultures in arriving at the conclusion that it is necessary to calculate the probable error of the results in accurately evaluating the significance of differences exhibited by different sets of cultures.

In a study of probable error he grew single plants in each of 10 bottles of 1200 cc. capacity, employing uniform methods and seed of a selected strain of rye. Four concentrations of nutrient solutions were used with the different lots. Experiments conducted during the early months of the year yielded results as follows: The greatest individual variation in any one lot amounted to never less than 70 per cent. In the weakest concentration the individual variation was 333 per cent. However, the probable error of the mean in these cases was only about 3-10 per cent of the mean dry weights. Comparable differences were found in cultures made later in the spring with a pure line of barley.

That considerable variability has been found by others is evident from the examination of the tables in any case in which the data have been given in detail. Livingston and Tottingham ('18) give a table from which it appears that while the culture R_1C_3 yields only a fair growth of roots the dry weight for the entire plant is third and for tops is the highest of all in the series. This solution, however, differs from R_8C_1 in containing one-eighth the concentration of KNO_3 , 3 times as much $Ca(H_2PO_4)_2$, and 6 times as much $MgSO_4$. R_8C_1 is regarded as "the best balanced for young wheat plants of all the nutrient solutions so far noted in the literature."

The Shive solution, on the one hand, and the Livingston-Tottingham solution, on the other, were of course designed with the idea of simplification. The 3 salts employed contain all the essential ions except iron. Theoretically, the phosphate, nitrate, and sulphate ions may be added in the form of the salts of either of the 3 bases or cations, K, Ca, and Mg. However, the relatively low solubility of Ca as sulphate may seem to render it less practicable to use this salt. There remain 7 possibilities in the selection of salts, and it might appear that in the selection of these the only important points might be, first, H-ion concentration, and second, the use of a base required in relatively low concentration with an anion which may be similarly reduced in strength.

From the emphasis in the literature, as is well known, an important consideration is an appropriate ratio between the ionic proportion of Ca and Mg. Other antagonistic relations

also require consideration. An analysis of the differences between the Shive and the Livingston-Tottingham solution shows that the latter contains a relatively greater concentration of K and NO_3 ions and a lower concentration of Ca, Mg, PO_4 , and SO_4 . Serious typographical errors in one of their tables (table three, page 345) have led Livingston and Tottingham ('18) into error in the statement that in the R_5C_2 solution there are 2.89 times as many atoms of Ca as of K per unit volume. As a matter of fact the partial volume atomic concentration of the R_8C_1 solution of Livingston and Tottingham contains more than 10 times as much K as Ca, while R_6C_1 contains more than 8 times as much K as Ca, and nearly 6 times as much Mg as Ca. The Mg : Ca ratio of R_8C_1 is very nearly 2 : 1. In both of the best Livingston-Tottingham solutions the ionic concentrations of K and NO_3 are greatest. It seems quite probable that this factor, together with the variability in H-ion concentration of KH_2PO_4 , is accountable for the better growth in these solutions.

SUMMARY AND TENTATIVE CONCLUSIONS

The experiments reported in this paper were undertaken primarily to determine the influence of variations in hydrogen ion concentration on the yield of certain seed plants in solution cultures. As the work progressed, however, many modifications were suggested, and some of these involved in no way a consideration of hydrogen ion concentration at points which might be regarded as critical for the growth of the crops used.

The selection of several culture solutions seemed necessary in order that some diversity might be introduced in the salt proportion or composition factors. The solutions employed, and their designations, were as follows: solution A, a slight modification of one of Shive's "best" solutions; solution C, a slight modification of one of the best Livingston-Tottingham combinations; and solution B, based in part upon the Crone combination of salts, but with this essential difference, namely, that "soluble ferric phosphate" was used in place of the "insoluble" iron salt. Each of the solutions first mentioned contains a monobasic phosphate, and with theoretically pure chemicals should yield culture solutions with a P_H exponent about 4.5. Solution B may vary, in my experience, from a hydrogen ion

concentration represented by P_H 5.4 to P_H 7.1; frequently, however, it is 6.6 to 7.1.

The experiments have been carried out in the greenhouse at different periods of the year, and represent, on the whole, a considerable range of environmental conditions. It has been impracticable to analyze these except in a very general way, or relatively. Wheat and corn have been employed in every series of experiments and Canada field peas in all series here reported except one.

Under the most favorable conditions, the 3 solutions mentioned above, without other modification, may all yield excellent growth. Plants grown in solution B are invariably of a deeper green, presenting a finer appearance, and the average of the growth quantities (green weight) is higher for wheat and corn than in either of the other 2 solutions. In the unmodified solutions A and C the green weight of peas averages higher than in the unmodified solution B.

Culture solutions prepared with monobasic phosphates may, however, exhibit a hydrogen ion concentration which is too high for the maintenance of the best growth under certain conditions, and especially is this true in the case of wheat.

Solutions made with monobasic potassium or calcium phosphate free from acid may, under certain conditions, yield maximum growth quantities, but there is often considerable variability in the duplicate cultures due to unknown factors. Certain grades of the phosphates mentioned—if not specially purified in the laboratory—exhibit a P_H which may be distinctly toxic. Correction of the P_H to about 4.8 or 5.2 by means of NaOH or by the use, in part, of a dibasic salt generally affords increased growth.

Under extreme conditions—effecting a high evaporation rate—it becomes more important to correct to the higher P_H exponent. Wheat, corn, and peas are sensitive in the order named to high hydrogen ion concentration.

Usually, the addition to solution B of small amounts of dibasic potassium phosphate, of solid calcium carbonate, and of aluminium hydroxide has given increased yields, often considerably above that of the unmodified solution. The results in the case of the aluminium compound are notable in the case of wheat

grown under the conditions described,—related in part, presumably, to adsorption and buffer action.

In general, it would seem that there may be no single "best" solution for the growth of any of the 3 plants employed in this work. In all probability a "best" solution, like the "optimum" temperature, is represented within the "optimum" concentration rather by considerable range of salt or ion proportions, influenced to a greater or less degree by environmental factors.

If the initial P_H of the culture solution is considerably less than neutrality there is generally a tendency for this to be shifted toward the neutral point, although this depends in part upon the composition of the solution and in part upon the plant grown.

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HUMIDITY IN RELATION TO MOISTURE IMBIBITION BY WOOD AND TO SPORE GERMINATION ON WOOD

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INTRODUCTION

In a previous publication the writer ('16) pointed out that between a certain minimum and maximum of moisture in wood *Lenzites saepiaria* and other similar wood-destroying fungi will grow and cause the destruction of the wood. Thus, the power of wood to absorb moisture, whether as vapor from the air or as water from objects in contact with the wood, is a factor of prime importance in its susceptibility to decay. It is no less true that any property of the wood which may influence its moisture-absorbing capacity is a factor in its durability. In this connection it has been suggested (Zeller, '16) that, although resin has no actual toxic effect on the growth of wood-destroying fungi, it does inhibit growth when in large percentages and its only inhibitive power probably lies in the fact that it excludes water from the fibre containing it (Zeller, '17).

With these previous results as a foundation further investigations have been conducted to ascertain (1) the amount of moisture which wood will absorb from the atmosphere at different relative humidities when the temperature remains constant; (2) whether the water-proofing effect of resin on wood can be measured; and (3) the relation of the moisture content of wood (or relative humidity of the atmosphere) to the propagation of wood-destroying fungi on wood. The purpose of the present paper is to report the results of these experiments.

EXPERIMENTATION

Materials used.—For the experiments reported below samples were selected from specimens of shortleaf pine (*Pinus echinata*) secured at the Fordyce Lumber Company, Fordyce, Arkansas, and from specimens of longleaf pine (*Pinus palustris*) secured at the

Calciseau Lumber Company, Lake Charles, Louisiana. From these samples approximately 250 specimens of each species were selected, so that a wide range in resin content and specific gravity as well as sap- and heart-wood might be represented.

The samples were allowed to air-dry for several weeks in a room at about 50 per cent relative humidity. They were then measured for volume and weighed, and the specific gravity determined for the whole sample. The samples were usually 2×6×48 inches. Of course, these specific gravities are not standard (Newlin and Wilson, '19), for the specimens were not *oven-dry* when weighed. Since the samples were obtained for the purpose of measuring the moisture-absorbing power of the wood they were not kiln-dried, for this tends to reduce the hygroscopic property of the wood below that obtaining in green samples (Tiemann, '07). This point was kindly called to my attention by C. H. Teesdale of the Forest Products Laboratory, Madison, Wisconsin, and in a report from that laboratory on "Wood in aircraft construction" (1919) the relation of kiln-drying of wood to its hygroscopicity is quite generally discussed. All samples finally selected for the moisture-absorption tests were marked and so labeled that after they were cut into blocks 2×2×4 inches, each block could be identified as to which sample it belonged and as to its position in the sample. From these small blocks uniformly clear pieces were selected for the preparation of shavings which were uniform in thickness. A preliminary experiment revealed the fact that the moisture-imbibing power of wood is not changed by shaving, but that imbibition is more rapid than when blocks were used. Therefore, in the experiments reported below shavings were used. The clear pieces selected were of a light color and had a resin content well below 5 per cent, except those otherwise designated in tables II and IV.

Description of humidors.—In order to determine the relation between the humidity gradient of the atmosphere and the moisture content of wood a closed chamber, or humidor, was devised so that a constant temperature would be maintained, and so that the humidity could be regulated either by different concentrations of sulphuric acid in trays enclosed in the chamber, by varying the evaporating surface of water in trays, or by hanging baskets of calcium chloride in the chamber. To pro-

duce the higher humidities, curtains of absorbent paper were hung in the chamber so that the lower portions were in contact with water in trays. This increase in evaporating surface proved very effective.

The humidor with apparatus complete as we used it is shown in plate 1. The humidor proper consists of two double-walled boxes, one within the other, built of spruce lumber. The double walls are packed with sawdust for insulation against temperature changes. For added insulation there is an air space separating the inner and outer box. The inner box, which is the chamber proper, has a double-walled door provided with a double-glass window, through which temperature and dew-point observations can be made without opening. The outer door is double-walled and packed with sawdust. The doors are provided with ordinary cold-storage catches. There are three one-inch openings, one through the top and one through each end. The inner walls of the humidor chambers were water-proofed in two ways: (1) Those of two humidors were brushed with hot paraffin (parawax) and were then thoroughly ironed with a hot electric iron. Further applications of the paraffin were made in the same manner. (2) The walls of two other humidors were primed and painted with several coats of a water-proof enamel and valspar. The paraffin treatment does not give as good an appearance as the enamel paints, but it proved to be the better water-proofing agent.

The temperature of the chamber was maintained at 25° C. by means of a bimetallic thermo-regulator in circuit with an electric light as a heating element.

Determination of relative humidity.—There was no difficulty in maintaining a constant relative humidity throughout any one experiment. The relative humidity of the chamber was determined by means of a Milliken dew-point apparatus, which consists of a highly polished, nickel, cylindrical cup provided with a three-hole stopper. One of these holes supports a thermometer and the other two provide an intake and outlet for the siphoning of water or freezing mixtures through the cup. This apparatus shows plainly in fig. 2, pl. 1. The dew-point is determined by the appearance and disappearance of the film of moisture on the polished cup as the temperature is changed by

allowing water to flow through the siphon. From the vapor pressures of the dew-point and the temperature of the chamber the relative humidity is obtained. The pressure of aqueous vapor at various temperatures was secured by recourse to the Smithsonian physical tables (Fowle, '10).

Method of weighing within the humidior.—The samples of wood shavings which were used to measure the imbibition of moisture from the atmosphere were planed as needed and placed in the wire baskets shown in fig. 1 and 2 of pl. 1. The baskets provided with hooks were hung on two wires which were stretched across the chamber, one on either side of the openings in the top and the right-hand side of the chamber. Balances were installed on the top of the humidior in such a position that a wire supporting a counterweight passed down through the opening leading to the chamber. The lower end of this wire is hooked so that the wire baskets can be hung upon the balance by means of a lever which passed into the opening in the right-hand end of the humidior. This operation can be performed without opening the chamber and thus changing the temperature and humidity within. The wire lever and the counterbalance wire are each provided with a cork, which can be slipped back when the device is in use or into the apertures when not in use. This device is an adaptation of that described by Dixon ('98).

A similar one to that described by the writer has been used for the same purpose by Mr. C. H. Teesdale in charge of the Section of Wood Preservation at the Forest Products Laboratory, Madison.

Determination of moisture content of wood.—After the samples of shavings had come to a constant weight in the humidior they were weighed and at the same time the relative humidity of the chamber was determined and recorded. The samples were then dried to constant weight in a dry-air oven at 100–105° C. The difference between the weight taken in the chamber and that after drying gave the total amount of moisture in the samples including that absorbed at the relative humidity of the chamber. The per cent of moisture absorbed was based on the oven-dry weight of the shavings.

Determination of resin content of wood.—To determine whether the influence of a high resin content on moisture absorption can

be measured experimentally samples were chosen and analyzed by the method previously reported (Zeller, '17).

RESULTS OF EXPERIMENTS ON MOISTURE ABSORPTION

The data from the experiments to show the relation between the relative humidity of the atmosphere and the moisture content both of sap- and heart-wood of shortleaf and longleaf pine are given in tables I, II, III, and IV.

From the data recorded in these four tables (I, II, III, and IV), the humidity-moisture curves shown in figs. 1, 2, 3, and 4, respectively, were plotted. These curves represent the ultimate moisture content at a given temperature and relative humidity of the surrounding atmosphere. The samples used in each experiment were of three distinct specific gravities chosen to represent the approximate average specific gravity of the species of wood, as well as densities both heavier and lighter than the average. In the case of heart-wood, however, an extra series of samples was used. These were highly resinous and consequently very dense. Other than these highly resinous pieces, the samples had a resin content well below 5 per cent.

The four curves are strikingly similar. In all cases where the samples of wood represented have specific gravities lying between .41 and .75 to .80 and small percentages of resin, the general curve for the moisture absorbed is followed up to a certain relative humidity where the percentage of moisture taken up by the wood of the three densities begins to vary according to the density. The lighter, or less dense, samples, from this point, take up more moisture with increased atmospheric humidity than do the denser samples. This occurs at a relative humidity averaging from 94.75 to 96 per cent. There seems to be but one explanation for a divergence of the curves at this juncture. Up to this point the wood fibre has not received enough moisture from the atmospheric humidity to satisfy its imbibition capacity, but beyond this point this hydration capacity is over-satisfied and the moisture over and above that absorbed by the fibre is adsorbed by the surfaces exposed. If this theory is correct the point of divergence of the three moisture-humidity curves represents the fibre-saturation point. As an irreversible colloid, wood is undoubtedly limited in further

TABLE I
 PERCENTAGE MOISTURE CONTENT OF SHORTLEAF PINE SAP-WOOD SHAVINGS AT
 VARIOUS ATMOSPHERIC HUMIDITIES AND AT 25° C.

Samples of .41 specific gravity		Samples of .61 specific gravity		Samples of .69 specific gravity	
I	II	III	IV	V	VI
Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)
4.12	11.0	2.5	6.6	3.0	7.5
5.50	19.5	6.62	24.8	4.87	15.25
7.25	28.0	7.5	31.8	6.12	22.75
7.80	33.2	7.9	35.8	7.88	34.6
8.70	45.5	8.4	40.4	8.70	42.5
9.00	49.5	9.2	47.5	9.7	53.
9.88	53.8	9.5	54.5	10.75	62.5
10.62	58.8	10.3	58.8	11.6	66.0
10.80	60.4	10.4	61.3	12.6	69.5
11.12	63.8	11.5	65.0	14.25	76.8
12.80	68.8	12.2	67.5	15.3	79.3
13.88	73.8	13.0	71.8	16.3	84.4
15.5	81.0	16.2	82.2	19.3	91.0
17.25	86.5	17.6	86.4	23.4	95.3
18.5	87.8	20.0	90.0	24.5	96.5
18.75	90.0	21.6	93.2	25.0	97.5
21.4	92.25	24.25	96.0	26.0	98.2
22.3	94.4	26.0	97.4	26.25	98.8
23.8	95.5	26.6	98.2	27.1	99.3
25.4	96.6	27.12	98.2	27.75	99.5
27.6	97.5	27.6	98.7	28.0	100.0
28.9	98.4	28.6	99.2		
30.25	98.7	29.0	99.5		
31.5	99.2	29.88	100.0		
32.0	99.5				
34.0	100.0				

TABLE II

PERCENTAGE MOISTURE CONTENT OF SHORTLEAF PINE HEART-WOOD SHAVINGS
AT VARIOUS ATMOSPHERIC HUMIDITIES AND AT 25° C.

Samples of .49 specific gravity		Samples of .61 specific gravity		Samples of .70 specific gravity		Resinous samples of .82-.90 specific gravity		
I	II	III	IV	V	VI	VII	VIII	IX
Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Per cent resin
3.8	10.3	3.2	8.0	3.875	9.4	6.62	24.8	15.6
4.75	13.6	6.2	20.4	5.12	15.6	7.9	33.6	16.2
6.5	23.2	7.0	26.2	6.00	19.0	8.5	38.5	16.7
7.2	30.2	7.6	31.8	7.12	27.8	9.32	43.5	16.2
7.5	33.2	7.7	34.6	7.5	30.3	10.2	49.6	15.6
9.0	41.5	8.4	36.	8.4	37.2	10.34	54.4	18.2
10.7	51.8	8.7	40.4	9.8	45.6	11.32	57.4	17.6
12.3	61.0	10.1	44.2	11.38	55.8	12.3	63.0	17.6
14.5	71.0	10.2	47.4	13.18	65.8	13.7	70.0	16.7
16.7	78.0	11.2	53.8	15.86	75.6	13.88	72.6	18.2
18.0	82.4	11.8	59.3	16.4	79.2	14.8	75.6	15.6
19.7	87.5	13.12	63.2	17.37	80.4	16.0	80.4	18.2
21.75	92.0	12.75	65.0	18.62	86.0	16.28	83.2	15.6
23.3	94.5	13.6	67.5	20.7	90.0	17.5	86.0	16.2
24.0	95.0	15.6	72.8	22.12	93.0	18.25	88.2	16.2
25.5	96.0	16.14	76.6	22.75	94.0	18.7	90.6	15.6
28.8	97.8	17.3	78.8	24.25	95.60	19.5	91.4	18.2
30.7	98.4	18.4	84.4	25.2	97.0	20.11	94.4	17.6
32.55	98.8	19.4	85.3	28.08	100.0	20.52	96.2	18.2
36.25	100.0	19.7	88.6			21.4	96.6	18.2
		20.3	88.8			21.41	98.6	17.6

TABLE II—Continued

PERCENTAGE MOISTURE CONTENT OF SHORTLEAF PINE HEART-WOOD SHAVINGS
AT VARIOUS ATMOSPHERIC HUMIDITIES AND AT 25° C.

Samples of .49 specific gravity		Samples of .61 specific gravity		Samples of .70 specific gravity		Resinous samples of .82-.90 specific gravity		
I	II	III	IV	V	VI	VII	VIII	IX
Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Per cent resin
		21.2	91.			22.25	100.0	17.6
		22.6	93.2					
		24.75	96.2					
		25.75	97.0					
		27.12	98.0					
		29.32	98.8					
		31.25	99.4					
		33.10	100.0					

TABLE III

PERCENTAGE MOISTURE CONTENT OF LONGLEAF PINE SAP-WOOD SHAVINGS AT VARIOUS ATMOSPHERIC HUMIDITIES AND AT 25° C.

Samples of .41-.42 specific gravity		Samples of .70 specific gravity		Samples of .75-.80 specific gravity	
I	II	III	IV	V	VI
Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)
3.88	9.3	4.64	12.3	5.4	15.8
6.78	28.10	6.24	21.4	6.89	26.1
8.24	37.4	7.21	28.2	7.88	34.0
9.52	47.8	7.30	31.4	8.64	40.6
10.83	56.4	9.21	44.7	9.78	50.8
12.2	64.2	10.11	49.4	10.68	55.1
13.77	71.6	10.38	53.6	11.27	61.2
14.82	75.8	11.50	58.6	12.77	67.3
17.59	83.7	12.54	65.8	15.73	79.0
20.31	88.2	13.42	69.3	19.32	87.2
22.38	92.5	14.15	73.8	21.71	91.2
24.14	94.6	16.51	80.3	23.58	94.6
24.88	95.4	17.07	82.5	23.96	95.4
25.76	96.2	18.48	85.5	24.54	96.1
26.63	96.7	20.74	89.7	24.74	97.2
28.64	97.8	23.35	94.2	25.32	97.7
30.52	98.7	23.76	94.6	26.14	98.8
32.18	99.1	24.26	95.3	27.02	100.0
35.76	100.0	25.61	96.8		
		26.80	97.4		
		27.63	98.6		
		28.59	99.1		
		30.28	100.0		

TABLE IV
 PERCENTAGE MOISTURE CONTENT OF LONGLEAF PINE HEART-WOOD SHAVINGS
 AT VARIOUS ATMOSPHERIC HUMIDITIES AND AT 25° C.

Samples of .51 specific gravity		Samples of .70 specific gravity		Samples of .75- .80 specific gravity		Resinous samples of .86-.94 specific gravity		
I	II	III	IV	V	VI	VII	VIII	IX
Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Moisture in shavings (per cent)	Relative humidity of chamber (per cent)	Per cent resin
3.89	10.6	3.68	9.8	4.12	11.8	6.25	23.1	19.3
4.48	12.6	5.0	15.0	5.62	18.6	7.24	31.2	17.1
5.32	17.6	5.88	20.0	7.14	26.6	7.9	38.3	18.4
6.78	26.0	7.14	28.2	7.16	29.4	9.42	51.6	16.4
7.82	31.6	7.64	33.0	7.8	34.8	9.36	55.4	19.3
8.84	46.6	8.25	40.0	8.88	49.6	9.71	58.7	19.3
10.08	54.8	8.62	42.2	9.87	53.0	10.58	58.7	18.4
11.06	59.8	9.28	48.2	10.21	57.6	10.27	60.8	17.1
12.2	66.4	9.31	50.0	10.68	61.2	11.28	64.4	16.4
13.8	74.4	10.78	60.0	11.28	62.5	11.76	66.0	16.4
15.52	81.4	11.64	63.6	11.72	65.1	12.26	68.7	18.4
17.10	85.4	12.72	70.0	13.38	72.9	12.2	70.8	16.4
20.10	90.8	16.22	83.8	14.27	76.6	12.81	71.7	17.1
21.78	93.4	17.4	86.8	18.54	88.3	13.02	74.3	18.9
23.68	95.6	19.21	89.4	19.71	90.7	13.94	78.0	17.1
25.1	96.6	22.79	94.6	20.86	92.1	14.31	78.7	16.4
26.62	97.4	24.36	96.51	23.27	95.6	14.82	82.4	19.3
27.8	98.0	26.11	98.	24.01	96.5	15.13	84.7	19.3
30.32	99.0	27.57	99.2	25.24	97.9	16.08	86.9	17.1
33.2	100.0	29.1	100.0	26.11	99.1	17.0	90.3	19.0
				26.89	100.0	16.75	91.5	16.4
						18.48	93.5	19.0
						17.41	93.8	19.3
						18.74	95.1	19.0
						19.66	95.3	16.4
						20.14	97.2	18.4
						20.15	99.1	18.4
						21.12	100.0	18.4

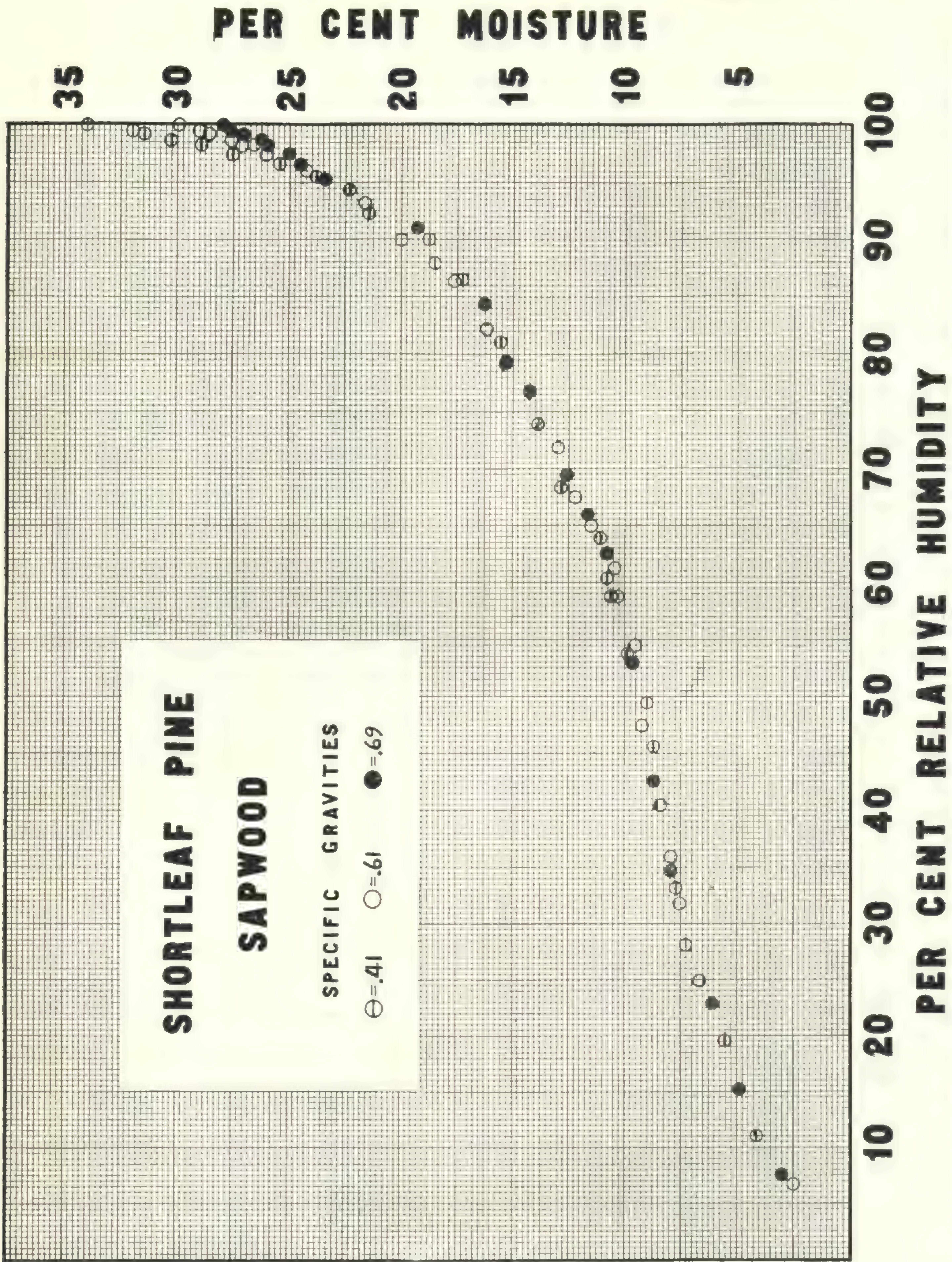


Fig. 1. Curve showing the moisture content of the sap-wood of shortleaf pine (*Pinus echinata*) at various atmospheric humidities and at 25° C.

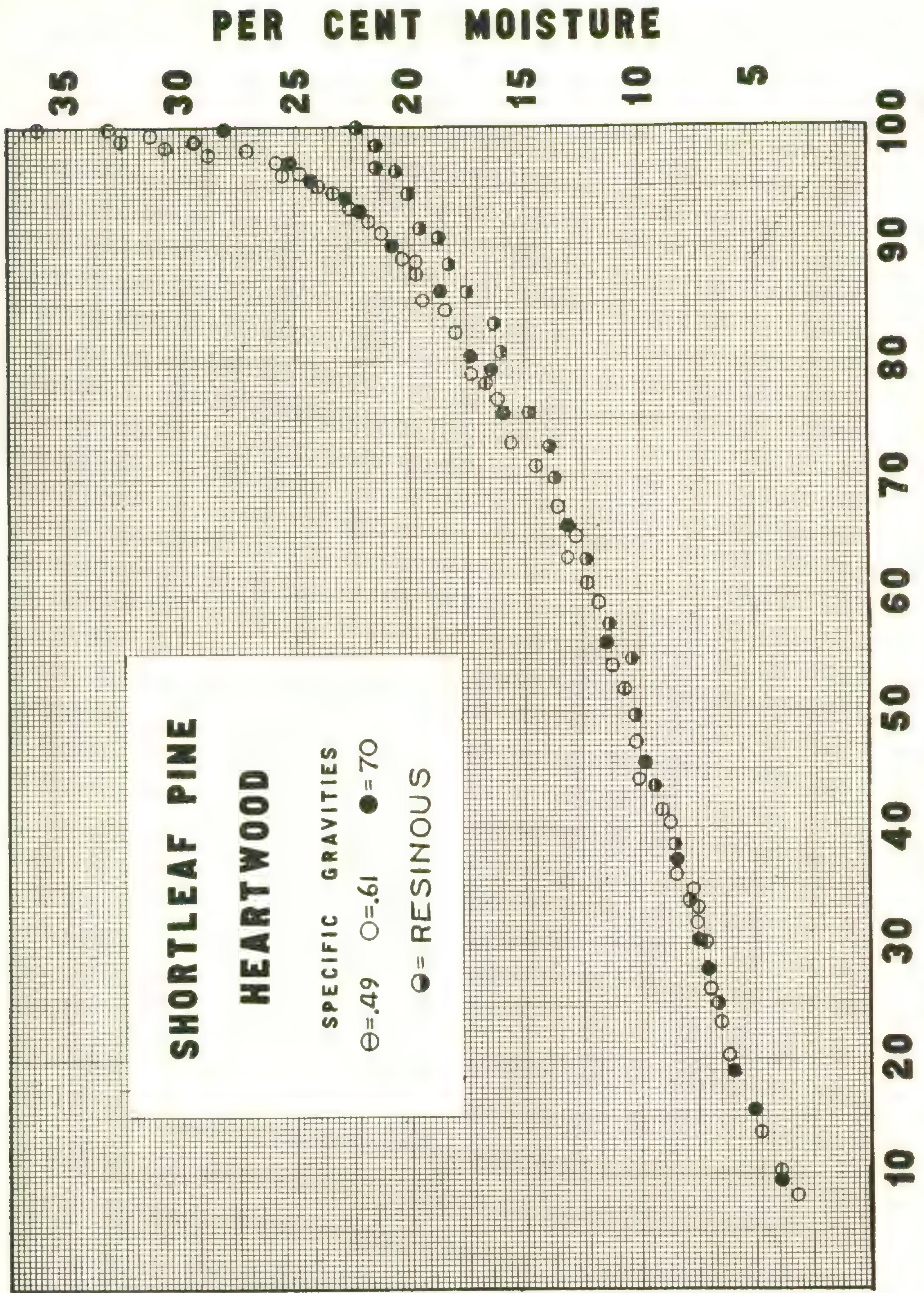
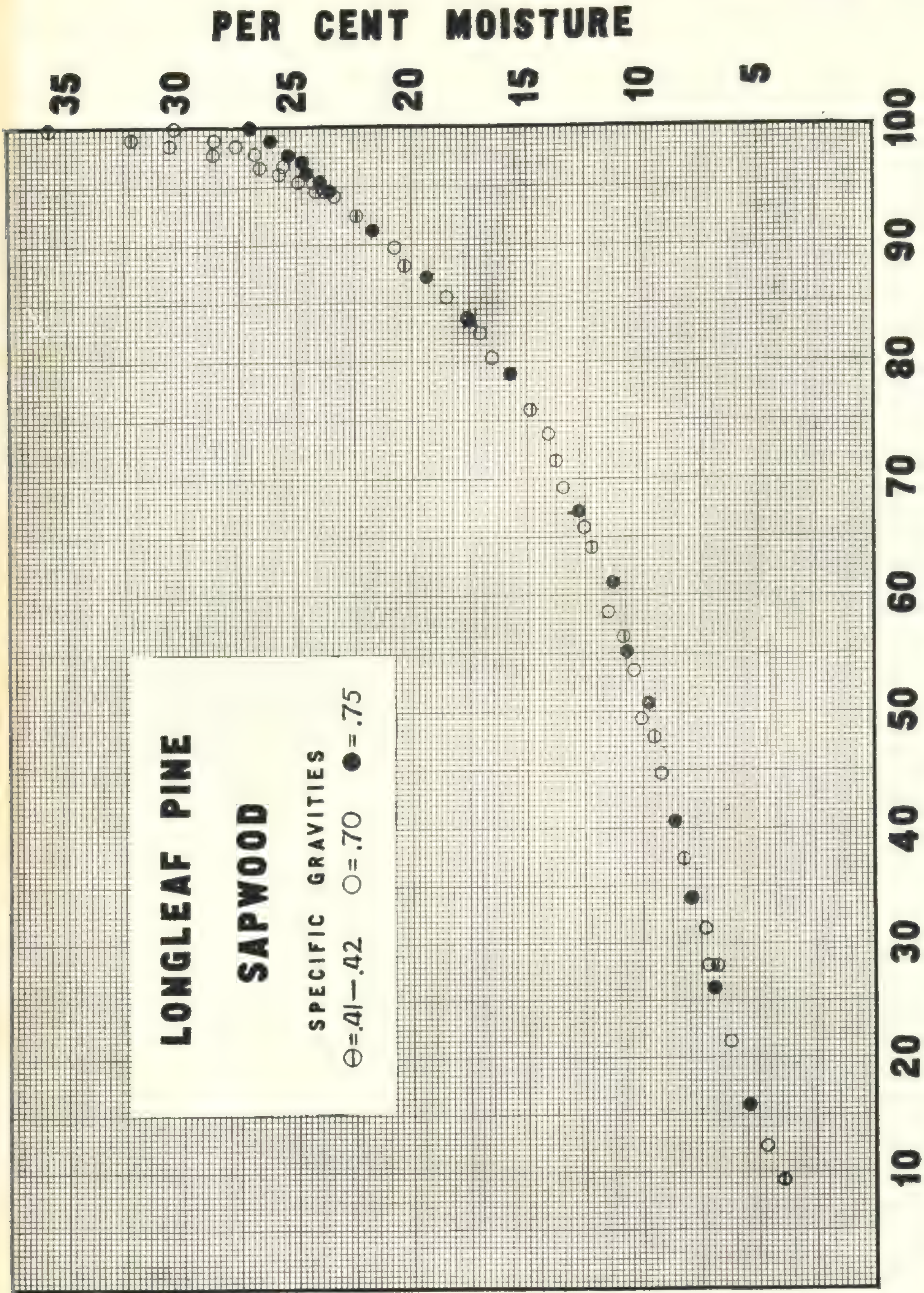


Fig. 2. Curve showing the moisture content of the heart-wood of shortleaf pine (*Pinus echinata*) at various atmospheric humidities and at 25° C.



PER CENT RELATIVE HUMIDITY

Fig. 3. Curve showing the moisture content of the sap-wood of longleaf pine (*Pinus palustris*) at various atmospheric humidities and at 25° C.

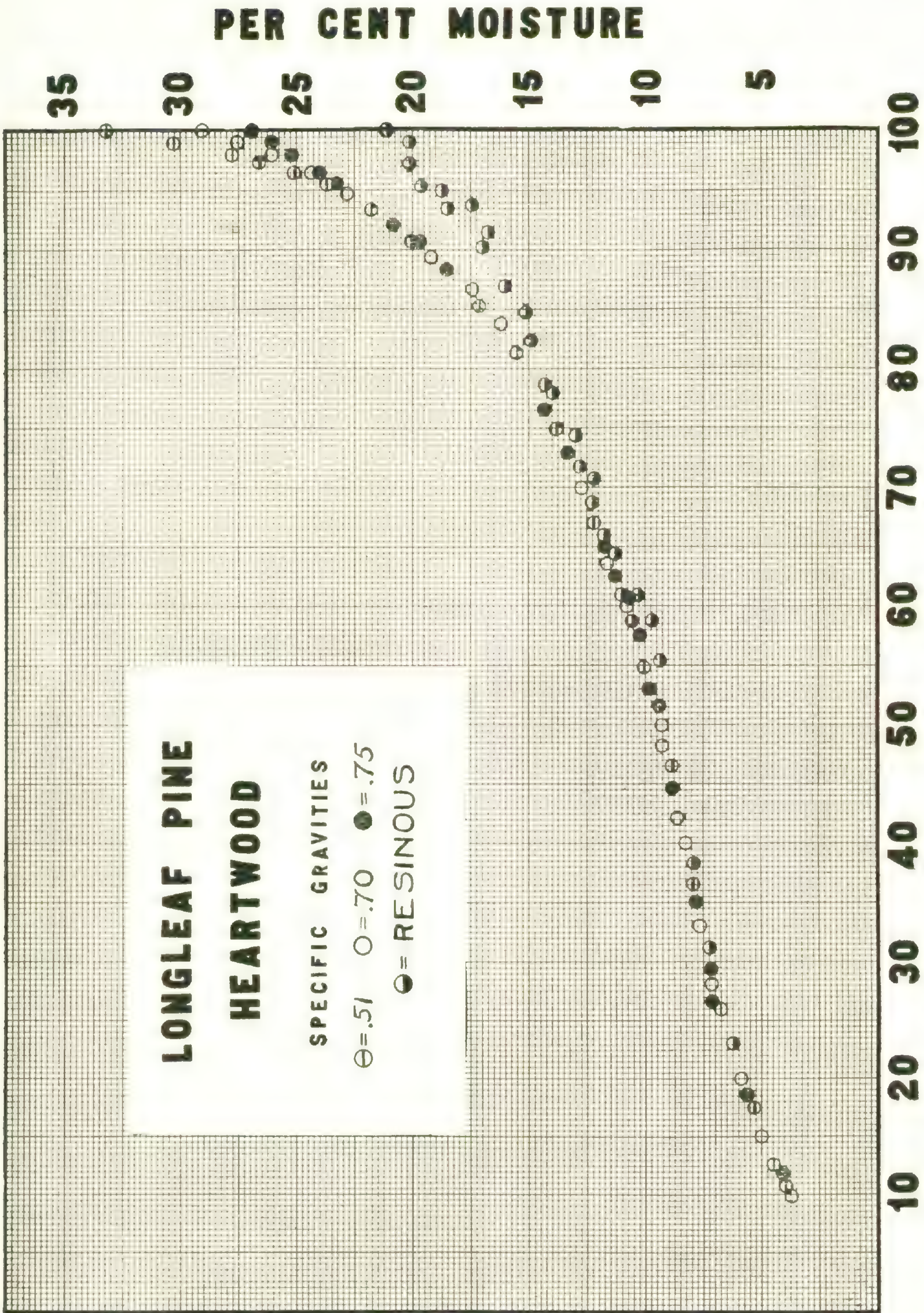


Fig. 4. Curve showing the moisture content of the heartwood of longleaf pine (*Pinus palustris*) at various atmospheric humidities and at 25° C.

absorption of moisture by certain morphological and mechanical properties of the woody tissues which vary with the different species of wood. This variation in morphological and mechanical characters in the wood of different species will account for the slight differences in moisture content at the fibre-saturation point of shortleaf and longleaf specimens. The moisture content at the so-called fibre saturation point of the four curves is approximately as follows: shortleaf pine sap-wood, 24.25 per cent, heart-wood, 24.5 per cent, and longleaf pine sap-wood, 23.75 per cent, and the heart-wood, 23.25 per cent.

In timber-testing laboratories the fibre-saturation point of wood has been determined by means of strength tests, and has been defined by Tiemann ('07) as "the degree of moisture at which maximum absorption by the cell walls is reached." After this point is reached added moisture does not lessen the strength. Beginning with the dry conditions, with the increase of moisture the strength falls off very rapidly at first, then more slowly as the fibre-saturation point is reached, and here it abruptly ceases to decrease. This abrupt break in the moisture-strength relation represents the fibre-saturation point. The moisture per cent at fibre-saturation for longleaf pine as determined by Tiemann ('07) by compression tests on small specimens averaged 25 per cent, with a maximum at 26 per cent and a minimum at 24 per cent. This is not far removed from the moisture content at which the curves representing the three different specific gravities of longleaf pine diverge in figs. 1 and 2.

If this divergence of the moisture-humidity curve represents the fibre-saturation point the appreciable increase in moisture up to 100 per cent humidity must be moisture in the form of a surface film; that is, the fibre-saturation point is the point where absorption or imbibition by the fibre is replaced by a surface phenomenon, adsorption. In a unit weight of wood fibre the thin-walled, large-lumened cells, having a lower specific gravity than the heavy-walled, small-lumened cells, present a much greater surface than the latter. If the greater concave curvature of the smaller-lumened cells has any tendency to thicken the surface film in proportion to that adsorbed by those having less curvature, the difference in the total moisture created in this way evidently is not great enough to overcome the difference resulting from the difference in surface.

This relation of the moisture content of wood at various relative humidities has been demonstrated for other woods by workers at the United States Forest Products Laboratory located at Madison, Wisconsin. This work is reported in "Wood in Aircraft Construction" (1919) which was prepared by the above-mentioned laboratory for the United States Navy Department. The five woods worked with were Sitka spruce, black walnut, white oak, yellow birch, and ash, and the maximum moisture content at 100 per cent humidity ranged from about 29.5 to 30.2 per cent for Sitka spruce to about 36.7 per cent for ash. A report by Pfeiffer on the physical properties of several Javanese woods includes a study of their moisture contents at various atmospheric humidities. The maximum moisture contents of the various woods at 100 per cent humidity were as follows: *Tectona grandis* (teak wood), 21 per cent; *Ensideroxylon Zwageri*, 22 per cent; *Shorea* sp., 24 per cent; *Dipterocarpus* sp., 23 per cent; *Shorea* sp., 30 per cent, and *Alstonia* sp., 25 per cent. The specific gravities of these woods were .64, 1.04, .88, .64, .41, and .34, respectively. Although the order of increase in maximum moisture content in these Javanese woods is not in exactly the same order as the decrease in their specific gravities, there is a tendency in that direction. Of course, a direct relation throughout could not be expected because of the great differences in morphological and physical structures between various species.

RESIN CONTENT IN RELATION TO MOISTURE ABSORPTION

The data on this subject as presented in tables II and IV and illustrated graphically in the curves shown in figs. 2 and 4 are self-explanatory and for the most part need no discussion. However, there are a few points of interest which might be discussed briefly. In the lower part of the curves, where the relative humidity is less than 50 per cent, the points representing the highly resinous samples of wood show no deviation from the moisture curves of those samples of wood containing less than 5 per cent resin. Above 50 per cent humidity, however, there is a gradual deviation of the curve representing highly resinous specimens. This moisture curve is lower than that representing specimens containing less than 5 per cent resin. This illustrates the fact that resin actually has a water-proof-

ing effect upon the wood containing it, and that this water-proofing effect is considerable as the fibre-saturation point is approached. In the shortleaf heart-wood at a relative humidity of 95 per cent the moisture absorption was decreased 15.6 per cent by 17.6 per cent resin, and at 100 per cent humidity the minimum moisture decrease was 20.8 per cent, and the average decrease was 31.5 per cent brought about by 17.6 per cent resin. In the longleaf pine heart-wood at a relative humidity of 95 per cent a resin content of 16.4–19 per cent had a water-proofing effect of 17.4 per cent, while at 100 per cent humidity the water-proofing effect of 18.4 per cent resin averaged 29.3 per cent, with a minimum of 21.5 per cent reduction in the moisture content.

Undoubtedly, this water-proofing effect of resin has its influence upon the durability of structural timber placed under *very* humid conditions, providing the resin content is sufficient to lower the moisture content of the wood below that which is conducive to the growth of wood-decaying fungi. Although the resin does have some influence in this direction, it is probably not sufficient to be relied upon as a test of durability. More reliance could be put upon resin as an index of durability in timbers containing, for example, 12 to 15 per cent resin, providing there was any reason to believe that it was equally distributed throughout the timber. With such an equal distribution of the resin the water-proofing would undoubtedly be more effective at lower relative humidities. Not only this, but mechanical resistance of resin equally distributed would undoubtedly be a great factor in the inhibition of fungous growth in the wood. This, however, is not the case. The resin is deposited in streaks in wood so that there are portions relatively free from resin. These resin-free portions, having a hygroscopicity sufficient to take up considerable moisture under the right moisture conditions, become sources of weakness because of the inroads of wood-destroying fungi. Examples of such decay are often reported as very destructive to the ceilings and structural timbers under the highly humid conditions produced in the paper- and pulp-mills of the eastern states and Canada and the knitting-sheds of the cotton industries of New England. Further experimentation along this line is advisable. Some practical process of treating resinous lumber, possibly by modifying the kiln-drying

processes so as to distribute the resin more evenly, is a worthy project of investigation of this important problem in these industries.

SPORE GERMINATION ON WOOD

The spores of wood-destroying fungi exhibit a marked similarity with regard to their requirements for germination. Some of the factors which influence germination are proper temperature and proper amounts of acidity and moisture. As early as 1860 Hoffmann ('60) found that in a period of five days spores of *Polyporus versicolor* germinated in moist air, and in a period of six days spores of *P. squamosus* germinated better in moist air than in water. On the other hand, Falck ('09) says that the spores of *Lenzites* on wood germinate only when the wood has been thoroughly saturated by rains.

To determine more accurately the relation of moisture to the germination of spores of a wood-destroying fungus the following experiments were conducted, using the spores of *Lenzites saepiaria*. The spores of this fungus were obtained from rejuvenated fruiting bodies as described in a previous paper (Zeller, '16). The spores were allowed to drop from the fruiting bodies directly upon thin shavings of shortleaf pine (*Pinus echinata*) sap-wood, or were caught in Petri dishes and transferred to the shavings in a loop of sterile distilled water and allowed to dry rapidly in the air.¹

The shavings upon which the spores were deposited were clamped in a small device which may be described as follows: Two pieces of sheet celluloid, about the size of a microscope slide, were riveted together at one end by means of a paper rivet, and a round hole about 1 cm. in diameter was cut through the middle of the two celluloid slides. The pieces of celluloid were bent apart while a shaving to which the spores were adhering was slipped between, the other end of the pieces of celluloid being clamped together by means of a paper clip. The shaving is thus held so that it covers the hole in the middle of the device

¹ A decoction from 60 gms. of shavings of shortleaf-pine sap-wood was prepared by steaming the shavings in a reflux with 10 cc. of distilled water. This decoction tested P_H 4.2, so that the actual active acidity of the shavings probably was not above P_H 3.8. This would be well toward the optimum acidity (P_H 3.1) for the germination of the spores of *Lenzites saepiaria* as reported by Webb ('19).

and is exposed to the air from both sides. These devices were numbered, and after the chamber of the humidor, described elsewhere in this paper, had come to a constant humidity, one of them was lowered into the chamber through the opening in the top. By means of the lever it was hung on a wire without opening the chamber. In this way spores were exposed to the atmospheric conditions of the chamber without coming in contact with any other object. A new shaving was added to the chamber on 12 successive days. All were removed at one time, examined under the microscope, and the percentage of germination estimated on the basis of the total number of spores in a unit field. In table v the percentages of germination

TABLE V

RELATION OF THE GERMINATION OF THE SPORES OF LENZITES SAEPIARIA TO THE RELATIVE HUMIDITY OF THE ATMOSPHERE AT 25° C.

Germination period (days)	Per cent germination (averages)	Per cent relative humidity	Germination period (days)	Per cent germination (averages)	Per cent relative humidity
10	1.5	63.0	5	76.0	96.5
10	2.5	65.0	5	85.5	98.5
10	3.5	67.4	5	100.0	99.0
10	2.5	72.5	5	100.0	98.0
7	4.0	78.5	5	95.0	98.0
7	7.5	82.5	6	57.5	96.0
7	5.5	85.5	6	80.0	98.0
7	10.0	89.8	6	87.5	98.0
5	20.5	90.5	6	92.0	99.0
5	25.5	92.5	6	96.5	99.0
5	70.0	95.5	6	100.0	98.5

are the averages of three or four counts. In fig. 5 the relation of spore germination to relative humidity is presented graphically. This curve indicates that until the fibre-saturation point is reached the percentage of spore germination is very low, but as soon as the humidity of the air is sufficiently high to supply free

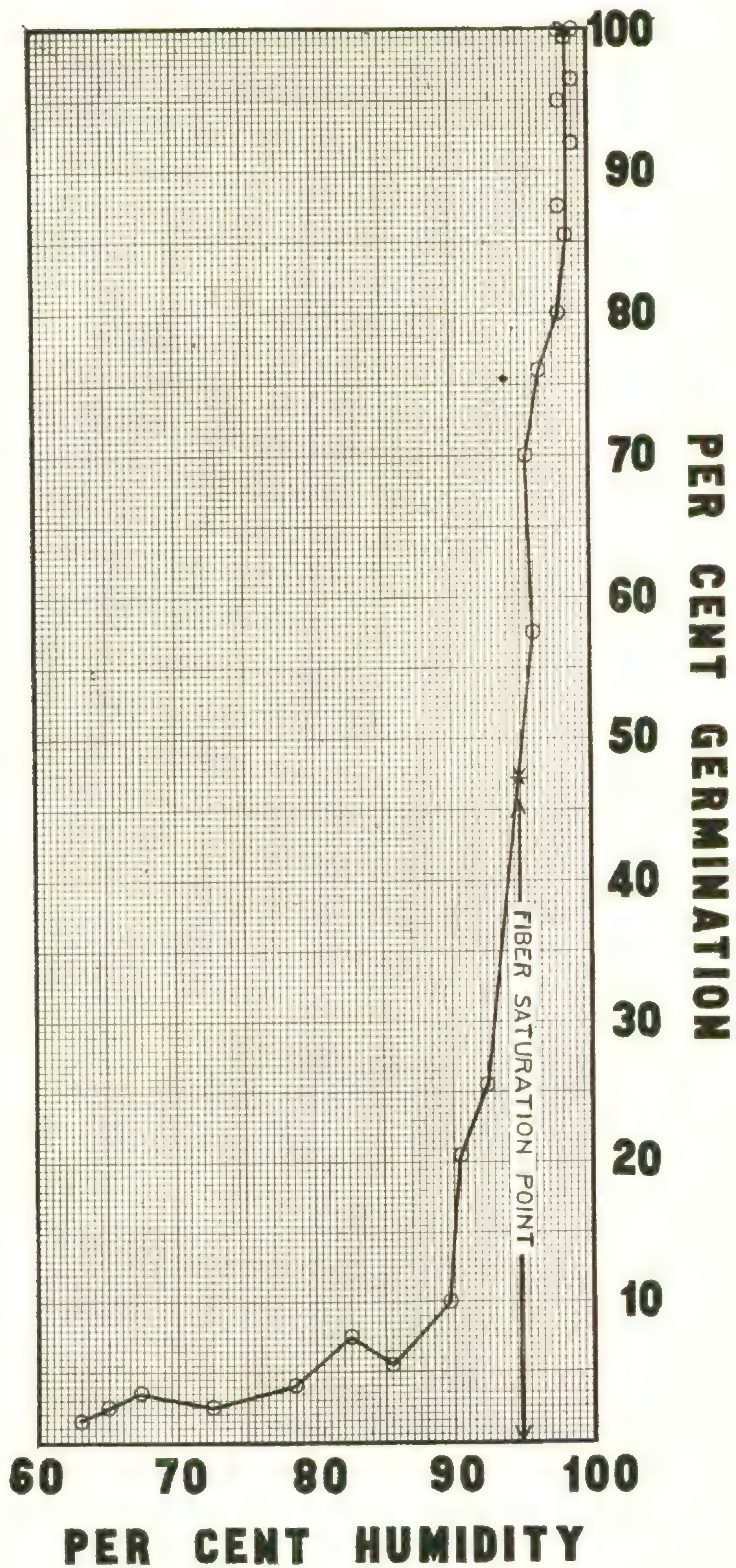


Fig. 5. Curve showing the percentage of germination of spores of *Lenzites saepiaria* on shavings of the sap-wood of *Pinus echinata* at various atmospheric humidities and at 25° C.

water as a film on the wood surface the spores of *Lenzites saepiaria* show a high percentage of germination.

By growing *Ceratostomella coerulea* upon blocks of pine sapwood Münch ('09) found that free-water on the wood was necessary to sustain growth. Growth is maintained if fibre-saturation is maintained, but if the water of imbibition falls below the saturation point the wood seems to demand water at the expense of the mycelium. Although true for *Ceratostomella* this very probably is not true for the mycelium of such fungi as *Lenzites saepiaria*, *Merulius lacrymans*, or *Coniophora cerebella*, which after becoming well established, seem to maintain a water supply from some unknown source. This is especially the case with *Merulius lacrymans*. Wehmer ('14) found that this fungus would not grow on blocks of wood in ordinary cellar humidity unless the blocks were first saturated with water. After the growth was well established, however, the water content of the wood was maintained by the fungus above that in sound wood under the same conditions.

It would seem then that for the germination of the spores and the establishment of the mycelium of wood-destroying fungi, the wood must contain enough moisture to saturate the wood fibre. This becomes a serious problem then in such buildings as paper- and pulp-mills and knitting factories where high humidities are maintained. If the temperatures fluctuate across the dew-point, the moisture content of any exposed woodwork is maintained up to fibre-saturation and the wood is sure to decay unless some method of treatment of the timbers is possible.

SUMMARY

In this paper are reported the results of experiments (1) showing the moisture content of wood at various atmospheric humidities and at 25° C. Curves are presented to illustrate this relation for the sap- and heart-wood of both longleaf and shortleaf pine.

(2) By testing the moisture content of any one species of wood samples having various specific gravities at the various humidities it is possible to approximate the fibre-saturation point of the wood.

(3) The moisture-humidity curves of highly resinous samples

of wood illustrate the water-proofing effect of resin on the wood, especially above 50 per cent humidity. It is believed that resin cannot be relied upon as an indication of the durability of lumber although present in amounts as high as 12-15 per cent, for it is seldom equally distributed in the wood. The regions of low resin content are sources of weakness if wood-destroying fungi gain access to them under favorable moisture conditions.

(4) The germination of the spores of *Lenzites saepiaria* on wood shavings was accomplished at various relative humidities ranging from 63 to 100 per cent. The germination curve illustrates the fact that spore germination is exceedingly accelerated when the atmospheric humidity is high enough to maintain fibre saturation of the wood.

(5) A humidior for maintaining constant humidity and temperature is described. It is provided with (1) a dew-point apparatus for the determination of humidity, and (2) a weighing device so that the samples can be weighed without opening the humidity chamber.

The writer wishes to express his appreciation of the financial aid accorded him by the Southern Pine Association, without which this work would have been impossible. Thanks are also due the staff of the Missouri Botanical Garden for coöperation and for facilities for the work, and to Dr. Hermann von Schrenk for helpful suggestions.

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DESCRIPTION OF PLATE

PLATE 1

Fig. 1. A general view of the humidior as described on page 53, with the balances in place and both doors open.

Fig. 2. The interior of the humidior showing the baskets containing the samples of shavings, one basket hanging on the balance and the Milliken dew-point apparatus in the central foreground.

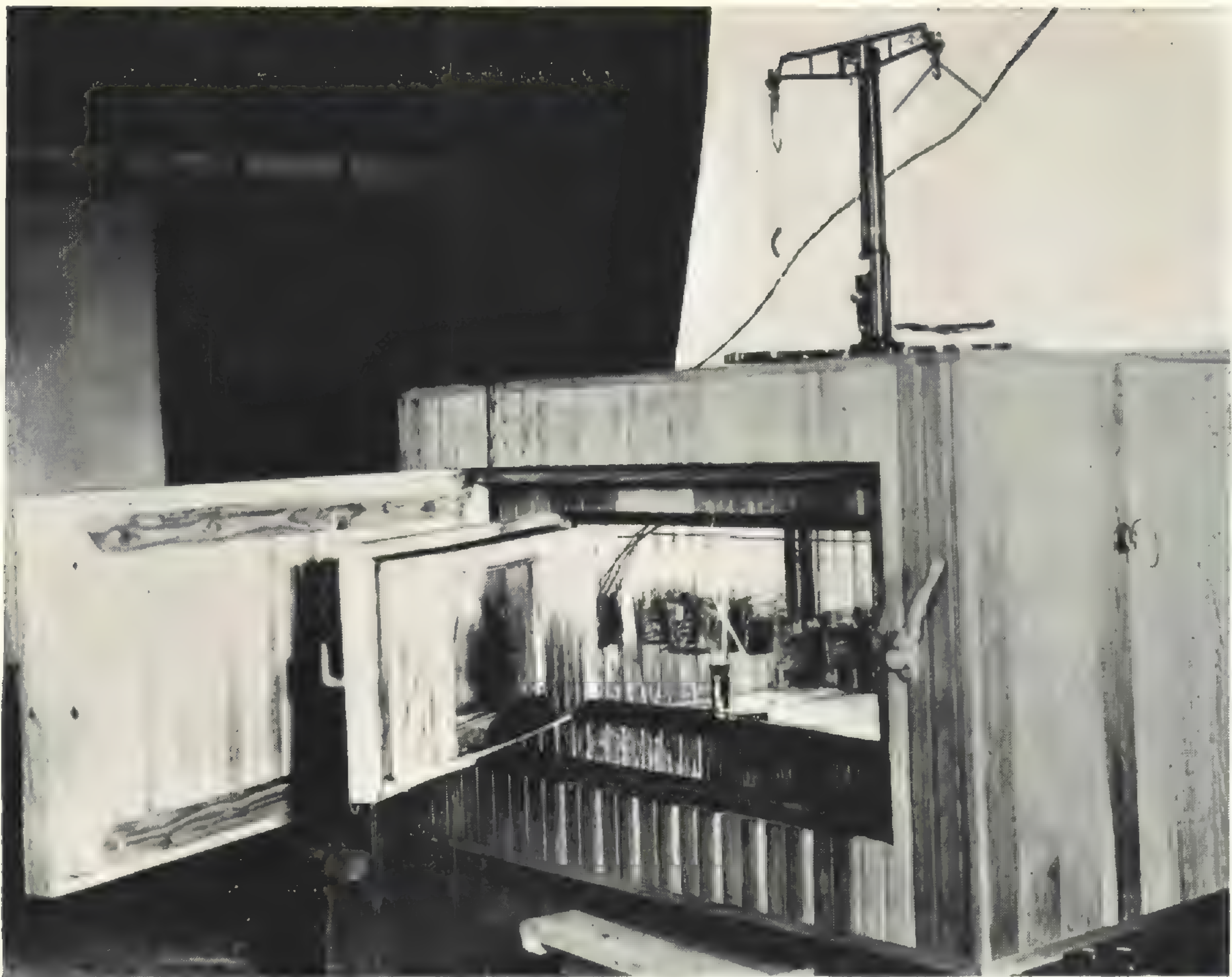


FIG. 1



FIG. 2

ZELLER, IMBIBITION BY WOOD, AND SPORE GERMINATION

ON CARBOHYDRATE CONSUMPTION BY AZOTOBACTER CHROOCOCCUM

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In a previous paper (Allen, '19) devoted mainly to the study of the cause of beneficial action resulting from mechanical agitation of *Azotobacter* solution cultures, the defects of existing experimental methods for the study of the physiology of this organism were pointed out. The present report covers a continuance of these studies aimed at the following improvements: (1) renewal of the energy source in the cultures; (2) simultaneous determinations of nitrogen and of residual carbohydrate at short intervals; and (3) mechanical improvements.

The object of the first of these improvements was, of course, to produce heavier growths in the cultures and therefore more marked changes in the amounts of metabolic products, thus increasing the reliability of the measurements of such changes. In view of the theoretical considerations of Duclaux ('98-'00) in regard to the rate of increase in the number of cells, we were justified in expecting a mounting rate of total physiological activity as growth proceeded, until the normal rate of development was checked by the accumulation of unfavorable by-products. The method of renewal of energy-supplying material has been used, for example, with marked success by Bonazzi ('19) in his investigations of the organisms of nitrification.

The second improvement was designed to furnish a more complete picture of growth processes of *Azotobacter* than is obtainable by the determination of one, or even two, metabolic products at the end of an arbitrarily chosen incubation period. Unfortunately, the "micro" determination of carbohydrate and nitrogen on the same sample proved more difficult than was expected, and had to be postponed for the time being. The present work, therefore, lacks this improvement over that reported previously.

The third improvement was to facilitate experimental manipulation and possibly obtain even better results from mechanical agitation. The type of agitation decided upon was a slow

rate of revolution of round-bottomed culture flasks held in a horizontal position. A rotating device was constructed, which held a vertical wooden wheel, to the rim of which were attached, horizontally, four one-liter round-bottomed flasks. The wheel revolving at the rate of one revolution in five minutes kept the culture medium in a slow, uniform motion.

Only one experiment was conducted, and, as pointed out above, it was lacking in the second improvement. Carbohydrate only was determined at short intervals, and the only renewal of this material was in two of the flasks on the rotator. The results obtained were so consistently contrary to expectation that the data from even the one experiment is of some interest; that is, as measured by carbohydrate consumption, the cultures showed a declining instead of an increasing metabolic activity.

The *Azotobacter* culture used was a later generation of the same strain used in previous work. The nutrient solution was prepared as follows:

Solution A:

Dipotassium phosphate	0.2 gm.
Sodium chloride	0.2 gm.
Dextrose	20.0 gms.
Water, distilled	500.0 cc.

Solution B:

Magnesium sulphate	0.2 gm.
Calcium sulphate	0.1 gm.
Water	500.0 cc.
Ferric chloride (10 per cent sol.)	3 drops

Solutions A and B were mixed, and 100-cc. portions then placed in each of four one-liter round-bottomed flasks and in each of two two-liter Erlenmeyers, all flasks receiving in addition 1 gm. calcium carbonate. The flasks were then plugged with cotton and capped with beakers in the usual way. After sterilization by the intermittent method, all except one round-bottomed flask were inoculated with a spiral of a suspension prepared from an agar slant, the round-bottomed flasks placed in position on the rotator, and the Erlenmeyers on a shelf nearby. The whole experiment was set up in a warm room kept at 28–30° C. by a thermostat.

The experiment was started March 14, 1919. Two days later a distinct turbidity appeared in the inoculated flasks on the

rotator, and a lesser one in the Erlenmeyers on the shelf. At short intervals 5-cc. samples were removed aseptically and submitted to duplicate sugar determinations by the modified Shaffer method described in the previous paper (Allen, '19). Cultures II and IV received on March 24, 25 cc. of an 8 per cent dextrose solution. Culture No. III was unfortunately lost at this point.

The data are reported as dextrose remaining per 100 cc. of culture solution, no correction being made for evaporation; that is, if a 5-cc. sample is found to contain 35 mgs., the value reported is 0.7000 gm., regardless of the total volume of the culture at the time.

The results appear in tabular form in tables I and II, and in graphical form in fig. 1.

TABLE I

NUMBER GRAMS RESIDUAL DEXTROSE PER 100 CC. CULTURE SOLUTION AT DIFFERENT PERIODS

Culture no.	March 17	March 19	March 24	March 28	April 2
Rotator: (round-bottomed flasks)					
I (Check)	2.1565				
II	1.2732	0.7600	0.110-2.060	1.976	1.255
III	1.4822	1.3507	0.908-Lost		
IV	0.9410	0.5700	0.069-2.023	1.842	1.358
Shelf: (Erlenmeyer flasks)					
V	1.7257		1.636	1.674	1.523
VI	1.5962		1.418	1.507	1.389

TABLE II

MILLIGRAMS DEXTROSE CONSUMED PER DAY IN EACH PERIOD

Culture no.	First 3 days	Next 2 days	Next 5 days	Additional 4 days	Additional 5 days
I Check					
II	295	256	130	21	144
III	225	65	88		
IV	405	185	100	45	97

In constructing the graphs the curves were plotted in the normal manner, with the amounts of dextrose on the Y axis and time on the X axis for the first ten days of the incubation period. In order to make the curves for cultures II and IV continuous and harmonic, the Y ordinate is shifted for these

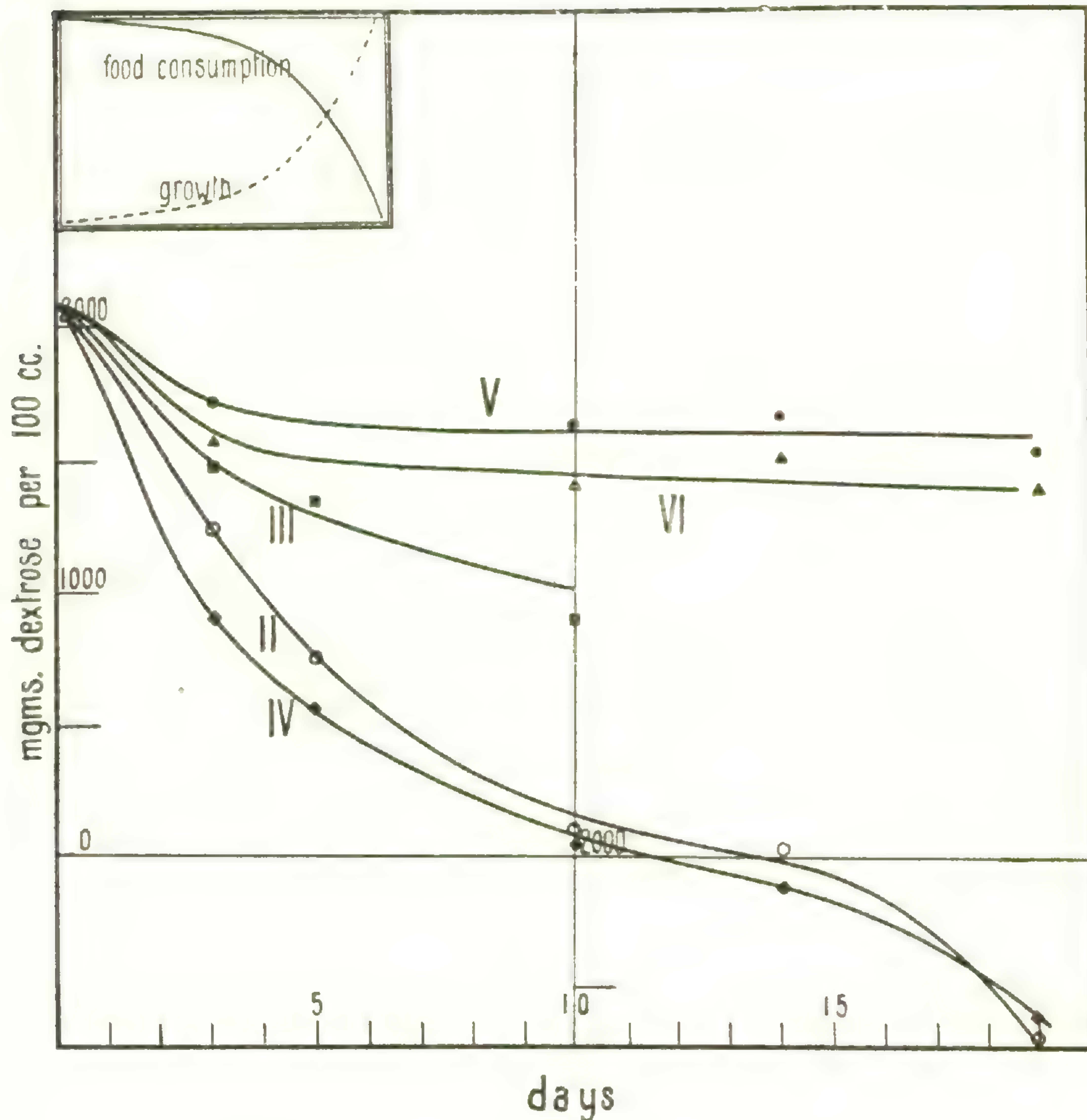


FIG. 1

cultures at the end of 10 days so that the 2000-mgm. point is on the original X axis. The dotted curve in the insert is the Duclaux curve for increase in number of cells, while the solid line represents the type of curve predicted on the assumption that carbohydrate consumption is a simple function of cell multiplication.

The results show that the rate of carbohydrate consumption in *Azotobacter* cultures does not proceed in a manner similar to

the rate of increase in cell numbers predicted by Duclaux for bacterial cultures in general. Indeed, the curves resemble the antipode of the Duclaux curve.

It might be argued that the decrease in rate of sugar consumption with increase of time in the cultures is due to accumulation of by-products, and that this decreased activity corresponds to the falling away from the purely mathematical curve in older cultures, as discussed by Duclaux. The production of toxic substances within seven days in cultures as slow growing and as dilute as these seems to us to be unlikely. Moreover, the fact that the cultures are able to utilize a second portion of sugar seems to us to be opposed to the idea of growth-inhibiting substances in the medium.

The results show also that the cultivation of the organism under the influence of mechanical agitation of a certain type influences to a marked extent the carbon assimilation in its time relations.

On the whole, the experiment emphasizes the need for more studies on the periodic changes in the culture of this organism.

In conclusion, the writer wishes to express his thanks to Professor P. A. Shaffer for rendering this work possible; to Professor B. M. Duggar for suggesting the method of attack, and to Mr. A. Bonazzi for suggestions in regard to the arrangement of the manuscript.

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THE THELEPHORACEAE OF NORTH AMERICA. XII¹

STEREUM

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STEREUM

Stereum Persoon, Roemer Neues Mag. Bot. 1:110. 1794; Obs. Myc. 1:35. 1797, and 2:90. 1799; Fries, Obs. Myc. 1:274. 1815, Gen. Hym. 14. 1836, Epicr. 545. 1838; Hym. Eur. 638. 1874; Berkeley, Brit. Fung. 270. 1860; Morgan, Cincinnati Soc. Nat. Hist. Jour. 10:193. 1888; Sacc. Syll. Fung. 6:551. 1888; Masee, Linn. Soc. Bot. Jour. 27:158. 1890; Engl. & Prantl, Nat. Pflanzenfam. (1:1**): 123. 1898.—*B. Sterea* of *Thelephora*, Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1:105. 1822.—*****Stereum* of *Thelephora*, Persoon, Myc. Eur. 1:116. 1822.—Includes *Podoscypha* Patouillard in Duss, Fl. Crypt. Antilles Fr. 230. 1904.—Includes *Lloydella* Bresadola in Lloyd, Myc. Writ. 1. Myc. Notes 6:51. 1901; Sacc. Syll. Fung. 16:1116. 1902.—Includes *Bresadolina* Brinkmann, Ann. Myc. 7:289. 1909.

Fructifications coriaceous to hard, stipitate, dimidiate or effuso-reflexed; hymenium inferior, not containing setae; intermediate layer of longitudinally arranged hyphae normally present; basidia simple; spores white, even—rough in but few instances.

The species mentioned or described as belonging in *Stereum*

¹ Issued Dec. 8, 1920.

upon its publication are *Stereum hirsutum*, *S. striatum*, *S. purpureum*, *S. nitidum*, and *S. rugosum*, no one of which was designated as the type species.

The species of *Stereum* are here arranged in the usual sections of central-stemmed, lateral-stemmed, merismatoid, and dimidiate and effuso-reflexed species; these sections are convenient for locating species approximately, but one should bear in mind that some species are ambiguous with regard to sectional characters; all the species are probably so variable that individuals may be selected from most gatherings which will prove very misleading for study. For example, *Stereum fasciatum* is properly included in the section of effuso-reflexed species, yet fructifications of this species do occur now and then with elongation of the umbo so great as to lead one to regard such a fructification as lateral-stemmed.

While *Stereum* is a large genus in the number of its North American species, its difficulty is not proportional to the number of species, for the species of each of its several sections differ among themselves microscopically in the absence or presence of definite recognizable organs or combinations of organs, such as conducting organs containing latex (milk), vesicular organs, gloeocystidia, cystidia of various kinds, and noteworthy paraphyses. In the determination of any species, one's effort is soon concentrated upon a small group of four or five species of common structure, some of which may be eliminated by geographic range, spore dimensions, etc. The structural features have been very important in working out the extensive multiplication of species which had arisen in this genus through disregard of the work of earlier mycologists.

As heretofore noted in the case of *Hymenochaete*, the east and west range of the species of *Stereum* is marked in comparison with north and south range; of our 77 species, only 7 range over both north temperate and tropical areas; the other 70 may be arranged in two groups, of which the 29 species comprising the northern group are in the region from Canada to the Gulf states; the other 41 species range from the Gulf states southward. The Gulf states are a region in which northern and southern species overlap in range. The excess of tropical and subtropical species over northern species is due to the small number of northern

stipitate and merismatoid species, of which we have only 5 as against 23 in the warmer southern region. The stipitate and merismatoid species grow sometimes on dead wood and sometimes on the ground; all 49 dimidiate and effuso-reflexed species grow on dead wood, causing its decay, and are distributed 24 in the northern and 18 in the southern area, while 7 others are the species already mentioned as ranging over both north temperate and tropical areas.

KEY TO THE SPECIES

- §I. Central-stemmed species.—Pileus more or less infundibuliform, sometimes deeply split on one side, usually stipitate; stem typically central or eccentric but lateral-stemmed forms are also present in many of the species. 1
- §II. Lateral-stemmed species.—Pileus dimidiate, flabelliform, or wedge-shaped—never infundibuliform—attenuated at the base into a more or less distinct stem. 9
- §III. Merismatoid species.—Pileoli several, somewhat infundibuliform, wedge-shaped, or strap-shaped, borne on or along a common stem. 12
- §IV. Sessile species, wholly lacking stem or stem-like base.—Pileus dimidiate-sessile, umbonate-sessile, or reflexed, all growing on wood—many typically reflexed species may sometimes occur wholly resupinate. 13

§I. CENTRAL-STEMMED SPECIES

1. Fructifications solitary or gregarious. 2
1. Fructifications cespitose. 8
2. Species with pileus always more or less infundibuliform, lacking dimidiate or other lateral-stemmed forms. 3
2. Species having lateral-stemmed forms occurring more or less frequently in collections. 5
3. Neither cystidia nor gloecystidia present; stem not radicated. 4
3. Gloecystidia present; growing on the ground, 1½–3 cm. high, 3 mm.–2 cm. in diameter; in South Carolina to Brazil. 3. *S. Ravenelii*
3. Gloecystidia present; growing on wood; in West Indies to Dutch Guiana. 4. *S. surinamense*
3. Hair-like cystidia present; pileus white, 2–4 cm. high; in New York to Missouri, and in Alabama, Washington and California. 10. *S. diaphanum*
3. Hair-like cystidia present; pileus slightly darker than *S. diaphanum*, 3–5 mm. high; in New York. 11. *S. exiguum*
3. Hymenial organs unknown; growing on the ground, with stem continued by a long radicated portion which penetrates deeply; in French Guiana. 5. *S. macrorrhiza*
4. Growing on wood, 2–15 cm. high and in diameter; upper surface with raised, radial ridges; in Gulf states to Bolivia. 1. *S. caperatum*
4. Growing on wood, 6–11 cm. high and in diameter; upper surface not ridged; pileus and stem velvety; in South America. 2. *S. hydrophorum*
5. Neither cystidia nor gloecystidia present; pileus cartridge-buff to pinard-yellow when fresh; in New Hampshire to North Carolina and Tennessee, and in Japan. 6. *S. Burtianum*
5. Hymenial organs unknown; pileus "straw-colored," 1½ mm. in diameter; stem 4 mm. high; growing on wet ground among moss in Cuba. 7. *S. rivulorum*
5. Cystidia present. 6
5. Gloecystidia present; no cystidia. 7
6. Pileus white, of soft, bibulous texture, 3–5 mm. broad, 5–7 mm. long; on bark and mosses in Cuba. 8. *S. quisquiliare*

6. Pileus drying bright yellow, finally fading in the herbarium, of bibulous texture; in West Indies to Paraguay.....9. *S. aurantiacum*
6. Pileus drying tawny olive to Saccardo's umber, not of bibulous texture but coriaceous-hard instead; lateral-stemmed forms are the more common; 5 mm.-2½ cm. high, 2-10 mm. broad; in New York to Cuba, and in Wisconsin.....12. *S. tenerrimum*
7. Somewhat cespitose, obscurely zonate, not bearing a cluster of coarse processes near base of the pileus, 1½-4 cm. high, 8 mm.-3 cm. in diameter; in Ohio and North Carolina to Mexico and West Indies.....13. *S. pergamenum*
7. With a crest of coarse hairs or processes towards base of the pileus; pileus 6-10 mm. across; on dead *Vitis* in South Carolina.....14. *S. cristatum*
8. Hair-like cystidia more or less numerous but no gloecystidia; pileus cartridge-buff, strigose-squamose; on the ground, Vermont to North Carolina, and in Europe.....15. *S. pallidum*
8. Gloecystidia barely distinguishable, but no cystidia; pileus plicate on both surfaces, with the upper diamine-brown and the hymenium white; on the ground, Porto Rico to British Guiana...16. *S. elegans*
8. Gloecystidia present but no cystidia; pileus drying pale cinnamon; on dead wood, Jamaica to Trinidad.....17. *S. decolorans*

§II. LATERAL-STEMMED SPECIES

9. Fructifications not cespitose..... 10
9. Fructifications cespitose; pileate segments pectinate along their margins; on decaying wood, Carolina to Bolivia.....24. *S. Hartmanni*
9. Fructifications rarely cespitose, usually gregarious; margin of pileus thick and entire; spores 6×5μ, becoming subangular; in Jamaica to Dutch Guiana.....18. *S. radicans*
10. Growing on ground; pileus white when fresh, drying smoke-gray, not zonate; spores 4-5½×3-5μ; in West Indies.....19. *S. pusiolum*
10. Growing on dead wood; pileus of soft bibulous texture, drying pinkish buff, 3-6 mm. wide, 5-7 mm. long; in Cuba and Porto Rico.....23. *S. cyphelloides*
10. Growing on dead wood; pileus not of soft bibulous texture..... 11
11. Pileus drying Verona-brown to chestnut, minutely velvety; stem velvety; spores 4-5×3-4μ; in the West Indies.....20. *S. glabrescens*
11. Pileus whitish when living, livid and pellucid upon drying, 4-6 cm. high, with stem ½-1 cm. long; in Guadeloupe.....21. *S. flabellatum*
11. Pileus white when fresh, drying "reddish brown," 8-15 mm. long, 3-15 mm. broad, often deeply split into segments; in Brazil.....22. *S. fissum*

§III. MERISMATOID SPECIES

12. Densely cespitose and concretescent throughout into a cluster 7 cm. in diameter, with color and aspect of *Tremellodendron pallidum*; in Mexico and Dutch Guiana.....25. *S. craspedium*
12. Fructification a sessile, rosette-shaped mass of reddish brown pileate flaps; in San Domingo.....26. *S. petalodes*
12. Fructification stipitate, white, with many pileate divisions extending out from a common stem; with aspect of doubled forms of *Thelephora caryophyllea* but white; in Cuba.....27. *S. anastomosans*
12. Fructifications cespitose, somewhat creeping by tips of branches becoming attached to the matrix by disks; pileate branches 1-1½ cm. long, 1-2 mm. broad; in Brazil.....28. *S. proliferum*

§IV. EFFUSO-REFLEXED SPECIES

13. Hyaline, flexuous gloecystidia conspicuous in the subhymenium and hymenium..... 15
13. Pyriform, vesicular organs present in trama, subhymenium, or hymenium... 16
13. Colored conducting organs in trama, subhymenium, or hymenium; cystidia absent; hymenium bleeds when wounded, if in vegetative condition. *S. hirsutum* and *S. rameale* sometimes have occasional colored conducting organs in the hymenium..... 17

13. Not having gloeocystidia, vesicular organs, nor colored conducting organs . . . 14
14. Hymenium lacking cystidia and paraphyses of noteworthy form or color 18
14. Cystidia present, incrustated or without incrustation and hair-like, hyaline, or colored 22
14. Paraphyses noteworthy by bottle-brush form, branching, or color. For species having cystidia in addition to noteworthy paraphyses, see 27 28
15. Coriaceous, dense, tawny, zonate, not sulcate, thin, 5-10 mm. in diameter; in Jamaica 29. *S. caespitosum*
15. Soft, spongy, snuff-brown to bistre, concentrically sulcate, reflexed 1-4 cm.; of wide range 30. *S. fuscum*
15. Coriaceous-fleshy, bursting out from the bark, wart-like, peltate, vinaceous-brown, 2-4 mm. in diameter; no cystidia; on poplar 31. *S. rufum*
15. Coriaceous-cartilaginous, shield-shaped, wood-brown, 1-4 mm. in diameter; cystidia present; on pine 32. *S. Pini*
16. Coriaceous-soft, tomentose, lacking cystidia 33. *S. purpureum*
16. Coriaceous-soft, tomentose, often with hairs becoming agglutinate into a rugose surface; hair-like cystidia present . . . 34. *S. rugosiusculum*
16. Corky, usually resupinate, sometimes reflexed and with the upper side a horny crust; vesicular bodies very numerous 35. *S. Murrayi*
16. Stony hard throughout, the cut surface with a horn-like luster, 1-5 mm. thick; vesicular bodies few; in Mexico and Jamaica . . 36. *S. saxitas*
17. Exuding a yellow milk, conducting organs of pale color; narrowly reflexed, tomentose; on *Liquidambar* and *Carpinus* in North Carolina and Alabama 37. *S. styracifluum*
17. Milk red, conducting organs dark, numerous; fructifications cespitose-imblicated, villose to hirsute, tobacco-colored; on oak, Canada to Alabama and westward 38. *S. gausapatum*
17. Milk red, conducting organs few; fructifications tomentose, concentrically sulcate, not cespitose; Florida to Brazil 39. *S. australe*
17. Milk red, conducting organs dark, numerous; fructifications narrowly reflexed; hymenium multizonate; on frondose species, Newfoundland to North Carolina 40. *S. rugosum*
17. Milk red, conducting organs numerous; on pine, spruce, and hemlock, Canada to Pennsylvania and westward to the Pacific coast. 41. *S. sanguinolentum*
18. Fructifications sulphur-colored, fading to cartridge-buff; intermediate layer not bordered by a golden, denser zone; Georgia to Brazil, and in Germany 42. *S. sulphuratum*
18. Fructifications at first some shade of buff by reason of the hairy covering, becoming grayish with age, and at length often zonate and shining where disappearance of the hairy covering reveals the hardened, colored surface of the intermediate layer 19
18. Fructifications white or whitish to cartridge-buff 20
18. Fructifications snuff-brown or black above 21
19. Effuso-reflexed, cream-buff at first, strigose-hirsute; hymenium warm buff, sometimes pale smoke-gray; intermediate layer bordered by a narrow golden zone; colored conducting organs rarely present in the hymenium; Newfoundland to South Carolina and westward to the Pacific coast. 43. *S. hirsutum*
19. Effuso-reflexed at first, becoming umbonate-sessile, tomentose, sometimes with the tomentum becoming torn into narrow concentric bands and showing the bared surface chestnut in the furrows; margin not normally lobate; fructifications 2-7 cm. in diameter; common throughout North America 44. *S. fasciatum*
19. Wedge-shaped to umbonate-sessile, with a thinner covering of tomentum than *S. fasciatum*, becoming more bared and zonate than the latter, thinner and flexible, and with the margin normally cut into 2 or 3 large lobes; New York and Wisconsin southward to Brazil 45. *S. lobatum*
19. Covering of silky, villous fascicles arranged radially, becoming glabrous, shining, and radially ridged, not lobed nor folded together laterally, nor crisped; Florida to Dutch Guiana 46. *S. versicolor*
19. Pilei 2-10 mm. long and broad, crowded together and folded or crisped, strigose-hairy towards the base; marginal portion shining and zoned,

- cinnamon-buff to hazel; colored conducting organs occasionally present
47. *S. rameale*
20. Fructifications 1-1½ cm. in diameter, plane, thin, papery, silvery to pale gray and with a silky luster; common on *Carpinus*, Canada, eastern United States to Mexico.....48. *S. sericeum*
20. Fructifications 3-10 mm. in diameter, pubescent, white.49. *S. pubescens*
20. *S. ochroleucum*, an imperfectly known species of Europe, formerly reported in America, belongs here. For description of authentic specimen, see "species imperfectly known."
20. Fructifications 2-4 mm. in diameter, conical, attached by the vertex and pendant, villose; Cuba.....50. *S. conicum*
21. Tobacco-colored, velvety-hirsute, becoming glabrous towards the margin and exposing the blackish, horny crust of the intermediate layer; hymenium pruinose; spores 4-5×2½-3μ; West Indies.....51. *S. vibrans*
21. Villose, blackening; intermediate layer not bordered by a crust; spores 9×4μ; Mexico.....52. *S. crassum*
21. Velutinous and black above; coloring matter of intermediate layer dissolved by KHO solution; hymenium ferruginous, radiately ridged; on coniferous wood, in northern United States.....53. *S. radiatum*
22. Cystidia hyaline, non-incrusted, hair-like.....23
22. Cystidia dark, or becoming dark, cylindrical, obtuse, distinguishable from colored conducting organs by more or less granule-incrustation; on conifers only.....24
22. Cystidia rough-walled or incrusted, somewhat colored either wholly or under the incrustation, pointed, not resembling conducting organs.....25
22. Cystidia incrusted, not at all colored except in *S. cinerascens* at times; paraphyses not noteworthy.....26
22. Cystidia incrusted, not colored; paraphyses noteworthy by color or form.....27
23. Cinnamon to bone-brown, hoary; hair-like cystidia very few; spores 9-10×3-4μ; Washington to New Mexico.....54. *S. patelliforme*
23. White, villose-tomentose; hymenium bright yellow; hair-like cystidia obtuse, 20-25×4-6μ, numerous.....55. *S. ochraceo-flavum*
24. Coriaceous-spongy, dry, usually resupinate; hymenium pruinose, multizonate; cystidia colored, cylindrical, 90-150×6-8μ; spores 9-13×4-5μ; northern United States.....56. *S. abietinum*
24. Very thick, felty, concentrically sulcate, drying with odor of anise; cystidia and basidiospores like those of *S. abietinum*; colored imbedded spores often present; Rocky Mountain states.....57. *S. rugisporum*
24. Narrowly reflexed, tomentose, Prout's brown; hymenium amber; cystidia and spores as in *S. abietinum*; Vermont and New York.....58. *S. ambiguum*
25. Vinaceous-lilac when young, becoming snuff-brown; cystidia colored, even, rough-walled or incrusted, 100-200×6-10μ; from North Carolina and Ohio southward.....59. *S. umbrinum*
25. Coriaceous-papery, thin, pliant, tomentose, concentrically sulcate, snuff-brown; hymenium velvety, snuff-brown, not multizonate; cystidia colored under the incrustation, conical, 30-75×12-25μ; Florida to Brazil.....60. *S. papyrinum*
25. With aspect of *S. papyrinum* but thinner; cystidia 45-60×5-12μ; hymenial layer 200μ thick; Jamaica.....61. *S. Earlei*
25. Coriaceous, tomentose, concentrically sulcate, hair-brown; cystidia slightly colored, roughened above, 50-120×4½μ; on conifers, northern United States and Canada, and in Rocky Mountains.....62. *S. Chailletii*
25. Corky, usually resupinate, 1100μ thick; hymenium drab, 600μ thick, containing innumerable, colored, rough cystidia 20-25×5-7μ; West Indies.....63. *S. ferreum*
26. Strigose-hairy, concentrically sulcate, buff, weathering gray; hymenium pinkish buff to drab, bristling with cystidia 100-150×12-20μ, sometimes brownish at the base; spores 10-12×6μ.....64. *S. cinerascens*
26. Coriaceous-gelatinous, small, whitish; cystidia 45-90×12-15μ; spores 15-20×12-14μ; Jamaica.....65. *S. magnisporum*

26. Spongy-soft, tomentose; cystidia $36-60 \times 9-12 \mu$; spores $5-9 \times 3-4 \mu$; New York to Mexico. 66. *S. spumeum*
26. Bursting out from the bark, forming a gray hymenium and becoming reflexed, $1-2\frac{1}{2}$ mm. in diameter. 67. *S. erumpens*
26. Corky, rigid, concentrically sulcate, bister; hymenium ruddy, becoming zonate; cystidia $30-50 \times 8-12 \mu$; spores $4-6 \times 3-5 \mu$; on hemlock and other conifers, Canada to Texas and westward to the Pacific coast. 68. *S. sulcatum*
26. Tobacco-colored and sulcate above, with a horn-like crust under the tomentum; hymenium whitish; cystidia $30-36 \times 7 \mu$; on oak, North Carolina and Ohio to Mexico. 69. *S. subpileatum*
27. With aspect of *S. subpileatum* as given above, but hymenium contains numerous and conspicuous bottle-brush paraphyses in addition to cystidia; Pennsylvania to Colombia. 70. *S. sepium*
27. With brown, velvety hymenium and a white margin; paraphyses filiform, colored; spores hyaline, $6-11 \times 3-4\frac{1}{2} \mu$ 71. *S. albobadium*
27. With aspect of dark specimens of *S. albobadium*, but with thicker, zonate hymenium and imbedded spores colored; Oregon to Mexico. 72. *S. heterosporum*
27. Becoming narrowly reflexed, fuscous, 2-10 mm. in diameter; hymenium velvety, bister; paraphyses colored, with bushy-branched tips; Canada to Alabama and Arkansas. 73. *S. versiforme*
28. Snuff-brown and sulcate above, tomentose; hymenium pruinose, zoned, containing bottle-brush paraphyses; on oak, Florida and Venezuela. 74. *S. insigne*
28. Fuscous, sulcate, not tomentose but with upper surface a horn-like crust, 2-3 mm. thick; Mexico. 75. *S. durum*
28. Woody, resupinate, crowded as if confluent and then broken into frustules, 2-4 mm. in diameter, above black and crust-like; hymenium pinkish buff to whitish and pruinose; on oak. 76. *S. frustulosum*
28. Usually resupinate, coriaceous-soft; hymenium light vinaceous-purple when young, becoming avellaneous, containing filiform paraphyses with short lateral prongs; aspect of *Corticium evolvens*; Canada to North Carolina. 77. *S. roseo-carneum*

1. *Stereum caperatum* (Berk. & Mont.) Masee, Linn. Soc. Bot. Jour. 27: 161. 1890; Lloyd, Myc. Writ. 4. Stip. Stereums, 17. text f. 531. 1913. Plate 2, fig. 1.

Thelephora caperata Berkeley & Montagne, Ann. Sci. Nat. Bot. III. 11: 241. 1849; Montagne, Syll. Crypt. 175. 1856; Sacc. Syll. Fung. 6: 523. 1888.

Illustrations: Lloyd, loc. cit.; Engl. & Prantl, Nat. Pflanzenfam. (1: 1**): 124. f. H-J.

Type: in Kew Herb.

Pileus coracelous, infundibuliform, drying pinkish buff, the upper side with elevated radial ridges and usually densely tomentose with coarse fibers; in structure 600-700 μ thick, composed of densely, longitudinally arranged, thick-walled, hyaline hyphae 3 μ in diameter; stem central or sometimes absent, with attachment by a tomentose disk; hymenium pale pinkish buff, somewhat radially rugose, glabrous; hair-like cystidia not incrustated, $3-4\frac{1}{2} \mu$ in diameter. flexuous, often constricted near the outer end,

protruding up to $12\ \mu$, are sometimes present; spores hyaline, even, $8-10 \times 3-4\frac{1}{2}\ \mu$.

Fructifications 2-10 cm. high, 2-15 cm. in diameter; stem, when present, 5 mm. - 2 cm. long, 2-5 mm. thick, often sessile.

On decaying wood of frondose species. Florida, Louisiana, and West Indies to Bolivia. June to April, probably throughout the year. Common.

S. caperatum is the largest infundibuliform *Stereum* of the Gulf states and the West Indies. Its large size, upper surface with elevated, radial ridges and usually heavy tomentum of coarse fibers, occurrence on wood to which it is attached by a villose or tomentose disk, constitute a group of characters by which the *S. caperatum* is readily recognized. Lloyd has published in his account of this species that it has true metuloids (incrusted cystidia) projecting $20-30\ \mu$, but I have found none whatever in either the type or in other collections referable to this species.

Thelephora lamellata Berk. & Curtis, a species of *Stereum* related to *S. caperatum* and of rather similar aspect, occurring on islands of the Pacific, shows in the type specimen from Fiji Islands conical incrusted cystidia $6-12\ \mu$ in diameter, protruding $12-25\ \mu$, and subglobose spores $3-3\frac{1}{2} \times 3\ \mu$. Since Lloyd cited *S. caperatum* as occurring in Samoa, the Philippines, and Australia, it is possible that his observations on incrusted cystidia of *S. caperatum* were based on specimens from the Pacific region really referable to *Stereum lamellatum* rather than on the true *S. caperatum* from the American continent. In *Hedwigia* 53:75, 1913, Bresadola gives *T. lamellata* as a synonym of *Cladoderris infundibuliformis* (Kl.) Fries. I have seen no American specimens referable to *S. lamellatum*.

Specimens examined:

Florida: New Smyrna, A. S. Bertolet; Ocala, W. H. Long, 12373 (in Mo. Bot. Gard. Herb., 55125).

Louisiana: A. B. Langlois, comm. by C. G. Lloyd, 2740; St. Martinville, A. B. Langlois, 2896 and an unnumbered specimen, C. J. Humphrey, 2518 (in Mo. Bot. Gard. Herb., 5111).

Cuba: C. Wright, 290, 509 (in Kew Herb.); Candelaria, Earle & Wilson, 201; Guantanamo (in Weir Herb., 10858);

Havana Province, *P. Wilson*, 1172, comm. by F. S. Earle; Herradura, *Earle & Murrill*, 180, comm. by N. Y. Bot. Gard. Herb.

Porto Rico: Manati, *Johnston & Stevenson*, 2006 (in Mo. Bot. Gard. Herb., 3396).

San Domingo: 259 (in Kew Herb.).

Jamaica: Cinchona, *L. M. Underwood*, 3172 (in N. Y. Bot. Gard. Herb. and in Mo. Bot. Gard. Herb., 56271); Cockpit Country, *E. G. Britton & D. W. Marble*, 338 (in N. Y. Bot. Gard. Herb.).

St. Kitts: Lambert Estate, *N. L. Britton & J. F. Cowell*, 672 (in N. Y. Bot. Gard. Herb.).

Brazil: Bahia, *Blanchet*, 19 (in Kew Herb.).

Bolivia: Yungas, *A. Miguel Bang*, 295 (in Mo. Bot. Gard. Herb.).

2. *S. hydrophorum* Berkeley, Ann. & Mag. Nat. Hist. I. 14: 327. pl. 9. f. 2. 1844; Hooker's Jour. Bot. 8: 273. pl. 6. 1856; Sacc. Syll. Fung. 6: 555. 1888; Masee, Linn. Soc. Bot. Jour. 27: 159. 1890; Lloyd, Myc. Writ. 4. Stip. Stereums, 29. text f. 547, 548. 1913. Plate 2, fig. 2.

Hymenochaete crateriformis P. Hennings, Hedwigia 43: 172. 1904; Sacc. Syll. Fung. 17: 166. 1905.

Illustrations: Ann. & Mag. Nat. Hist. I. 14: pl. 9. f. 2; Hooker's Jour. Bot. 8: pl. 6; Lloyd, loc. cit.

Type: in Kew Herb.

Pileus stipitate, coriaceous, infundibuliform, drying Prout's brown, obscurely zonate, velvety, sometimes bearing large, branched hairs at the center and bottom of the cups, the margin entire; stem central, cylindrical, solid, velvety, colored like the pileus, enlarged at the base and attached by disk; hymenium even, drying snuff-brown, not setulose; in structure 600 μ thick, composed of intermixed and interwoven hyaline and slightly colored hyphae, the latter of which give their color to the pileus and hymenium and curve into the hymenium as cylindrical, obtuse, slightly colored paraphyses 3 μ in diameter, not emergent above its surface; no cystidia, gloeocystidia, nor setae; spores hyaline, globose, even, 3 μ in diameter.

Pileus 4–10 cm. in diameter, 3–6 cm. deep; stem 3–5 cm. long, 4–5 mm. thick.

On wood on the ground. Venezuela, British Guiana, and Brazil. November.

This South American species ranges so far to the north that it may possibly occur also in the West Indies or Central America. The fructifications have dimensions and general aspect of those of *S. caperatum* but are distinguishable by darker color of pileus, stem and hymenium, by velvety covering of pileus and stem, and by absence of elevated longitudinal ridges on the surface of the pileus.

Specimens examined:

Exsiccati: Ule, Myc. Brasil., 40, type distribution of *Hymenochaete crateriformis*.

Venezuela: Maripa, *M. A. Carriker*, comm. by W. G. Farlow, III; Rio Mato, *M. A. Carriker*, comm. by W. G. Farlow, IV.

Brazil: *Spruce* (in Curtis Herb.); Amazonas, Marmellos, *E. Ule*, in Ule, Myc. Brasil., 40.

3. *S. Ravenelii* Berk. & Curtis, *Grevillea* 1: 162. 1873; *Sacc. Syll. Fung.* 6: 552. 1888; *Massee, Linn. Soc. Bot. Jour.* 27: 164. *pl. 7. f. 2.* 1890; *Lloyd, Myc. Writ.* 4. *Stip. Stereums*, 25. *text f. 543.* 1913. Plate 2, fig. 3.

Illustrations: *Lloyd, loc. cit.*; *Massee, loc. cit.*

Type: type distribution in *Ravenel, Fungi Car.* 4: 13.

Fructifications gregarious, coriaceous, thin, often growing from a common mycelium; pileus infundibuliform, sometimes



Fig. 1.

S. Ravenelii.

Gloecystidia ×
665.

From authentic
specimen.

split on one side, even, drying cinnamon-buff to bay, often shining and zonate; stem slender, equal, minutely tomentose, drying pale olive-buff to pinkish buff; hymenium even, glabrous, colored like the stem; pileus in section 300–500 μ thick, composed of densely and longitudinally arranged hyaline hyphae 3 μ in diameter; flexuous gloecystidia 30–60 \times 4½–7 μ curve into the hymenium but do not protrude above its surface; no cystidia; spores hyaline, even, 3–4 \times 2½–3 μ .

Fructifications 1½–5 cm. high, 3 mm.–3 cm. in diameter; stem 5–10 mm. long, ½–1½ mm. thick.

On the ground, rarely on wood humus. South Carolina to Mexico, West Indies, and Brazil. July to April.

S. Ravenelii is near *S. pergamenum* in microscopic characters but is constantly infundibuliform, with slender, more conspicuous stem, and occurs on the ground except very rarely, and is gregarious rather than cespitose. The range of *S. Ravenelii* southward to Brazil is so much greater than has been noted heretofore that it would be well to compare with it authentic specimens of some of the imperfectly described South American species of central-stemmed *Stereums*

Specimens examined:

Exsiccati: Ravenel, *Fungi Car.* 4: 13.

South Carolina: *H. W. Ravenel*, in *Ravenel, Fungi Car.* 4: 13, type distribution.

Alabama: *Beaumont*, 207 in part (the small specimens on right of the card in *Curtis Herb.*, 4629); *Montgomery*, *R. P. Burke*, 26, 181 (in *Mo. Bot. Gard. Herb.*, 10305, 57059).

Louisiana: *Baton Rouge*, *C. W. Edgerton*, 1544, and *C. J. Humphrey & C. W. Edgerton*, comm. by *C. J. Humphrey*, 2523, 2522 (in *Mo. Bot. Gard. Herb.*, 42921 and 42939 respectively); *St. Martinville*, *A. B. Langlois*, 1847.

Mexico: *San Luis Potosi*, *C. G. Pringle* (in *Farlow Herb.*).

Cuba: *C. Wright*, 255 (under the name *Stereum elegans* in *Curtis Herb.*); *Candelaria*, *Earle & Wilson*, 205, 207; *Herradura*, *N. L. Britton*, *E. G. Britton*, *F. S. Earle & C. S. Gager*, 6397 (in *N. Y. Bot. Gard. Herb.* and *Mo. Bot. Gard. Herb.*, 56303).

Trinidad: *Carrengo*, *Carriker* (in *Farlow Herb.*, 1).

Brazil: *Blumenau*, *A. Möller*, the *Stereum elegans* of *Hedwigia* 35: 288. 1896, comm. by *G. Bresadola*.

4. *S. surinamense* *Léveillé*, *Ann. Sci. Nat. Bot.* III. 2: 209. 1844; *Sacc. Syll. Fung.* 6: 556. 1888; *Massee*, *Linn. Soc. Bot. Jour.* 27: 161. 1890; *Lloyd*, *Myc. Writ.* 4. *Stip. Stereums*, 26. *text f.* 544. 1913. Plate 2, fig. 4.

Stereum fulvo-nitens *Berkeley*, *Ann. & Mag. Nat. Hist.* II. 9: 198. 1852; *Sacc. Syll. Fung.* 6: 556. 1888; *Massee*, *Linn. Soc. Bot. Jour.* 27: 162. 1890.

Illustrations: *Lloyd*, *loc. cit.*

Type: in *Museum of Paris Herb.* presumably.

Pileus coriaceous, infundibuliform, sometimes more elongated on one side, glabrous, shining, lineate or striate, drying tawny to hazel, faintly zonate with numerous very narrow zones; stem central or eccentric, cylindric, drying avellaneous to burnt umber, fibrillose to minutely tomentose, attached at the base by a mycelial pad; hymenium glabrous, even, avellaneous to cinnamon; pileus in section 400 μ thick, composed of a broad layer of densely and longitudinally arranged, thick-walled, hyaline hyphae 3 μ in diameter and of a hymenial layer 45–90 μ thick, the subhymenial portion of which may become thicker than the palisade layer of basidia and gloeocystidia and appears granular and composed of very fine hyphae; gloeocystidia 15–30 μ long, with ventricose base 6–9 μ in diameter, sometimes barely emergent above the basidia; spores hyaline, even, 3–4 \times 2–3 μ .

Fructifications 1½–4 cm. high, 1–2½ cm. in diameter; stem 3–7 mm. long, about 1½ mm. in diameter.

On dead wood. West Indies, Honduras, and Dutch Guiana. November.

Lloyd's account and figures have made possible the reference to *S. surinamense* of the collections cited below, for the original description by L veill  is fragmentary and does not even note whether the specimens were growing on the ground or on wood. I have not seen the types of either *S. surinamense* or *S. fulvomitens*. The specimens cited below are characterized by the attachment to the wood by a conspicuous mycelial pad, by rich hazel and shining upper surface of the large, narrowly zonate pileus, by the gloeocystidia, and by the minutely granular subhymenial region in which the hyphae are much finer than in the main hyphal layer and run at right angles to the latter.

Specimens examined:

San Domingo: Consuelo, *N. Taylor*, 176 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56293).

Trinidad: *R. Thaxter*, comm. by W. G. Farlow (in Mo. Bot. Gard. Herb., 44304).

British Honduras: *M. E. Peck* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56326).

5. *S. macrorrhizum* (L veill ) Lloyd, *Myc. Writ.* 4. *Stip. Stereums*, 28. 1913.

Thelephora macrorrhiza Léveillé, Ann. Sci. Nat. Bot. III. 5: 146. 1846; Sacc. Syll. Fung. 6: 524. 1888.

Type: in Museum of Paris Herb., according to Léveillé and Lloyd.

Pileus infundibuliform, coriaceous, somewhat membranaceous, rufescent, striatulate, the margin erect, possibly lacinate; hymenium sulcate, rather pallid; stem rather long, radicated.

On ground, French Guiana. Coll. *Melinon*.

Pileus coriaceous, nearly membranaceous, infundibuliform, russet, with rugosity from base to margin, the latter thin, lacinate; hymenium glabrous, rugose like upper surface of pileus; stem 1-2 decimeters long, glabrous, continued by a long radicated portion which extends perpendicularly into the ground. This character and also the absence of hairy covering of the stem afford a great difference between this species and *Stereum surinamense*.

The above is a translation of the original description. I have not seen authentic specimens; Lloyd notes, *loc. cit.*, that they are, "*Stereum elegans*, of an unusually regular growth. Not so confluent as ordinary."

6. S. Burtianum Peck, N. Y. State Mus. Bul. 75: 21. *pl. O. f. 30-34*. 1904; Sacc. Syll. Fung. 17: 163. 1905; Lloyd, Myc. Writ. 4. Stip. Stereums, 21. *text f. 537*. 1913. Plate 2, fig. 5. Illustrations: Peck, *loc. cit.*; Lloyd, *loc. cit.*

Type: in N. Y. State Mus. Herb. and in Burt Herb.

Fructifications gregarious, coriaceous, thin, infundibuliform, sometimes split to the stem on one side, sometimes dimidiate, the upper surface slightly uneven with radiating fibrils and fibrillose ridges, cartridge-buff when fresh, drying Sayal-brown to hazel, the margin lobed or incised; stem solid, minutely tomentose, Sayal-brown in the herbarium; hymenium even or radiately uneven, glabrous, yellow ocher to pinard-yellow when fresh, becoming pinkish buff to Sayal-brown in the herbarium; pileus in section 600 μ thick, composed of densely and longitudinally arranged hyphae 2 μ in diameter; no cystidia nor gloeocystidia; spores hyaline, even, subglobose, 3-4 μ in diameter, or 4 \times 3 μ .

Fructifications usually 12-20 mm. high, 5-15 mm. in diameter; stem 3-8 mm. long, $\frac{2}{3}$ -1 $\frac{1}{2}$ mm. thick.

On the ground in frondose woods. New Hampshire to North Carolina and Tennessee, and in Japan. July to October.

Distinguishing characters of this species are the radially arranged fibrils and fibrillose ridges of the upper surface of the pileus, bright yellow hymenium of fresh specimens, small subglobose spores, and absence of zonation, cystidia, and gloeocystidia. These characters separate the species from *S. aurantiacum* and *S. Ravenelii* and from specimens of *S. diaphanum* which have become discolored in the herbarium. The sections crush out and tissues spread apart when slight pressure is applied to the cover glass—a character unusual in stipitate Stereums. The specimen from Tennessee consists of two dimidiate pilei $2 \times 2\frac{1}{2}$ cm. At Amherst, Massachusetts, Professor Anderson saw perhaps a thousand fructifications of this growing in an area of a square rod; to him I am indebted for the color observations on fresh specimens and for specimens in growing condition showing the colors and also the fact that the consistency of the pileus is not fleshy enough for inclusion of this species in *Craterellus*.

Specimens examined:

- New Hampshire: Chocorua, *W. G. Farlow*, three collections (two of which are in Mo. Bot. Gard. Herb., 55242 and 55571, and the third in Farlow Herb.).
- Vermont: Lake Dunmore, *W. G. Farlow* (in Farlow Herb.).
- Massachusetts: Amherst, *P. J. Anderson* (in Mo. Bot. Gard. Herb., 56364, 56365).
- New York: Shokan, Ulster Co., *C. H. Peck*, type.
- North Carolina: Asheville, *H. C. Beardslee*, 2.
- Tennessee: Elkmont, *C. H. Kauffman*, 80 (in Mo. Bot. Gard. Herb., 44994).
- Japan: Sendai, *A. Yasuda*, 21 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56290).

7. *S. rivulorum* Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 330. 1868; Sacc. Syll. Fung. 6: 552. 1888; Masee, Linn. Soc. Bot. Jour. 27: 167. 1890; Lloyd, Myc. Writ. 4. Stip. Stereums, 21. 1913.

Type: in Kew Herb. and probably in Curtis Herb.

I failed to take any notes of the type specimens of this species

when there was opportunity and have seen no collections which seem referable here. The translation of the original description follows:

Minute, straw-colored; pileus cyathiform, decurrent into a stem dilated above, the margin undulate; hymenium glabrous.

On wet ground amongst moss. Cuba, *C. Wright*, 533.

Pileus $1\frac{1}{2}$ mm. across; stem 4 mm. high, oblique but not really lateral. Habit of a small stipitate *Peziza*. Spores globose, $2-2\frac{1}{2}$ μ according to Masee.

8. *S. quisquiliare* (Berk. & Curtis) Lloyd, *Myc. Writ.* 4. *Stip. Stereums*, 36. *text f.* 567. 1913. Plate 2, fig. 6.

Thelephora quisquiliaris Berk. & Curtis, *Linn. Soc. Bot. Jour.* 10: 329. 1868; *Sacc. Syll. Fung.* 6: 524. 1888.

Illustrations: Lloyd, *loc. cit.*

Type: in Kew Herb. and Curtis Herb.

Pileus very small, flabellate or rarely cyathiform, tomentose, shining white; stem lateral, short, thickened above; pileus in section composed of loosely arranged hyphae 3-4 μ in diameter; cystidia hair-like, not incrusted, 6 μ in diameter, protruding up to 40 μ beyond the basidia; spores hyaline, even, $4 \times 3-4$ μ .

Pileus 3-5 mm. broad, and 5-7 mm. long including the stem-like base.

On particles of bark among moss and on mosses. Cuba.

The fructifications of *S. quisquiliare* are small and of soft bibulous texture and resemble in aspect those of *S. cyphelloides* and *Cyphella muscigena*, but are distinguished from both these species by the hair-like cystidia, of which I noted the presence upon examination of the type but which no longer show well in the permanent microscopical preparation. I had hoped that recent collections would confirm the note as to hair-like cystidia and enable me to be more confident that *Thelephora quisquiliaris* should not be transferred to *Cyphella*.

Specimens examined:

Cuba: *C. Wright*, 519, type (in Curtis Herb.).

9. *S. aurantiacum* (Pers.) Lloyd, *Myc. Writ.* 4. *Stip. Stereums*, 22. *text f.* 538. 1913. Plate 6, fig. 7.

Thelephora aurantiaca Persoon in Gaudichaud, *Voy. Urania Bot.* 176. 1827; Fries, *Epier.* 536. 1838; *R. Soc. Sci. Up-*

sal. Actis III. 1: 108. 1851; Montagne in d'Orbigny, Voy. Am. Merid. Bot. 2: 48. 1839; in Ramon de la Sagra, Fl. Cub. 4: 228. pl. 14. f. 1. 1853; Berkeley & Curtis, Linn. Soc. Bot. Jour. 10: 328. 1868; Sacc. Syll. Fung. 6: 526. 1888.—*T. sericella* Berkeley & Curtis, Linn. Soc. Bot. Jour. 10: 328. 1868; Sacc. Syll. Fung. 6: 522. 1888.—*T. affinis* Berkeley & Curtis, Linn. Soc. Bot. Jour. 10: 329. 1868 (not *T. affinis* Pers.); Sacc. Syll. Fung. 6: 530. 1888.—*Podoscypha aurantiaca* (Pers.) Patouillard in Duss, Fl. Crypt. Antilles Fr. 230. 1904.—An *T. spectabilis* Léveillé, Ann. Sci. Nat. Bot. III. 2: 206. 1844?—An *Stereum xanthellum* Cooke, Grevillea 9: 12. 1880?

Illustrations: Lloyd, *loc. cit.*; Montagne, *loc. cit.*

Fructifications coriaceous, soft, everywhere drying Naples-yellow, losing the bright color in the herbarium; upper surface sericeous, lineate-striate, the margin variable, often somewhat fimbriate; stem thin, with yellowish tomentum at the base and sometimes with tomentose mycelial strands; hymenium even, or nearly so, setulose with hyaline hairs under a lens; cystidia hair-like, not incrustated, cylindric, obtuse, 6–8 μ in diameter, protruding up to 40 μ ; spores hyaline, even, 5–8 \times 3–4 μ .

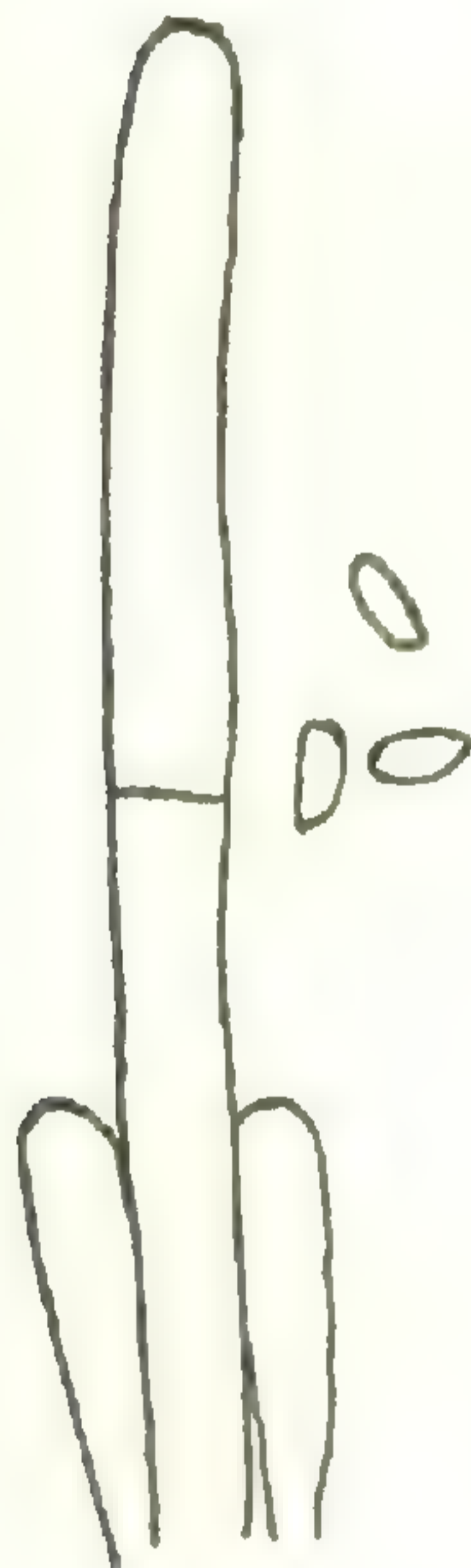


Fig. 2.
S. aurantiacum.
Cystidium, basidia,
and spores,
 \times 665.

Fructifications 2–3 cm. high; pileus 1–2 cm. in diameter when infundibuliform and 5 mm.–4 cm. when flabelliform; stem 1 cm. long, about 1 mm. thick.

On ground and dead wood. West Indies to Paraguay. June to February. Apparently frequent.

S. aurantiacum is unique among the stipitate Stereums by its bright yellow color. Lloyd states that old specimens may lose their bright yellow color and become brown, and the figures by Montagne indicate this also. I have seen only one gathering in which some of the specimens have discolored brownish; this gathering from Porto Rico, by Prof. Stevenson, bears the field note: "nearly pure white when collected; became yellow in drying; no yellow showed until partly dried." The extensive synonymy of this species is due to its occurrence sometimes on the ground, sometimes on wood, sometimes being wholly infundi-

buliform and sometimes wholly flabelliform, but occasionally a gathering shows both infundibuliform and flabelliform specimens. The soft texture of the pilei—like filter-paper or like wash leather—the large, cylindric, non-incrusted cystidia, and large elongated spores are a good combination of characters for the recognition of *S. aurantiacum* independently of the yellow color. Lloyd gives *Thelephora spectabilis* and *Stereum xanthellum* as synonyms of *S. aurantiacum*, and this seems quite probable according to the original descriptions of these species, but he does not state that he has studied the authentic specimens; I have not been able to examine them.

Unless there is more than one edition of Gaudichaud's 'Voy. Urania Bot.,' there is an error, as noted by Lloyd, in the citation by Fries in 'Epicrisis,' followed by later authors, of a figure of *T. aurantiaca* by Persoon. Dr. Farlow kindly searched for me for such a figure in his copy but without success.

Specimens examined:

Jamaica: Port Antonio, *F. S. Earle*, 600, comm. by N. Y. Bot. Gard. Herb.; *A. E. Wight*, comm. by W. G. Farlow; Troy and Tyre, *W. A. Murrill & W. Harris*, 1112, comm. by N. Y. Bot. Gard. Herb.

Cuba: *C. Wright*, 237, type of *Thelephora sericella* (in Curtis Herb.); *C. Wright*, 198, 263, type of *Thelephora affinis* B. & C. (in Curtis Herb.); Banao Mts., *Leon & Clement*, 5570 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56262); Ceballos, *C. J. Humphrey*, 2683 (in Mo. Bot. Gard. Herb., 8267); Guantanamo, *Hioram* (in J. R. Weir Herb., 10583, and Mo. Bot. Gard. Herb., 56217); Omaja, *C. J. Humphrey*, 3025 (in Mo. Bot. Gard. Herb., 8632); Nipe Bay, *F. S. Earle*, No. A.

Porto Rico: Rio Piedras, *J. R. Johnston*, comm. by J. A. Stevenson, 1987 (in Mo. Bot. Gard. Herb., 10660); *J. A. Stevenson*, 3354, 5585 (in Mo. Bot. Gard. Herb., 17720 and 6908).

San Domingo: Consuelo, *N. Taylor*, 178 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56304).

10. *S. diaphanum* (Schw.) Cooke in Sacc. Syll. Fung. 6: 558. 1888; Masee, Linn. Soc. Bot. Jour. 27: 162. 1890; Lloyd, Myc. Writ. 4. Stip. Stereums, 19. text f. 534. 1913.

Plate 2, figs. 8 and 9.

Thelephora diaphana Schweinitz in Berk. & Curtis, Acad. Nat. Sci. Phila. Jour. 2: 278. 1853.—*T. Willeyi* Clinton in Peck, N. Y. State Mus. Rept. 26: 71. 1874; Sacc. Syll. Fung. 6: 524. 1888.—An *T. Sullivantii* Montagne, Syll. Crypt. 176. 1856?

Type: in Herb. Schweinitz, in Curtis Herb., and in Kew Herb.

Fructifications coriaceous, thin, deeply infundibuliform, sometimes deeply split, white, drying diaphanous, sericeous, fibrillose, striate, sometimes with slightly elevated ridges, sometimes obscurely zoned, the margin thin, entire or laciniately toothed; stem slender, cylindric, more or less clothed with white matted down which is usually present at the base and binds the earth together in a ball; pileus of type in section 200 μ thick, composed of longitudinally arranged, thin-walled hyaline hyphae 3 μ in diameter, densely crowded together; hymenium white, setulose with hyaline hairs under a lens; cystidia hair-like, not incrustated, cylindric, obtuse, 6–9 μ in diameter, protruding 20–60 μ ; spores hyaline, even, 4–5 \times 2½–3 μ .



Fig. 3.
S. diaphanum.
Cystidium,
basidia, and
spores, \times 665.

Fructifications 2–4 cm. high, 8 mm.–2 cm. in diameter; stem 1–3 mm. in diameter.

On the ground in moist woods of frondose species. New York to Missouri, and in Alabama, Washington, and California.

S. diaphanum, as collected by Schweinitz and shown in pl. 2, fig. 8, differs from *S. aurantiacum* in absence of bright yellow color, in shorter spores, and in stem and ground at base of stem being merely white-downy. In western New York, this species attains a more luxuriant growth than the small specimens collected by Schweinitz, has a larger and rather thicker pileus and thicker stem as shown in pl. 2, fig. 9; such larger specimens were published as *Thelephora Willeyi*, but the intergradations with *S. diaphanum* are so numerous and close that it should be kept with the latter in my opinion.

Specimens examined:

New York: Buffalo, Clinton, type of *Thelephora Willeyi* (in N. Y. State Mus. Herb.); Chappaqua, Mrs. C. E. Ryder & Mrs. W. A. Murrill (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56289); Freeville, V. B. Walker, 15

(in Mo. Bot. Gard. Herb., 8407); Geddes, *G. E. Morris, G.*; Ithaca, *C. Thom* (in Cornell Univ. Herb., 9992); Jamesville, *H. D. House* (in N. Y. State Mus. Herb. and in Mo. Bot. Gard. Herb., 55498), and *L. M. Underwood*; Lowville, *C. H. Peck* (in N. Y. State Mus. Herb.); Orville, *G. E. Morris, G.*

Ohio: Gnaddenhutte, *Schweinitz*, type (in Herb. Schweinitz and in Curtis Herb.).

Missouri: Valley Park, *E. A. Burt & L. O. Overholts* (in Mo. Bot. Gard. Herb., 44059).

Alabama: Montgomery, *R. P. Burke, 25* (in Mo. Bot. Gard. Herb., 13146.).

Washington: Seattle, *W. A. Murrill, 128, 143, 144* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 55745, 55729, 55726).

California: Tamalpais, *H. W. Harkness* (under the herbarium name *Thelephora Harknessii* Peck in N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb., 55925).

11. *S. exiguum* (Peck) Burt, n. comb. Plate 2, fig. 10.
Thelephora exigua Peck, N. Y. State Mus. Bul. 54: 953. 1902;
Sacc. Syll. Fung. 17: 161. 1905.

Type: in N. Y. State Mus. Herb. and in Burt Herb.

Pileus coriaceous-membranaceous, very thin, diaphanous, infundibuliform, radiately fibrous-striate, becoming bister in the herbarium, originally "pale alutaceous" according to Peck, the margin lacerate; stem slender, solid, pruinose, and bearing a few whitish hairs which are present also on the ground about the base; pileus in section 100 μ thick, composed of longitudinally arranged, hyaline hyphae $2\frac{1}{2}$ –3 μ in diameter, closely crowded together; cystidia hair-like, not incrustated, cylindric, obtuse, 7 μ in diameter, protruding 25 μ beyond the basidia; spores hyaline, even, $4\frac{1}{2} \times 2$ μ , borne 4 to a basidium.

Fructifications 1–3 mm. in diameter, 3–5 mm. high; stem 2 mm. long, $\frac{1}{4}$ – $\frac{1}{3}$ mm. in diameter; pileus $\frac{1}{10}$ mm. thick.

On the ground, Westport, New York. October.

S. exiguum is miniature *S. diaphanum* of slightly darker color. It is known from the original collection only. The smallest specimens of *S. diaphanum* are many times larger than

the largest specimen of *S. exiguum*. While differences in size are not generally a good criterion for specific distinction, I am inclined to think that they will prove so in this instance.

Specimens examined:

New York: Westport, *C. H. Peck*, type (in N. Y. State Mus. Herb. and in Burt Herb.).

12. *S. tenerrimum* Berk. & Ravenel, *Grevillea* 1: 162. 1873; *Sacc. Syll. Fung.* 6: 551. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 165. 1890. Plate 2, fig. 11.

Type: in Kew Herb. and Curtis Herb.

Pileus coriaceous, thin, infundibuliform or flabelliform, soon lobed and split, upper surface slightly rough, fibrillose-striate, not zonate or only very indistinctly "pale tan" when collected, becoming tawny olive to Saccardo's umber in the herbarium; stem filiform, whitish, bearing some fibrils towards the base; hymenium even, concolorous, setulose with hyaline hairs under a lens; pileus in section 300 μ thick, composed of longitudinally and densely arranged hyaline hyphae 3 μ in diameter; cystidia hair-like, not incrusted, 4–8 μ in diameter, protruding 30–50 μ ; spores hyaline, even, subglobose, 4–5 \times 3–4 μ .

Fructifications 2–10 mm. broad, 5mm.–2½ cm. high; stem 3–7 mm. long, ¼–½ mm. thick.

On ground among mosses. New York, Wisconsin, South Carolina, and Cuba. July to November. Rare.

The collections which I have referred to *S. tenerrimum* are from the widely separated localities stated above and only a single gathering of several fructifications at each locality. There are slight differences between the specimens of the several gatherings, but not great enough to preclude their reference to a single species, although doing so has required some generalization from the original description.

S. tenerrimum is related to *S. undulatum* of northern Europe as known to me by the specimens distributed in Karsten, *Fungi Fennicae*, 912, and by the extended account by Maire, *Ann. Myc.* 7: 426–431, *text f.* 1, 2. 1909, but the latter species attains much larger size, has a coarser stem, and is infundibuliform with central stem. None of the collections of *S. tenerrimum* are composed wholly of specimens with infundibuliform

pilei and the stem central; the original collections have some specimens with pileus longer on one side than the other and stem eccentric; in more recent gatherings some specimens are even flabelliform. *S. tenerrimum* appears to be a distinct species.

Specimens examined:

New York: Croghan, *C. H. Peck* (in N. Y. State Mus. Herb.).

South Carolina: Society Hill, *H. W. Ravenel*, type (in Curtis Herb., 5029, and in Kew Herb.).

Wisconsin: Afton, *R. A. Harper*.

Cuba: Havana Province, *Huo Leon*, 1456 (in N. Y. Bot. Gard. Herb. and in Mo. Bot. Gard. Herb., 56307).

13. *S. pergamenum* Berk. & Curtis, *Grevillea* 1: 161. 1873; *Sacc. Syll. Fung.* 6: 552. 1888; *Massee, Linn. Soc. Bot. Jour.* 27: 161. 1890; *Lloyd, Myc. Writ.* 4. *Stip. Stereums*, 27. *text f.* 545. 1913. Plate 2, fig. 12.

An *Stereum nitidulum* Berkeley, *Hooker's London Jour. Bot.* 2: 638. 1843?

Type: type distribution in *Ravenel, Fungi Car.* 3: 25.

Fructifications somewhat cespitose and grown together, stipitate; pileus coriaceous, infundibuliform, sometimes split and petaloid, minutely lineate, drying hazel, obscurely zoned, the margin thin, often toothed or lacinate; stem cylindrical, drying pinkish buff, very minutely tomentose; hymenium drying pinkish buff, glabrous; pileus in section 500 μ thick, composed of densely and longitudinally arranged hyaline hyphae 3 μ in diameter; flexuous, clavate, curved gloeocystidia, 50 \times 6 μ , extend into the hymenium but do not rise to its surface; cystidia none; spores hyaline, even, slightly flattened on one side, 4-4 $\frac{1}{2}$ \times 3-3 $\frac{1}{2}$ μ .

Fructifications 1 $\frac{1}{2}$ -4 cm. high, 8 mm.-3 cm. in diameter; stem 2-10 mm. long, 1-3 mm. in diameter.

On stumps or buried wood, perhaps rarely on the ground. Ohio and North Carolina to Mexico and in the West Indies. September to January.



Fig. 4.
S. pergamenum.
Gloeocystidia
 \times 665.

S. pergamenum may be recognized by its occurrence in small clusters on wood at or near the surface of the ground, by small and nearly globose spores, and by the presence of gloeocystidia. It is probably more frequent in the West Indies than in the United States. When studying the specimens of this species in Kew Herbarium I compared with them the type of *Stereum nitidulum* Berk., collected by Gardner in Goyaz, Brazil, and concluded that it is probably the same species as *S. pergamenum*. In that early stage of my work I did not record the presence of gloeocystidia in the types of either *S. pergamenum* or *S. nitidulum*, and since I have no permanent preparation from the type of the latter, further, more critical study may show that it is a distinct species. The collection from Cuba, referred by Berkeley to *S. nitidulum*, has gloeocystidia and is referable to *S. pergamenum*.

Specimens examined:

Exsiccati: Ravenel, *Fungi Car.* 3: 25.

Ohio: Preston, *T. G. Gentry* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56301).

North Carolina: Blowing Rock, *G. F. Atkinson*, from Bot. Dept. of Cornell Univ., 4182.

Alabama: *J. M. Peters*, in Ravenel, *Fungi Car.* 3: 25, type distribution; *J. M. Peters*, 601 and another specimen (in Curtis Herb., the latter, Curtis Herb., 3814); *Beaumont*, 207 in part, the large zonate specimen mounted on left side of card with specimens of *S. Ravenelii* (in Curtis Herb., 4629 in part); Auburn, *F. S. Earle* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56306).

Louisiana: Ville Platte, *A. B. Langlois*, 2897.

Mexico: Motzorongo, near Cordoba, *W. A. & Edna L. Murrill*, 994 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 54596).

Cuba: *C. Wright*, 836 (in Curtis Herb., under the name *S. nitidulum* Berk.); Herradura, *F. S. Earle*, 545, and *N. L. Britton*, *E. G. Britton*, *F. S. Earle & C. S. Gager*, 6326 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56305 and 56263 respectively); Sumidero, *J. A. Shafer*, 13905 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56264).

San Domingo: Bonao, *J. A. Stevenson*, 7010 (in Mo. Bot. Gard. Herb., 55656).

14. *S. cristatum* Berk & Curtis, *Grevillea* 1: 163. 1873; *Sacc. Syll. Fung.* 6: 556. 1888; *Massee, Linn. Soc. Bot. Jour.* 27: 167. 1890; *Lloyd, Myc. Writ.* 4. *Stip. Stereums*, 38. 1913.

Type: in Kew Herb., not found by me in Curtis Herb. although sought for.

Pileus coriaceous, flabelliform or obliquely cyathiform, pallid to light bay-brown, somewhat zoned, glabrous and shining towards the margin, bearing a cluster of coarse hairs towards the base; stem, when present, cylindric, scarcely 2 mm. long; hymenium even, paler than the upper surface; in structure 200–250 μ thick, composed of longitudinally arranged and somewhat interwoven hyaline hyphae 3 μ in diameter; no cystidia; gloeocystidia pyriform, 9–12 \times 7½ μ ; spores, as found in a crushed preparation, hyaline, even, 4 \times 2½ μ , few found—noted by Massee as subglobose, 5–6 μ in diameter.

Pileus 6–10 mm. across.

On dead *Vitis* in swamps. South Carolina.

Reexamination of my preparation of the type of *S. cristatum* fails to demonstrate that the pyriform organs in its hymenium are longitudinally septate; furthermore some of these organs are more elongated than stated above and irregular in form. For these reasons I regard the bodies as pyriform gloeocystidia rather than possibly miniature basidia of the longitudinally septate type, the demonstrated presence of which would require transfer of this species to *Eichleriella*. The occurrence of *S. cristatum* on dead grape vines, the crest of coarse hairs towards the base of the pileus, the small size of the latter, and the pyriform organs in the hymenium are a good group of characters for identification of this species, although known so far only from the original collections.

Specimens examined:

South Carolina: Santee Swamp, *H. W. Ravenel*, Curtis Herb.



Fig. 5.
S. cristatum.
Gloeocystidia \times
665. From type.

No. 2038, type and an *unnumbered specimen* (both in Kew Herb.).

15. *S. pallidum* (Pers.) Lloyd, Myc. Writ. 4. Stip. Stereums, 31. *text f. 536, 550.* 1913. Plate 3, fig. 13, 14.

Craterella pallida Persoon, Ic. et Descr. Fung. 1: 3. *pl. 1. f. 3.* 1798.—*Thelephora pallida* Persoon, Syn. Fung. 565. 1801; Myc. Eur. 1: 111. 1822; Fries, Hym. Eur. 633. 1874; Sacc. Syll. Fung. 6: 527. 1888.—*Helvella pannosa* Sowerby, Col. Figs. Eng. Fungi, *pl. 155.* 1788, in part.—*Thelephora pannosa* Sowerby ex Fries, in part, and *T. pannosa* var. *pallida* (Pers.) Fries, Syst. Myc. 1: 430. 1821.—*T. Sowerbeyi* Berkeley, Outlines Brit. Fungi, 266. 1860; Ann. & Mag. Nat. Hist. III. 15: 320. 1865; Fries, Hym. Eur. 633. 1874; Sacc. Syll. Fung. 6: 522. 1888.—*Stereum Sowerbeyi* (Berk.) Masee, Linn. Soc. Bot. Jour. 27: 164. 1890.—*Bresadolina pallida* (Pers.) Brinkmann, Ann. Myc. 7: 289. 1909.

Illustrations: Persoon, Ic. et Descr. Fung. 1: *pl. 1. f. 3;* Sowerby, Col. Figs. Eng. Fungi, *pl. 155;* Lloyd, Myc. Writ. 4. Stip. Stereums, *text f. 536, 550.*

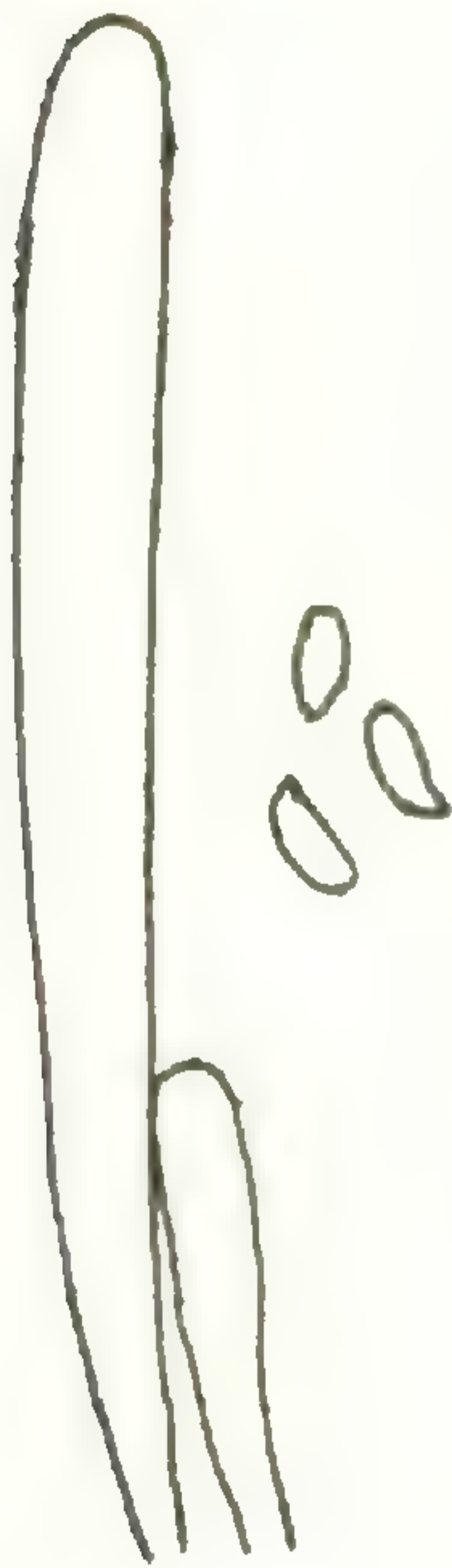


Fig. 6.
S. pallidum.
Cystidium, basidium, and spores,
× 665. From
Bresadola.

Fructifications cespitose, laterally confluent, infundibuliform, coriaceous-spongy, rather thick, becoming cartridge-buff to cream-color in the herbarium, the upper side strigose-squamose; stem short, villose at the base; hymenium with slight, very obtuse, radial folds, under a lens more or less setulose with hyaline hairs; cystidia hair-like, not incrusted, cylindric, 6–8 μ in diameter, protruding 10–50 μ beyond the basidia, usually very numerous but sometimes only few found; spores hyaline, even, flattened on one side, 6–8 × 4–5 μ .

Fructifications 1–3 cm. in diameter, 2–3 cm. high.

On the ground in woods. Vermont to North Carolina. July to November. Rare.

American specimens of *S. pallidum* agree well with the European specimen received from Bresadola, and, like the latter, are paler than the otherwise excellent figures of *Thelephora*

pallida in Persoon's 'Icones et Descriptiones Fungorum' already cited. Our specimens and that from Bresadola have the hymenium distinctly setulose with hair-like cystidia. Some of the specimens in Kew Herbarium under the name of *Thelephora Sowerbeyi* have hair-like cystidia, but these organs are few or absent in whole sections from other specimens. The original specimen of *Helvella pannosa* from Sowerby in Berkeley Herbarium at Kew has hair-like cystidia. I concluded that these cystidia are variable in abundance in English specimens and that *Thelephora Sowerbeyi* and *Helvella pannosa* as represented by the specimen from Sowerby should be kept with *Thelephora pallida*. Although the specific name *pannosa* of Sowerby was at first adopted by Fries, this was dropped later when Berkeley found this species, as understood by Sowerby, to be based upon a mixture of two species which were separated as *Thelephora Sowerbeyi* and *T. multizonata*; *T. pallida* has priority over *T. Sowerbeyi*.

S. pallidum may be distinguished from *T. Willeyi* forms of *S. diaphanum* by its occurrence in small conerescent clusters, by short villose or tomentose stem, and by thicker pileus with upper surface split radially into stiff straight fibrils.

Specimens examined:

Austria: *G. Bresadola*.

England: from Sowerby, under the name *Helvella pannosa* (in Kew Herb.); Cornwall, *C. Rea*, 1 (in Mo. Bot. Gard. Herb., 56241); Hereford, *Mrs. Wynne* (in Kew Herb., under the name *Thelephora Sowerbeyi*).

Vermont: Brattleboro, *C. C. Frost* (in Univ. Vermont Herb.); Grand View Mountain, *E. A. Burt*.

Connecticut: Waterbury, *C. C. Hanmer*, 1191.

North Carolina: Blowing Rock, *G. F. Atkinson*, comm. by Cornell Univ. Herb., 4192.

16. *S. elegans* (Meyer) Lloyd, Myc. Writ. 4. Stip. Stereums, 24. text f. 539. 1913. (Not *S. elegans* of earlier authors.)

Plate 3, fig. 15.

Thelephora elegans Meyer, Fl. Essequeboensis, 305. 1818; Fries, Syst. Myc. 1: 430. 1821; Epicr. 545. 1838. (But here abridged in an important respect so that following authors modified the description to apply to more common species).

An *T. macrorrhiza* Léveillé, Ann. Sci. Nat. Bot. III. 5: 146. 1818? See Lloyd, *loc. cit.*, p. 28.

Illustrations: Lloyd, *loc. cit.* Not by the figures under this name in other works, as Engl. & Prantl, Nat. Pflanzenfam., for example.

Fructifications cespitose, coriaceous, confluent, infundibuliform and deeply split on one side, or little developed on one side and prolonged and petaloid on the other; upper surface of pilei glabrous, radially plicate, drying diamine-brown, the margin paler and more or less lobed; stems solid, buffy brown, short, tomentose, branched above; hymenium radially plicate, nearly white, pruinose, often cracked; pileus in section $400\ \mu$ thick, composed of densely and longitudinally arranged, hyaline hyphae $3\ \mu$ in diameter; no cystidia; gloeocystidia $4\frac{1}{2}\ \mu$ in diameter, barely distinguishable from the basidia; spores hyaline, even, subglobose, $3\frac{1}{2}$ – $4\frac{1}{2}\ \mu$ in diameter.



Fig. 7.
S. elegans.
Gloeocystidia
 $\times 665$.

Fructifications 4–5 cm. high; pilei 1–2 cm. in diameter; stems about 1 cm. long, 1–2 mm. in diameter.

In a dense cluster of about 16 fructifications springing from an area of 2 square centimeters on the ground. Porto Rico to British Guiana. Summer.

I have not seen the type of *Stereum elegans* from Dutch Guiana nor reference to its existence; a collection from Porto Rico on which the preceding description is based has fructifications growing on the ground closely together and concretescent where in contact; the pilei are plicate on both surfaces and contrast so greatly in color that it seems as though fuscous in connection with the upper side and whitish flesh-color and pruinose for the under side might have been used for the color difference. The specimens of this collection are not zonate; infundibuliform without any qualification of this character does not seem accurate; hence it may be that this Porto Rican collection is merely near, rather than the true, *Stereum elegans*. However, solitary fructifications growing on wood, as figured in Engl. & Prantl, Pflanzenfam., are certainly a very different species from *S. elegans*, the original description of which is as follows:

"1. *Thelephora elegans*. nob.

"*T. subcaespitosa infundibuliformis carnosu-coriacea plicata utrinque glabra, superne dilute fusco-fasciata, inferne albescenti-carnea pruinosa.*

"Ad terram argillosam.

"Viget Junio.

"*Adumbr.* Pulchra species. Gregarie crescens, subcarnosa, tenuis, glabra. Pileus substipitatus, 1-2 uncialis, infundibuliformis, subcompressus, undulato-plicatus, margine irregulariter crenatus, interne rufescens, et fasciis dilute fuscis eleganter variegatus, nitens, externe albescenti-carneus, opacus, pruinusus."

Specimens examined:

Porto Rico: Mayaguez, *B. Lopez Santiago*, 17 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56265).

17. *S. decolorans* (Berk. & Curtis) Lloyd, Myc. Writ. 4. Stip. Stereums, 36. 1913. Plate 3, fig. 234.

Thelephora decolorans Berkeley & Curtis, Linn. Soc. Bot. Jour. 10: 328. 1868; Sacc. Syll. Fung. 6: 530. 1888.—*Podoscypha decolorans* (Berk. & Curtis) Patouillard in Duss, Fl. Crypt. Antilles Fr. 231. 1904.

Type: in Kew Herb. and Curtis Herb.

Fructifications coriaceous, gregarious or somewhat caespitose, stipitate; pileus split on one side quite, or nearly, to the stem, usually wedge-shaped to broadly flabelliform, sometimes radially lineate, drying cinnamon; stem cylindrical, colored like the pileus, tomentose, attached by a mycelium common to several fructifications; hymenium colored like the pileus and stem, sometimes lineate; pileus in section 200-400 μ thick, composed of densely and longitudinally arranged hyaline hyphae 3-3 $\frac{1}{2}$ μ in diameter; no cystidia; gloeocystidia flexuous, 45-90 \times 3-6 μ , between the basidia or curving into the hymenium; spores hyaline, even, subglobose, 4-4 $\frac{1}{2}$ \times 3-4 μ .

Fructifications 1-3 cm. long, 5-13 mm. broad; stem 2-10 mm. long, $\frac{1}{2}$ -1 mm. thick.

On dead wood. Jamaica to Trinidad. May to January.

S. decolorans is stated in the original description to have been white, drying ochraceous; I have seen only dried specimens which are pale cinnamon throughout. The occurrence of the

fan-shaped fructifications in clusters on dead wood, pale cinnamon color when dry, presence of gloeocystidia, and small subglobose spores constitute a group of characters by which dried specimens of *S. decolorans* may be distinguished from other species in our region.

Specimens examined:

Jamaica: *W. A. Merrill, 1181* (in N. Y. Bot. Gard. Herb.).

Cuba: *C. Wright 234, 248*, type (in Kew Herb. and Curtis Herb.); Santiago de las Vegas, *Van Herman*, comm. by *F. S. Earle, 257*.

Trinidad: Carengo, *M. A. Carriker*, comm. by *W. G. Farlow, 1*.

18. *S. radicans* (Berk.) Burt, n. comb. Plate 3, fig. 16.

Thelephora radicans Berkeley, Hooker's London Jour. Bot. **3**: 190. 1844; Berkeley & Curtis, Linn. Soc. Bot. Jour. **10**: 329. 1868; Sacc. Syll. Fung. **6**: 525. 1888.—*Podoscypha radicans* (Berk. & Curtis) Patouillard in Duss, Fl. Crypt. Antilles Fr. 230. 1904.

Type: in Kew Herb. probably.

"Plant $1\frac{1}{2}$ inch high, $\frac{3}{4}$ of an inch broad, spathulate or subinfundibuliform, split on one side and slightly lobed, minutely striate, with raised lines, tawny, coriaceous. Stem $\frac{3}{4}$ of an inch high, $1\frac{1}{2}$ line thick, incrassated at the base, and sending off strong branched roots. Hymenium nearly even, fuliginous; spores apparently fuliginous."

The above is the original description of the type specimens, collected in Surinam, Guiana, by Hostmann, 489. My knowledge of the species is based upon a later collection made in Cuba by C. Wright and determined by Berkeley. This specimen and the others cited below show well the longitudinal raised lines on the upper surface of the pileus, which is thicker than in related species, being $1-1\frac{1}{4}$ mm. thick, and the hymenium $100-200 \mu$ thick; some specimens have dried with the upper surface pinkish buff and others from wood-brown to Verona-brown; hymenium even, wood-brown to fuscous; stem $10-15$ mm. long, $3-4$ mm. in diameter, sometimes radicated to reach buried wood; no cystidia nor gloeocystidia; spores hyaline, even, becoming minutely rough-walled and sometimes slightly angular, $6 \times 5 \mu$.

Specimens examined:

Cuba: *C. Wright, 209*, authentic (in Curtis Herb.).

Jamaica: Castleton Gardens, *W. A. & Edna L. Merrill*, 66, comm. by N. Y. Bot. Gard. Herb.

Trinidad: *R. Thaxter* (in Farlow Herb.).

Grenada: *W. E. Broadway*, September collection (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56316); St. George's, *W. E. Broadway* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56317).

British Honduras: *M. E. Peck* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56321).

19. *S. pusiolum* Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 330. 1868; Sacc. Syll. Fung. 6: 558. 1888; Masee, Linn. Soc. Bot. Jour. 27: 168. 1890; Lloyd, Myc. Writ. 4: Stip. Stereums, 39. 1913. Plate 3, fig. 17.

Type: in Kew Herb. and Curtis Herb.

Fructifications gregarious, stipitate, coriaceous, curling in drying; pileus flabelliform or wedge-shaped, tapering to the stem, more or less split when large, minutely tomentose or hoary, white at first, drying smoke-gray, the margin thick and entire; stem short, solid, a little larger towards the base, colored like the pileus; hymenium even, mouse-gray, thick, contracting and sometimes cracking in drying; pileus in section 400–800 μ thick, composed of closely and longitudinally arranged hyaline hyphae $2\frac{1}{2}$ μ in diameter; no cystidia, gloeocystidia, nor conducting hyphae; spores hyaline, even, apiculate at base, $4-5\frac{1}{2} \times 3-5$ μ .

Fructifications 1–2 cm. high, 1–15 mm. broad; stem 5–8 mm. long, $\frac{1}{2}$ – $1\frac{1}{2}$ mm. thick.

On clay ground. West Indies. November to March.

The white pileus, drying gray of nearly the shade of *Polyporus adustus*, minutely hairy, wedge-shaped, and without zonation, the much darker hymenium—dark as in *P. adustus*—the rather large spores, and the absence of gloeocystidia afford a group of characters highly distinctive for *Stereum pusiolum*, the description of which I have changed materially from that published by the authors of the species. They disregarded Wright's note that the specimens were white and were collected on banks by roadside and published instead "rufobrunneum" and "on root-lets." The recent collections, cited below, which I have compared with the type, show also that the dimensions of the fructifications are usually much larger than those of the type collection.

Specimens examined:

Cuba: *C. Wright*, 510, type (in Curtis Herb.); El Yunque, Baracoa, *L. M. Underwood & F. S. Earle*, 1087, 1141, comm. by N. Y. Bot. Gard. Herb., 1141 (in Mo. Bot. Gard. Herb., 56588).

Porto Rico: Rio Piedras, *J. R. Johnston*, 89 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56284).

20. *S. glabrescens* Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 330. 1868; Sacc. Syll. Fung. 6: 558. 1888; Masee, Linn. Soc. Bot. Jour. 27: 169. 1890; Lloyd, Myc. Writ. 4. Stip. Stereums, 37. text f. 558. 1913. Plate 3, fig. 18.

Illustrations: Lloyd, *loc. cit.*

Type: in Kew Herb. and Curtis Herb.

Fructifications scattered, sometimes two from a common mycelial pad, stipitate; pileus flabelliform, zonate, minutely velvety, sometimes nearly glabrous, drying Verona-brown to chestnut, the margin paler, tapering behind into a short stem; stem lateral, nearly equal, velvety; hymenium even, concave, drying pinkish buff; no cystidia nor gloeocystidia; spores hyaline, even, $4-5 \times 3-4 \mu$.

Pileus 5-20 mm. long, 5-20 mm. broad; stem 2-10 mm. long, $\frac{1}{2}$ - $1\frac{1}{2}$ mm. thick.

On fallen twigs and mossy rotten wood. West Indies. May to September.

S. glabrescens has small, rather scattered fructifications, with firm, coriaceous, minutely velvety pileus and stem, small subglobose spores, and no cystidia, and it occurs on wood. Some collections are nearly glabrous. A mycelial pad is usually present at base of stem.

Specimens examined:

Cuba: *C. Wright*, 520, type (in Curtis Herb.); Pinar del Rio, *J. A. Shafer*, 13906 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56298).

Porto Rico: Ponce, *F. S. Earle*, 163, comm. by N. Y. Bot. Gard. Herb.

Jamaica: Hollymount, *L. M. Underwood*, 3427 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56299).

Dominica: Landat, *F. E. Lloyd*, 380, comm. by N. Y. Bot. Gard. Herb.

21. *S. flabellatum* Patouillard, Soc. Myc. Fr. Bul. 16: 179. 1900; Sacc. Syll. Fung. 16: 187. 1902; Lloyd, Myc. Writ. 4. Stip. Stereums, 39. 1913.

Podoscypha flabellata Patouillard in Duss, Fl. Crypt. Antilles Fr. 231. 1904.

Pileus membranaceous, thin, expanded anteriorly, regularly attenuated posteriorly into a lateral stipe which is compressed; margin papyraceous, deeply incised or lobed; dorsal surface marked by slight puberulence of projecting hairs or crests which are slightly diverging or fan-shaped, not zonate; hymenium inferior, glabrous, even; stem becoming pubescent, short, enlarged at the base into a disk for attachment.

Fructification 4–6 cm. high; stem $\frac{1}{2}$ –1 cm. long, 1–2 mm. thick. Fructification erect, spathulate, often confluent by the margin with neighbors, whitish when living, livid and pellucid upon drying.

On rotting wood on the ground. Guadeloupe.

The above is a translation of Patouillard's description. Lloyd saw a specimen in the museum at Berlin and states that the dried specimens are dark reddish bay.

22. *S. fissum* Berkeley, Hooker's Jour. Bot. 8: 273. 1856; Masee, Linn. Soc. Bot. Jour. 27: 169. 1890; Sacc. Syll. Fung. 11: 120. 1895; Lloyd, Myc. Writ. 4. Stip. Stereums, 37. *text f. 559.* 1913. Plate 3, fig. 19.

S. Huberianum P. Hennings, Hedwigia 41: (15). 1902; 43: 173. 1904.

Illustrations: Lloyd, *loc. cit.*

Type: in Kew Herb. and in Curtis Herb.

Pilei gregarious, occurring singly, sessile or short-stipitate, coriaceous, flabelliform or wedge-shaped, often divided into wedge-shaped segments, glabrous, even, not shining nor zonate, white when fresh, now reddish brown in the herbarium, attached by a flat mycelial pad; hymenium even; in structure 300–400 μ thick, composed of densely and longitudinally arranged hyaline hyphae 3 μ , or some 4 μ , in diameter; no cystidia nor gloeocystidia; the few detached spores found are hyaline, even, 6 \times 4 μ .

Pileus 8–15 mm. long, 3–15 mm. broad.

On dead twigs, Brazil.

S. fissum may yet be found as far north as the West Indies and Central America. The species is noteworthy by its occurrence on dead twigs in scattered, solitary, azonate fructifications which are often deeply split into segments, and by absence of cystidia and gloeocystidia.

Specimens examined:

Exsiccati: Ule, *Myc. Brasil.*, 42, under the name *Stereum Huberianum*.

Brazil: Panure, *Spruce*, 27, type (in Curtis Herb.); Amazonas, Marmellos, and Jurná, *E. Ule*, in Ule, *Myc. Brasil.*, 42.

23. *S. cyphelloides* Berk. & Curtis, *Linn. Soc. Bot. Jour.* 10: 331. 1868; *Sacc. Syll. Fung.* 6: 558. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 172. 1890; Lloyd, *Myc. Writ.* 4. *Stip. Stereums*, 35. 1913. Plate 3, fig. 20.

Type: in Kew Herb. and Curtis Herb.

Pileus small, flabelliform or spatulate, drying pinkish buff, longitudinally fibrillose, bibulous, the margin entire, narrowed behind into a short stem-like base; in structure up to 600 μ thick, composed of thin-walled, hyaline hyphae $2\frac{1}{2}$ –3 μ in diameter, interwoven in the subhymenium; hymenium even, drying of same color as upper surface of pileus; no conducting organs, gloeocystidia, nor cystidia; spores hyaline, even, $4\text{--}5 \times 3\text{--}3\frac{1}{2}$ μ .

Pileus 3–6 mm. wide, 5–7 mm. long.

On a bank among moss. West Indies. February and March.

S. cyphelloides differs from most *Stereums* in not having a hard compact structure, as in *S. rameale*, for example; it is of soft and bibulous texture but rather too thick for a *Cyphella*. The stem-like base is flattened in the same plane with the pileus and has the hymenium continued along its whole length, hence it is merely a narrowed portion of the pileus.

Specimens examined:

Cuba: *C. Wright*, 511, type (in Curtis Herb.).

Porto Rico: Monte Cerrote, near Adjuntas, *N. L. Britton & Stewardson Brown*, 5449 (in *N. Y. Bot. Gard. Herb.* and *Mo. Bot. Gard. Herb.*, 56261).

24. *S. Hartmanni* (Mont.) Lloyd, *Myc. Writ.* 4. *Stip. Stereums*, 34. *text f.* 553. 1913. Plate 3, fig. 21.

Thelephora Hartmanni Montagne, Ann. Sci. Nat. Bot. II. 20: 366. 1843; Syll. Crypt. 176. 1856; Sacc. Syll. Fung. 6: 535. 1888.—*T. dissecta* Léveillé, Ann. Sci. Nat. Bot. III. 5: 146. 1846; Sacc. Syll. Fung. 6: 531. 1888; Lloyd, *loc. cit.*, 39.

Illustrations: Lloyd, *loc. cit.*

Type: authentic specimen from Montagne in Kew Herb.

Pilei solitary or cespitose, sessile or barely stipitate, coriaceous, thin, white, wedge-shaped, deeply cleft into narrow segments which are more or less pectinate along their margins and apex and have these teeth-like portions incurved; no cystidia; no gloeocystidia; spores hyaline, even, subglobose, $4-5 \times 3\frac{1}{2}-4 \mu$.

Pileus 7–50 mm. long, 5–40 mm. broad.

On decaying wood and bark and dead herbaceous stems. Carolina to Bolivia. July to September in West Indies and February in Bolivia.

The pilei of *S. Hartmanni* occur in small tufts of two or three in the specimens which have been seen; they are very dainty and unique by the narrow pectinate margins and tips which are more or less incurved; rarely these teeth occur on the lower surface of segments of the pileus in a manner suggestive of teeth of an *Irpex* but they are in most cases marginal. The maximum dimensions of the pileus are from the Porto Rican collection; the other specimens do not have pilei more than 2–3 cm. long. I have not seen the type of *Thelephora dissecta* Lév., which was collected in Guadeloupe; the description agrees so well with *S. Hartmanni* that I have followed Lloyd's conclusion that *T. dissecta* is a synonym of *S. Hartmanni*.

Specimens examined:

Carolina: *Hartmann*, authentic, from Montagne (in Kew Herb.).

Porto Rico: Luquillo Mountain, *P. Wilson*, 313 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56302).

St. Kitt's: *N. L. Britton & J. F. Cowell*, 706, comm. by N. Y. Bot. Gard. Herb.

Bolivia: *R. E. Fries*, 272, comm. by L. Romell, 447 (in Mo. Bot. Gard. Herb., 54780).

25. *S. craspedium* (Fries) Burt, n. comb. Plate 3, fig. 22.

Thelephora (Merisma) craspedia Fries, R. Soc. Sci. Upsal. Actis III. 1: 108. 1851; Sacc. Syll. Fung. 6: 533. 1888; Lloyd, Myc. Writ. 4. Stip. Stereums, 34. 1913.

Type: a fragment in Kew Herb., according to Lloyd.

Erect, cespitose, membranaceous-soft, fragile when dry, palmately branched, complanate, ribbed, dilated above, lacerate-fimbriate at the apex; hymenium definitely inferior, pallid gilvus; spores white.

In pine woods, Pico de Orizaba, 10,000 ft. altitude, Mexico. Collected by Liebman.

An extraordinary species, similar to *Thelephora tuberosa* and *Tremellodendron pallidum* but with the substance thin, somewhat membranaceous, fragile when dry, and with the pileus foliaceous-complanate, ribbed (ribs commonly simple as in *Alaria*), very distinct. More than an inch high. Hymenium occupying the whole lower surface, at length floccose-collapsing and often foveolate, almost porose; basidia evidently 4-spored.

The above is a translation of the original description. I did not find the type in Herb. Fries at Upsala nor see the fragment which Lloyd has reported as preserved at Kew.

The specimen from Dutch Guiana, which is cited below, is so similar in aspect to *Tremellodendron pallidum* that it is probably *S. craspedium*. This cluster is 7 cm. in diameter and 3-4 cm. high, and agrees well with details of the original description. The basidia are simple, only detached spores found. These are hyaline, even, globose, 3 μ in diameter.

Specimens examined:

Dutch Guiana: *Jacob Samuels* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56300).

26. *S. petalodes* Berkeley, Ann. & Mag. Nat. Hist. II. 9: 198. 1852; Sacc. Syll. Fung. 6: 557. 1888; Masee, Linn. Soc. Bot. Jour. 27: 165. 1890; Lloyd, Myc. Writ. 4. Stip. Stereums, 32. text f. 551. 1913. Plate 3, fig. 23.

Illustrations: Lloyd, *loc. cit.*

Type: in Kew Herb. according to Lloyd.

Pileus coriaceous, sessile, at first infundibuliform, soon split into numerous lobes which are again more or less divided, dull reddish brown, marked with long grooves or striae; hymenium pale, much cracked, sometimes so much so as to be nearly granulated.

San Domingo. Coll., *Salle*, 52.

The above is the original description of *S. petalodes*, a species of which I have seen no specimen. Lloyd's figure of the type shows the fructification to be a rosette-shaped mass 4 cm. high and 6 mm. in diameter, composed of many elongated pileate flaps, each of which is flattened and up to 7 mm. broad. No record was published by Berkeley as to whether *S. petalodes* grows on ground or on wood.

27. *S. anastomosans* (Berk. & Curtis) Lloyd, Myc. Writ. 4. Stip. Stereums, 35. 1913.

Thelephora anastomosans Berkeley & Curtis, Linn. Soc. Bot. Jour. 10: 329. 1868; Sacc. Syll. Fung. 6: 534. 1888.

Type: in Curtis Herb. and Kew Herb.

Fructification stipitate, white, with the pileus divided into many segments; pileate branches and branchlets more or less laterally grown together above, somewhat flabeliform and fimbriate, below more or less distinct or confluent into the common stem; hymenium even, inferior; no cystidia nor gloeocystidia; spores copious, hyaline, even, subglobose, $4-4\frac{1}{2} \times 3\frac{1}{2}-4 \mu$.

Fructifications about $2\frac{1}{2}$ cm. high.

On stump. Cuba. October.

It was noted by the authors of the species that *S. anastomosans* is allied to *S. craspedium*, but the divisions of its pileus are narrower than I understand them to be in the latter. *S. anastomosans* is somewhat suggestive of *S. Hartmanni* and *S. proliferum* but differs in having many pileate divisions grow out from a common trunk so as to form a rosette-like mass, as in doubled forms of *Thelephora caryophyllea*.

Specimens examined:

Cuba: *C. Wright*, 280, type (in Curtis Herb.).

28. *S. proliferum* (Berk.) Lloyd, Myc. Writ. 4. Stip. Stereums, 34. text f. 554. 1913. Plate 4, fig. 24.

Thelephora prolifera Berkeley, Hooker's Jour. Bot. 8: 272. 1856; Sacc. Syll. Fung. 6: 542. 1888.

Illustrations: Lloyd, *loc. cit.*

Type: in Kew Herb. and Curtis Herb.



Fig. 8.
S. anastomosans.
Spores $\times 665$.
From type.

Fructifications cespitose, stipitate, coriaceous, erect, white, now between light buff and cartridge-buff throughout; stem cylindric, branched above, the branches either slender, cylindric, sterile bodies, or flattened, membranous pilei 1–2 mm. broad, 1–1½ cm. long; hymenium on the lower side, even; a few detached spores hyaline, even, $3\frac{1}{2} \times 3 \mu$, none found on basidia.

Fructifications about 3 cm. high; stems ½ mm. in diam.; pileate branches 1–1½ cm. long, 1–2 mm. broad.

On roots of trees. Brazil.

Berkeley described *S. proliferum* as somewhat creeping and having the branches with tips attached again to the matrix by means of large, orbicular, radiated and lacinated disks. These characters should render this species easy for the collector to recognize, but the herbarium specimen which I studied did not show the above feature noticeably; it had somewhat the aspect of *S. Hartmanni* but without the pectinate margins of the latter. The hymenium of the specimen studied is in poor condition and the spore characters, as given above, are uncertain. I studied for N. Y. Bot. Gard. Herb., No. 508, a fungus collected at Church Cove, Bermuda, which has the general aspect of *S. proliferum* but with spores hyaline, even, $13\text{--}16 \times 6\text{--}7 \mu$, and is probably a distinct species. Still it is well to keep *S. proliferum* in mind in connection with species of the West Indies.

Specimens examined:

Brazil: Rio Negro, *Spruce*, 17, type (in Curtis Herb.).

29. *S. caespitosum* Burt, n. sp.

Plate 4, fig. 25.

Type: in Burt Herb.

Fructifications coriaceous, thin, cespitose, effuso-reflexed, with the resupinate portion small and bearing a cluster of broader and longer, imbricate, pileate lobes which are somewhat furfuraceous or with minute tomentum on the upper side, glabrate towards the margin, drying tawny and zonate with ochraceous, tawny zones, the margin entire; hymenium even, whitish to light buff; in structure 500–700 μ thick, with the intermediate layer bordered above by a narrow, slightly colored zone and composed of densely longitudinally arranged, hyaline, thick-walled hyphae $3\frac{1}{2} \mu$ in diameter; hymenial layer up to 120 μ thick, containing numerous slender, flexuous gloeocystidia

$3\frac{1}{2}$ –5 μ in diameter near the base, tapering outward; no colored conducting organs nor noteworthy paraphyses; spores hyaline, even, 4 – $4\frac{1}{2}$ \times 3 – $3\frac{1}{2}$ μ , copious.

Resupinate portion covers area 6×5 mm., reflexed lobes 5–10 mm. in diameter—about 10 in the cluster.

On broken lateral stub of dead limb of a frondose species. Jamaica. January. Probably rare.

Viewed from above, *S. caespitosum* has the general aspect and coloration of species of *Stereum* in sections having stems, as *S. pergamenum* and *S. decolorans*, but is excluded from these sections by attachment to the substratum by a distinctly resupinate portion. The species is unique in the effuso-reflexed section in the above resemblance, and with additional characters of clustered, imbricated habit of growth and presence of gloeocystidia, should be readily recognized.

Specimens examined:

Jamaica: Moneague to Union Hill, *W. A. Merrill, 1181*, type, comm. by N. Y. Bot. Gard. Herb.

30. *S. fuscum* Schrader ex Quelet, *Fl. Myc. France*, 14. 1888; Bresadola, *I. R. Accad. Agiati Atti III.* 3: 106. 1897.

Plate 4, fig. 26.

Thelephora fusca Schrader, *Spic. Fl. Germ.* 184. 1794; Persoon, *Syn. Fung.* 568. 1801, and *Myc. Eur.* 1: 122. 1822 (in both places renaming the species *T. bicolor*); Fries, *Syst. Myc.* 1: 438. 1821 (following Persoon).—*T. bicolor* Persoon, *Syn. Fung.* 568. 1801; Fries, *Syst. Myc.* 1: 438. 1821.—*Stereum bicolor* Persoon, *Myc. Eur.* 1: 122. 1822 (under **** *Stereum* of *Thelephora*); Fries, *Epier.* 549. 1838; *Hym. Eur.* 640. 1874; Morgan, *Cincinnati Soc. Nat. Hist. Jour.* 10: 195. 1888; *Sacc. Syll. Fung.* 6: 565. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 177. 1890.—*S. coffeatum* Berk. & Curtis, *Grevillea* 1: 164. 1873; *Sacc. Syll. Fung.* 6: 568. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 190. 1890.

Illustrations: Fries, *Icones Hym.* pl. 197. f. 2; Karsten, *Icones Hym.* pl. 2. f. 9.



Fig. 9.
S. caespitosum.
Gloeocystidia
and spores \times
665.
From type.

Fructifications somewhat membranaceous, soft, spongy, sometimes resupinate, usually becoming conchate-reflexed, often

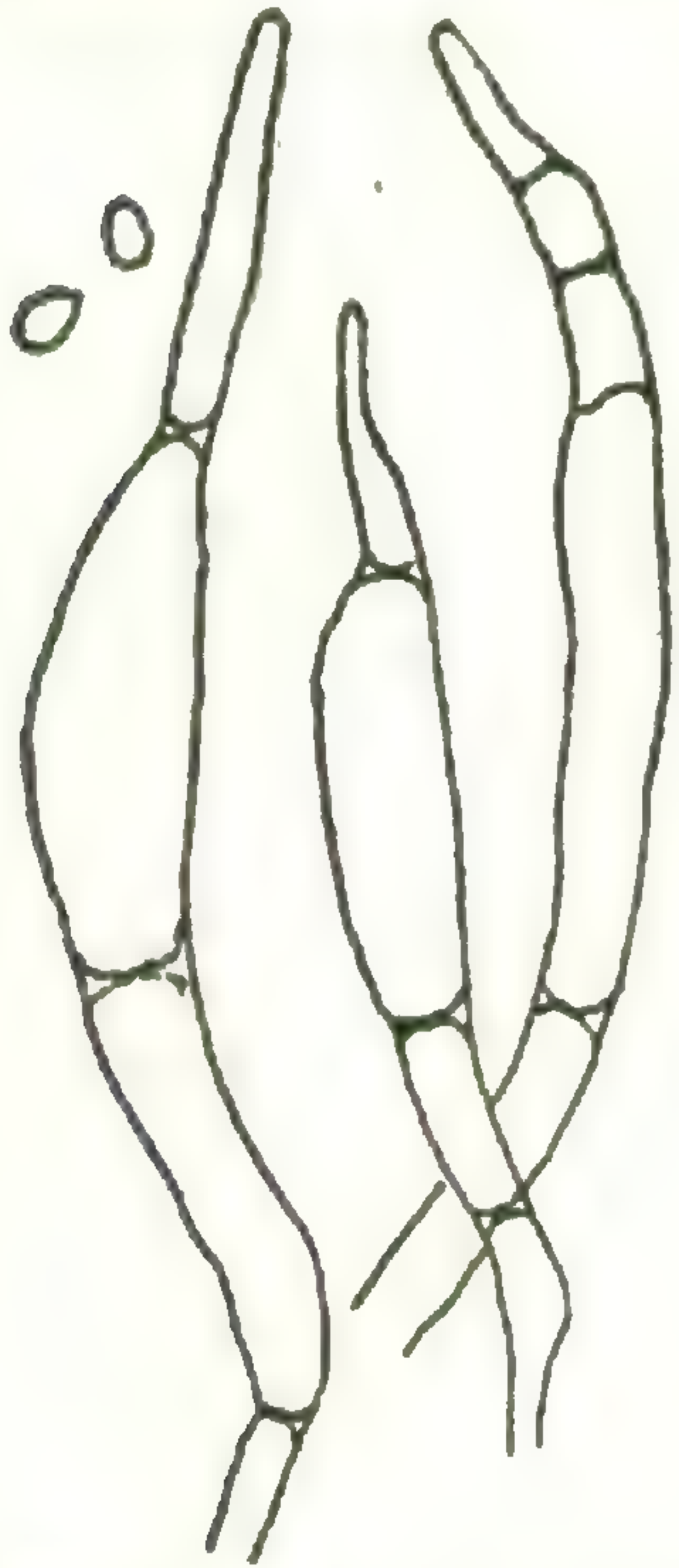


Fig. 10. *S. fuscum*.
Gloeocystidia and spores
× 665.

imbricated, villose, becoming glabrous, somewhat concentrically sulcate, drying snuff-brown to bister; hymenium even, glabrous, white, drying cream-color to pallid mouse-gray; in structure 1000 μ thick, composed of longitudinally and loosely interwoven hyphae 3 μ in diameter, colored towards the upper surface, hyaline towards the hymenium; hymenium not zonate, containing flexuous gloeocystidia 20–60 \times 5–7 μ , rarely 90 μ , long; spores hyaline, 3–4½ \times 2–3 μ .

Reflexed pileus 1–4 cm. long, 2–5 cm. wide; resupinate specimens 3–10 \times 1–3 cm.

On rotting frondose limbs usually, but sometimes on pine. Canada to Texas, westward to Oregon, in the West Indies, and also in Europe. April to December. Not rare.

Reflexed specimens of *S. fuscum* may be recognized at sight by the soft, pliant pileus, brown and felt-like above, with a white hymenium. Gloeocystidia are so rare in the hymenium of a *Stereum* that their presence in abundance in this species affords a decisive specific character. Wholly resupinate specimens have the color of the hymenium of reflexed fructifications and have similar consistency and gloeocystidia. So many reflexed species occur resupinate that one should be sure to gather the more or less reflexed fructifications which can usually be secured associated with the resupinate specimens. Since both Persoon and Fries recognized the priority of Schrader's specific name *fuscum* and substituted *bicolor*, presumably because highly distinctive and appropriate for the species, the restoration of the original name by recent mycologists seems just.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 1207; Ell. & Ev., Fungi Col., 1019; Rabenhorst, Fungi Eur., 3233; Ravenel, Fungi Am., 9; Ravenel, Fungi Car. 2: 33; de Thümen, Myc. Univ., 1704.

- Finland: Mustiala, *P. A. Karsten*, in de Thümen, *Myc. Univ.*, 1704.
- Sweden: Femsjö, *L. Romell*, 402.
- England: Selby, *E. A. Burt*.
- France: Allier, *H. Bourdot*, 16141.
- Hungary: *Kmet*, comm. by *G. Bresadola*.
- Canada: *J. Macoun*, 76, 280.
- Ontario: Ottawa, *J. Macoun*, 21, 59; Toronto, *J. H. Faull*, *Univ. Toronto Herb.*, 361 (in *Mo. Bot. Gard. Herb.*, 44863).
- Vermont: Middlebury, *E. A. Burt*; North Ferrisburg, *E. A. Burt*.
- New York: Bronx Park, New York, *H. D. House* (in *N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb.*, 54392), and *W. A. Murrill* (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56773); Staten Island, *W. H. Ballou* (in *Burt Herb.*, *N. Y. Bot. Gard. Herb.*, and *Mo. Bot. Gard. Herb.*, 56774); Syracuse, *D. C. Mills* (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56281).
- Pennsylvania: Kittanning, *D. R. Sumstine*; West Chester, *Everhart & Haines*, in *Ellis, N. Am. Fungi*, 1207.
- District of Columbia: *C. L. Shear*, 1039; Takoma Park, *C. L. Shear*, 954.
- South Carolina: *H. W. Ravenel*, in *Ravenel, Fungi Car.* 2: 33; Santee Canal, *H. W. Ravenel*, 910 (in *Curtis Herb.*), and *Curtis Herb.*, 2923, type of *Stereum coffeatum* (in *Kew Herb.*); Salem, *Schweinitz* (in *Herb. Schweinitz*).
- Georgia: Atlanta, *E. Bartholomew*, 5680 (in *Mo. Bot. Gard. Herb.*, 44219); Tipton, *C. J. Humphrey*, 156.
- Florida: Gainesville, *H. W. Ravenel*, in *Ravenel, Fungi Am.*, 9; Lake City, *P. L. Ricker*, 898; New Smyrna, *C. G. Lloyd*, 2118.
- Alabama: Auburn, *L. M. Underwood*, comm. by *U. S. Dept. Agr. Herb.*, *F. S. Earle* (in *Mo. Bot. Gard. Herb.*, 5058), and *F. S. Earle & C. F. Baker*; Fayette Co., *P. V. Siggers*, comm. by *A. H. W. Povah*, 15 (in *Mo. Bot. Gard. Herb.*, 9226); Montgomery Co., *R. P. Burke*, 33 (in *Mo. Bot. Gard. Herb.*, 15763).
- Mississippi: Chicou (in *Mo. Bot. Gard. Herb.*, 43014).
- Louisiana: Abita Springs, *A. B. Langlois*; New Orleans, *F. S.*

- Earle* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56775); St. Martinville, *A. B. Langlois*, bz, 2095, and a specimen comm. by Lloyd Herb., 2737.
- Texas: San Antonio, *W. H. Long*, 21703 (in Mo. Bot. Gard. Herb., 55164).
- Ohio: *A. P. Morgan* (in Lloyd Herb.) and *C. G. Lloyd*, in Ell. & Ev., Fungi Col., 1019; Linwood, *C. G. Lloyd*, 1154, 1326; Norwood, *C. G. Lloyd*, V.
- Indiana: Greencastle, *L. M. Underwood* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56276, 56278); Hibernian Mills, *Whetzel & Reddick*, comm. by D. Reddick, 3.
- Wisconsin: Madeline Island, *V. B. Walker*, 6a (in Mo. Bot. Gard. Herb., 8359); Madison, *Miss A. O. Stucki*, 26.
- Missouri: Marianna, *H. von Schrenk* (in Burt Herb. and Mo. Bot. Gard. Herb., 42836); Oran, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42835); Perryville, *C. H. Demetrio*, in Rabenhorst, Fungi Eur., 3233; Williamsville, *B. M. Duggar*, 482.
- Arkansas: Cass, *W. H. Long*, 19923 (in Mo. Bot. Gard. Herb., 13266); Levisque, *P. Spaulding* (in Mo. Bot. Gard. Herb., 5057).
- Idaho: Kooskia, *J. R. Weir*, 589 (in Mo. Bot. Gard. Herb., 56776).
- British Columbia: Agassiz, *J. R. Weir*, 603 (in Mo. Bot. Gard. Herb., 36748).
- Oregon: Corvallis, *C. E. Owens*, 2037 (in Mo. Bot. Gard. Herb., 43871).
- Cuba: Alto Cedro, *L. M. Underwood & F. S. Earle*, 1571, 1581, comm. by N. Y. Bot. Gard. Herb.; Baracoa, *L. M. Underwood & F. S. Earle*, 504, comm. by N. Y. Bot. Gard. Herb.
- Jamaica: Cinchona, *W. A. & E. L. Merrill*, 462, comm. by N. Y. Bot. Gard. Herb.; Hope Gardens, *F. S. Earle*, 500, comm. by N. Y. Bot. Gard. Herb.; Mandeville, *A. E. Wight*, comm. by W. G. Farlow; Troy and Tyre, *W. A. Merrill & W. Harris*, 1073, comm. by N. Y. Bot. Gard. Herb.

31. *S. rufum* Fries, Epicr. 553. 1838; Hym. Eur. 644. 1874;
Sacc. Syll. Fung. 6: 575. 1888; Romell, Bot. Not. 1895:
71. 1895. Plate 4, fig. 27.

Thelephora rufum Fries, Elenchus Fung. 1:187. 1828.—*Cryptochaete rufa* (Fries) Karsten, Finska Vet.-Soc. Bidrag Natur och Folk 48:408. 1889.—*Tubercularia pezizoidea* Schweinitz, Am. Phil. Soc. Trans. N. S. 4:301. 1832; Sacc. Syll. Fung. 4:644. 1886.—*Hypocrea Richardsonii* Berkeley & Montagne, Grevillea 4:14. 1875; Sacc. Syll. Fung. 2:528. 1883; Ellis & Everhart, N. Am. Pyrenomycetes, 86. 1892.—*Corticium pezizoideum* (Schw.) von Schrenk, Torr. Bot. Club Bul. 21:385. pl. 218. 1894.

Illustrations: von Schrenk, Torr. Bot. Club Bul. 21: pl. 218. 1894.

Type: in Herb. Fries.

Fructifications scattered or gregarious, coriaceous-fleshy, bursting out from the bark, verruciform, plicate-tuberculose,

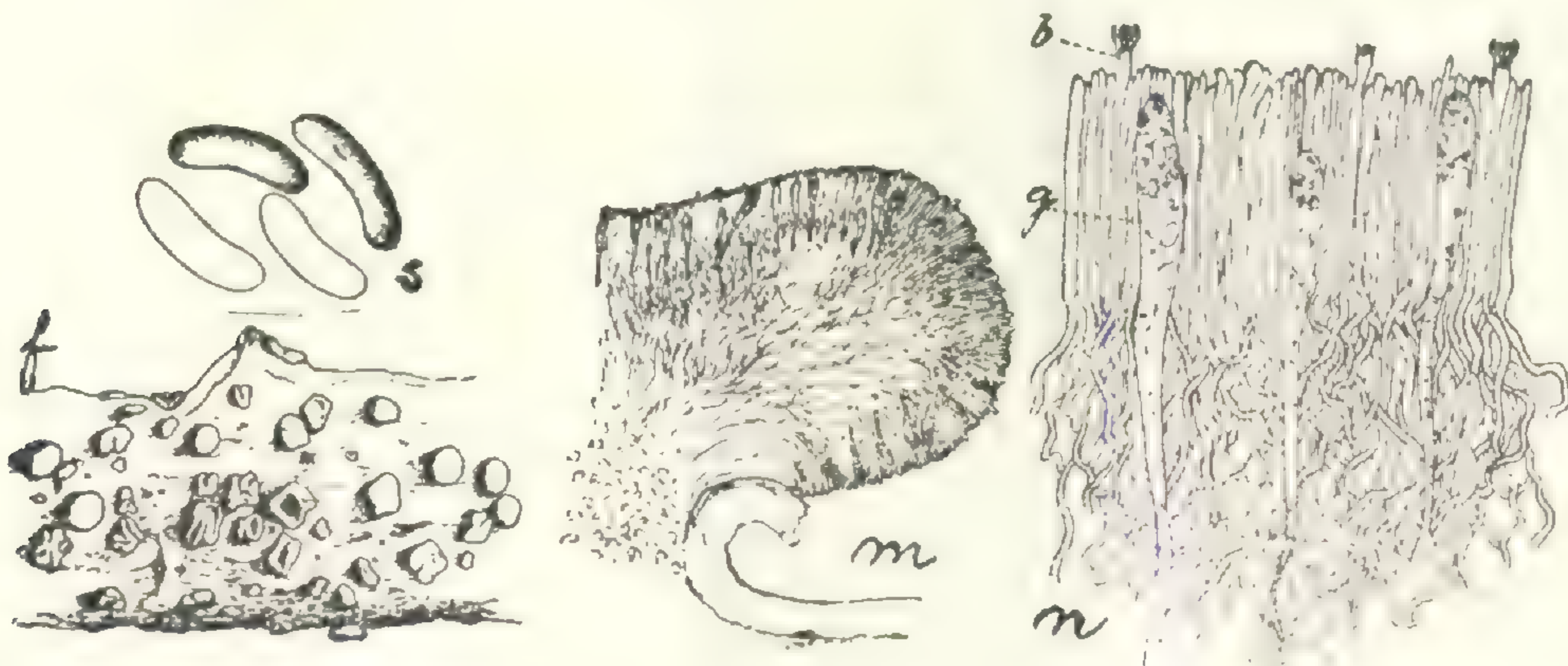


Fig. 11. *S. rufum*. Fructifications, *f*; section of fructification, *m*; section of hymenial region, *n*; spores, *s*. After von Schrenk.

peltate, vinaceous-brown to hematite-red, under side glabrous, the margin free all around; hymenium becoming coarsely wrinkled, vinaceous-brown, often grayish pruinose; in structure 1–2 mm. thick at the center, 600–800 μ thick in the marginal portion, composed of ascending, loosely interwoven, incrustated, hyaline hyphae 4–4½ μ in diameter over the incrustation; flexuous gloeocystidia 50–90 \times 7–10 μ are scattered in or near the hymenium but not protruding; spores white in spore collection, even, curved, 6–8 \times 1½–2 μ .

Fructifications 2–4 mm. in diameter.

On dead fallen *Populus tremuloides*. Newfoundland to Massachusetts and westward to North Dakota and Colorado. March to December. Common. Occurs in Scandinavia also.

S. rufum may be recognized at sight by its occurrence on prostrate poplar limbs and logs in the form of small vinaceous fructifications with the hymenium gyrosely wrinkled. The fructifications become peltate when full grown, attached by the center, and with the marginal portions free and turned outward.

Specimens examined:

Exsiccati: Bartholomew, *Fungi Col.*, 1817, under the name *Corticium rufo-marginatum*, and 2716; Ellis, *N. Am. Fungi*, 1329; Romell, *Fungi Scand. Exs.*, 123; Shear, *N. Y. Fungi*, 88.

Norway: Christiania, *M. N. Blytt*, authentic specimen (in *Herb. Fries*).

Sweden: Stockholm, *L. Romell*, in *Romell, Fungi Scand. Exs.*, 123; Upsala, *L. Romell*, 39.

Newfoundland: *B. L. Robinson & H. von Schrenk* (in *Mo. Bot. Gard. Herb.*, 42944); Bay of Islands, *A. C. Waghorne* (in *Mo. Bot. Gard. Herb.*, 17692).

Ontario: Toronto, *T. Langton*, *Univ. Toronto Herb.*, 595 (in *Mo. Bot. Gard. Herb.*).

Maine: Orono, *F. L. Harvey*, 6 (in *Mo. Bot. Gard. Herb.*, 16620); Portage, *L. W. Riddle*, 10.

New Hampshire: Shelburne, *W. G. Farlow* (in *Mo. Bot. Gard. Herb.*, 14796).

Vermont: Middlebury, *E. A. Burt*, two collections; North Ferrisburg, *E. A. Burt*.

Massachusetts: Peabody, *A. R. Sweetser*; Waverley, *H. von Schrenk* (in *Mo. Bot. Gard. Herb.*, 16623).

New York: Alcove, *C. L. Shear*, in *Shear, N. Y. Fungi*, 88; East Galway, *E. A. Burt*; Ithaca, *G. F. Atkinson* (in *Mo. Bot. Gard. Herb.*, 4775); Willsboro Point, *C. O. Smith*, in *Bartholomew, Fungi Col.*, 1817.

Pennsylvania: Trexlertown, *W. Herbst*.

Michigan: Mackinac Island, *E. T. & S. A. Harper*, 707; Northport, *H. von Schrenk* (in *Mo. Bot. Gard. Herb.*, 22481).

Wisconsin: La Crosse, *W. Trelease* (in *Mo. Bot. Gard. Herb.*, 14794); Madison, *W. Trelease*, in *Ellis, N. Am. Fungi*, 1329, and (in *Mo. Bot. Gard. Herb.*, 14794, 16621); Palmyra, *Miss A. O. Stucki*, 27; Syene, *W. Trelease*, 3022 (in *Mo. Bot. Gard. Herb.*, 14793).

Nebraska: Lincoln, *Miss L. B. Walker*, 7 (in Mo. Bot. Gard. Herb., 44818).

North Dakota: Fargo, *F. J. Seaver*, 25, 54 (in Mo. Bot. Gard. Herb., 16222, 16637).

Montana: Helena, *F. W. Anderson*, 202 (in Mo. Bot. Gard. Herb., 21165).

Colorado: Blind Cañon Placer, *C. L. Shear*, 1021; Golden, *E. Bartholomew & E. Bethel*, in Bartholomew, Fungi Col., 2716, and *E. Bethel & L. O. Overholts*, comm. by L. O. Overholts, 1754 (in Mo. Bot. Gard. Herb., 54875); Ouray, *C. L. Shear*, 1187.

32. *S. Pini* Fries, Epicr. 553. 1838; Hym. Eur. 643. 1874; Sacc. Syll. Fung. 6: 574. 1888. Plate 4, fig. 28.

Thelephora Pini Fries, Syst. Myc. 1: 443. 1821; Elenchus Fung. 1: 187. 1828.—*Sterellum Pini* (Schleich.) Karsten, Finska Vet.-Soc. Bidrag Natur och Folk 48: 405. 1889.

Illustrations: Smith, Brit. Basidiomycetes, text f. 98 E, F.

Fructifications gregarious, coriaceous-cartilaginous, orbicular, resupinate, with the margin free and attached by the center, shield-shaped, finally bullate, drying rigid, Benzo-brown; hymenium wood-brown to Benzo-brown, somewhat pruinose, becoming somewhat

tuberculose; in structure 500 μ thick, thinning out towards the margin, with the intermediate layer bordered on each side by a narrow, colored zone and composed of longitudinally arranged, densely interwoven, hyaline hyphae with walls gelatinously

modified, the subhymenium olivaceous-colored; cystidia incrusted, $24 \times 8 \mu$, sometimes very few to be found; fusoid or irregular gloeocystidia, $30-40 \times 10-15 \mu$, are sparingly present in or near the hymenium; spores hyaline, even, curved, $5-6 \times 2-2\frac{1}{2} \mu$.

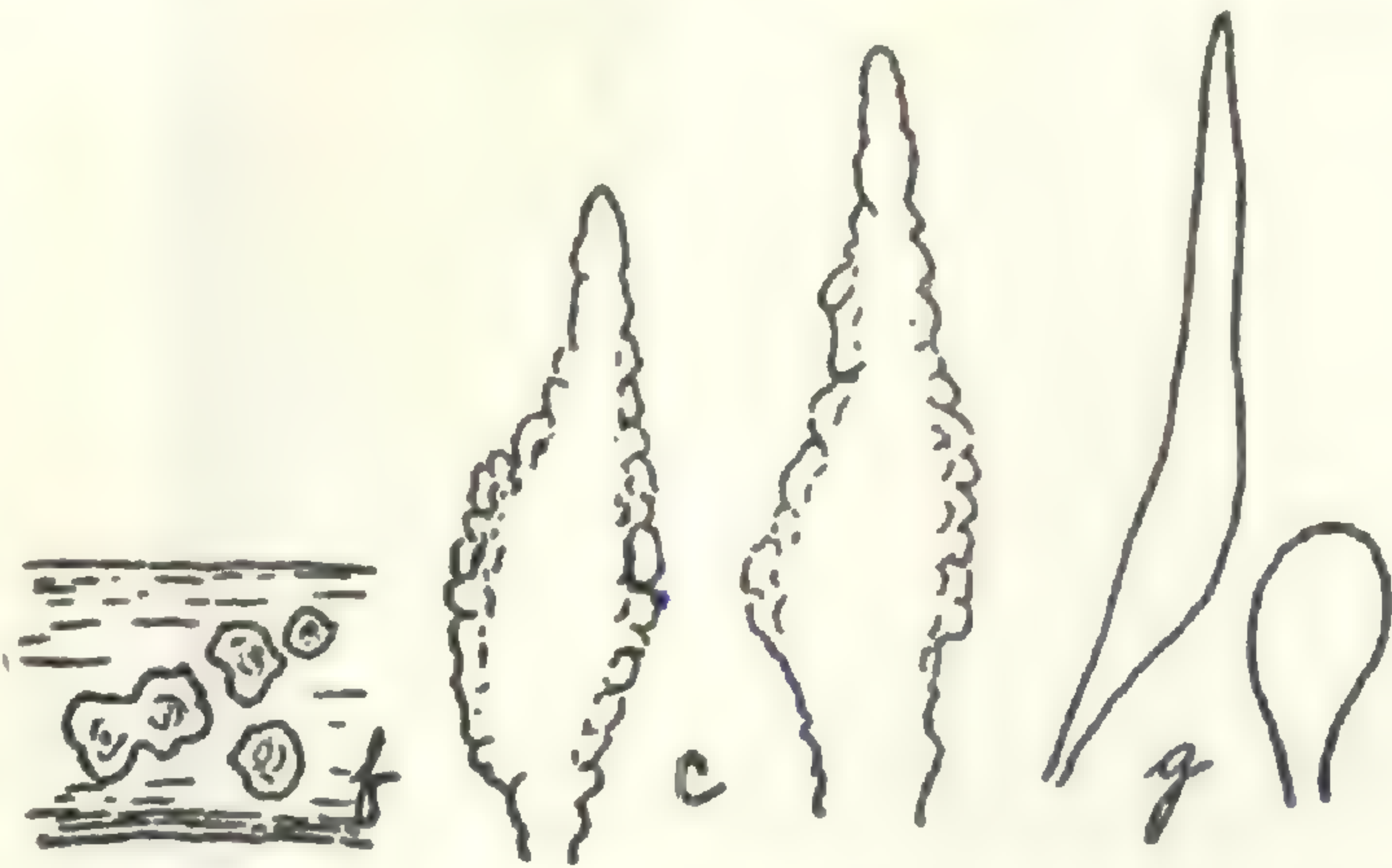


Fig. 12. *S. Pini*. Fructifications, *f*, natural size; cystidia, *c*, and gloeocystidia, *g*, $\times 665$.

Fructifications 1–4 mm. in diameter.

On bark of fallen limbs of *Pinus resinosa*. Maine and New Hampshire. August. Rare.

The fructifications are so near the color of the bark of the dead pine limbs upon which they grow that they are likely to be overlooked, or, if collected, roughly classed among the *Discomycetes* on account of their resemblance to these fungi in aspect. The occurrence on pine bark, small, shield-shaped fructifications Benzo-brown in color, and showing in section both cystidia and gloeocystidia are a combination of characters which should not fail to identify this species.

Specimens examined:

Exsiccati: Krieger, *Fungi Sax.*, 364; Rabenhorst, *Herb. Myc.*, 213.

Finland: Mustiala, *P. A. Karsten*.

Sweden: Stockholm, *L. Romell*, 32.

Germany: Dresden, in Rabenhorst, *Herb. Myc.*, 213; Königs-
tein, Saxony, *W. Krieger*, in Krieger, *Fungi Sax.*, 364.

France: St. Priest, Allier, *H. Bourdot*, 15067.

Maine: *J. Blake*, 659 (in Curtis Herb.).

New Hampshire: Chocorua, *W. G. Farlow*, 37.

33. *S. purpureum* Persoon, *Roemer Neues Mag. Bot.* 1: 110. 1794; *Obs. Myc.* 2: 92. 1799; Fries, *Epicr.* 548. 1838; *Hym. Eur.* 639. 1874; Berkeley, *Brit. Fung.* 270. 1860; Morgan, *Cincinnati Soc. Nat. Hist. Jour.* 10: 194. 1888; *Sacc. Syll. Fung.* 6: 563. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 186. 1890. Plate 4, fig. 29.

Thelephora purpurea Persoon, *Syn. Fung.* 571. 1801; *Myc. Eur.* 1: 121. 1822; Fries, *Syst. Myc.* 1: 440. 1821.—*Stereum vorticosum* Fries, *Obs. Myc.* 2: 275. 1818; *Epicr.* 548. 1838; *Hym. Eur.* 639. 1874; *Sacc. Syll. Fung.* 6: 563. 1888.

Illustrations: *Fl. Danica* 3: *pl. 534. f. 4*; Hussey, *Ill. Br. Myc. pl. 20. f. A*; Istvanffi, *Jahrbüch. f. wiss. Bot.* 29: *pl. 6. f. 37–39*; Lanzi, *Fungi di Roma, pl. 11. f. 2*; Sowerby, *Col. Figs. Eng. Fungi, pl. 388. f. 1*.

Type: authentic specimen from Persoon in Kew Herb.

Fructifications coriaceous-soft, drying rigid, sometimes resupinate, usually more or less reflexed, often imbricated, the

upper side villose-tomentose, light buff to cartridge-buff, the margin entire; hymenium even, glabrous, light purple-drab to dark vinaceous-drab; in structure about 500–800 μ thick excluding the tomentum, with the intermediate layer more loosely arranged on its under side in the subhymenial region and containing pyriform, or subglobose, vesicular organs 15–30 \times 12–25 μ ; no cystidia; spores hyaline, even, flattened on one side, 5–7 \times 2½–3 μ .

Fructifications with resupinate portion about 1–2 cm. in diameter; reflexed portion 5–20 mm. broad, and sometimes crisped or lobed with lobes 5 mm. in diameter.

On dead stumps and logs of *Populus*, *Betula*, and other frondose species. Newfoundland to Delaware and westward to British Columbia and Oregon, also in Uruguay and in Europe. June to April. Common but not ranging into torrid regions.

S. purpureum is usually recognized by its buff, tomentose pileus, purplish hymenium which does not bleed when wounded, and occurrence on poplar. Sectional preparations show characteristic vesicular organs in the subhymenial region, such as are present in the closely related *S. rugosiusculum*, but no hair-like cystidia in the hymenium, by the absence of which *S. purpureum* is distinguished from the latter.

The authentic specimen of *S. vorticosum* in Herb. Fries at Upsala is 2–3 \times 1½ cm., narrowly reflexed, with dark purplish hymenium, and with the usual microscopic structure and spores of *S. purpureum*.

Specimens examined:

Exsiccati: Bartholomew, Fungi Col., 3489; Berkeley, Brit. Fungi, 147; Cooke, Fungi Brit., 12; Ell. & Ev., N. Am. Fungi, 2018, 2601; Klotzsch, Fungi Germ., 50; Krieger, Fungi Sax., 1852; Rabenhorst, Herb. Myc., 504; Romell, Fungi Scand. Exs., 27; Shear, N. Y. Fungi, 311.

Europe: authentic specimen of *Thelephora purpurea* from Persoon (in Herb. Hooker in Kew Herb.).

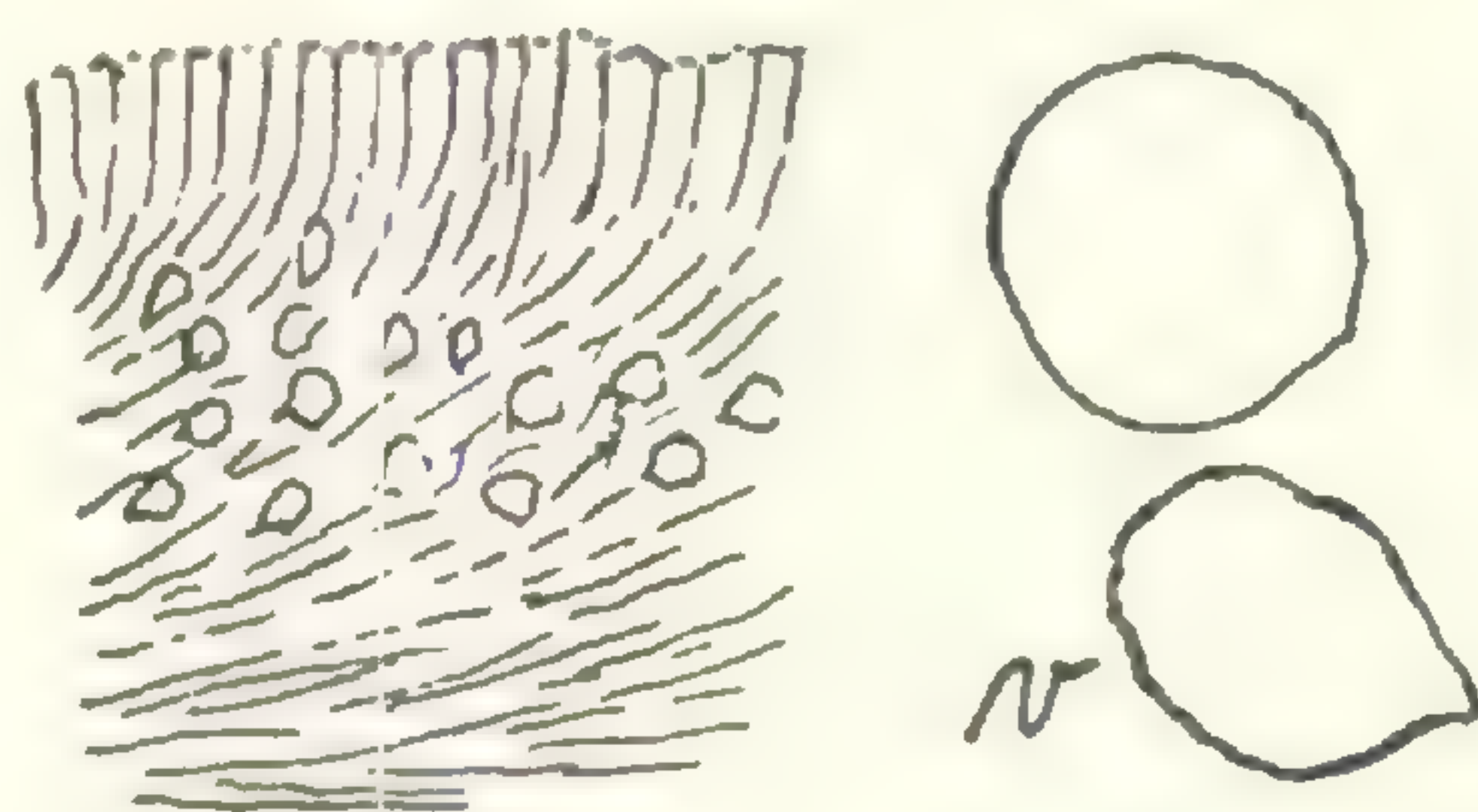


Fig. 13. *S. purpureum*. Section of hymenial region \times 90, and vesicular bodies \times 665. From authentic specimen.

- Sweden: *E. Fries* (in Kew Herb.); Femsjö, authentic specimen of *Stereum vorticosum* (in Herb. Fries); Stockholm, *L. Romell*, 34, 288, and in Romell, *Fungi Scand. Exs.*, 27.
- England: *M. J. Berkeley*, in Berkeley, *Brit. Fungi*, 147; Hampstead, *M. C. Cooke*, in Cooke, *Fungi Brit.*, 12.
- France: Corrombles, comm. by Lloyd Herb., 3355; St. Priest, Allier, *H. Bourdot*, 12459, 12461.
- Germany: *Klotzsch*, in Klotzsch, *Fungi Germ.*, 50; Dresden, in Rabenhorst, *Herb. Myc.*, 504; Winterberge, *Wagner & Krieger*, in Krieger, *Fungi Sax.*, 1852.
- Austria: *Stapf*, *Fl. Exs. Austro-Hungarica*, 3543 (in Mo. Bot. Gard. Herb., 5125, 715171).
- Italy: Trento, *G. Bresadola*.
- Newfoundland: Bay of Islands, *A. C. Waghorne*, 20, 86 (in Mo. Bot. Gard. Herb., 5091, 5092).
- Ontario: Harraby, *E. T. & S. A. Harper*, 641; Ottawa, *J. Macoun*, 17, 39; *J. M. Macoun*, comm. by N. Y. State Mus. Herb. (in Mo. Bot. Gard. Herb., 56085); Port Credit, *J. H. Faull*, Univ. Toronto Herb., 646 (in Mo. Bot. Gard. Herb., 44944); Toronto, *R. P. Wodehouse*, *J. H. Faull*, *G. H. Graham*, Univ. Toronto Herb., 310, 311, 677, respectively (in Mo. Bot. Gard. Herb., 44887, 44889, 44920); Wilcox Lake, *J. H. Faull*, Univ. Toronto Herb., 377 (in Mo. Bot. Gard. Herb., 44929).
- Maine: Manchester, *F. L. Scribner*, comm. by U. S. Dept. Agr. Herb.; Orono, *F. L. Harvey*, 3 (in Mo. Bot. Gard. Herb., 43850) and in Ell. & Ev., *N. Am. Fungi*, 2018; Portage, *L. W. Riddle*, 6.
- Vermont: Brattleboro, *E. A. Burt*; Little Notch, *E. A. Burt*; Middlebury, *E. A. Burt*, three collections; North Ferrisburg, *E. A. Burt*; Ripton, *E. A. Burt*, three collections; Walden, *L. S. Orton*, 4 (in Mo. Bot. Gard. Herb., 44081).
- Massachusetts: Cambridge (in Mo. Bot. Gard. Herb., 5094).
- Connecticut: *C. C. Hanmer*, 2326, 2061 (in Mo. Bot. Gard. Herb., 43847/8).
- New York: *Sartwell* (in Mo. Bot. Gard. Herb., 5151, 5156); Alcove, *C. L. Shear*, 1120, 1122, and in Shear, *N. Y. Fungi*, 311; East Galway, *E. A. Burt*; Ithaca, *G. F. Atkinson*, 2093, 2141, *C. J. Humphrey*, 307, *H. S. Jackson & C. Lewis*,

- 19396; Long Lake, *A. H. W. Povah* (in Mo. Bot. Gard. Herb., 9227); North Elba, *C. H. Kauffman*, 8 (in Mo. Bot. Gard. Herb., 16701); Rome, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 55022, 55024/5).
- Pennsylvania: Bethlehem, *Schweinitz* (in Herb. Schweinitz); Trexlertown, *W. Herbst*, 16, 28, and comm. by Lloyd Herb., 3603.
- Delaware: Wilmington, *A. Commons*, in Ell. & Ev., N. Am. Fungi, 2601.
- Ohio: Norwood, *C. G. Lloyd*, 1787, and (in Mo. Bot. Gard. Herb., 5093).
- Indiana: Indianapolis, *J. B. Demaree*, comm. by G. W. Hoffer (in Mo. Bot. Gard. Herb., 54790); Lafayette, *C. R. Orton*, 5 (in Mo. Bot. Gard. Herb., 44082).
- Wisconsin: Madison, *W. Trelease* (in Mo. Bot. Gard. Herb., 5043); Star Lake, *Miss A. O. Stucki*, Univ. Wis. Herb., 59.
- Minnesota: Park Rapids, comm. by E. L. Jensen, 10 (in Mo. Bot. Gard. Herb., 11100).
- Montana: Helena, Monarch, *J. R. Weir*, 587, 598 (in Mo. Bot. Gard. Herb., 56738, 56739).
- Wyoming: Boulder, *F. S. Wolpert*, comm. by J. R. Weir, 7949 (in Mo. Bot. Gard. Herb., 56219).
- Idaho: Priest River, *J. R. Weir*, 10.
- British Columbia: Sidney, *J. Macoun*, 74 (in Mo. Bot. Gard. Herb., 55352); Vancouver Island, *J. Macoun*, 51 (in Mo. Bot. Gard. Herb., 5737), and comm. by J. Demaree, V88 (in Mo. Bot. Gard. Herb., 22752).
- Washington: Bingen, *W. N. Suksdorf*, 766, 767; Easton, *C. J. Humphrey*, 6449; Olympia, *C. J. Humphrey*, 6292; Seattle, *S. M. Zeller*, 108 (in Mo. Bot. Gard. Herb., 44140).
- Oregon: Corvallis, *C. E. Owens*, 2076 (in Mo. Bot. Gard. Herb., 44038).
- Uruguay: Montevideo, *W. Mitten* Herb., 1325 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56691).

34. *S. rugosiusculum* Berk. & Curtis, *Grevillea* 1: 162. 1873; Morgan, *Cincinnati Soc. Nat. Hist. Jour.* 10: 193. 1888; Sacc. *Syll. Fung.* 6: 567. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 187. 1890. Plate 4, fig. 30.

Stereum Micheneri Berk. & Curtis emend. Masee, Linn. Soc. Bot. Jour. 27: 183. 1890.—*S. Micheneri* Berk. & Curtis, Grevillea 1: 162. 1873 (in part). See Ann. Mo. Bot. Gard. 1: 214. 1914.—*Corticium Nyssae* Berk. & Curtis, Grevillea 1: 166. 1873; Sacc. Syll. Fung. 6: 609. 1888; Masee, Linn. Soc. Bot. Jour. 27: 120. 1890.—*C. siparium* Berk. & Curtis, Grevillea 1: 177. 1873; Sacc. Syll. Fung. 6: 636. 1888; Masee, Linn. Soc. Bot. Jour. 27: 139. 1890.

Illustrations: Berkeley, Ann. & Mag. Nat. Hist. I. 1: 94. pl. 5. f. 45.

Type: in Kew Herb. and Curtis Herb.

Fructifications coriaceous-soft, rarely resupinate, usually more or less broadly reflexed, upper surface tomentose, spongy, some-

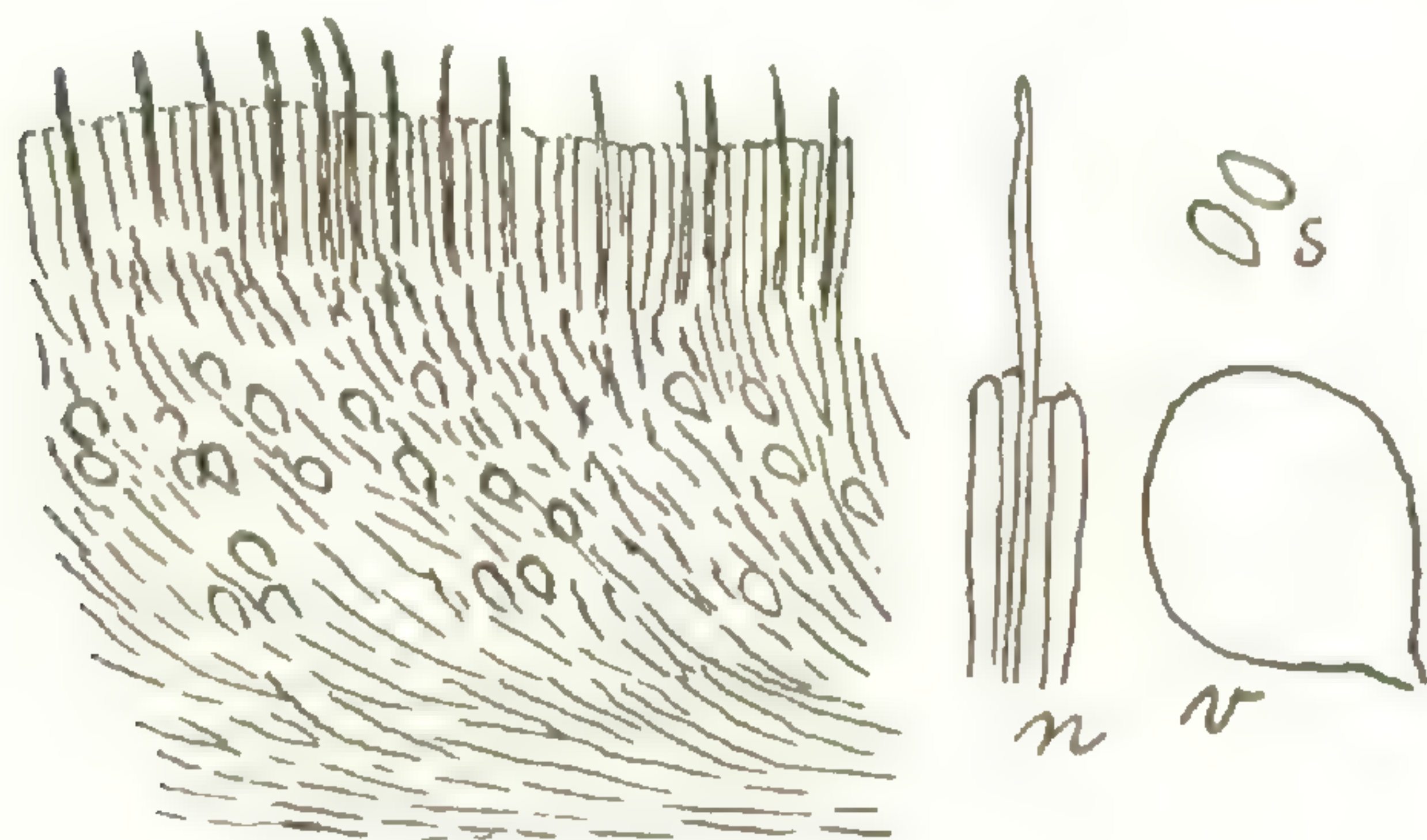


Fig. 14. *S. rugosiusculum*. Section of hymenial region $\times 90$; cystidium and basidia, n , vesicular body, v , and spores, s , $\times 665$.

times with projecting hairs collapsed together into a plane or wrinkled surface, drying cartridge-buff to cinnamon-buff, the margin entire; hymenium even, drying vinaceous-buff to fawn color; in structure up to $1-1\frac{1}{2}$ mm. thick inclusive of the tomentum, with the intermediate layer on its under side in the subhymenial region, loosely interwoven, and containing more or less numerous, pyriform vesicular bodies $15-30 \times 10-20 \mu$; cystidia slender, thin-walled, tapering hairs, not incrustated, $4-5 \mu$ in diameter, protruding up to 25μ beyond the basidia; spores white in spore collection, even, flattened on one side, $4\frac{1}{2}-6 \times 2-3 \mu$.

Resupinate specimens up to 6 cm. in diameter; reflexed portion 1-2 cm. broad, 2-6 cm. laterally along substratum.

On logs and stumps of *Salix* and other frondose species. Ontario to Alabama, in Missouri, and in British Columbia to Mexico; occurs also in Sweden, France, Italy, England, and Japan. August to April.

Stereum rugosiusculum is probably more frequent and more widely distributed than shown by the specimens received, for

the general aspect and microscopic structure of specimens are usually so similar to *S. purpureum* that it is distinguishable from the latter only by the presence of weak flexuous hairs in the hymenium which are not visible until sectional preparations are examined with the compound microscope. Such hymenial hairs were in 1839 figured by Berkeley, *loc. cit.*, in illustrating the hymenium of what he regarded as *Thelephora purpurea* but which now appears to have been *S. rugosiusculum*. All specimens in which these hair-like cystidia have been demonstrated have been either resupinate or with simple, reflexed portion not narrowly lobed or complicate. It has not been possible to observe a specimen throughout its whole season of growth to determine whether the hair-like cystidia are a constant character. In forming the glabrous, rugulose surface upon which the specific name is based, the specimens do not become denuded of their original tomentose covering, for sectional preparations of such specimens, mounted in liquid medium, show this hairy covering to be of the original thickness and with the tips of the hairs no longer adhering together into a plane surface but now floating free. Probably the gluing together of the hairs into a glabrous surface is a weather phenomenon.

Specimens examined:

Exsiccati: *Bartholomew*, Fungi Col., 3489, under the name *Stereum purpureum*; *Cavara*, Fungi Longobardiae, 60, under the name *Stereum purpureum*; *Ellis*, N. Am. Fungi, 323, under the name *Stereum purpureum*.

Sweden: Stockholm, *L. Romell*, 33.

England: *M. J. Berkeley*, under the name *Stereum vorticosum* (in Kew Herb.).

France: *Fautrey*, determined by *Patouillard* as *S. purpureum*, comm. by *Lloyd Herb.*, 4339, 4363.

Italy: *F. Cavara*, in *Cavara*, Fungi Longobardiae, 60.

Ontario: London, *J. Dearness*, in *Bartholomew*, Fungi Col., 3489.

Maine: *Morse*, comm. by *Sprague* (in *Curtis Herb.*, 5413, type of *Stereum Micheneri* as emended by *Masse*); *Harrison*, *J. Blake*, comm. by *P. L. Ricker*; *Piscataquis Co.*, *W. A. Merrill*, 1850, 2153 (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56692, 56693).

Vermont: Ripton, *E. A. Burt*.

Massachusetts: *Sprague*, 492, type (in Kew Herb. and Curtis Herb., 5412); Cambridge, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 4774), and *A. B. Seymour*, T 19 (in Mo. Bot. Gard. Herb., 43886).

New York: Ithaca, *G. F. Atkinson*, K, 2818a; Lake Placid, *W. A. & E. L. Murrill*, 445 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56694); White Plains, *L. M. Underwood* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56268).

New Jersey: *J. B. Ellis*, in *Ellis*, N. Am. Fungi, 323.

Pennsylvania: *E. Michener*, 509, type of *Corticium Nyssae* (in Curtis Herb., 3486); Ohiopyle, *W. A. Murrill*, 1043 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56695); Trexlertown, *W. Herbst*.

Virginia: Blacksburg, *W. A. Murrill*, 351 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56710).

Alabama: *Peters*, 858, type of *Corticium siparium* (in Curtis Herb., 5239); Montgomery Co., *R. P. Burke* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56792).

Missouri: Creve Coeur Lake, *E. A. Burt* (in Mo. Bot. Gard. Herb., 13031).

Idaho: Priest River, *J. R. Weir*, 595 (in Mo. Bot. Gard. Herb., 36740).

British Columbia: *J. Macoun*, 62 (in Mo. Bot. Gard. Herb., 5740).

Washington: Bellingham, *J. R. Weir*, 604 (in Mo. Bot. Gard. Herb., 36741); Seattle, *W. A. Murrill*, 129, 139, 147, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55743, 55732, 55728); *W. A. Murrill*, 136, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55735), and *S. M. Zeller*, 129 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 129).

Oregon: Corvallis, *W. A. Murrill*, 892a, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55724); Kiger Island, *S. M. Zeller*, 1788 (in Mo. Bot. Gard. Herb., 56653).

California: *R. A. Harper*, 36 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56697); Sierra Nevada Mts., *Harkness*, 1060 (in Herb. Cooke in Kew Herb., under the name *Stereum muscigenum*).

Mexico: Guernavaca, *W. A. & E. L. Merrill*, 410, 546, 547 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 54535, 54581, 54582).

Japan: Kushiro, *A. Yasuda*, 64 (in Mo. Bot. Gard. Herb., 56136).

35. *S. Murrayi* (Berk. & Curtis) Burt, n. comb.

Plate 4, figs. 31, 32.

Thelephora Murrayi Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 329. 1868; *Grevillea* 1: 150. 1873; spelling of specific name changed to *Murrayi* in Sacc. Syll. Fung. 6: 546. 1888.—*Stereum tuberculosum* Fries, Hym. Eur. 644. 1874; Sacc. Syll. Fung. 6: 586. 1888; Masee, Linn. Soc. Bot. Jour. 27: 204. 1890; Romell, Bot. Not. 1895: 70. 1895.—*S. pulverulentum* Peck, Torr. Bot. Club Bul. 27: 20. 1900; Sacc. Syll. Fung. 16: 187. 1902.

Illustrations: Lloyd, Myc. Writ. 5. Myc. Notes 62: pl. 148. f. 1690. 1920.

Type: in Kew Herb. and Curtis Herb.

Fructifications corky, adnate, usually resupinate and broadly effused, sometimes reflexed, the reflexed upper surface a hard, horny crust, not shining, concentrically sulcate, fuscous-black or aniline-black, the margin entire; hymenium drying from pale olive-buff to avellaneous, tubercular, deeply cracking; in structure 300 μ thick at first, then becoming stratose and thickening to 800–2000 μ , composed of densely interwoven, rather suberect hyaline hyphae $2\frac{1}{2}$ –4 μ in diameter and of very numerous, hyaline, pyriform vesicular organs 15 – 20×12 – 15μ which are distributed throughout the whole fructification; no colored conducting organs nor cystidia; spores white in spore collection, even, flattened on one side, $4\frac{1}{2}$ – $5 \times 2\frac{1}{2} \mu$.

Resupinate specimens 1–10 cm. in diameter, becoming confluent, reflexed part 3–10 mm. broad.



Fig. 15. *S. Murrayi*. Section of hymenial region $\times 488$, showing vesicular bodies.

On rotting logs and limbs of frondose species such as *Acer*, *Betula*, *Fagus*, *Quercus*, and *Tilia*. Canada to West Indies and westward to British Columbia. April to October in the north and October to March in the West Indies. Common. Occurs in Scandinavia also.

The specimens upon which were based the original descriptions of *S. Murrayi* and its synonyms were resupinate; in each instance the species was included in *Stereum* or *Thelephora*, although longitudinally arranged hyphae are not present and do not constitute an intermediate layer. The distinguishing characters of the resupinate specimens are their thickness, pallid to pale avellaneous color, tubercular and deeply cracked hymenium, abundance of vesicular organs throughout the whole thickness of the fructification, and occurrence on a frondose substratum. The horny crust forming the upper side of the pileus is similar to that of some species of *Fomes* and is unique among our *Stereums*, but the reflexed stage is so rare that this character does not often afford help in recognizing the species. The geographical distribution in three widely separated areas is remarkable; it seems probable that the European stations in Norway and Sweden should be regarded as merely outlying stations of a common North American species; it is very strange that a species presumably northern should be well established in Cuba and Jamaica and absent from Florida and the Carolinas, yet specimens from all three isolated regions are identical in aspect and microscopical structure.

Specimens examined:

Exsiccati: Ell. & Ev., *Fungi Col.*, 704, under the name *Stereum rugosum*; Ell. & Ev., *N. Am. Fungi*, 2903, under the name *Corticium colliculosum*; Shear, *N. Y. Fungi*, 51, under the name *Stereum rugosum*.

Norway: *M. N. Blytt*, type of *Stereum tuberculosum* (in *Herb. Fries*).

Sweden: Island of Gotland, on *Abies excelsa*, *L. Romell*, 135.

Canada: *J. Macoun*, 18, 43, 60; Billings Bridge, *J. Macoun*, 44; Lower St. Lawrence Valley, *J. Macoun*, 69, 72.

Ontario: *J. Dearness*, 1022 (in *Mo. Bot. Gard. Herb.*, 22682); Blackwater, *J. McFarlane*, Univ. Toronto *Herb.*, 330 (in *Mo. Bot. Gard. Herb.*, 44865); Harraby, Lake Rosseau,

E. T. & S. A. Harper, 730; London, *J. Dearness*, two collections, and in Ell. & Ev., Fungi Col., 704; Ottawa, *J. Macoun*, 12, and 676—the latter comm. by W. G. Farlow (in Mo. Bot. Gard. Herb., 56757); Toronto, Algonquin Park and Lorne Park, *J. H. Faull*, Univ. Toronto Herb., 500 and 333 respectively (in Mo. Bot. Gard. Herb., 44854 and 44873).

Maine: *F. L. Harvey*, comm. by P. L. Ricker, and *F. L. Harvey*, type of *Stereum pulverulentum* (in N. Y. State Mus. Herb.) and cotype comm. by P. L. Ricker; Portage, *L. W. Riddle*, 19; Sebec Lake, *W. A. Murrill*, 2304 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56755).

New Hampshire: Chocorua, *W. G. Farlow*; Crawford Notch, *L. O. Overholts*, 4582 (in Mo. Bot. Gard. Herb., 55640); Groton, *J. Blake*, comm. by P. L. Ricker; Hebron, *P. Wilson* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56756); Shelburne, *W. G. Farlow* (in Farlow Herb.).

Vermont: Bristol, *E. A. Burt*; Grand View Mt., *E. A. Burt*, two collections; Middlebury, *E. A. Burt*, two collections; Ripton, *E. A. Burt*, two collections and also near Abby Pond and Lost Pleiad Lake.

Massachusetts: *Murray*, comm. by Sprague, 546, authentic specimen of *Thelephora Murrayi* (in Curtis Herb., 5809).

New York: Alcove, *C. L. Shear*, 1206, 1311, and in Shear, N. Y. Fungi, 51; Altamont, *E. A. Burt*; Floodwood, *E. A. Burt*; Fulton Center, *L. M. Underwood* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56274); Horicon, *C. H. Peck* (in N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb., 56107); Ithaca, *C. J. Humphrey*, 549; Lake Placid, *W. A. & E. L. Murrill*, 194 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56756); North Elba, *C. H. Peck*, 1; Seventh Lake, Adirondack Mts., *B. M. Duggar & F. C. Stewart*; West Ann, *S. H. Burnham*, 4 (in Mo. Bot. Gard. Herb., 43997).

West Virginia: Nuttallburg, *L. W. Nuttall*, in Ell. & Ev., Fungi Col., 704.

Michigan: Houghton, *C. H. Kauffman*, comm. by N. Y. State Mus. Herb. (in Mo. Bot. Gard. Herb., 55812); Sailors' Encampment, *Miss A. O. Stucki*, 5; Vermilion, *A. H. W. Povah*, 190 (in Mo. Bot. Gard. Herb., 17615).

Wisconsin: Ladysmith, *C. J. Humphrey*, 1914 (in Mo. Bot. Gard. Herb., 42916).

Idaho: Priest River, *J. R. Weir*, 362, 379 (in Mo. Bot. Gard. Herb., 16533, 17115).

British Columbia: Agassiz, *J. R. Weir*, 351 (in Mo. Bot. Gard. Herb., 8066).

Cuba: *C. Wright*, 269, type (in Kew Herb. and Curtis Herb.); Alto Cedro, *Earle & Murrill*, 491, comm. by N. Y. Bot. Gard. Herb.; Ciego de Avila, *Earle & Murrill*, 590, comm. by N. Y. Bot. Gard. Herb.; Herradura, *Earle & Murrill*, 188, comm. by N. Y. Bot. Gard. Herb.

Porto Rico: Rio Piedras, *J. A. Stevenson*, 3360 (in Mo. Bot. Gard. Herb., 7584).

Jamaica: Constant Spring Hotel grounds, *W. A. & E. L. Murrill*, 34, comm. by N. Y. Bot. Gard. Herb.; New Haven Gap, *W. A. & E. L. Murrill*, 771, comm. by N. Y. Bot. Gard. Herb.; Port Antonio, *F. S. Earle*, 575, comm. by N. Y. Bot. Gard. Herb.

36. *S. saxitas* Burt, n. sp.

Plate 4, fig. 33.

Type: in Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.

Fructification thick, stratose, stony-hard throughout, resupinate, effused, becoming narrowly reflexed, the reflexed portion

black above, irregular, stony; hymenium even or tubercular, not shining, drying cartridge-buff to whitish; in structure 1–5 mm. thick, stratose, composed of alternating pale and darker layers but with a horn-like translucent luster throughout when cut; a few vesicular organs $20-25 \times 12-15 \mu$ present along the under portion of each stratum; no cystidia; spores hyaline, even, $4-5 \times 3-4 \mu$.

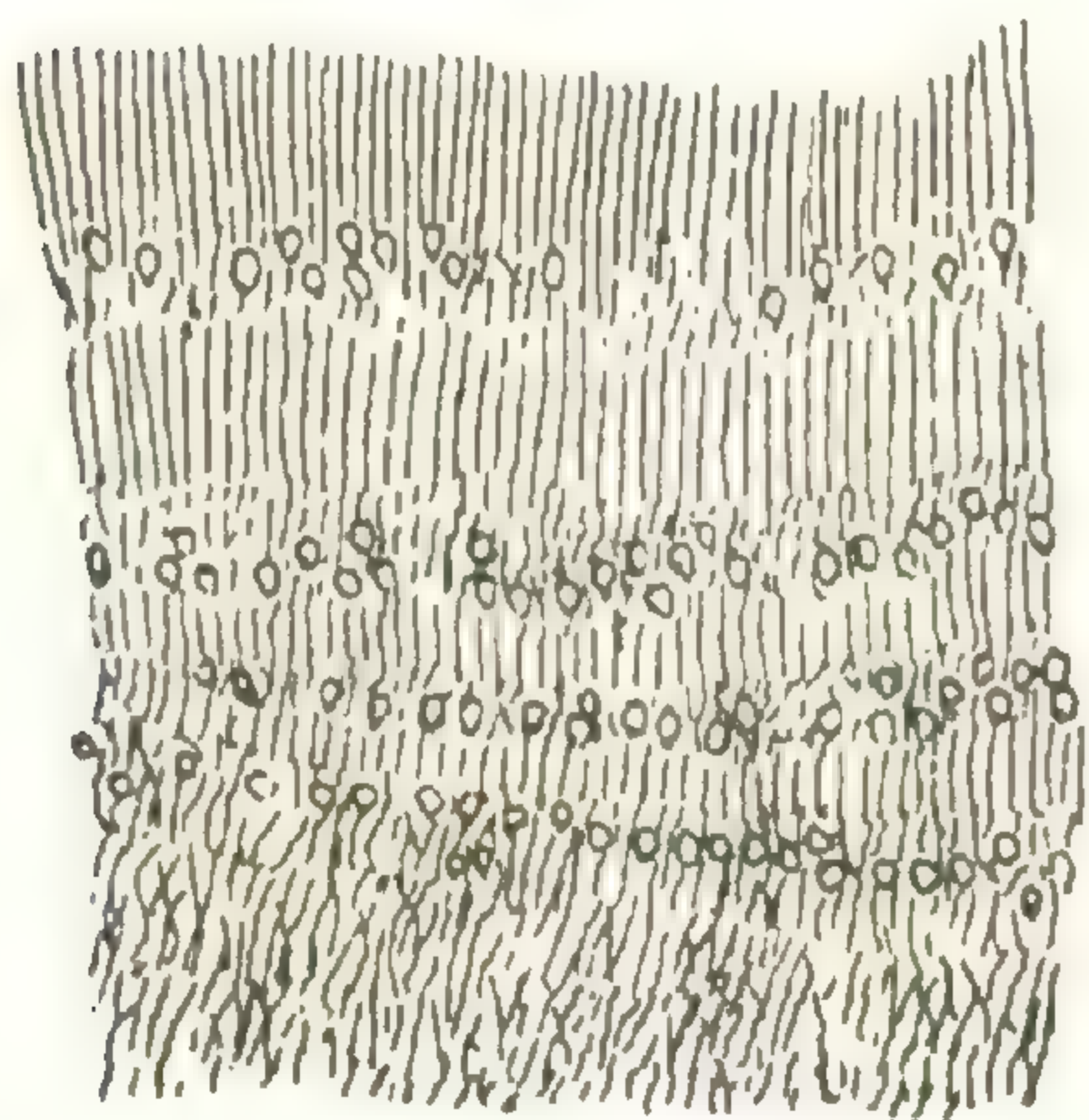


Fig. 16. *S. saxitas*. Section of hymenial region $\times 90$, showing vesicular bodies; spores, *s*, $\times 665$.

Resupinate portion 3–6 cm. in diameter; reflexed margin 2–4 mm. broad.

On bark of apparently a frondose species. Mexico and Jamaica. December and May.

S. saxitas resembles in aspect *S. Murrayi*, and relationship to this species is further shown by the presence of vesicular organs; however, it is thicker than *S. Murrayi*, stony-hard throughout, contains but few vesicular cells, and has subglobose spores. Its structure is so extremely hard that it has been possible to cut sections for microscopic details of only the hymenium and nearly adjacent regions even after prolonged soaking in water.

Specimens examined:

Mexico: Guernavaca, *W. A. & E. L. Merrill*, 419, type, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54552).
 Jamaica: John Crow Peak, *D. S. Johnson* (in N. Y. Bot. Gard. Herb., Mo. Bot. Gard. Herb., 56758, and Burt Herb.).

37. *S. styracifluum* Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1: 105. 1822 (under *B. Sterea* of *Thelephora*); Fries, Epicr. 549. 1838; Sacc. Syll. Fung. 6: 569. 1888.

Plate 4, figs. 34, 35.

Thelephora styraciflua Schweinitz in Fries, Elenchus Fung. 1: 177. 1828; Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 167. 1832.

Type: in Herb. Schweinitz and portions in Herb. Fries and Curtis Herb.

Fructification coriaceous, resupinate and effused, with a narrow, free marginal portion, or slightly reflexed, tomentose, drying pinkish buff to cinnamon-buff; hymenium dull, pruinose, not multizonate, drying pinkish buff, exuding a yellow milk when compressed and becoming dark-discolored, contracting in drying and splitting; in structure 700–800 μ thick, with the intermediate layer bordered on its upper side by a pale golden zone not denser than the rest of the layer, composed of very densely arranged hyphae $2\frac{1}{2}$ –3 μ in diameter, with pale-colored conducting organs 3–3 $\frac{1}{2}$ μ in diameter which curve into the hymenium; no cystidia; spores hyaline, even, slightly curved, $5-8 \times 2\frac{1}{2}-3$ μ .

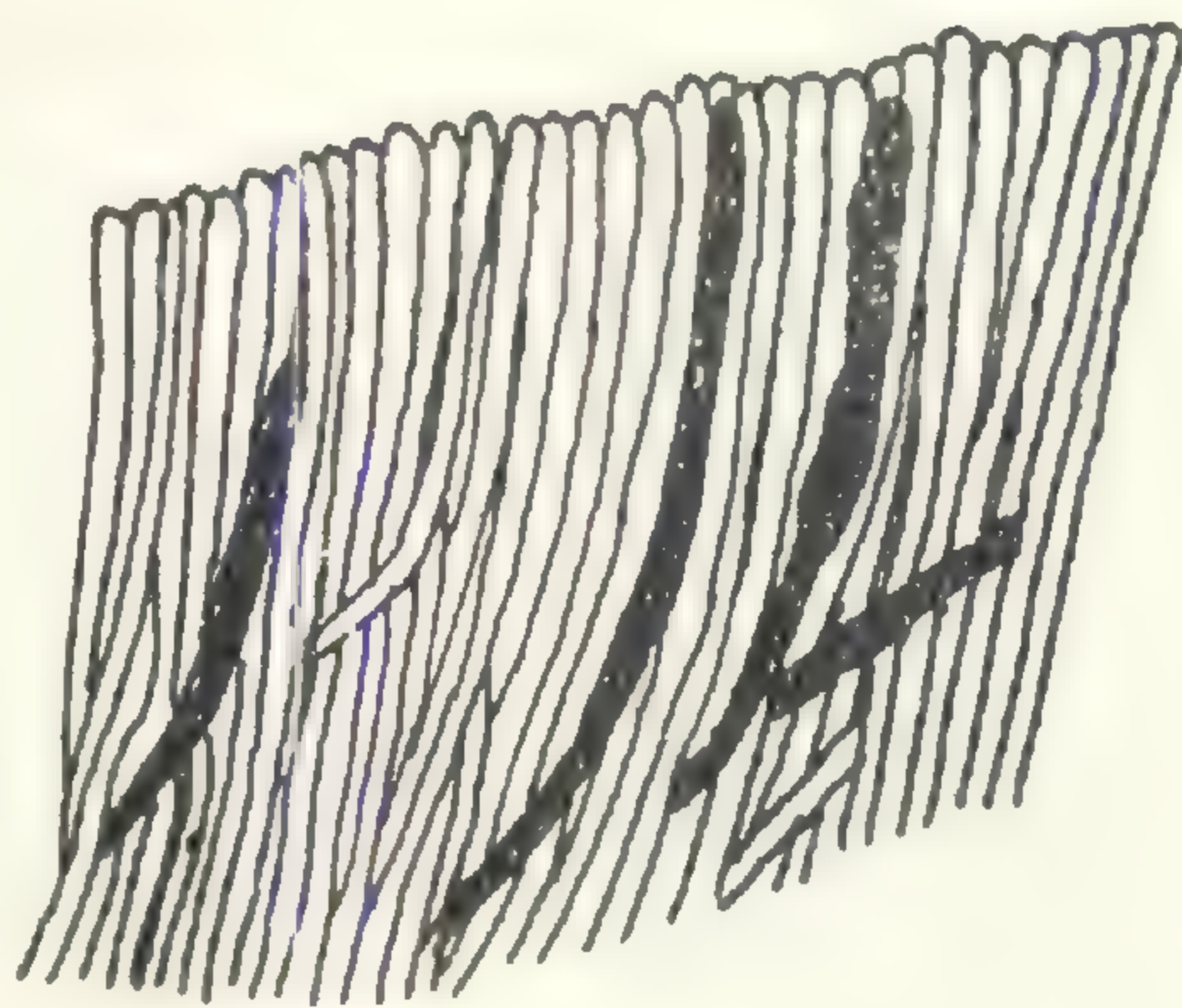


Fig. 17. *S. styracifluum*. Section of hymenial region $\times 488$, showing conducting organs. From type.

Resupinate portion 3×2 cm.; the free margin up to 5 mm. broad.

On under side of dead, fallen limbs of *Liquidambar* and mossy dead trunk of *Carpinus*. North Carolina and Alabama. January. Rare.

S. styracifluum is intermediate between *S. rameale* and *S. rugosum*; in the region where it occurs it is likely to be regarded as a resupinate form of *S. rameale*, from which it differs in darker and more irregular hymenial surface, greater thickness of fructification, margin sometimes with a black edge, and reflexed part tomentose to the margin; the pale-colored conducting organs are similar in the two species but rather more abundant in *S. styracifluum*. The general aspect is so similar to that of *S. rugosum*, very common in Europe, that the yellow milk of *S. styracifluum* was properly regarded by Schweinitz as an important distinctive character of the American species; other differences are that the intermediate layer is much broader and denser than that of *S. rugosum*, that the hymenium is only 20–30 μ broad, never zonate, and that the conducting organs are much less numerous and paler than in *S. rugosum*.

Specimens examined:

North Carolina: Salem, *Schweinitz*, type (in *Schweinitz Herb.*, *Fries Herb.*, and *Curtis Herb.*).

Alabama: Auburn, on *Carpinus*, *F. S. Earle & C. F. Baker* (in *Burt Herb.* and *Mo. Bot. Gard. Herb.*, 5061).

38. *S. gausapatum* Fries, *Hym. Eur.* 638. 1874; *Sacc. Syll. Fung.* 6: 560. 1888; *Massee, Linn. Soc. Bot. Jour.* 27: 180. 1890. Plate 4, fig. 36.

Thelephora gausapata Fries, *Elenchus Fung.* 1: 171. 1828; *Epicr.* 538. 1838.—*T. spadicea* Fries, *Elenchus Fung.* 1: 176. 1828 (not *T. spadicea* Persoon, *Syn. Fung.* 568. 1801. See *Bresadola, I. R. Accad. Agiati Atti III.* 3: 106. 1897).—*Stereum spadiceum* Fries, *Epicr.* 549. 1838; *Hym. Eur.* 640. 1874; *Berkeley, Outlines Brit. Fung.* 270. 1860; also of more recent English authors.—*S. spadiceum* var. *plicatum* Peck, *N. Y. State Mus. Rept.* 50: 132. 1897.—*S. cristulatum* Quelet, *Champ. Jura et Vosges* 3: 15. pl. 1. f. 15. 1875.—*S. occidentale* Lloyd, *Myc. Writ.* 5. Letter 69:12. 1919.

Type: specimen from Fries in Kew Herb.

Fructifications coriaceous, effuso-reflexed or somewhat dimidiate, usually cespitose-imbricated, confluent, varying from villose to hirsute, buckthorn-brown, more or less radially plicate; hymenium bleeding when fresh if cut or bruised, drying snuff-brown and more or less darker discolored; in structure 600–700 μ thick exclusive of the hairy covering, composed of densely and longitudinally arranged hyphae, with flexuous, colored conducting organs 75–120 \times 5 μ , very numerous in the hymenium; no cystidia; spores hyaline, even, 5–8 \times 2½–3½ μ .

Singly or covering areas up to 10 cm. and more in diameter; reflexed portion about 1 cm. broad, 1–2½ cm. long or more, or with small pilei or lobes 1–1½ cm. in diameter.

On stumps of *Quercus* usually. Canada to Alabama and westward to Washington and California. August to March. Common.

S. gausapatum is usually recognizable at sight by its clustered fructifications tobacco-colored above and clothed with a heavy villose or strigose coat, by the rather dark hymenium which bleeds when cut and becomes somewhat darker discolored in drying, and by the occurrence on oak. Sectional preparations show very numerous, colored conducting organs in the hymenium. *S. australe* of the Gulf states bleeds and has colored conducting organs, although fewer, but its fructifications do not form dense clusters and are not radially plicate. *S. sanguinolentum* has the same geographical distribution as *S. gausapatum* and bleeds when fresh and has colored conducting organs, but has small fructifications occurring on conifers only. The hairy covering of the pileus is greedily devoured by herbarium insects, leaving the pilei bare of their normal covering if specimens are not protected against their depredations, but, except for insect depredation, this covering is a persistent character.

Fries described the effuso-reflexed stage of *S. gausapatum* under the name *T. spadicea*, confusing this stage with the more southern and specifically different *Thelephora spadicea* of Persoon, which does not occur in America. It seems preferable

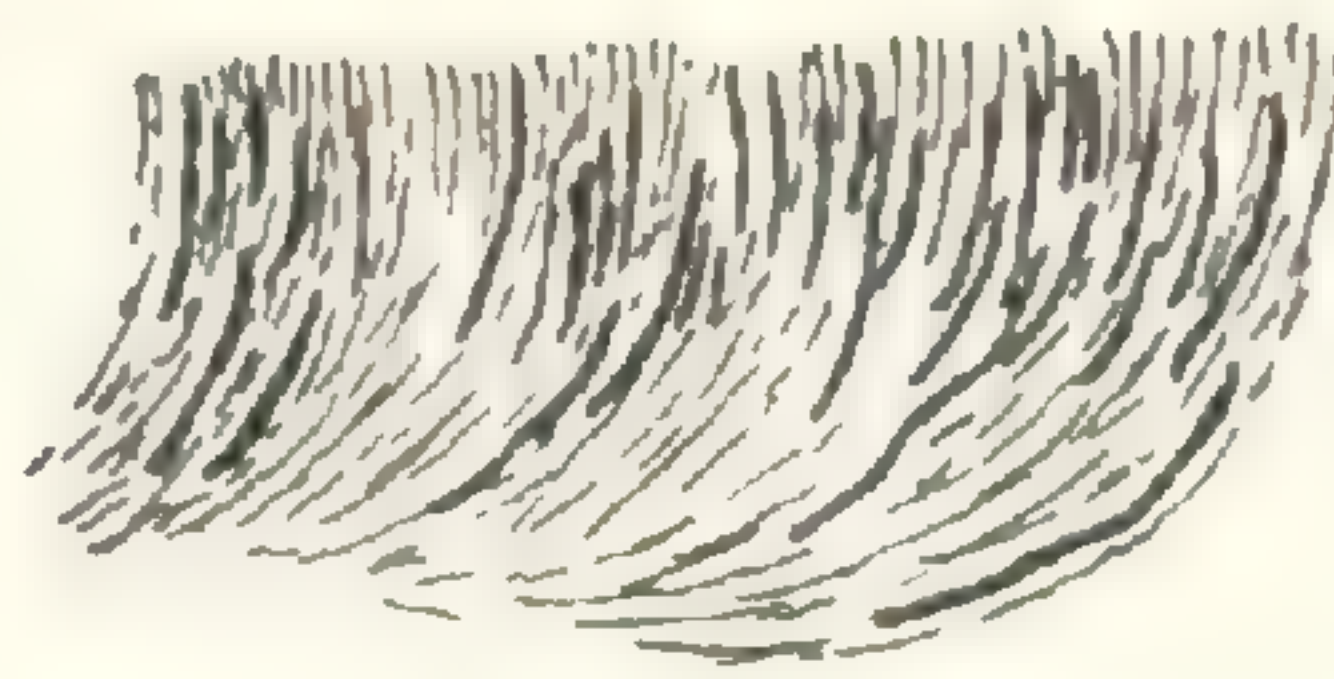


Fig. 18. *S. gausapatum*. Section of hymenial region \times 68, showing distribution of conducting organs.

to use the name *S. gausapatum* for our species, although unfortunately the other name is in general use in England, and leave the name *S. spadiceum* available for use in its original sense as continental mycologists do. It is surprising that specimens of *S. gausapatum* do not occur in Herb. Schweinitz under some name or other.

Specimens examined:

Exsiccati: Bartholomew, Fungi Col., 2883, 4292; Berkeley, Brit. Fungi, 144; Cooke, Fungi Brit., 107; Ellis, N. Am. Fungi, 325; Ell. & Ev., N. Am. Fungi, 3413, under name *Stereum hirsutum*; Ell. & Ev., Fungi Col., 218; Ravenel, Fungi Car. 2: 32; Fungi Am., 447; Romell, Fungi Scand. Exs., 28, 122.

Sweden: Stockholm, L. Romell, 45, 46, 238, and in Romell, Fungi Scand. Exs., 28, 122.

England: M. J. Berkeley, in Berkeley, Brit. Fungi, 144; Epping, M. C. Cooke, in Cooke, Fungi Brit., 107.

Holland: Amsterdam, C. A. J. A. Oudemans, in Oudemans, Fungi Neerland., 239 (in Mo. Bot. Gard. Herb.).

France: authentic specimen of *Stereum cristulatum* from Quelet (in Herb. Fries); wall of German trench, Lieut. G. W. Martin, comm. by P. J. Anderson, 3 (in Mo. Bot. Gard. Herb., 55848); St. Sernin, Aveyron, A. Galzin, 1265, comm. by H. Bourdot, 16234; Corrombles, F. Fautrey, from Lloyd Herb., 3312.

Italy: Trentino, G. Bresadola.

Canada: Carleton Place, J. Macoun, 419.

Ontario: Lake Joseph, T. Langton, Univ. Toronto Herb., 590 (in Mo. Bot. Gard. Herb., 44846); London, J. Dearness; Swansea, J. H. Faull, Univ. Toronto Herb., 375 (in Mo. Bot. Gard. Herb., 44931); Toronto, J. H. Faull, G. H. Graham, T. Langton, R. P. Wodehouse, Univ. Toronto Herb., 372, 376, 676, 679, 591, 597, 368 (in Mo. Bot. Gard. Herb., 44946, 44932, 44923, 44935, 44849, 44840, 44855, respectively).

Vermont: Lake Dunmore, E. A. Burt, three collections; Middlebury, E. A. Burt.

Massachusetts: Mt. Auburn, E. A. Burt; Stoneham, C. L. Shear, 1233; Wayland, A. B. Seymour, T36 (in Mo. Bot.

- Gard. Herb., 13939); Waverly, *G. R. Lyman*, 121; Weston, *A. B. Seymour*, T10 (in Mo. Bot. Gard. Herb., 19621).
- Connecticut: West Hartford, *C. C. Hanmer*, 2670 (in Mo. Bot. Gard. Herb., 42605).
- New York: *Sartwell* (in Mo. Bot. Gard. Herb., 5046, 5102); Cold Spring Harbor, *H. J. Banker* (in Mo. Bot. Gard. Herb., 54434); Green Lake, *P. Wilson*, 52 (in Mo. Bot. Gard. Herb., 54745); Ithaca, *G. F. Atkinson*, 223 *O. S.*, 2140, 7986, 7986b, *H. H.*, 5088, *C. J. Humphrey*, *F. A. Wolf*, 22943; N. Greenbush, *C. H. Peck*, in *Ellis*, *N. Am. Fungi*, 325; Poughkeepsie, *W. R. Gerard*, 271 (in *N. Y. Bot. Gard. Herb.*); Shakers, *S. H. Burnham*, 16 (in Mo. Bot. Gard. Herb., 44010); St. Regis Falls, *L. A. Zimm*, 94 (in Mo. Bot. Gard. Herb., 21941); Williamsbridge, *P. Wilson*, 2 (in Mo. Bot. Gard. Herb., 54746); White Plains, *L. M. Underwood* (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56700).
- New Jersey: Newfield, *J. B. Ellis*, in *Ell. & Ev.*, *Fungi Col.*, 218.
- Pennsylvania: Kittanning, *D. R. Sumstine*, 5, 6, 8; Spruce Creek, *J. H. Faull*, *Univ. Toronto Herb.*, 371, 672 (in Mo. Bot. Gard. Herb., 44925, 44938); Trexlertown, *C. G. Lloyd*, 0054.
- Delaware: Newark, *H. S. Jackson*.
- Maryland: Takoma Park, *C. L. Shear*, 1018, 1201, 1270, 1273.
- Virginia: Clarendon, *W. H. Long*, 12617 (in Mo. Bot. Gard. Herb., 55103); Park Lane, *W. H. Long*, 12860 (in Mo. Bot. Gard. Herb., 55109).
- North Carolina: Biltmore, *C. Harrison*, comm. by *P. L. Ricker*, *E. Bartholomew*, 5663 (in Mo. Bot. Gard. Herb., 44262); Blowing Rock, *G. F. Atkinson*, 4318, 4328; Chapel Hill, *W. C. Coker*, 334, 3821 (in Mo. Bot. Gard. Herb., 56670, 56671).
- South Carolina: Aiken, *H. W. Ravenel*, in *Ravenel*, *Fungi Am.*, 447; Black Oak, *H. W. Ravenel*, in *Ravenel*, *Fungi Car.* 2: 32.
- Georgia: Tallulah Falls, *A. B. Seymour*, comm. by *W. G. Farlow*, *C. C.* (in Mo. Bot. Gard. Herb., 44604).
- Alabama: Auburn, *F. S. Earle* (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56287, 56703), and *C. F. Baker*,

- 50 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56702); Montgomery Co., *R. P. Burke*, 24, 38 (in Mo. Bot. Gard. Herb., 17651, 4925).
- Louisiana: St. Martinville, *A. B. Langlois*, 165.
- Michigan: *Beal*, 57, comm. by N. Y. State Mus. Herb. (in Mo. Bot. Gard. Herb., 55810); Ann Arbor, *C. H. Kauffman*, 37 (in Mo. Bot. Gard. Herb., 18995); Glen Lake, *C. G. Lloyd*, 02551.
- Ohio: Cincinnati, *C. G. Lloyd*, 02820; College Hill, *W. Holden*, comm. by Lloyd Herb.
- Indiana: Millers, *E. T. & S. A. Harper*, 678.
- Illinois: River Forest, *E. T. & S. A. Harper*, 708; Riverside, *E. T. & S. A. Harper*, 686.
- West Virginia: Nuttallburg, *L. W. Nuttall*, in *Ell. & Ev.*, N. Am. Fungi, 3413.
- Kentucky: *S. A. Price* (in Mo. Bot. Gard. Herb., 5136).
- Wisconsin: Madison, *E. T. & S. A. Harper*, 942, *Miss A. D. Stucki*, 32, and *W. Trelease*, 84 (in Mo. Bot. Gard. Herb., 5101).
- Iowa: Webster Co., *O. M. Oleson*, 2, 3, 5.
- Missouri: Columbia, *B. M. Duggar*, 358, 392, 573; St. Louis, *C. R. Ball & H. H. Hume*, and *E. A. Burt* (in Mo. Bot. Gard. Herb., 5023, 21989).
- Arkansas: Fayetteville, *E. Bartholomew*, in *Bartholomew*, Fungi Col., 2883; Womble, *W. H. Long*, 19849 in part (in Mo. Bot. Gard. Herb., 20271).
- Texas: Joaquin, *E. Bartholomew*, in *Bartholomew*, Fungi Col., 4292.
- Nebraska: Lincoln, *C. L. Shear*, 1017; Roco, *C. L. Shear*, 1012.
- Kansas: Bourbon Co., *A. G. Garrett*, 86, 129.
- British Columbia: Kootenai Mts., near Salmo, *J. R. Weir*, 502 (in Mo. Bot. Gard. Herb., 21630).
- Washington: Seattle, *S. M. Zeller*, 109 (in Mo. Bot. Gard. Herb., 44142); *T. C. Frye*, 2007 (in N. Y. Bot. Gard. Herb.); Whidley Is., *N. L. Gardner*, Univ. Calif. Herb., 1033 (in Mo. Bot. Gard. Herb., 44151).
- Oregon: Corvallis, *C. E. Owens*, 2085 (in Mo. Bot. Gard. Herb., 44247), *W. A. Murrill*, 903, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55720); Portland, *J. R. Weir*, 396 (in Mo. Bot. Gard. Herb., 14094).

California: *I. M. Johnston*, comm. by C. G. Lloyd, part of type of *Stereum occidentale* (in Mo. Bot. Gard. Herb., 56762); Alameda Co., *L. S. Smith*, Univ. Calif. Herb., 403 (in Mo. Bot. Gard. Herb., 44150); Preston's Ravine, Palo Alto, *W. A. Murrill & L. S. Abrams*, 1190, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55711); Redwood Park, *W. H. Long*, 12604 (in Mo. Bot. Gard. Herb., 55100); Santa Barbara, *O. M. Oleson*, 7, 15.

Arizona: C. G. Pringle, comm. by W. G. Farlow.

Mexico: San Luis Potosi, comm. by U. S. Dept. Agr. Herb.

39. *S. australe* Lloyd, Myc. Writ. 4. Letter 48: 10. 1913; and *ibid.* Letter 60: 15. 1916. Plate 4, fig. 37.

An *Thelephora mytilina* Fries, Elenchus Fung. 1: 175. 1828?

Type: in Lloyd Herb. and Mo. Bot. Gard. Herb.

Fructification coriaceous, attached by the resupinate side and umbo, broadly reflexed, sometimes laterally confluent, densely tomentose, becoming concentrically furrowed and very rarely glabrous and showing the shining chestnut surface of the pileus in one or more of the furrows, the margin entire, sometimes becoming blackish; hymenium even, glabrous, drab-gray to avel-laneous, becoming red-discolored where cut or bruised, and sometimes bleeding; in structure 900 μ thick, composed of densely, longitudinally arranged hyphae, among which are a few colored conducting organs $3\frac{1}{2}$ – $4\frac{1}{2}$ μ in diameter which curve into the hymenium between the basidia; no cystidia nor gloeocystidia present; spores hyaline, even, flattened on one side, 4 – $4\frac{1}{2}$ \times $2\frac{1}{2}$ – 3 μ , few found.

Fructifications with resupinate portion 1–3 cm. broad, reflexed portion 1–4 cm. broad, 1–5 cm. long and sometimes more by lateral confluence.

On hardwood logs. Florida and Mississippi to Brazil. August to December in the north and in July in Brazil. Apparently rare.

Stereum australe combines the characters of *S. fasciatum* and *S. gausapatum*. Its general aspect resembles that of specimens of *S. fasciatum* in a middle period of development when they are effuso-reflexed and have the umbo developed, but the specimens of *S. australe* have a broader resupinate portion than those of *S.*

fasciatum and are not wedge-shaped and attached merely by the umbo in any specimens which I have seen; the bleeding or red-discoloration of the hymenium when cut or bruised and the presence of colored conducting organs are additional characters which separate *S. australe* from *S. fasciatum*. *S. australe* may be distinguished from *S. gausapatum* by not having its reflexed portion crisped nor consisting of small pilei which stand out near together and in imbricate arrangement from a common resupinate portion.

In case of the collection from Mississippi, it was noted that the substratum was badly sap-rotted.

If original specimens of *Thelephora mytilina*, collected by Lund in Brazil, are still in existence, I believe that they will be found cospecific with *S. australe*. The geographical range of *S. australe* and the description of *T. mytilina* favor this belief. Fries's description was probably based on dried specimens, and it does not mention bleeding of the hymenium nor such a microscopical character as colored conducting organs, for such a microscopic detail was not noted in those days, but the blackening of the edge of the pileus which was observed by Fries is an indication of a bleeding hymenium and colored conducting organs.

Specimens examined:

Florida: type comm. by C. G. Lloyd (in Mo. Bot. Gard. Herb., 56608); Kissimme, C. J. Humphrey, 3532 (in Mo. Bot. Gard. Herb., 3370).

Mississippi: Laurel, C. J. Humphrey, 5434.

Mexico: Jalapa, W. A. & E. L. Merrill, 189, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54446).

Canal Zone: Gatun, M. A. H. (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56707).

Grenada: W. E. Broadway (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56625, 56626).

Venezuela: Caracas, Mr. & Mrs. J. N. Rose, 22038 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56657).

Brazil: Rio de Janeiro, J. N. Rose & P. G. Russell, 21480 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56627).

40. *S. rugosum* Persoon, Roemer Neues Mag. Bot. 1: 110. 1794; Fries, Epicr. 552. 1838; Myc. Eur. 643. 1874; Berk-

eley, Brit. Fungi, 271. 1860; Sacc. Syll. Fung. 6: 572. 1888; Masee, Linn. Soc. Bot. Jour. 27: 191. 1890.

Plate 4, figs. 38, 39.

Thelephora rugosa Persoon, Syn. Fung. 569. 1801; Myc. Eur. 1: 127. 1822; Albertini & Schweinitz, Consp. Fung. 274. 1805; Fries, Syst. Myc. 1: 439. 1821; Elenchus Fung. 1: 177. 1828.

Illustrations: Istvanffi, Jahrbuch. f. wiss. Bot. 29: pl. 4. f. 11; pl. 5. f. 19.

Fructifications coriaceous-corky, usually resupinate and effused, with a narrow, free, marginal portion, or sometimes reflexed, silky at first and pinkish buff, at length concentrically furrowed, radially pitted and weathering gray, the margin thick, entire; hymenium dull, pruinose, drying pinkish buff to drab-gray, when fresh bleeding where wounded; in structure 500–1800 μ thick, with the intermediate layer bordered on the upper side by a dense golden zone and on the lower side by a two- to many-zoned hymenial layer 120–1200 μ thick, hyphae of intermediate layer $2\frac{1}{2}$ –3 μ in diameter; dark-colored conducting organs very numerous, 3–6 μ in diameter; no cystidia; spores hyaline, even, flattened on one side, $7-10 \times 3-4 \mu$.

Resupinate on areas 2–6 cm. in diameter; free or reflexed margin 2–12 mm. broad.

On stumps of *Alnus*, *Corylus*, *Quercus*, *Betula*, and other frondose species. Newfoundland, Ontario, New York, and mountains of North Carolina. July to October. Rare in North America, common in Europe.

Although usually resupinate and likely to be regarded as a *Corticium* by collectors, nevertheless sectional preparations show the highly developed characteristic structure of a *Stereum*, with intermediate layer of longitudinally arranged hyphae, golden crust, etc. The bleeding of the hymenium and the abundant colored conducting organs locate the species among the *Stereums* in the group with *S. gausapatum*, *S. australe*, and *S.*



Fig. 19. *S. rugosum*. Section $\times 19$; intermediate layer, *i*; dense golden zone, *z*; the scattered darker lines in hymenial zones show distribution of conducting organs.

sanguinolentum, from each of which *S. rugosum* is sharply distinct by its two- to several-zoned hymenium—a character by which the species is also separable in dried herbarium condition from *S. styracifluum* when no observations have been recorded as to the color of the milk of specimens in fresh condition.

Specimens examined:

Exsiccati: Berkeley, Brit. Fungi, 145; Krieger, Fungi Sax., 1853, 1853b; Rabenhorst, Herb. Myc., 503; Romell, Fungi Scand. Exs., 30; de Thümen, Myc. Univ., 1009.—All specimens distributed as *S. rugosum* in American exsiccati were misdetermined.

England: *M. J. Berkeley*, in Berkeley, Brit. Fungi, 145; Epping Forest, *E. A. Burt*; Kew Garden, *G. Masee*.

Sweden: *L. Romell*, 40–42; Femsjö, *E. A. Burt*; Stockholm, *L. Romell*, in Romell, Fungi Scand. Exs., 30; Upsala, *E. P. Fries* (in Curtis Herb.).

Finland: Mustiala, *P. A. Karsten*, in de Thümen, Myc. Univ., 1007.

Germany: Dresden, in Rabenhorst, Herb. Myc., 503; Saxony, Uttewalder Grunde, *W. Krieger*, in Krieger, Fungi Sax., 1853, 1853b.

Hungary: Tatra Magna, Löcse, *V. Greschik*, comm. by *G. Bresadola*.

Italy: Trentino, *G. Bresadola*, two collections.

France: Allier, St. Priest, *H. Bourdot*, 15023.

Newfoundland: Bay of Islands, *A. C. Waghorne*, 160 (in Mo. Bot. Gard. Herb., 5096); Trinity Bay, *A. C. Waghorne*, 1 (in Mo. Bot. Gard. Herb., 5098).

Quebec: Gaspé, *J. Macoun*, and 254 (in N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb., 56094).

Ontario: Ottawa, *J. Macoun*, 38.

New York: Fall Creek, *G. F. Atkinson*, 949.

North Carolina: Blowing Rock, *G. F. Atkinson*, 4189.

41. *S. sanguinolentum* Albertini & Schweinitz, Consp. Fung 274. 1805 (under *B. Sterea* of *Thelephora*); Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1: 106. 1822; Fries, Epicr. 549. 1838; Hym. Eur. 640. 1874; Berkeley, Brit. Fungi, 271. 1860; Sacc. Syll. Fung. 6: 564. 1888; Masee, Linn. Soc. Bot. Jour. 27: 189. 1890. Plate 5, fig. 40.

Thelephora sanguinolenta Alb. & Schw. in Fries, Syst. Myc. 1: 440. 1821; Elenchus Fung. 1: 178. 1828.—*Stereum balsameum* Peck, N. Y. State Mus. Rept. 27: 99. 1875; *ibid.* 30: 75. 1879; Sacc. Syll. Fung. 6: 584. 1888; Masee, Linn. Soc. Bot. Jour. 27: 196. 1890.—*S. balsameum* form *reflexum* Peck, N. Y. State Mus. Rept. 47: 152. 1894.—*S. rigens* Karsten, Finska Vet.-Soc. Bidrag Natur och Folk 37: 243. 1882; *ibid.* 48: 396. 1889; Sacc. Syll. Fung. 11: 121. 1895.

Illustrations: Gillet, Hymenomyces; Greville, Crypt. Fl. 4: pl. 225; Istvanffi, Jahrbüch. f. wiss. Bot. 29: pl. 4. f. 7-10; Klotzsch in Dietrich, Fl. Reg. Borussici, pl. 381; Nees, Syst. 2nd ed. pl. 28. f. 1-3; Patouillard, Tab. Anal. f. 28.

Fructifications coriaceous, thin, effused, and reflexed, with upper surface villose to silky and the hairs appressed and somewhat radiately arranged, drying pinkish buff to pale olive-buff, the margin thin; hymenium glabrous, bleeding where wounded, contracting in drying and cracking to the substratum in the resupinate portion, drying avellaneous to wood-brown; in structure 400-600 μ thick, with intermediate layer bordered on the upper side by a narrow, dense golden zone, and composed of densely arranged hyaline hyphae 3 μ in diameter and of colored conducting organs 3-4 μ in diameter which curve into the hymenium and are usually numerous there; no cystidia; spores white in spore collection, even, slightly curved, 6-7 \times 2½ μ .

Resupinate portions 1-5 cm. in diameter, reflexed margins 2-10 mm. broad.

On stumps and logs of *Pinus*, *Abies*, and *Tsuga*. Ontario to Pennsylvania and westward to British Columbia and California. July to March. Frequent.

S. sanguinolentum is commonly resupinate or barely reflexed, so that it is best recognized by its occurrence on conifers and bleeding of the hymenium where wounded, or becoming merely red-discolored along the edges of the wound if the wound is

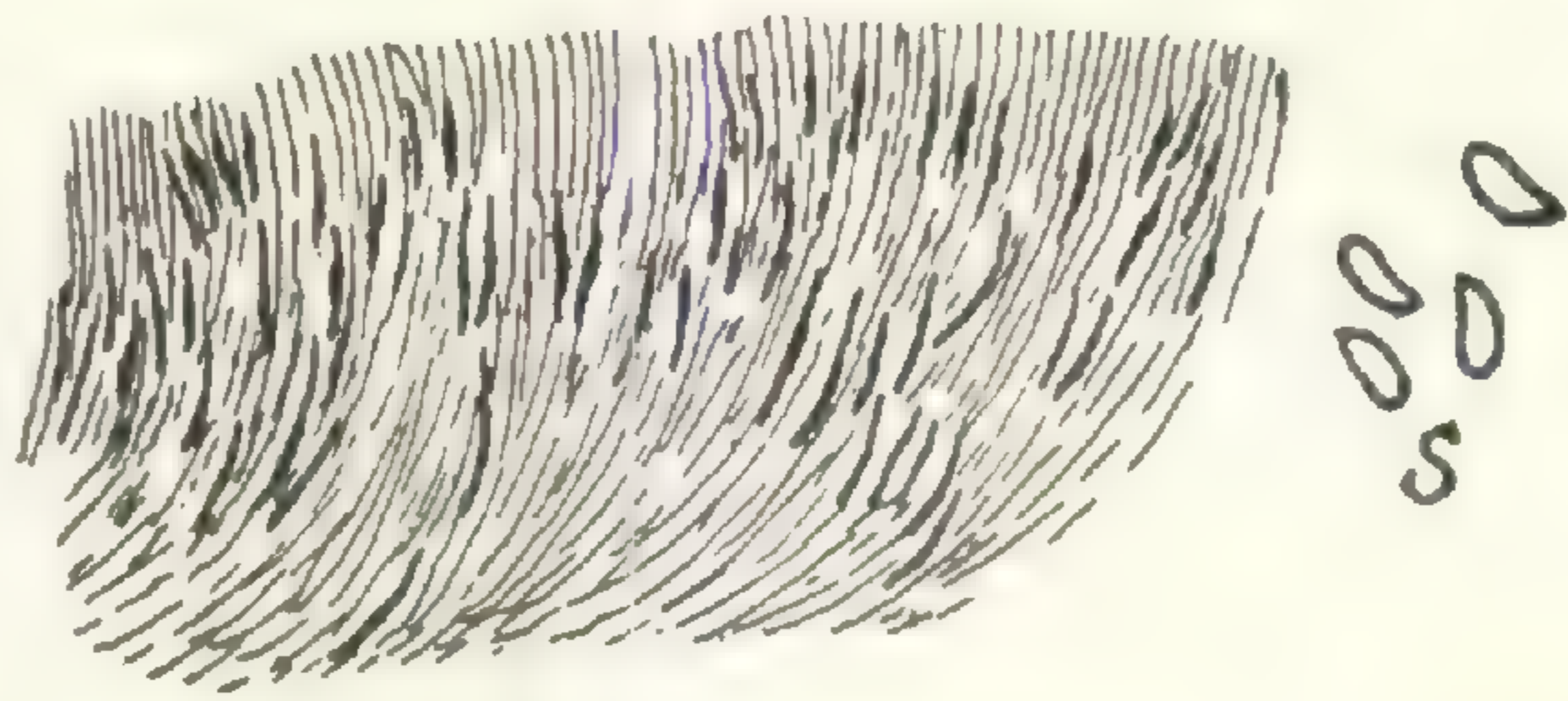


Fig. 20. *S. sanguinolentum*. Section of hymenial region \times 68, showing distribution of conducting organs; spores, s, \times 488.

made during dry weather. The somewhat drab color the hymenium assumes in drying and its deep cracks are highly characteristic of dried specimens. Colored conducting organs are abundant in the hymenium and subhymenium and should be demonstrated if other characters leave the determination doubtful.

Specimens examined:

Exsiccati: Krieger, *Fungi Sax.*, 160; Romell, *Fungi Scand. Exs.*, 29; de Thümen, *Myc. Univ.*, 2010, and 2111, under the name *Stereum rigens*.

Sweden: *L. Romell*, 43, 44; Lapland, *L. Romell*, 401 bis; Stockholm, *L. Romell*, in *Romell, Fungi Scand. Exs.*, 29; Upsala, *E. A. Burt*.

Finland: Mustiala, *P. A. Karsten*, in de Thümen, *Myc. Univ.* 2010, 2111.

France: Allier, *H. Bourdot*, 5586, 7591.

Italy: *G. Bresadola*; Florence, *G. Arcangeli* (in *Mo. Bot. Gard. Herb.*, 44565).

Newfoundland: Bay of Islands, *A. C. Waghorne*, 337, 350, the latter determined by Peck as *S. balsameum* (in *Mo. Bot. Gard. Herb.*, 5099, 5056).

Canada: comm. by *J. B. Ellis*, 5070 (in *Kew Herb.*, under the name *Stereum triste* as determined by Cooke).

Quebec: Montreal, *R. J. Blair*, comm. by *L. O. Overholts*, 3787, 4107 (in *Mo. Bot. Gard. Herb.*, 55097, 55638).

Ontario: Bond Lake, *J. H. Faull*, *Univ. Toronto Herb.*, 320 (in *Mo. Bot. Gard. Herb.*, 44875); Casselman, *J. Macoun*, 359; Lake Nipegon, *J. Macoun*, 103; Ottawa, *J. Macoun*, 11; Toronto, *R. P. Wodehouse*, *Univ. Toronto Herb.*, 369 (in *Mo. Bot. Gard. Herb.*, 44850); York Mills, *J. H. Faull*, *Univ. Toronto Herb.*, 318 (in *Mo. Bot. Gard. Herb.*, 44877).

Maine: Piscataquis Co., *W. A. Murrill*, 2029 (in *N. Y. Bot. Gard. Herb.* and *Mo. Bot. Gard. Herb.*, 56705); Portage, *L. W. Riddle*, 18.

New Hampshire: Chocorua, *W. G. Farlow*, 4; Tuckerman's Ravine, Mt. Washington, *L. O. Overholts*, 4949 (in *Mo. Bot. Gard. Herb.*, 56343).

Vermont: Little Notch, Middlebury, and Ripton, *E. A. Burt*.

Massachusetts: *R. J. Blair*, 327, comm. by *L. O. Overholts*,

- 4118 (in Mo. Bot. Gard. Herb., 55641), and *D. W. Weis*, comm. by *C. G. Lloyd*, 129 (in Mo. Bot. Gard. Herb., 56708).
- New York: Adirondack Mts., *C. H. Peck*, type of *Stereum balsameum* (in N. Y. State Mus. Herb.); Alcove, *C. L. Shear*, 1136; Cayuga Lake Basin, *G. F. Atkinson*, *f*, 3028, 8271, and *H. Hasselbring*, 3408; Glasco, *P. Wilson*, 38 (in Mo. Bot. Gard. Herb., 54743); Ithaca, *C. J. Humphrey*, 305.
- Pennsylvania: Shingleton Gap, *A. S. Rhoads*, 9 (in Mo. Bot. Gard. Herb., 44086).
- North Carolina: Salem, *Schweinitz* (in Herb. Schweinitz).
- Michigan: Gogebic Co., *E. A. Bessey*, 224 (in Mo. Bot. Gard. Herb., 56563).
- Montana: Anaconda, *J. R. Weir*, 11973 (in Mo. Bot. Gard. Herb., 56727); Elkhorn, *J. R. Weir*, 9749 (in Mo. Bot. Gard. Herb., 56224); Evaro, *J. R. Weir*, 413 (in Mo. Bot. Gard. Herb., 14773).
- Colorado: Ouray, *C. L. Shear*, 1186.
- New Mexico: Sandia Mts., *W. H. Long*, 21576, 21597 (in Mo. Bot. Gard. Herb., 55154, 55116); Tyom Experiment Station, *W. H. Long*, 21554 (in Mo. Bot. Gard. Herb., 55115).
- Idaho: Priest River, *J. R. Weir*, 47, 347 (the latter in Mo. Bot. Gard. Herb., 9989); Sandpoint, *E. E. Hubert*, comm. by *J. R. Weir*, 11612 (in Mo. Bot. Gard. Herb., 56726).
- British Columbia: Agassiz, *J. R. Weir*, 387 (in Mo. Bot. Gard. Herb., 20887); Hastings, *J. Macoun*, 27; Kootenai Mts., near Salmo, *J. R. Weir*, 507 (in Mo. Bot. Gard. Herb., 22700); Sidney, *J. Macoun*, 411 (in Mo. Bot. Gard. Herb., 55311).
- Washington: Bingen, *W. N. Suksdorf*, 871; Falcon Valley, *W. N. Suksdorf*, 723; Hoquiom, *C. J. Humphrey*, 6383; Olympia, *C. J. Humphrey*, 6306; Renton, *C. J. Humphrey*, 6439.
- California: Muir Woods, *W. A. Murrill*, 1153 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 55705); Olema, *M. A. H.* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56590); Sutro Woods, *R. A. Harper* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56704).
- Arizona: Coronada Nat. Forest, Santa Catalina Mts., *G. G.*

Hedgcock & W. H. Long, comm. by C. G. Humphrey, 2561 (in Mo. Bot. Gard. Herb., 9438).

42. *S. sulphuratum* Berkeley & Ravenel, Linn. Soc. Bot. Jour. 10: 331. 1868; *Grevillea* 1: 163. 1873; Sacc. Syll. Fung. 6: 566. 1888; Masee, Linn. Soc. Bot. Jour. 27: 192. 1890.

Plate 5, fig. 41.

Stereum ochroleucum Bresadola, Ann. Myc. 1: 91. 1903. Not *Stereum ochroleucum* Fries, Hym. Eur. 639. 1874, nor *Corticium ochroleucum* Fries, Epicr. 557. 1838.

Type: in Kew Herb. and Curtis Herb.

Fructifications coriaceous, stiff, effuso-reflexed, finally umbonate along the line of attachment to the substratum, and lobed,

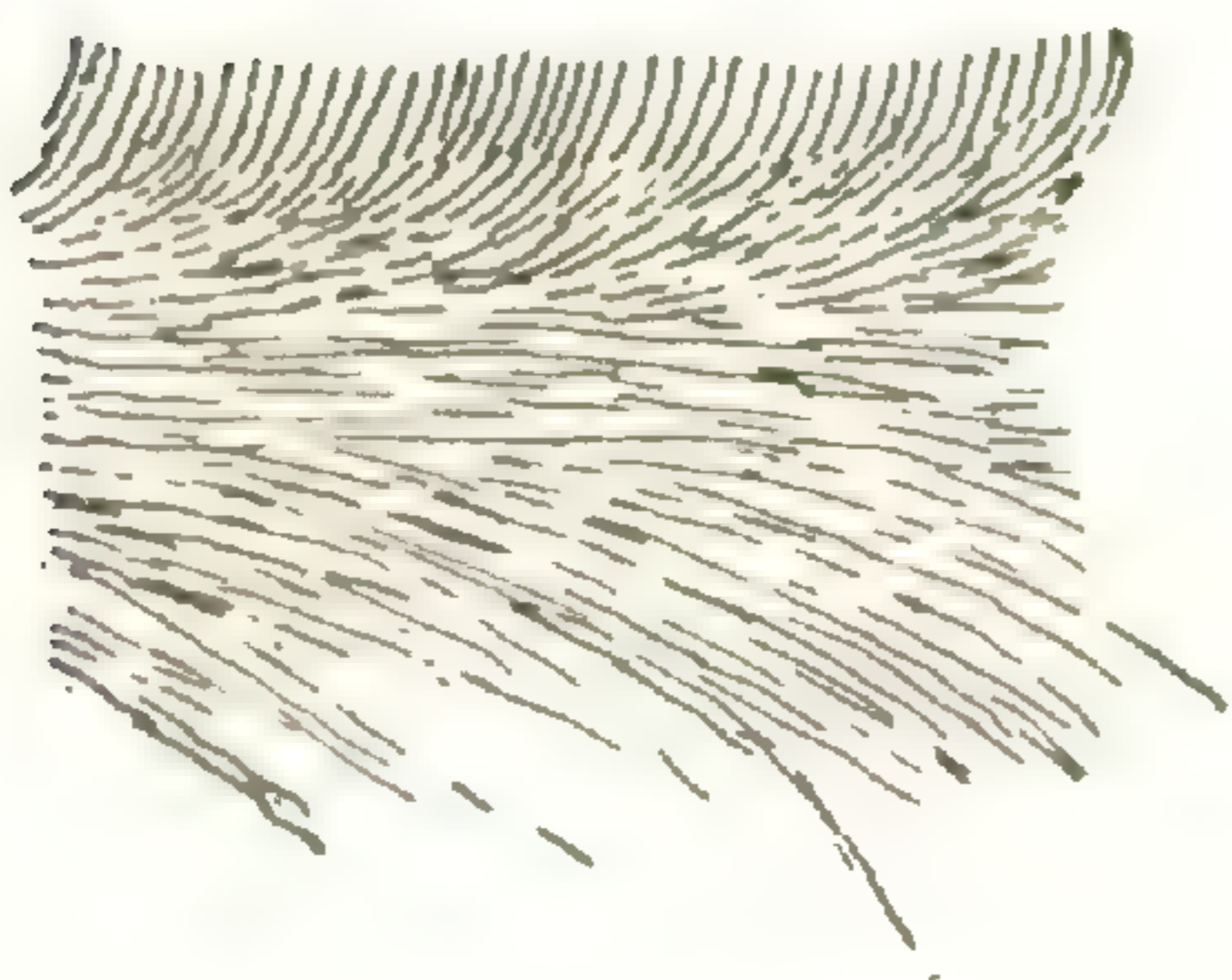


Fig. 21. *S. sulphuratum*. Section of type $\times 68$. The outer border of intermediate layer not a colored, crust-like zone.

upper surface tomentose-hirsute, concentrically furrowed, "sulphur colored" when fresh, becoming cartridge-buff to gray in the herbarium, the surface not hardened and crust-like under the hairy covering; hymenium even, glabrous, becoming pinkish buff to dirty tiller-buff in the herbarium; in structure 200–400 μ thick under the hairy covering, with the intermediate layer not differentiated on its upper side into a dense golden zone but hyaline throughout and with the longitudinally arranged

hyphae 3–3½ μ in diameter, curving outward on the upper side to form the hirsute covering and curving downward on the under side to form the hymenium; no colored conducting organs, gloeocystidia, nor cystidia; spores hyaline, even, 6–8 \times 2–3 μ .

Fructifications with resupinate portion ½–2 cm. broad, 10 cm. and more long on under side of limbs; reflexed lobes ½–1½ cm. broad, ½–2½ cm. long.

On dead limbs of *Betula* and other frondose species. Georgia to Mexico, West Indies, Venezuela, and Brazil. September to January. Not common.

In growing condition, the sulphur color attributed to specimens of *S. sulphuratum* and the heavy, hirsute covering of the pilei, taken in connection with geographic range wholly south

of that of *S. hirsutum*, should render specimens of the former species easily distinguishable. All gatherings of *S. sulphuratum* which I have seen had already faded to the gray color of old, weathered *S. hirsutum* and in this condition are best distinguished by not having underneath the hairy covering a thin hardened crust as the upper surface of the intermediate layer, nor a dense, somewhat golden zone on the upper border of the intermediate layer when sectional preparations are examined with the microscope.

S. sulphuratum occurs also in Westphalia, Germany, apparently an isolated station, and has been confused there with *Stereum ochroleucum* Fries, a species of thicker and softer structure having hyphae interwoven instead of densely and longitudinally arranged—for which reason Fries was doubtful about its being a true *Stereum* and published the species originally as a *Corticium*. Collections from Sweden and France communicated to me as conspecific with the Westphalian gatherings have the upper surface of the intermediate layers with a crust-like golden zone and are referable to *S. hirsutum* instead.

Specimens examined:

Exsiccati: Brinkmann, *Westfälische Pilze*, 49, under name of *Stereum ochroleucum*; Rick, *Fungi Austro-Am.*, 260, under name of *Stereum ochroleucum*.

Germany: Westphalia, Lengerich, *W. Brinkmann*, comm. by G. Bresadola, and in Brinkmann, *Westfälische Pilze*, 49.

Georgia: Catoosa Springs, *H. W. Ravenel* (in Kew Herb. and in Curtis Herb., 1731).

Florida: *C. G. Lloyd*, 2131.

Alabama: Auburn, *Ala. Biol. Surv.*, comm. by F. S. Earle; Montgomery, *R. P. Burke*, 4 (in Mo. Bot. Gard. Herb., 22017).

Mexico: Jalapa, *W. A. & E. L. Murrill*, 316, 343, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54438, 55477).

Cuba: *C. Wright*, 292, type (in Kew Herb.).

Jamaica: *Farr* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56667); Cinchona, *W. A. & E. L. Murrill*, 480, 546, comm. by N. Y. Bot. Gard. Herb.; Morce's Gap, *W. A. & E. L. Murrill*, 723, comm. by N. Y. Bot. Gard.

Herb.; Monkey Hill, *W. A. & E. L. Merrill, 784*, comm. by N. Y. Bot. Gard. Herb.; Sir John Peak, *L. M. Underwood, 3182* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56668).

Venezuela: *Fendler, 169* (in Curtis Herb.).

Brazil: Sao Leopoldo, *Rick*, in *Rick, Fungi Austro-Am.*, 260.

43. *S. hirsutum* Willdenow ex Fries, *Epicr.* 549. 1838; *Hym. Eur.* 639. 1874; Persoon, *Roemer Neues Mag. Bot.* 1: 110. 1794; *Obs. Myc.* 2: 90. 1799; Berkeley, *Outlines Brit. Fung.* 270. *pl. 17.f. 7.* 1860; *Sacc. Syll. Fung.* 6: 563. 1888.

Plate 5, fig. 42.

Thelephora hirsuta Willdenow, *Fl. Berol. Prod.* 397. 1787; Fries, *Syst. Myc.* 1: 439. 1821; Persoon, *Syn. Fung.* 570. 1801; *Myc. Eur.* 1: 116. 1822.—*Auricularia reflexa* Bulliard, *Herb. de la France* 1: 281. *pl. 274.* 1785.—*Thelephora ochracea* Schweinitz, *Naturforsch. Ges. Leipzig Schrift.* 1: 106. 1822, but not of Fries.—*T. subzonata* Fries, *Elenchus Fung.* 1: 181. 1828; Schweinitz, *Am. Phil. Soc. Trans. N. S.* 4: 167. 1832.—*Corticium subzonatum* Fries, *Epicr.* 557. 1838; *Sacc. Syll. Fung.* 6: 608. 1888.—*Stereum variicolor* Lloyd, *Myc. Writ.* 4. Letter 53: 10. 1914.

Illustrations: Berkeley, *Outl. Brit. Fung. pl. 17.f. 7*; Bolton, *Hist. Fung. pl. 82*; Bulliard, *Herb. de la France, pl. 274*; Hussey, *Ill. Brit. Myc.* 1: *pl. 58*; Sowerby, *Col. Figs. Brit. Fung. pl. 27*; Stevenson, *Brit. Fungi* 2: 267. *text f. 86.* See *Sacc. Syll. Fung.* 20: 890, for reference to other illustrations.

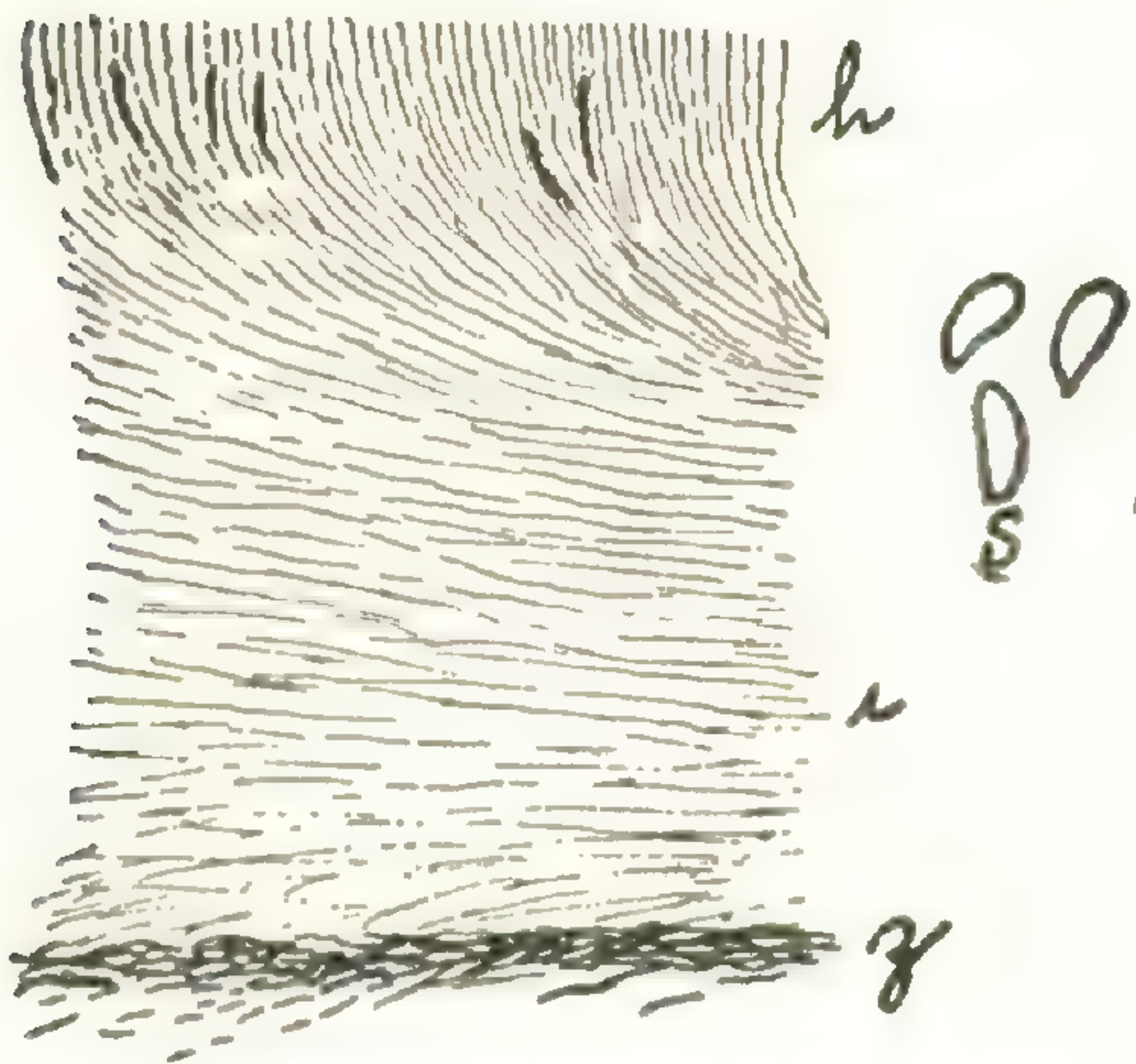


Fig. 22. *S. hirsutum*. Section $\times 68$; intermediate layer, *i*; golden, crust-like zone, *z*; hymenium containing very few conducting organs, *h*; spores, *s*, $\times 488$.

Fructifications coriaceous, stiff, effuso-reflexed, rarely wholly resupinate, strigose-hirsute, somewhat concentrically furrowed, not complicate, cream-buff at first, becoming grayish when old and weathered, with a thin, hardened, crust-like surface bearing the hairy covering, the margin entire;

hymenium even, warm buff at first, sometimes becoming pale smoke-gray, unchanged when cut or bruised; in structure 500–700 μ thick under the hairy covering, with the intermediate layer bordered next to the hairy covering by a very dense, narrow, golden zone, the rest of the intermediate layer composed of densely and longitudinally arranged hyaline hyphae 3–4 μ in diameter, some of which in the subhymenium are thick-walled, up to 5–6 μ in diameter, and very rarely have golden-brown contents as seen between the basidia; no colored conducting organs, cystidia, nor gloeocystidia; spores white in spore collection, even, flattened on one side, $5-7\frac{1}{2} \times 2-2\frac{3}{4} \mu$.

Reflexed portion varying from barely reflexed up to 2 cm. broad, 1–2 cm. long; fructifications merely gregarious or confluent, and imbricated.

On logs and stumps of birch, beech, and other frondose species. Newfoundland to South Carolina and westward to British Columbia and California, and in Mexico. July to November in the east and to February in the Pacific states. Common.

Stereum hirsutum is characterized by its strigose-hirsute, buff-colored pileus, weathering more or less gray, and by its warm buff hymenium, sometimes smoke-gray, which does not exude a red juice when wounded; as in *S. rameale*, *S. versicolor*, *S. fasciatum*, *S. lobatum*, *S. australe*, and *S. gausapatum*, the upper surface of the intermediate layer is differentiated into a thin, golden, somewhat horny crust from which the hairy covering springs. This golden zone shows well under the microscope, and its presence is a decisive character for separating *S. hirsutum* from the southern *S. sulphuratum*, a species of somewhat similar aspect.

Specimens examined:

Exsiccati: Berkeley, Brit. Fungi, 146; Cavara, Fungi Longobardiae, 61; Cooke, Fungi Brit., 108; Ellis, N. Am. Fungi, 1204; Krieger, Fungi Sax., 118; Rabenhorst, Herb. Myc., 211; Romell, Fungi Scand. Exs., 26.

Sweden: Femsjö, L. Romell, two collections, and E. A. Burt; Mauritzberg, W. A. & E. L. Murrill, 4078 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56671); Stockholm, L. Romell, 30, 401, and in Romell, Fungi Scand. Exs., 26.

- England: *M. J. Berkeley*, in *Berkeley*, *Brit. Fungi*, 146; *Epping*, *M. C. Cooke*, in *Cooke*, *Fungi Brit.*, 108; *Kew Gardens*, *G. Masee*; *Selby*, *E. A. Burt*.
- France: *Fautrey*, comm. by *Lloyd Herb.*, 3326; *Aveyron*, *A. Galzin*, 8459, comm. by *H. Bourdot*, 7813; *St. Priest*, *Allier*, *H. Bourdot*, 19770.
- Germany: *Nossen*, *Saxony*, *W. Krieger*, in *Krieger*, *Fungi Sax.*, 118.
- Italy: *A. Carestia*, 784, 1215, comm. by *G. Bresadola*; *Pavia*, *F. Cavara*, in *Cavara*, *Fungi Longobardiae*, 61.
- Newfoundland: *A. C. Waghorne*, 118 (in *Mo. Bot. Gard. Herb.*, 5082).
- Canada: *J. Macoun*, 69.
- Ontario: *Ottawa*, *J. Macoun*, 16, 466a; *Port Credit*, *J. H. Faull*, *Univ. Toronto Herb.*, 353 (in *Mo. Bot. Gard. Herb.*, 44858); *Toronto*, *G. H. Graham*, *Univ. Toronto Herb.*, 678 (in *Mo. Bot. Gard. Herb.*, 44919).
- Maine: *Milo*, *W. A. Merrill*, 2024 (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56682).
- New Hampshire: *North Conway*, *L. O. Overholts*, 5009 (in *Mo. Bot. Gard. Herb.*, 56346).
- Vermont: *Middlebury*, *E. A. Burt*; *Ripton*, *E. A. Burt*; *Smugglers Notch*, *E. A. Burt*, two gatherings.
- Massachusetts: *Boston*, *L. C. Monahan* (in *Mo. Bot. Gard. Herb.*, 15309); *Cambridge*, *E. A. Burt*; *Mt. Auburn*, *E. A. Burt*; *Nahant*, *A. B. Seymour*, *T 31* (in *Mo. Bot. Gard. Herb.*, 12954); *Waverly*, *A. B. Seymour*, *T 25*, *T 26* (in *Mo. Bot. Gard. Herb.*, 16364, 18372); *Waltham*, *A. B. Seymour*, *T 16* (in *Mo. Bot. Gard. Herb.*, 17912).
- Connecticut: *Broad Brook*, *C. C. Hanmer*, 2682 (in *Mo. Bot. Gard. Herb.*, 42606); *Mansfield*, *P. W. Graff*, 13 (in *Mo. Bot. Gard. Herb.*, 44817); *Storrs*, *P. W. Graff*, 29 (in *Mo. Bot. Gard. Herb.*, 44804).
- New York: *G. F. Atkinson*, 8026, and *W. H. Wright*, comm. by *G. F. Atkinson*, 7990; *Alcove*, *C. L. Shear*, 995; *Fall Creek*, *W. H. Wright*, 7992; *Floodwood*, *E. A. Burt*.
- Pennsylvania: *Spruce Creek*, *J. H. Faull*, *Univ. Toronto Herb.*, 337 (in *Mo. Bot. Gard. Herb.*, 44883); *West Chester*, *Everhart & Haines*, in *Ellis*, *N. Am. Fungi*, 1204.

- North Carolina: *Schweinitz*, types of *T. ochracea* and *T. subzonata* (in Herb. Schweinitz); Blowing Rock, *G. F. Atkinson*, 4308.
- South Carolina: Clemson College, *P. H. Rolfs*.
- Michigan: Cadillac, *H. D. House*, 1225 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56673); Isle Royale, *Miss A. D. Stucki*, Univ. Wis. Herb., 23; Vermilion, *A. H. W. Povah*, 199 (in Mo. Bot. Gard. Herb., 15145).
- Indiana: Crawfordsville, *D. Reddick*, 5, 7, and another specimen, comm. by *H. H. Whetzel*.
- West Virginia: Paw Paw, *C. L. Shear*, 1173.
- Tennessee: Elkmont, *C. H. Kauffman*, 62 (in Mo. Bot. Gard. Herb., 3972).
- Wisconsin: Blue Mounds, *Miss A. D. Stucki*, Univ. Wis. Herb., 8, 9; Madison, *Miss A. D. Stucki*, Univ. Wis. Herb., 34, and *W. Trelease*, 5, 26 (in Mo. Bot. Gard. Herb., 56683, 56684); Palmyra, *Miss A. D. Stucki*, Univ. Wis. Herb., 33.
- Minnesota: Lake Itaska, comm. by *E. L. Jensen*, 9 (in Mo. Bot. Gard. Herb., 11088).
- Missouri: *B. M. Duggar*, 95; Meramec, *P. Spaulding* (in Mo. Bot. Gard. Herb., 5025).
- Arkansas: Womble, *W. H. Long*, 19844, 19883 (in Mo. Bot. Gard. Herb., 8963, 14651).
- Nebraska: Lincoln, *C. L. Shear*, 1023.
- Montana: Evaro, *J. R. Weir*, 431 (in Mo. Bot. Gard. Herb., 22515); Mystic Lake, *C. L. Shear*, 1102.
- Colorado: Steamboat Springs, *E. Bartholomew*, 5578 (in Mo. Bot. Gard. Herb., 9185, 44584); Tolland, *F. J. Seaver & E. Bethel* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56674).
- New Mexico: Albuquerque, *W. H. Long*, 21153 (in Mo. Bot. Gard. Herb., 55112); Cloudcroft, *F. S. Earle*, 495, comm. by N. Y. Bot. Gard. Herb., and *W. H. Long*, 19542 (in Mo. Bot. Gard. Herb., 55111); Tejano Exp. Station, *W. H. Long*, 21875, 21894, 21907 (in Mo. Bot. Gard. Herb., 55161–55163); Tyom Exp. Station, *W. H. Long*, 21365, 21366, 21426 (in Mo. Bot. Gard. Herb., 55113, 55114, 55160); Ute Park, *P. C. Standley*, 14197, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 44953); Weeds,

L. Wymans, comm. by W. H. Long, 12969 (in Mo. Bot. Gard. Herb., 55110).

Idaho: Priest River, *J. R. Weir*, 19, 31, 48.

British Columbia: New Westminster, *A. I. Hill* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56675); Oak Bay, *J. Macoun*, 579a (in Mo. Bot. Gard. Herb., 55310); Sidney, *J. Macoun*, 46, 47, 49, 52, 52 bis, 53, 54, 84 (in Mo. Bot. Gard. Herb., 5736, 6674, 6694, 6682, 55361, 6698, 6697, 6704 respectively).

Washington: Bingen, *W. N. Suksdorf*, 692, 693, 709, 874, 891, 893, 916, 953; Kalama, *C. J. Humphrey*, 6140; Chehalis, *C. J. Humphrey*, 6254 (in Mo. Bot. Gard. Herb., 16677); Olympia, *C. J. Humphrey*, 6310; Seattle, *S. M. Zeller*, 119 (in Mo. Bot. Gard. Herb., 44139); Tacoma, *W. A. Murrill*, 127, 142, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55744, 55730).

Oregon: Corvallis, *C. E. Owens*, 2036, 2054, 2057, 2084, 2135, 2136, 2139, 2142, 2143 (in Mo. Bot. Gard. Herb., 43872, 43878, 43877, 44249, 44695, 44694, 44693, 44699, 44702 respectively), and *S. M. Zeller*, 1814 (in Mo. Bot. Gard. Herb., 56332); Eugene, *C. J. Humphrey*, 6050, 6063, 6076 (in Mo. Bot. Gard. Herb., 17175); Mt. Hood, *G. G. Hedgcock*, comm. by C. J. Humphrey, 2569 (in Mo. Bot. Gard. Herb., 16418); Granite Pass, *J. R. Weir*, 8680, 8681 (in Mo. Bot. Gard. Herb., 36752, 36753).

California: *R. A. Harper*, 8, 109, 141, 143 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56678–56681), and *Miss E. Hyatt*, comm. by C. L. Shear, 1089; Berkeley, *C. J. Humphrey*, 5970, 5982, *H. A. Lee*, Univ. Calif. Herb., 1015, 1016, 1019, 1021, 1022 (in Mo. Bot. Gard. Herb., 44154–44156, 44152, 44157 respectively), *W. A. Setchell*, Univ. Calif. Herb., 1023, 1024 (in Mo. Bot. Gard. Herb., 44153, 44245), and *G. Courvoisier*, Univ. Calif. Herb., 1025 (in Mo. Bot. Gard. Herb., 44149); Claremont, *D. L. Crawford*, D 12, comm. by L. O. Overholts, 3280 (in Mo. Bot. Gard. Herb., 10479); Coast Range, *C. F. Baker*, 82, 101, comm. by N. Y. Bot. Gard. Herb.; Fair Oaks, *R. A. Harper* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56676); Julian, *E. Bethel*, 28272 (in Mo. Bot. Gard. Herb., 55439); North-

brae, *L. S. Smith*, Univ. Calif. Herb., 416 (in Mo. Bot. Gard. Herb., 44148); Muir Woods, *W. A. Murrill*, 1133 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 55713); Pinehurst, *E. Bethel*, 26269, 26274 (in Mo. Bot. Gard. Herb., 55438, 55440); Preston's Ravine, *W. A. Murrill & L. S. Abrams*, 1171, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55707); San Francisco, *W. A. Setchell & C. C. Dolier*, *W. A. Murrill*, 1111, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55702); Santa Barbara, *O. M. Oleson*, 6, 9, 16; Santa Cruz, *G. J. Streater* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56677); Sutro Forest, *A. S. Rhoads*, 1 (in Mo. Bot. Gard. Herb., 56045).

Mexico: Coyoacan, *Roldan*, comm. by J. R. Weir, 14937, 14999 (in Mo. Bot. Gard. Herb., 56795, 56796).

44. *S. fasciatum* Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1: 106. 1832 (under *B. Sterea* of *Thelephora*); Fries, Epicr. 546. 1838 Sacc. Syll. Fung. 6: 560. 1888; Masee, Linn. Soc. Bot. Jour. 27: 180. 1890.

Plate 5, figs. 43-45.

Thelephora versicolor β *fasciata* (Schw.) Fries, Elenchus Fung. 1: 175. 1828; Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 167. 1832.—*T. ostrea* Blume & Nees, Acad. Leop.-Carol. Nov. Acta 13¹: 13. pl. 2. 1826.—*Stereum ostrea* (Bl. & Nees) Fries, Epicr. 547. 1838; Sacc. Syll. Fung. 6: 571. 1888; Bresadola, Hedwigia 51: 321. 1912.—*Thelephora* (*Stereum*) *mollis* Léveillé, Ann. Sci. Nat. Bot. III. 5: 147. 1846.—*Stereum molle* Léveillé in Sacc. Syll. Fung. 6: 577. 1888; Masee, Linn. Soc. Bot. Jour. 27: 175. 1890.—*S. arcticum* Fries, Hym. Eur. 639. 1874.

Type: in Herb. Schweinitz and in Curtis Herb.

Fructifications coriaceous, rigid, in the north at first broadly effuso-reflexed with the resupinate portion narrow, soon umbonate sessile—perhaps so from the first in the tropics—often laterally confluent, sometimes pseudo-stipitate by prolongation

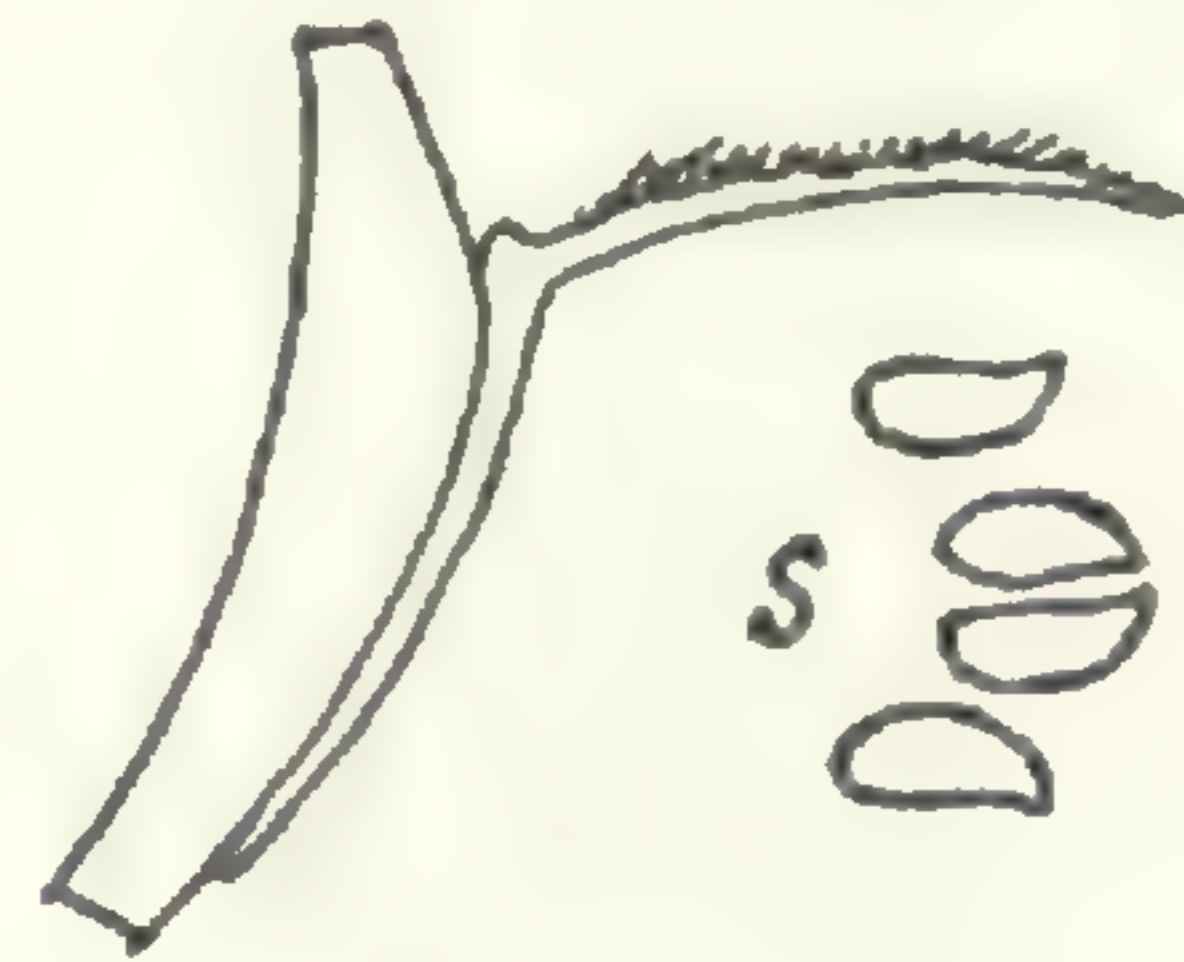


Fig. 23. *S. fasciatum*. Section of reflexed stage, natural size; spores, s, \times 665.

of the umbo, at first densely tomentose and drying warm buff to tawny olive, at length weathering to pale smoke-gray to neutral gray and sometimes with the tomentum torn apart in narrow zones and showing the hazel or chestnut surface of the bared areas, the margin normally entire; in structure 400–700 μ thick, with the intermediate layer composed of very densely arranged, hyaline hyphae 4 μ in diameter and bordered on the upper side by a broad dark zone which bears the tomentum of the upper surface; hymenium glabrous, usually warm buff to cinnamon-buff, sometimes assuming violaceous tints; no cystidia, gloeocystidia, nor conducting organs; spores from spore collections white, even, flattened on one side, $5\frac{1}{2}$ – $7\frac{1}{2}$ \times $2\frac{1}{2}$ –3 μ .

Fructifications 2–7 cm. in diameter, often laterally confluent.

On logs and stumps of *Quercus* and other hardwood species. Common throughout North America from Canada southward, in the West Indies, and in South America; occurs also in Norway, Sweden, Formosa, and Java, although apparently rare in the Old World. In vegetative condition from June onward in the north, persisting throughout the year.

Specimens of *S. fasciatum* may be distinguished from those of the less common *S. lobatum* by the thicker tomentose covering of the former, which may continue unbroken throughout the year or become torn apart so as to show rather few and narrow, bared chestnut zones; the pileus of *S. fasciatum* is thicker than that of *S. lobatum*, and the margin has a lobate tendency but rarely. Towards the northern part of its range where I have observed the development of fructifications throughout the season, the fructifications are at first effuso-reflexed with the resupinate portion up to 1 cm. broad, the reflexed portion $1\frac{1}{2}$ cm. from base to margin, and with a lateral extent along the substratum of 2–8 cm.; umbos soon form at points 1–2 cm. apart along line of intersection of the plane of reflexed portion with the substratum; by further growth outward of the laterally confluent pilei these umbos become the final points of attachment of the pilei with the substratum. In Washington and California the fructifications may continue broadly reflexed when old and are difficult to distinguish from luxuriantly grown *S. hirsutum*.

The specimens from Formosa, cited below, are in the stage in

which the fructifications are still with a resupinate portion but with the umbos distinctly outlined, and exactly agree in all respects, even including spore dimensions, with my Vermont collections of the same stage. The authentic specimen of *Thelephora ostrea* from Java is in the final stage with attachment by umbo only and is clothed over its whole upper surface with a thick coat of tomentum, and matches well most of the specimens of the type collection of *Stereum fasciatum* in Herb. Schweinitz. I infer from the lack of specimens of *S. fasciatum* from the East Indies and the Philippines in published exsiccati, that this species is very rare there and that what frequently has been listed as *S. ostrea* is really the very common *S. concolor* instead.

Schweinitz's original description of *S. fasciatum* presents at such length the disappearance of tomentum from the upper surface of the pileus and the broad, glabrous, shining surface with many vari-colored zones, that it seems probable he may have intended the description to comprehend not only *S. fasciatum* as treated by me but also *S. lobatum*, which he must have seen about him in North Carolina; nevertheless, the ample collection of specimens in Herb. Schweinitz which were preserved as the type of *S. fasciatum* contains no fructifications referable to *S. lobatum*.

Specimens examined:

Exsiccati: Bartholomew, Fungi Col., 2590, under the name *S. versicolor*, 2884, under the name *S. versicolor*, 2985, 3985, 4291, and 4986; Ellis, N. Am. Fungi, 18, under the name *S. versicolor* v. *fasciata*, 514a, and c, both under the name *S. versicolor*; Ell. & Ev., N. Am. Fungi, 1714, under the name *S. purpureum*; Ellis & Ev., Fungi Col., 306, under the name *S. versicolor*; Ravenel, Fungi Am., 220, under the name *S. versicolor*, and 721; Smith, Central Am. Fungi, 145, under the name *S. versicolor*; de Thümen, Myc. Univ., 2011, mixed with *S. lobatum*.

Norway: Bosekon, Finmark, *M. N. Blytt*, type of *Stereum arcticum* (in Herb. Fries).

Sweden: on *Alnus*, North Sweden, comm. by L. Romell, 400.

Canada: *J. Macoun*, 12.

Prince Edward Island: *J. Macoun*, 346 (in Macoun Herb.).

Quebec: *J. Macoun*, 77, 239, 249, 464 (all in Macoun Herb.)

- Ontario: Bond Lake, *J. H. Faull*, Univ. Toronto Herb., 319 (in Mo. Bot. Gard. Herb., 44874); Ottawa, *J. Macoun*, 50; Port Credit, *J. H. Faull*, Univ. Toronto Herb., 352, 354 (in Mo. Bot. Gard. Herb., 44857, 44856); Rondeau Park, *J. H. Faull*, Univ. Toronto Herb., 358 (in Mo. Bot. Gard. Herb., 44870); Toronto, *J. H. Faull*, Univ. Toronto Herb., 356 (in Mo. Bot. Gard. Herb., 44868), *T. Langton*, Univ. Toronto Herb., 501 (in Mo. Bot. Gard. Herb., 44853), *G. H. Graham*, Univ. Toronto Herb., 680 (in Mo. Bot. Gard. Herb., 44937).
- Maine: Harrison, *J. Blake*, comm. by P. L. Ricker; Orono, *F. L. Harvey*, comm. by P. L. Ricker; Portage, *L. W. Riddle*, 2, 17.
- Vermont: Middlebury, *E. Brainerd*, *E. A. Burt*, nine collections; Ripton, *E. A. Burt*.
- Massachusetts: Amherst, *P. J. Anderson*, 2, 4 (in Mo. Bot. Gard. Herb., 55846, 55845 respectively).
- Connecticut: Mansfield, *P. W. Graff*, 30 (in Mo. Bot. Gard. Herb., 44803); New Haven, *W. A. Setchell*; Norwich, *W. A. Setchell*.
- New York: *Sartwell*, 19 (in Mo. Bot. Gard. Herb., 5076); Alcove, *C. L. Shear*, 1327; Canandaigua, *L. M. Underwood*, 21, distributed under the name *S. versicolor* (in Mo. Bot. Gard. Herb., 5117); East Galway, *E. A. Burt*; Floodwood, *E. A. Burt*; Freeville, *G. F. Atkinson*, 2821; Glasco, *P. Wilson*, 48, 43 (in Mo. Bot. Gard. Herb., 54752, 54754); Grand View, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42811, 43025); Ithaca, *G. F. Atkinson*, 2819, 2820, 8027, Bot. Dept. Cornell Univ., 133 O. S., 2871, *H. S. Jackson*, comm. by Bot. Dept. Cornell Univ., 14397-14399, *Van Hook*, comm. by Bot. Dept. Cornell Univ., 8084, *W. C. Muenscher*, 147, 205, 211 (in Mo. Bot. Gard. Herb., 56602-56604); Palisades, *P. Wilson*, 20, 18, 12 (in Mo. Bot. Gard. Herb., 54755, 54756, 54759); Yonkers, *P. Wilson*, 61 (in Mo. Bot. Gard. Herb., 54753).
- New Jersey: Alpine, *P. Wilson*, 17, 13, 7 (in Mo. Bot. Gard. Herb., 54757, 54758, and 54760 respectively); Belleplain, *C. L. Shear*, 1250; Newfield, *J. B. Ellis*, in *Ellis*, N. Am. Fungi, 18, 514c, and *Ell. & Ev.*, Fungi Col., 306.

- Pennsylvania: *E. Michener*, 88 (in Mo. Bot. Gard. Herb., 5044); Germantown, *E. A. Burt*; Huntington Co., *A. S. Rhoads*, 7 (in Mo. Bot. Gard. Herb., 44084); Lancaster City, *Mrs. A. F. Eby* (in Mo. Bot. Gard. Herb., 5083); Kittanning, *D. R. Sumstine*, 4, 7, 7; Philadelphia, *A. S. Rhoads*, 19 (in Mo. Bot. Gard. Herb., 44096); in coal mine, Pottsville, *C. J. Humphrey*, 310; Spruce Creek, *J. H. Faull*, Univ. Toronto Herb., 357, 359, 334, 670, 355, 667 (in Mo. Bot. Gard. Herb., 44869, 44871, 44888, 44917, 44926, and 44934 respectively); Shingleton Gap, *A. S. Rhoads*, 15 (in Mo. Bot. Gard. Herb., 44093); State College, *C. R. Orton*, 1, 18 (in Mo. Bot. Gard. Herb., 44079, 44095), comm. by *L. O. Overholts*, 2658, 5003 (in Mo. Bot. Gard. Herb., 5721, 56345), *A. S. Rhoads*, 16 (in Mo. Bot. Gard. Herb., 44094); Trexlertown, *C. G. Lloyd*, 0084; in coal mine, Wadesville Colliery, *C. J. Humphrey*, 21583.
- Maryland: Glen Sligo, *C. L. Shear*, 1133.
- District of Columbia: Takoma Park, *P. L. Ricker*, 820, *C. L. Shear*, 956.
- Virginia: Great Falls, *O. F. Cook*, comm. by *P. L. Ricker*; Mt. Vernon, *P. L. Ricker*, 1121 in part; Mountain Lake, *W. A. Murrill*, 408 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56618); Norton, *A. B. Seymour* (in Mo. Bot. Gard. Herb., 16405).
- North Carolina: *Schweinitz*, type (in Herb. Schweinitz and Curtis Herb.); Blowing Rock, *G. F. Atkinson*, 4178, 4180, 4315; Chapel Hill, *W. C. Coker*, 938 (in Mo. Bot. Gard. Herb., 56665); Leicester, *B. B. Higgins*, in Bartholomew, Fungi Col., 2985.
- South Carolina: Clemson College, *P. H. Rolfs*, 1613, 1616, 1619, 1620, 1624, 1629, 1631, 1635.
- Georgia: Darien, *H. W. Ravenel*, in Ravenel, Fungi Am., 220, 721; Dixie, *R. M. Harper*, 1633b, comm. by N. Y. Bot. Gard. Herb.; Tallulah Falls, *A. B. Seymour*, comm. by *W. G. Farlow*, 6 (in Mo. Bot. Gard. Herb., 55290).
- Florida: *C. G. Lloyd* (in Mo. Bot. Gard. Herb., 44068); Coconut Grove, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 43097); Eustis, *L. M. Underwood*, 1368, 1801 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56616, 56617).

- Alabama: Adger, *C. J. Humphrey*; Montgomery Co., *R. P. Burke*, 34 (in Mo. Bot. Gard. Herb., 4273); Maplesville, *C. S. Hill*, comm. by *C. J. Humphrey*, 251.
- Mississippi: Laurel, *C. J. Humphrey*, 5431, 5435; Ocean Springs, *F. S. Earle* (in Mo. Bot. Gard. Herb., 5118).
- Louisiana: Baton Rouge, *C. W. Edgerton*, 848, comm. by *C. J. Humphrey*; St. Martinville, *A. B. Langlois*, 2902, *bf*.
- Ohio: Cincinnati, *D. L. James*, in *Ellis*, *N. Am. Fungi*, 514c, *C. G. Lloyd*, 1579, 4499, 4501, 4506; Columbus, *W. A. Kellerman*, in *Kellerman*, *Ohio Fungi*, 33, under the name *S. versicolor*; Granville, *H. L. Jones*; Linwood, *C. G. Lloyd*, 2436, 02821, 02830; Penfield, *F. D. Kelsey* (in Mo. Bot. Gard. Herb., 5075); Worthington, *Dr. Paddock* (in Mo. Bot. Gard. Herb., 5114, 5157).
- Kentucky: Bowling Green, *Miss S. F. Price* (in Mo. Bot. Gard. Herb., 5038, 5112, 56604); Mammoth Cave, *C. G. Lloyd*.
- Tennessee: Algood, *C. J. Humphrey*, 308.
- Michigan: Isle Royale, *Allen & Stuntz*, 22, 60; Sailor's Encampment, *E. T. & S. A. Harper*, 710; Vermilion, *A. H. W. Povah*, 142 (in Mo. Bot. Gard. Herb., 15144).
- Wisconsin: Bayfield, *V. B. Walker*, 6b (in Mo. Bot. Gard. Herb., 9733); Blanchardville, *Miss A. O. Stucki*, 47; Blue Mounds, *Miss A. O. Stucki*, 49; Ithaca, *W. Trelease*, 89 (in Mo. Bot. Gard. Herb., 56606); Madison, *E. T. Bartholomew*, in *Bartholomew*, *Fungi Col.*, 3985, *Miss A. O. Stucki*, 31, 35, 36, 50, *W. Trelease* (in Mo. Bot. Gard. Herb., 56605); Syene, *W. Trelease*, 90 (in Mo. Bot. Gard. Herb., 5072).
- Indiana: Greencastle, *L. M. Underwood*, 2 (in Mo. Bot. Gard. Herb., 44101); Hibernian Mills, *Whetzel & Reddick*, comm. by *D. Reddick*, 6, 8; Ladoga, *P. J. Anderson*, 1 (in Mo. Bot. Gard. Herb., 55838); Wabash "bottom", *W. Trelease* (in Mo. Bot. Gard. Herb., 5073).
- Illinois: Brownsville, *E. T. & S. A. Harper*, 951; Cobden (in Mo. Bot. Gard. Herb., 44102); Grand Pass Club, *W. Trelease* (in Mo. Bot. Gard. Herb., 5053); Jacksonville, *E. Bartholomew*, in *Bartholomew*, *Fungi Col.*, 2590.
- Missouri: Bismarck, *L. O. Overholts* (in Mo. Bot. Gard. Herb., 43702); Clayton, *A. M. Ferguson* (in Mo. Bot. Gard. Herb., 5131); Columbia, *B. M. Duggar*, 346a, 562, 580; Creve

- Coeur, *E. A. Burt* (in Mo. Bot. Gard. Herb., 8727); Lincoln Co., *C. Trenning* (in Mo. Bot. Gard. Herb., 4098); Meramec, *P. Spaulding*, 1, and (in Mo. Bot. Gard. Herb., 5020), *Spaulding & Johnson* (in Mo. Bot. Gard. Herb., 5013–5015); Meramec Highlands, *N. M. Glatfelter* (in Mo. Bot. Gard. Herb., 42583); Old Orchard, *L. H. Pammel* (in Mo. Bot. Gard. Herb., 5020, 5041); Piedmont (in Mo. Bot. Gard. Herb., 4783); Upper Creve Coeur, *E. A. Burt* (in Mo. Bot. Gard. Herb., 44057); Valley Park, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42859); White House, *E. A. Burt* (in Mo. Bot. Gard. Herb., 43808), contains mesopod specimen; Willow Springs, *H. von Schrenk*, 1, 2 (in Burt Herb. and Mo. Bot. Gard. Herb., 42886, 42851).
- Arkansas: Bertig, *W. Trelease* (in Mo. Bot. Gard. Herb., 5148); Big Flat, *W. H. Long*, 19859 (in Mo. Bot. Gard. Herb., 8268); Fayetteville, *E. Bartholomew*, in Bartholomew, Fungi Col., 2884; Womble, *W. H. Long*, 19866 (in Mo. Bot. Gard. Herb., 8889); Wynne, *W. Trelease* (in Mo. Bot. Gard. Herb., 5147, 5152).
- Oklahoma: Poteau, *W. Trelease* (in Mo. Bot. Gard. Herb., 5052); Spiro, *E. Bartholomew*, in Bartholomew, Fungi Col., 4291.
- Texas: *L. H. Pammel* (in Mo. Bot. Gard. Herb., 56607); Austin, *W. H. Long, Jr.*, 739; Gillespie County, *G. Jermy* (in Mo. Bot. Gard. Herb., 5048–5050) and 443, comm. by U. S. Dept. Agr. Herb.; Joaquin, *E. Bartholomew*, in Bartholomew, Fungi Col., 4986; Quitman, *W. H. Long*, 12099 (in Mo. Bot. Gard. Herb., 55126); Waco, *W. H. Long, Jr.*, 508.
- South Dakota: Black Hills, *J. R. Weir*, 10012 (in Mo. Bot. Gard. Herb., 55793).
- Nebraska: Memphis, *T. A. Williams*, comm. by C. L. Shear, 1059; Nebraska City, *V. B. Walker*, 10 (in Mo. Bot. Gard. Herb., 12963).
- Kansas: Bourbon County, *A. G. Barrett*, 112, 115, 126, 127; Topeka, *E. T. & S. A. Harper*, 753.
- Colorado: Golden, *Bethel & Overholts*, comm. by L. O. Overholts, 1758 (in Mo. Bot. Gard. Herb., 54871).
- New Mexico: Clouderoft, *F. S. Earle*, 495 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 1546).

- Montana: Moeville, *J. A. Hughes*, comm. by *J. R. Weir*, 9750 (in *Mo. Bot. Gard. Herb.*, 56225).
- Idaho: Moscow, *J. R. Weir*, 7946 (in *Mo. Bot. Gard. Herb.*, 56218); Priest River, *J. R. Weir*, 6, 11, 49.
- British Columbia: Secamons, *J. Macoun*, 166; Sidney, *J. Macoun*, 57, 70, 71 (in *Mo. Bot. Gard. Herb.*, 5739, 5746, 5747).
- Washington: Bingen, *W. N. Suksdorf*, 694; Friday Harbor, *V. B. Walker*, 2 (in *Mo. Bot. Gard. Herb.*, 8359); Lake Waldemen, *C. H. Kauffman* (in *Mo. Bot. Gard. Herb.*, 20763); Seattle, *S. M. Zeller*, 63, 118 (in *Mo. Bot. Gard. Herb.*, 44137, 44143); Tacoma, *E. Bartholomew*, 4929 (in *Mo. Bot. Gard. Herb.*, 20810).
- Oregon: Corvallis, *C. E. Owens*, 2032, 2026, 2055, 2140, 2141 (in *Mo. Bot. Gard. Herb.*, 43874–43876, 44700, 44701); Granite Pass, *J. R. Weir*, 8675 (in *Mo. Bot. Gard. Herb.*, 36750); Wallowa, *C. J. Humphrey*, 265; Siskiyou National Forest, *J. R. Weir*, 8678 (in *Mo. Bot. Gard. Herb.*, 36751).
- California: *R. A. Harper*, 39, 108, 142 (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56610–12); *C. R. Orcutt*, in *Ell. & Ev.*, *N. Am. Fungi*, 714; La Honda, *Edna Hyatt*, comm. by *C. L. Shear*, 1088, 1091; Muir Woods, *W. A. Murrill*, 1158, comm. by *N. Y. Bot. Gard. Herb.* (in *Mo. Bot. Gard. Herb.*, 55715); Redding, *C. J. Humphrey*, 1035; San Francisco, *A. S. Rhoads*, 2 (in *Mo. Bot. Gard. Herb.*, 56046); Saratoga, *E. B. Copeland*, 1806.
- Arizona: Crown King, *G. G. Hedgcock*, comm. by *C. J. Humphrey*, 2564 (in *Mo. Bot. Gard. Herb.*, 10752).
- Mexico: Cordoba, *W. A. & E. L. Murrill*, 996, comm. by *N. Y. Bot. Gard. Herb.* (in *Mo. Bot. Gard. Herb.*, 54609); Guernavaca, *W. A. & E. L. Murrill*, 415, 416, 412, comm. by *N. Y. Bot. Gard. Herb.* (in *Mo. Bot. Gard. Herb.*, 54518, 54519, 54543); Jalapa, *W. A. & E. L. Murrill*, 75, 148, 193, comm. by *N. Y. Bot. Gard. Herb.* (in *Mo. Bot. Gard. Herb.*, 11275, 10360, 54436), *C. L. Smith*, in *Smith, Central Am. Fungi*, 145; Oaxaca, *E. W. D. Holway*; Orizaba, *W. A. & E. L. Murrill*, 758, comm. by *N. Y. Bot. Gard. Herb.* (in *Mo. Bot. Gard. Herb.*, 54632); Parral, *E. O. Matthews* (in *Mo. Bot. Gard. Herb.*, 5722, 10459).
- Guatemala: *Maxon & Hay*, 3250, comm. by *U. S. Bur. Pl. Ind.*

- Honduras: *P. Wilson*, 138, comm. by N. Y. Bot. Gard. Herb.
- Cuba: Ciego de Avila, *Earle & Murrill*, 568, comm. by N. Y. Bot. Gard. Herb.; Fecha, *F. S. Earle*, 146, *Earle & Wilson*, 224; Guantanamo, *J. R. Weir*, 10644 (in Mo. Bot. Gard. Herb., 56237); Oriente, *J. A. Shafer*, 3392, 8468 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56613, 56614); San Diego de los Baños, *Earle & Murrill*, 331, comm. by N. Y. Bot. Gard. Herb.
- Porto Rico: Bayamon, *J. A. Stevenson*, 5427 (in Mo. Bot. Gard. Herb., 8180); Mayaguez, *F. S. Earle*, 89, comm. by N. Y. Bot. Gard. Herb.; Rio Piedras, *Johnston & Stevenson*, comm. by J. A. Stevenson, 1764, 1937, 2005 (in Mo. Bot. Gard. Herb., 9824, 14220, 14270); San Jaun, *Mr. & Mrs. A. S. Heller*, 700, comm. by N. Y. Bot. Gard. Herb.
- Jamaica: Cinchona, *W. A. & E. L. Murrill*, 450, 499, 521, comm. by N. Y. Bot. Gard. Herb., *H. von Schrenk* (in Mo. Bot. Gard. Herb., 43630); Chester Vale, *W. A. & E. L. Murrill*, 282, 316, comm. by N. Y. Bot. Gard. Herb.; Monkey Hill, *W. A. Murrill*, 817, comm. by N. Y. Bot. Gard. Herb.; Moore Town, *W. A. & E. L. Murrill*, 160, comm. by N. Y. Bot. Gard. Herb.
- Brazil: *Malme* (in Romell Herb.).
- Formosa: Urai, *S. Kusano*, II.16 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56587).
- Java: *Junghuhn*, authentic specimen of *Thelephora ostrea*, comm. by G. Bresadola.
- Philippine Islands: Luzon, *H. M. Curran*, Forestry Bureau, 9665 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56583); Mindanao, *A. D. E. Elmer*, 10556, Philippine Is. Pl. (in Mo. Bot. Gard. Herb., 705743).

45. *S. lobatum* (Kunze) Fries, Epicr. 547. 1838; Sacc. Syll. Fung. 6: 568. 1888; Masee, Linn. Soc. Bot. Jour. 27: 175. 1890. Plate 5, fig. 46.

Thelephora lobata Kunze in Weigelt Exsiccati, 1827; Fries, Linnaea 5: 527. 1830.—*Stereum Sprucei* Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 331. 1868; Sacc. Syll. Fung. 6: 567. 1888.—An *S. concolor* Junghuhn, Crypt. Java, 38. 1838? See Sacc. Syll. Fung. 6: 561. 1888; Bresadola, Hedwigia 51: 321. 1912.

Illustrations: Engl. & Prantl, Nat. Pflanzenfam. (1:1**): 124. *text f. 69, A-B*; Hard, Mushrooms, 455. *text f. 382*, as *S. versicolor*.

Type: type distribution in Weigelt Exs.

Fructifications coriaceous, rigid, thin, wedge-shaped to umbonate, sessile, often laterally conerescent, at first tomentose and drying tawny olive, at length with the tomentum becoming pale smoke-gray to whitish, disappearing more or less near the margin and in narrow zones and showing the glabrous, shining, hazel surface of the bared areas, the margin undulate and usually more or less lobed; in structure 300 μ thick, with the intermediate layer composed of densely arranged, thick-walled, hyaline hyphae 4-4½ μ in diameter; hymenium glabrous, even, usually drying pinkish buff; no setae, gloecystidia, nor conducting organs; spores hyaline, even, flattened on one side, 4-5 \times 1½-2 μ , but few seen.

Pileus usually 3-7 cm. long, 2-6 cm. broad, sometimes much larger by lateral confluence.

On dead branches, logs, and stumps of frondose species in the cases noted. A tropical species ranging northward to New York and Wisconsin and southward to Brazil. Occurs in the Philippine Islands and East Indies also, if *S. concolor* is a synonym.

S. lobatum may be distinguished from the related *S. fasciatum*, *S. versicolor*, and *S. radians* by having a more or less lobate pileus which is also very thin, somewhat flexible, zonate on the upper side, with glabrous, shining hazel zones alternating with whitish tomentose zones of soft, matted hairs. No specimens of this species which I have examined have the pileus effuso-reflexed when young. Specimens of *S. fasciatum* occasionally have a somewhat lobate margin but the pileus is thicker, more heavily clothed with a tomentum which is more persistent than that of *S. lobatum*, and in its more northern stations where I have been able to observe the development, the young fructifications are often effuso-reflexed at first.

S. lobatum is primarily an American species described from collections made in Surinam, Dutch Guiana, but it seems probable that this species has a more extended geographical range through the tropical lands of the Eastern Hemisphere also. The recent collections in Philippine Islands, determined by

Bresadola as *S. concolor* (Jungh.) and distributed in Elmer, Philippine Islands Plants, show that this species is but slightly, if at all, different from *S. lobatum*. The general aspect is the same but the Philippine specimens are the larger; none of them have their tomentum as soft and whitish as in *S. lobatum*. Some of these specimens have shown in crushed preparations spore-like bodies $3\ \mu$ in diameter; spore collections of oriental specimens should be made.

Specimens examined:

Exsiccati: Bartholomew, Fungi Col., 4586, under the name *S. fasciatum*; Ellis, N. Am. Fungi, 514b, under the name *S. versicolor* v. *fasciata*, 514d, under the name *S. versicolor* v. *petaliforme*; Ravenel, Fungi Car. 1: 28, mixed with *S. fasciatum*; de Thümen, Myc. Univ., 2011, mixed with *S. fasciatum*.

New York: Alcove, *C. L. Shear*, 1019; Ithaca, *L. A. Zinn*, 82a (in Mo. Bot. Gard. Herb., 43074).

Pennsylvania: West Chester, *J. B. Gray*, in Ellis, N. Am. Fungi, 514b.

North Carolina: Black Oak, *H. W. Ravenel*, in Ravenel, Fungi Car. 1: 28; Blowing Rock, *G. F. Atkinson*, 4311, 4314; Chapel Hill, *W. C. Coker*, 331 (in Mo. Bot. Gard. Herb., 56663); Transylvania County, *W. A. Murrill & H. D. House*, 425 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56602).

Georgia: Flint River, *R. M. Harper*, 1401a, comm. by N. Y. Bot. Gard. Herb. (also in Mo. Bot. Gard. Herb., 5087); Dixie, *R. M. Harper*, 1633 (in Mo. Bot. Gard. Herb., 56603).

Florida: *C. G. Lloyd*, 4833; Crescent City, *Dr. G. Martin*, in Ellis, N. Am. Fungi, 514d; Eustis, *G. V. Nash*, 2128 (in Mo. Bot. Gard. Herb., 5118), and *L. M. Underwood*, 1371 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56601); Lake City, *P. L. Ricker*, 893; New Smyrna, *C. G. Lloyd*, 183; Tallahassee, *E. Bartholomew*, in Bartholomew, Fungi Col., 4586.

Alabama: Auburn, *F. S. Earle*, from Lloyd Herb., 3459; Chehaw, *E. A. Burt*, two collections; Fayette Co., *P. V. Siggers*, comm. by A. H. W. Povah, 14 (in Mo. Bot. Gard. Herb., 9229).

- Louisiana: Natchitoches, *G. F. Atkinson*, 5118, 5119; St. Martinville, *A. B. Langlois*, *be*.
- Ohio: Cincinnati, *C. G. Lloyd*, 1677, 4495, 4502.
- Wisconsin: Madison, *C. J. Humphrey*, 2508 (in Mo. Bot. Gard. Herb., 42927).
- Kentucky: Mammoth Cave, *C. G. Lloyd*.
- Missouri: Kennett, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42996); Neeleyville, *F. C. Dewart* (in Mo. Bot. Gard. Herb., 5132, 5135).
- Mexico: *W. Trelease* (in Mo. Bot. Gard. Herb., 5123); Guernavaca, *E. W. D. Holway*.
- Honduras: *P. Wilson*, 180, 671, comm. by N. Y. Bot. Gard. Herb.
- Cuba: *C. Wright*, 197, 271 (in Curtis Herb.), and 521, the type of *S. Sprucei* (in Kew Herb.); Baracoa, *L. M. Underwood & F. S. Earle*, 796, 1068, comm. by N. Y. Bot. Gard. Herb.; Ceballos, *C. J. Humphrey*, 2722 (in Mo. Bot. Gard. Herb., 8638).
- Porto Rico: Sauerce, *Mr. & Mrs. A. A. Heller*, 843, 882, comm. by N. Y. Bot. Gard. Herb.; Luquillo Mts., *P. Wilson*, 203 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56600).
- Guadeloupe: in de Thümen, *Myc. Univ.*, 2001.
- St. Kitts: *N. L. Britton & J. F. Cowell*, 502, comm. by N. Y. Bot. Gard. Herb.
- Jamaica: *A. E. Wight*, comm. by W. G. Farlow; Castleton Gardens, *W. A. & E. L. Merrill*, 113, comm. by N. Y. Bot. Gard. Herb.; Cinchona, *W. A. & E. L. Merrill*, 530, comm. by N. Y. Bot. Gard. Herb.; Moneague, *W. A. Merrill*, 1140, comm. by N. Y. Bot. Gard. Herb.; Troy and Tyre, *W. A. Merrill & W. Harris*, 996, 1037, comm. by N. Y. Bot. Gard. Herb.
- Trinidad: Carengo, *M. A. Carriker*, comm. by W. G. Farlow, II.
- Grenada: Grand Etang, *R. Thaxter*, comm. by W. G. Farlow, 3.
- Venezuela: Margarita, *A. F. Blakeslee*, comm. by W. G. Farlow.

46. *S. versicolor* (Swartz) Fries, *Epier.* 547. 1838; Berkeley, *Ann. & Mag. Nat. Hist.* I. 10: 382. *pl.* 11. *f.* 13. 1842; Sacc.

Syll. Fung. 6: 561. 1888; Masee, Linn. Soc. Bot. Jour. 27: 172. 1890; Lloyd, Myc. Writ. 4. Letter 46:3. 1913.

Plate 5, fig. 47.

Helvella versicolor Swartz, Prodr. 149. 1788.—*Thelephora versicolor* Swartz, Fl. Ind. Oc. 3: 1934. 1806; Fries, Syst. Myc. 1: 438. 1821.—*Stereum radians* Fries, R. Soc. Sci. Upsal. Actis III. 1: 110. 1851; Sacc. Syll. Fung. 6: 573. 1888; Masee, Linn. Soc. Bot. Jour. 27: 188. *pl. 7. f. 5.* 1900.

Illustrations: Berkeley, *loc. cit.*; Masee, *loc. cit.*

Type: authentic specimen in Herb. of Brit. Mus. according to Berkeley.

Fructification coriaceous-rigid, very thin, sometimes buff-yellow, clothed with silky, villous fascicles all lying in a radiating direction, becoming glabrous and shining and minutely radially ridged or lineate, wood-brown to cinnamon-brown, the margin entire, not complicate; in structure 300–400 μ thick, composed of densely, longitudinally arranged hyphae 3–3½ μ in diameter; hymenium even, glabrous, cream-color to avellaneous; no colored conducting organs, gloeocystidia, nor cystidia; spores hyaline, even, 4–5 \times 2–2½ μ .

Fructifications 1–2½ cm. broad, 1½–4 cm. long, often laterally confluent.

On dead wood. Florida, West Indies, Mexico, Dutch Guiana. September to February. Probably common in Jamaica.

S. versicolor is a species intermediate between *S. lobatum* and *S. rameale*; its fructifications are smaller than those of *S. lobatum*, thinner, more completely glabrous at length, with margin not normally lobed, and usually retaining attachment by a narrow, resupinate side of the pileus as well as by the umbo, in which respect there is resemblance to the middle stage of development of *S. fasciatum*; the radial arrangement of the hairs and villous fascicles on the upper surface of the pileus is a highly distinctive character, as first pointed out by Berkeley. The coloration and hairy covering of fructifications of *S. versicolor* are somewhat similar to these characters in *S. rameale*, but the fructifications of the former are not lobed and folded together laterally and crisped nor as slender as those of *S. rameale*, as pointed out by Fries in his description of his *S. radians*. *S. versicolor* was formerly confused with *S. fasciatum*, especially in American

literature; it is doubtful whether *S. versicolor* occurs in the United States except very rarely in Florida.

Specimens examined:

Florida: Dade County, *J. K. Small*, 7089, 7122 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56650, 56651); Eustis, Lake County, *L. M. Underwood*, 1377 (in N. Y. Bot. Gard. Herb., Burt Herb., and Mo. Bot. Gard. Herb., 42764).

Cuba: *C. Wright*, 291 (in Curtis Herb.); Ceballos, *C. J. Humphrey*, 2740 (in Mo. Bot. Gard. Herb., 15720); San Diego de los Baños, *Bro. Leon*, 4861 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56647).

Porto Rico: Maricao, *N. L. Britton*, *J. F. Cowell* & *S. Brown*, 4420 (in N. Y. Bot. Gard. Herb., Burt Herb., and Mo. Bot. Gard. Herb., 56574); Rio Piedras, *J. R. Johnston*, 129, 282 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56648, 56641); Sierra de Naguabo, *J. A. Shafer*, 3211, 3692, 3693 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56653–56655).

Jamaica: *Farr* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56640); Cinchona, *L. M. Underwood*, 3239 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56595), *N. L. Britton*, 295, 296 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56642, 56643), *F. S. Earle*, 409, comm. by N. Y. Bot. Gard. Herb., *W. A. & E. L. Murrill*, 526, 539, comm. by N. Y. Bot. Gard. Herb. and 473 (in N. Y. Bot. Gard. Herb., Burt Herb., and Mo. Bot. Gard. Herb., 56644); John Crow Peak, *L. M. Underwood*, 2433, comm. by N. Y. Bot. Gard. Herb.; Monkey Hill, *W. A. Murrill*, 814, comm. by N. Y. Bot. Gard. Herb.; Rose Hill, *F. S. Earle*, 50, 282, 305, comm. by N. Y. Bot. Gard. Herb.; Sir John Peak, *E. G. Britton*, 1212 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56641); Troy and Tyre, *W. A. Murrill* & *W. Harris*, 853, 856, 1036, 1048, comm. by N. Y. Bot. Gard. Herb.

Montserrat: Soufriere, *J. A. Shafer*, 919 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56645).

Grenada: Annandale, *W. E. Broadway* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56656); Grand Etang, *R. Thaxter*, comm. by *W. G. Farlow*, 10.

Mexico: Trap. de la Concepcion, *Liebman*, type of *Stereum radians* (in Herb. Fries); Jalapa, *W. A. & E. L. Merrill*, 343, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55477).

47. *S. rameale* Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1: 106. 1822 (under *B. Sterea* of *Thelephora*). Plate 5, fig. 48.

Thelephora hirsuta Fries, Elenchus Fung. 1: 178. 1828, but not of Syst. Myc. 1: 439. 1821.—*T. hirsuta* β *ramealis* Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 167. 1832.—*Stereum complicatum* Fries, Epicr. 548. 1838; Sacc. Syll. Fung. 6: 579. 1888; Masee, Linn. Soc. Bot. Jour. 27: 178. 1890.—*S. radians* of Morgan, Cincinnati Soc. Nat. Hist. Jour. 10: 194. 1888, but not *S. radians* Fries.—*Telephora lobata* Bertolonii, Accad. Sci. Bologna Mem. I. 7: 360. pl. 19. f. e-g. 1856; Underwood & Earle, Ala. Agr. Exp. Sta. Bul. 80: 232. 1897.—*Stereum Bertolonii* Saccardo, Sacc. Syll. Fung. 11: 120. 1895.

Illustrations: Berkeley & Broome, Linn. Soc. Bot. Trans. 2: pl. 14. f. 12-14. 1883; Bertolonii, *loc. cit.*

Type: in Herb. Schweinitz and in Herb. Fries.

Fructifications coriaceous, thin, rigid, effuso-reflexed, rarely resupinate, with the reflexed portion consisting of small, umbonate pilei, which are sometimes subdivided into lobes, the pilei or lobes drying folded together or crisped, fibrose-strigose, becoming glabrous on the marginal portion, shining, with innate fibers radiating from the base, cinnamon-buff to hazel, more or less zoned; hymenium even, glabrous, light buff to cream-buff; in structure 300-450 μ thick, composed of densely, longitudinally arranged, hyaline hyphae 3-3 $\frac{1}{2}$ μ in diameter, colored conducting organs 3-3 $\frac{1}{2}$ μ in diameter occasionally present; no cystidia nor gloeocystidia; spores white in spore collection, even, slightly curved, 6 \times 2-2 $\frac{1}{2}$ μ .



Fig. 24.
S. rameale.
Spores \times 650.

Fructifications sometimes covering areas only 5-10 mm. in diameter, and gregarious, at other times irregularly confluent over areas up to 3 cm. broad and 10 cm. and more long; individual pilei 2-10 mm. broad, 3-10 mm. long.

On dead twigs and stumps of oak and other frondose species.

Canada, throughout the United States, except in the Rocky Mountain region, in Mexico and the West Indies. July to January. Common in the United States.

S. rameale varies somewhat under the different conditions as to climate and substratum in the great extent of North America where it is our commonest species of *Stereum*. In the United States and Canada one will hardly go amiss in referring to *S. rameale* any *Stereum* with numerous small pilei densely crowded together imbricately or laterally, strigose hairy near the region of attachment, and with marginal side shining, somewhat zonate, and pinkish buff to hazel in color, and with these pilei drying folded together along the sides, or radially plicate in a laterally confluent form. The pileus of *S. rameale* is thinner than that of *S. hirsutum*, only partially covered with hairs, which do not form as heavy a covering where present, and the pilei are folded together laterally and are smaller than those of *S. hirsutum*. *S. sericeum* has small, shining, very thin pilei between whitish and pale drab-gray on both surfaces—wholly lacking ruddy ochraceous coloration—and almost always growing on *Carpinus caroliniana*.

Schweinitz communicated to Fries specimens of *S. rameale* which are still preserved in the herbarium at Upsala; Fries published the species as a synonym of *S. hirsutum* in Elenchus Fung.; Schweinitz yielded to the authority of Fries but protested that *S. rameale* was a distinct variety, at least. Other American specimens of this species were received by Fries, who described and published them in 1838 as *S. complicatum*, overlooking the earlier and nearly identical specimens from Schweinitz and the earlier, appropriate name for the species.

Specimens examined:

Exsiccati: Bartholomew, Fungi Col., 2881, 4289, 4689, 4985; Ellis, N. Am. Fungi, 324; Ell. & Ev., Fungi Col., 307; Ravenel, Fungi Car. 2: 30; Fungi Am., 117; Smith, Cent. Am. Fungi, 96, 97—the latter under the name *S. sericeum*; de Thümen, Myc. Univ., 1404.

Canada, Ontario: Belleville, *J. Macoun*, 240; Port Credit, *J. H. Faull*, Univ. Toronto Herb., 317 (in Mo. Bot. Gard. Herb., 44878); Toronto, *R. P. Wodehouse*, Univ. Toronto Herb., 316 (in Mo. Bot. Gard. Herb., 44879).

- Maine: Oldtown, *P. L. Ricker*.
- Vermont: Brattleboro, Grand View Mt., Lake Dunmore, Middlebury, and Ripton, *E. A. Burt*.
- Massachusetts: Arlington, *E. A. Burt*; Amherst, *P. J. Anderson*, 6 (in Mo. Bot. Gard. Herb., 55850); Cambridge, *W. Trelease*, 81 (in Mo. Bot. Gard. Herb., 5062); Stony Brook, *E. A. Burt*; Waltham, *A. B. Seymour*, 12 (in Mo. Bot. Gard. Herb., 22096); Wellesley, *L. W. Riddle*, 12; Worcester, *G. E. Francis*.
- Connecticut: *C. C. Hanmer*, 2075 (in Mo. Bot. Gard. Herb., 43849); Mansfield, *P. W. Graff*, 12 (in Mo. Bot. Gard. Herb., 9854); New Canaan, *P. Wilson*, 63 (in Mo. Bot. Gard. Herb., 54739); South Windsor, *C. C. Hanmer*.
- New York: *Sartwell* (in Mo. Bot. Gard. Herb., 5062, 44235); Albany, *H. D. House* (in N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb., 15954); Alcove, *C. L. Shear*, 1137, 1320, 1323, 1331; Catskill Mts., *C. H. Peck*, in Ellis, N. Am. Fungi, 324; East Galway, *E. A. Burt*, three collections; Glasco, *P. Wilson*, 34, 37, 41, 57 (in Mo. Bot. Gard. Herb., 54728, 54741, 54742, 54727); Ithaca, *G. F. Atkinson*, 190 *O. S.*, 2121, 7989, 22969, 22973–22975, *C. J. Humphrey*, 227, *H. S. Jackson*, Cornell Univ. Herb., 14375, 14376, *W. A. Murrill*, Cornell Univ. Herb., 3058, *Van Hook*, Cornell Univ. Herb., 7991, *K. M. Wiegand*, Cornell Univ. Herb., 3258, *L. A. Zimm*, 83 (in Mo. Bot. Gard. Herb., 9064); Palisades, *P. Wilson*, 16, 21 (in Mo. Bot. Gard. Herb., 54732, 54731); Scarsdale, *Livingston & Crane*, comm. by N. Y. Bot. Gard. Herb., *P. Wilson*, 1, 25 (in Mo. Bot. Gard. Herb., 54737, 54730); West Fort Ann, *S. H. Burnham*, 15 (in Mo. Bot. Gard. Herb., 44011); Williams Bridge, *P. Wilson*, 3, 31 (in Mo. Bot. Gard. Herb., 54740, 54729); Yonkers, *P. Wilson*, 1 (in Mo. Bot. Gard. Herb., 54727).
- New Jersey: *Laning* (in Mo. Bot. Gard. Herb., 5051, 44236, 44238); Alpine, *P. Wilson*, 15, 9, 14, 5, 4 (in Mo. Bot. Gard. Herb., 54733–54736, 54738); Newfield, *J. B. Ellis*, in Ellis, Fungi Col., 307, and in de Thümen, Myc. Univ., 1404; New Brunswick, *H. D. House* (in N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb., 54353).
- Pennsylvania: Bear Meadow, *C. R. Orton & A. S. Rhoads*, 13,

14 (in Mo. Bot. Gard. Herb., 44090, 44091); Bellefonte, L. O. Overholts, 3715 (in Mo. Bot. Gard. Herb., 54996); Kittanning, D. R. Sumstine, 3, 9, 12; North Garden, E. Michener, 437 (in Mo. Bot. Gard. Herb., 44237); Shingleton Gap, A. S. Rhoads, 11 (in Mo. Bot. Gard. Herb., 44089); Spruce Creek, J. H. Faull, Univ. Toronto Herb., 313 (in Mo. Bot. Gard. Herb., 44885).

Delaware: Newark, H. S. Jackson, B9.

Maryland: Cabin John Bridge, C. L. Shear, 1045; Cabin John Creek, A. S. Rhoads, comm. by L. O. Overholts (in Mo. Bot. Gard. Herb., 55069); Chevy Chase, comm. by Mrs. F. W. Patterson (in Mo. Bot. Gard. Herb., 43730); Takoma Park, A. S. Rhoads, comm. by L. O. Overholts (in Mo. Bot. Gard. Herb., 55049), C. L. Shear, 1160.

District of Columbia: Takoma Park, P. L. Ricker, 818.

Virginia: Mt. Vernon, P. L. Ricker, 1121 in part.

North Carolina: Schweinitz, type (in Herb. Schweinitz and Herb. Fries); Chapel Hill, W. C. Coker, 3802, 2026, 1047, 362, 333 (in Mo. Bot. Gard. Herb., 56657-56661); Salem, Schweinitz, the *Thelephora ochroleuca* of Schweinitz, Syn. N. Am. Fungi, 644 (in Herb. Schweinitz).

South Carolina: H. W. Ravenel, in Ravenel, Fungi Car. 2: 30; Clemson College, P. H. Rolfs, 1614, 1628; Davidson River, H. von Schrenk (in Mo. Bot. Gard. Herb., 42964); Society Hill, H. W. Ravenel (in Curtis Herb., 1439, under the name *Stereum plicatum*).

Georgia: Atlanta, E. Bartholomew, 5674 (in Mo. Bot. Gard. Herb., 44217); Glenbrook Ravine, A. B. Seymour, from Farlow Herb., J (in Mo. Bot. Gard. Herb., 44649); Thomson, H. H. Bartlett, comm. by W. G. Farlow.

Florida: C. G. Lloyd, 4851, 4852; Camp Pinchot, W. H. Long, 12212 (in Mo. Bot. Gard. Herb., 55143); Daytona, D. L. James, comm. by U. S. Dept. Agr. Herb.; Gainesville, H. W. Ravenel, in Ravenel, Fungi Am., 117; New Smyrna, C. G. Lloyd, 2112.

Alabama: Dr. Gates, probably from the type collection of *Thelephora lobata* Bertolonii, from Torrey Herb. (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56295); Auburn, F. S. Earle, four specimens in Burt Herb., and two

- others (in Mo. Bot. Gard. Herb., 5107, 56619—the last in N. Y. Bot. Gard. Herb. also); Montgomery Co., *R. P. Burke*, 28 (in Mo. Bot. Gard. Herb., 17856).
- Mississippi: Biloxi, *F. S. Earle*, 29; Hattiesburg, *C. J. Humphrey*, 5451; Jackson, *E. Bartholomew*, 5779, 5797, 5784 (in Mo. Bot. Gard. Herb., 44223–44225) and Bartholomew, Fungi Col., 4689; Laurel, *C. J. Humphrey*, 5430; Ocean Springs, *F. S. Earle*, 177 (in Mo. Bot. Gard. Herb., 5065).
- Louisiana: *A. B. Langlois*, 2906; Alden Bridge, *W. Trelease* (in Mo. Bot. Gard. Herb., 5047); Baton Rouge, *C. J. Humphrey*, 5699 (in Mo. Bot. Gard. Herb., 14102); New Orleans, *E. Bartholomew*, 5764 (in Mo. Bot. Gard. Herb., 5440, 44222), *E. A. Burt*; St. Martinville, *A. B. Langlois*, bc (in Burt Herb.), 1101 (in Mo. Bot. Gard. Herb., 5063); Shreveport, *E. Bartholomew*, in Bartholomew, Fungi Col., 4689.
- Ohio: Cincinnati, *A. P. Morgan*, comm. by Lloyd Herb., 2633; College Hill, *C. G. Lloyd*, 1457; Linwood, *C. G. Lloyd*, 02833.
- Indiana: Avilla, *W. H. Rankin* (in Mo. Bot. Gard. Herb., 9183); Crawfordsville, *D. Reddick*, 12; Greencastle, *L. M. Underwood* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56277).
- Illinois: Bowmansville, comm. by Univ. Wis. Herb., 4, and *E. T. & S. A. Harper*, 436; River Forest, *E. T. & S. A. Harper*, 709.
- Kentucky: Bowling Green, *S. F. Price* (in Mo. Bot. Gard. Herb., 5036).
- Tennessee: Elkmont, *C. H. Kauffman*, 58, 61, 63 (in Mo. Bot. Gard. Herb., 16384, 3993, 1678); Nashville, *E. Bartholomew*, 5634 (in Mo. Bot. Gard. Herb., 44214).
- Michigan: Chelsea, *C. H. Kauffman*, 23; New Richmond, *C. H. Kauffman*, 44, 43 (in Mo. Bot. Gard. Herb., 22507, 22856).
- Minnesota: *E. L. Jensen*, 2 (in Mo. Bot. Gard. Herb., 3939).
- Wisconsin: Miss *A. D. Stucki*, Univ. Wis. Herb., 7; Blue Mounds, *Miss A. D. Stucki*, Univ. Wis. Herb., 6; Madison, *Miss A. D. Stucki*, Univ. Wis. Herb., 10.
- Iowa: *E. W. D. Holway*.
- Missouri: *B. M. Duggar*, 568; Bismarck, *L. O. Overholts* (in Mo. Bot. Gard. Herb., 43701); Cox's Switch, *H. von*

- Schrenk* (in Mo. Bot. Gard. Herb., 42892); Creve Coeur, *E. A. Burt* (in Mo. Bot. Gard. Herb., 44757); Columbia, *L. E. Cline*, comm. by *B. M. Duggar*, A555; Gasconade Co., *W. Trelease* (in Mo. Bot. Gard. Herb., 5128); Meramec, *P. Spaulding* (in Mo. Bot. Gard. Herb., 5019); Neeleyville, *Dewart* (in Mo. Bot. Gard. Herb., 5127, 5130); St. Francis River, *W. Trelease* (in Mo. Bot. Gard. Herb., 5129); St. Louis, *E. A. Burt* (in Mo. Bot. Gard. Herb., 8724, 44757), and *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42873); Williamsville, *B. M. Duggar & H. S. Reed*, 47.
- Arkansas: Arkadelphia, *L. M. Underwood* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56620); Batesville, *E. Bartholomew*, in *Bartholomew*, Fungi Col., 2881; Cass, *W. H. Long*, 19835 (in Mo. Bot. Gard. Herb., 6384); Womble, *W. H. Long*, 19671, 19649, 19865 (in Mo. Bot. Gard. Herb., 6386, 6385, 8887); Wynne, *W. Trelease* (in Mo. Bot. Gard. Herb., 5039).
- Texas: *H. W. Ravenel*, 40 (in U. S. Dept. Agr. Herb.); Joaquin, *E. Bartholomew*, in *Bartholomew*, Fungi Col., 4985; Somerville, *H. von Schrenk*, 1.
- Colorado: Tolland, *L. O. Overholts*, 2000 (in Mo. Bot. Gard. Herb., 54872).
- British Columbia: Hastings, *J. Macoun*; Sidney, *J. Macoun*, 14, 382 (in *Macoun* Herb.) and 56, 72 (in Mo. Bot. Gard. Herb., 5738, 5748).
- Washington: Bellingham, *J. R. Weir*, 543, 547, 593 (in Mo. Bot. Gard. Herb., 18629, 18712, 36745); Metaline Falls, *J. R. Weir*, 5245, 590 (in Mo. Bot. Gard. Herb., 55650, 36744); Seattle, *W. A. Murrill*, 137, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55736).
- Oregon: Corvallis, *W. A. Murrill*, 892b, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55719), and *C. E. Owens*, 2033, 2134, 2147 (in Mo. Bot. Gard. Herb., 43873, 44697, 9186).
- California: *R. A. Harper*, 121, 128 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56621, 56622); Palo Alto, *W. A. Murrill & L. S. Abrams*, 1170, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 55710).
- Mexico: Jalapa, *W. A. & E. L. Murrill*, 57, 70, 348, comm. by

N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 23108, 3732, 54475), and *C. L. Smith*, in *Smith, Central Am. Fungi*, 96, 97; Orizaba, *W. A. & E. L. Murrill*, 799, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54624); Trap. de la Conception, *Liebman*, authentic specimen of *Stereum complicatum* (in Herb. Fries).

Porto Rico: Indiera Fria, *N. L. Britton, J. F. Cowell & S. Brown*, 4483 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56623).

Jamaica: Abbey Green, *W. Harris*, 1022; Cinchona, *F. S. Earle*, 360, and *W. A. & E. L. Murrill*, 600, both numbers comm. by N. Y. Bot. Gard. Herb.; Hope, *F. S. Earle*, 119, comm. by N. Y. Bot. Gard. Herb.; New Haven Gap, *W. A. & E. L. Murrill*, 770, comm. by N. Y. Bot. Gard. Herb.; Monkey Hill, *W. A. Murrill*, 790, 802, comm. by N. Y. Bot. Gard. Herb.; Rose Hill, *F. S. Earle*, 309, 312, comm. by N. Y. Bot. Gard. Herb.

48. *S. sericeum* Schweinitz, *Naturforsch. Ges. Leipzig Schrift.* 1: 106. 1822 (in *B. Sterea* of *Thelephora*); Morgan, *Cincinnati Soc. Nat. Hist. Jour.* 10: 195. 1888; *Sacc. Syll. Fung.* 6: 579. 1888. Plate 5, fig. 49.

Thelephora striata Fries, *Elenchus Fung.* 1: 178. 1828; Schweinitz, *Am. Phil. Soc. Trans. N. S.* 4: 167. 1832.—*Stereum striatum* Fries, *Epicr.* 548. 1838, but not of p. 551 nor of *Hym. Eur.* 641. 1874.

Illustrations: *Hard, Mushrooms*, 456. *text f.* 383.

Type: not found by me in Herb. Schweinitz although studied by Berkeley & Curtis, *Acad. Nat. Sci. Phila. Jour.* 3: 220. 1856.

Fructifications coriaceous, small, very thin and papery, effuso-reflexed, laterally confluent, with reflexed portion divided into small pilei, sometimes orbicular and attached by a central point with margin free all around, the upper side whitish to cartridge-buff, shining, silky, with minute radiate fibrils, the margin entire, thinning to subfimbriate, not complicate; hymenium even, wood-brown when most deeply colored, becoming bleached; in structure 250–300 μ thick, composed of densely and longitudinally arranged hyaline

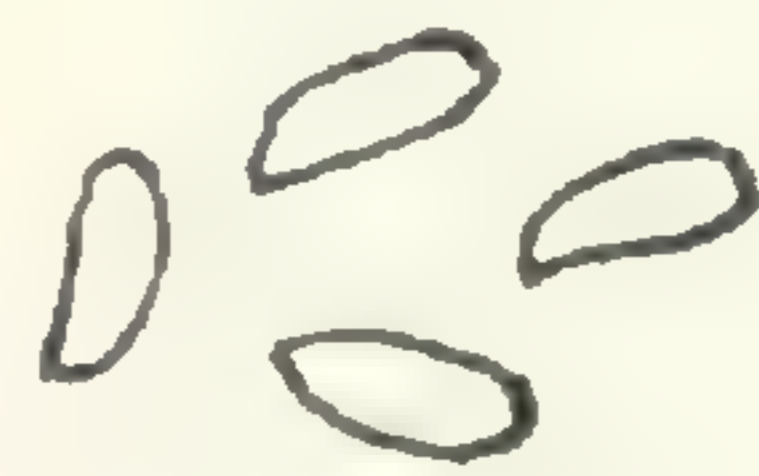


Fig. 25.
S. sericeum.
Spores \times 665.

hyphae $3-3\frac{1}{2}$ μ in diameter; no colored conducting organs, gloeocystidia, nor cystidia present; spores hyaline, even, flattened on one side, $6-7\frac{1}{2} \times 3-3\frac{1}{2}$ μ .

Fructifications $1-1\frac{1}{2}$ cm. in diameter, confluent along limbs 10 cm. and more, the reflexed portion 5-10 mm. broad, 3-10 mm. long.

In swampy woods on under side of dead twigs of *Carpinus caroliniana*, recorded rarely on *Liquidambar* and *Nyssa*. Canada to Louisiana and westward to Missouri and in Mexico. Throughout the year. Infrequent.

Stereum sericeum is very appropriately named, for its silvery to pale gray pilei are noteworthy by their silky or satiny luster; they are smaller, thinner, and more flexible than those of *S. rameale* and with innate rather than fibrose-strigose fibrils; these pilei lack the ruddy and ochraceous hues characteristic of *S. rameale*; furthermore the pilei of *S. sericeum* are plane, while those of *S. rameale* are folded laterally or crisped. Nevertheless I have received some scanty specimens of *S. rameale* from the West and South which were sparsely developed and bleached out so as to simulate *S. sericeum*. In New England and New York, *S. sericeum* has been invariably on *Carpinus caroliniana* when the substratum has been recorded, but elsewhere *S. rameale* has sometimes been recorded on other substrata.

The concept of *S. sericeum* is that held by all American mycologists and is in conformity with the specimens in Curtis Herbarium determined by Berkeley and Curtis who studied the authentic specimen.

Specimens examined:

Exsiccati: Ellis, N. Am. Fung., 19; Ell. & Ev., Fungi Col., 705; Ravenel, Fungi Car. 1: 21; Shear, N. Y. Fungi, 312.

Ontario: London, J. Dearness; Ottawa, J. Macoun, 20, 30, 277; Toronto, G. H. Graham, Univ. Toronto Herb., 675 (in Mo. Bot. Gard. Herb., 44918), and T. Langton, Univ. Toronto Herb., 518, 594 (in Mo. Bot. Gard. Herb., 44842, 44848).

Vermont: Middlebury, E. A. Burt, five collections.

Massachusetts: Wayland, A. B. Seymour, T23 (in Mo. Bot. Gard. Herb., 22097).

Connecticut: Goshen, L. M. Underwood, 224 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56658).

- New York: *Sartwell* (in Mo. Bot. Gard. Herb., 5045); Alcove, *C. L. Shear*, 1047, 1124, 1211, 1314, 1325, 1332, and in *Shear*, N. Y. Fungi, 312; Glasco, *P. Wilson*, 36 (in Mo. Bot. Gard. Herb., 54744); Grand View, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42795); Ithaca, *G. F. Atkinson*, 178 O. S., 2827, 22968, and *W. C. Muenscher*, 4 (in Mo. Bot. Gard. Herb., 56594); McLean, *W. C. Muenscher*, 98 (in Mo. Bot. Gard. Herb., 56596); Taughannock Gorge, *W. C. Muenscher*, 199 (in Mo. Bot. Gard. Herb., 56595).
- New Jersey: Newfield, *J. B. Ellis*, in *Ellis*, N. Am. Fungi, 19, Ell. & Ev., Fungi Col., 705, and (in Mo. Bot. Gard. Herb., 5103).
- Pennsylvania: *E. Michener*, 399 (in Mo. Bot. Gard. Herb., 5104); State College, *L. O. Overholts*, 3054 (in Mo. Bot. Gard. Herb., 5688).
- District of Columbia: Takoma Park, *C. L. Shear*, 957.
- North Carolina: Chapel Hill, *W. C. Coker*, 1043 (in Mo. Bot. Gard. Herb., 56668).
- South Carolina: Black Oak, *H. W. Ravenel*, in *Ravenel*, Fungi Car. 1: 31.
- Florida: Tallahassee, comm. by *W. G. Farlow*.
- Alabama: Auburn, *F. S. Earle* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56661–56663); Fayette Co., *P. V. Diggers*, comm. by *A. H. W. Povah*, 17 (in Mo. Bot. Gard. Herb., 20803); Montgomery Co., *R. P. Burke*, 32, 137 (in Mo. Bot. Gard. Herb., 15929, 10934); Tuskegee, *C. W. Carver*, 369 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56664).
- Mississippi: Biloxi, *F. S. Earle*, 27.
- Louisiana: New Orleans, *F. S. Earle* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56660).
- Ohio: Cleveland, *H. C. Beardslee*; Columbus, *W. A. Kellerman*, in *Kellerman*, Ohio Fungi, 139 (in Mo. Bot. Gard. Herb., 5042); Norwood, *C. G. Lloyd*, 2270; Oberlin, and also Penfield, *F. D. Kelsey* (in Mo. Bot. Gard. Herb., 56665 and 56666 respectively).
- Indiana: Scottsburg, *J. R. Weir*, 5803 (in Mo. Bot. Gard. Herb., 55643).
- Michigan: Agricultural College, *Hicks*, comm. by *W. G. Farlow*.
- Missouri: Columbia, *B. M. Duggar*, 553.

Mexico: Jalapa, *W. A. & E. L. Merrill*, 343 in part, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 56672).

49. *S. pubescens* Burt, n. sp. Plate 5, fig. 50.

Type: in Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Burt. Herb.

Fructification coriaceous, thin, orbicular, conchate-reflexed, attached by one side and the center, reflexed all around but more broadly on the upper side, white, pubescent with soft matted hairs, not zonate nor sulcate; hymenium drying even or somewhat radiately rugose, sorghum-brown to dusky drab, shining; in structure 600 μ thick exclusive of the tomentum, with the occasional hymenial wrinkles standing out up to 120 μ further; intermediate layer bordered next to the tomentum by a narrow, dense, colored zone and composed of longitudinally arranged and somewhat loosely interwoven hyaline, thick-walled hyphae $3\frac{1}{2}$ μ in diameter; no vesicular organs, conducting organs, gloeocystidia, nor cystidia present; hymenium composed of a single layer of simple basidia with 4 sterigmata; spores hyaline, even, oval, 6×4 μ .

Fructifications 3–10 mm. in diameter, reflexed 1–3 mm.

On dead limbs of a frondose species. Montana. April. Probably rare.

S. pubescens has small fructifications with some resemblance in aspect to those of *Cenangium furfuraceum* but white and pubescent with soft matted hairs. Specimens from this gathering were communicated by Ellis, No. 7014, to Cooke and were regarded by Cooke as a young *Stereum*, related to *Stereum purpureum* and, perhaps, young specimens of this species. *S. pubescens* differs sharply from *S. purpureum* in having no pyriform, vesicular organs. The specimens are so mature that many basidia bearing sterigmata are present and occasionally spores. In the smaller specimens the hymenium is even but in those 1 cm. in diameter some broad, obtuse, radiating wrinkles are present, which may necessitate the transfer of this species from *Stereum* when better known from future collections.

Specimens examined:

Montana: Sheridan, *Mrs. L. A. Fitch*, in Ellis Collection, 7014, type (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56784).

50. *S. conicum* Burt, n. sp. Plate 5, fig. 51.

Type: in Farlow Herb. and in Mo. Bot. Gard. Herb.

Pileus coriaceous, small, rather thick, conical, sessile, attached by the vertex, villose, with some specimens whitish to pale olive-buff and others between wood-brown and Sayal-brown; intermediate layer not bordered by a dark zone, nearly colorless, containing many thick-walled and somewhat incrustated hyphal ends $15-25 \times 6 \mu$ but no colored conducting organs; hymenium even, drab, without cystidia; spores hyaline, even, $4-4\frac{1}{2} \times 2\frac{1}{2} \mu$.

Pileus 2-4 mm. in diameter, 2-4 mm. high, about $\frac{2}{5}-\frac{1}{2}$ mm. thick.

Singly on small, dead, frondose twigs. Cuba.

If carelessly glanced at, specimens of this species might be referred to *S. ochraceo-flavum*, but in *S. conicum* each of the eight fructifications which I have seen is truly conical, pendant, and attached by its vertex, while the pilei of *S. ochraceo-flavum*, *S. ochroleucum*, etc., are reflexed; the hymenium of *S. conicum* is glabrous, while that of *S. ochraceo-flavum* contains even-walled, non-incrustated cystidia $20-25 \times 4-6 \mu$, protruding 15μ . *S. conicum* is noteworthy by the very numerous thick-walled and somewhat incrustated hyphal ends which are present in its intermediate layer. On the hymenial side these bodies curve towards the hymenium but do not reach its surface; on the opposite side they curve to the upper surface of the pileus and protrude as incrustated hairs forming a part of the villose covering of the pileus, a structural feature suggestive of *Cyphella*. The specimens of *S. conicum* were collected by Charles Wright during his last trip to Cuba in about 1860 but were not sent to Berkeley and Curtis for study.

Specimens examined:

Cuba: Fungi Cubensis Wrightiani, 842, *C. Wright*, type, comm. by W. G. Farlow (in Mo. Bot. Gard. Herb., 43906 and in Farlow Herb.).

51. *S. vibrans* Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 332. 1868; Sacc. Syll. Fung. 6: 577. 1888. Plate 5, fig. 52.

An *Stereum cupulatum* Patouillard in Duss, Fl. Crypt. Antilles Fr. 233. 1904?

Type: in Curtis Herb. and Kew Herb.

Fructifications coriaceous, orbicular, and attached by the center, or fan-shaped and laterally confluent, lobed, the upper surface velvety hirsute on the region of recent growth, becoming somewhat glabrous in the older region near place of attachment, narrowly concentrically sulcate, somewhat zonate, snuff-brown, becoming Saccardo's umber; hymenium even, Saccardo's umber to drab, somewhat pruinose; in structure 600–800 μ thick, with the intermediate layer connected with the hairy covering by a blackish dense crust; hyphae of intermediate layer snuff-brown, blackening by action of dilute potassium hydrate, longitudinally arranged, thick-walled, $3\frac{1}{2}$ –4 μ in diameter; hymenial layer simple; no colored conducting organs, cystidia, nor aculeate paraphyses; spores hyaline, even, $4-5 \times 2\frac{1}{2}-3 \mu$.

Pileus 2–5 cm. in diameter.

On logs. Cuba and Jamaica. October and November. Rare.

S. vibrans is related to *S. crassum* but seems distinct by having smaller spores and a thin, blackish, horn-like crust under the hairy covering; the other histological details are very similar however. *S. vibrans* may be distinguished from the other species of the West Indies by its tobacco color, pruinose hymenium, and lack of cystidia, gloecystidia, conducting organs, and bottle-brush paraphyses. *S. papyrinum* is of similar coloration, but is more spongy, has incrusted cystidia, and does not have its intermediate layer bordered above by a crust.

Specimens examined:

Cuba: *C. Wright*, 530, type (in Curtis Herb.).

Jamaica: Rose Hill, *F. S. Earle*, 299, 303, comm. by N. Y. Bot. Gard. Herb.

52. *S. crassum* Fries, R. Soc. Sci. Upsal. Actis III. 1: 111. 1851 (not *Thelephora crassa* Léveillé); Sacc. Syll. Fung. 6: 582. 1888.

Type: in Herb. Fries.

Fructification coriaceous, resupinate, effused, sometimes reflexed, villose, blackening, the margin obtuse, determinate, paler; hymenium even, dark chestnut-brown; in structure 1000 μ thick, with intermediate layer not bordered by a darker denser zone or crust, composed of longitudinally and rather loosely

arranged, dark-colored, thick-walled, stiff hyphae $3\frac{1}{2}$ – $4\frac{1}{2}$ μ in diameter, not incrusted, which give their color to the fructification; no colored conducting organs, gloeocystidia, nor cystidia; spores hyaline, 9×4 μ .

According to the original collection of *S. crassum* in Herb. Fries, this is a very distinct species, characterized by very dark color throughout and by absence of colored conducting organs, cystidia, and gloeocystidia. It is probably of local distribution, for I have seen but one collection which is even doubtfully referable to *S. crassum*. This specimen, collected at Motzorongo, is wholly resupinate, with hyphae dark-colored and ascending obliquely from the substratum instead of running longitudinally, and the hymenium has dried pinkish buff.

Specimens examined:

Mexico: Mirador, *Liebman*, type (in Herb. Fries); Motzorongo, near Cordoba, *W. A. & E. L. Merrill*, 985 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 54648).

53. *S. radiatum* Peck, Buffalo Soc. Nat. Hist. Bul. 1:62. 1873; N. Y. State Mus. Rept. 26:72. 1874; Sacc. Syll. Fung. 6:571. 1888; Masee, Linn. Soc. Bot. Jour. 27:195. 1890.

Plate 5, fig. 53.

S. radiatum var. *reflexum* Peck, N. Y. State Mus. Rept. 49:45. 1896; Sacc. Syll. Fung. 14:217. 1900.—An *Thelephora* (*Stereum*) *corrugata* Léveillé, Ann. Sci. Nat. Bot. III. 5:150. 1846?

Type: in N. Y. State Mus. Herb.

Fructification coriaceous, resupinate, with the margin free all around, sometimes reflexed on the upper side, the reflexed portion becoming black above, velutinous, crisped, and somewhat lobed; hymenium uneven, not polished, marked with thick ridges radiating from the center, Sudan-brown, rarely black when turned upward and exposed to direct sunlight and weather; in structure 1000 μ thick, composed of densely and longitudinally arranged, colored hyphae $3\frac{1}{2}$ – 4 μ in diameter, whose color is dissolved by dilute potassium hydrate solution; no cystidia; spores from spore collections white, even, slightly curved, 9 – $10 \times 3\frac{1}{2}$ – 4 μ .



Fig. 26. *S. radiatum*.
Spores $\times 665$.

Fructifications 2 cm. in diameter up to 10×3 cm.; reflexed portion 2–8 mm. broad.

Under side of hemlock, spruce, and pine boards and logs and charred wood. Canada to Pennsylvania and westward to Montana; received also from Russia where growing on rotten wood in greenhouse.

S. radiatum is readily recognized by its bright, ferruginous hymenium with shallow broad ridges radiating from the center to the margin, and by the black upper side of the pileus when reflexed. The general aspect, coloration, and color changes with KHO solution are suggestive of some species of *Hymenochaete* but no setae are present. I endeavored to have comparison made with the type of *Thelephora corrugata* in Museum of Paris Herbarium but Patouillard could not find the specimen there.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 407.

Russia: on rotting wood in a greenhouse, *Janczewsky* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 6173).

Ontario: Harraby, *E. T. & S. A. Harper*, 636.

Vermont: *Howe* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 5962); Lake Willoughby, *W. G. Farlow*; Middlebury, *E. A. Burt*, four collections.

Massachusetts: Cambridge, *W. G. Farlow*; Sharon, *A. P. D. Piquet*, comm. by *W. G. Farlow*, O (in Mo. Bot. Gard. Herb., 55002).

New York: Albany, *C. H. Peck*, in Ellis, N. Am. Fungi, 407; Alcove, *C. L. Shear*, 1301; Freeville, *G. F. Atkinson*, Cornell Univ. Herb., 18185; Ithaca, *C. O. Smith*, *H. H. Whetzel*, *L. M. Wiegand*, Cornell Univ. Herb., 8029, 13809, and 3254 respectively.

Pennsylvania: State College, *L. O. Overholts*, 2653 (in Mo. Bot. Gard. Herb., 5917); Trexlertown, *W. Herbst*.

Michigan: Seney, *C. J. Humphrey*, 1843 (in Mo. Bot. Gard. Herb., 17766).

Montana: Darby, *J. R. Weir*, 363 (in Mo. Bot. Gard. Herb., 16472).

54. *S. patelliforme* Burt, n. sp.

Plate 5, fig. 54.

Type: In Burt Herb.

Fructification coriaceous-fleshy, resupinate, the margin becoming free or narrowly reflexed, hoary with a few short hairs, drying cinnamon to bone-brown, the margin entire; hymenium even, waxy, cracking in drying, drying cinnamon to bone-brown; in structure 500–800 μ thick, composed of longitudinally and densely arranged, hyaline hyphae 3–3 $\frac{1}{2}$ μ in diameter, with the intermediate layer not bordered on the upper side by a denser, darker zone; hair-like cystidia hyaline, cylindric, flexuous, 50–60 \times 5–6 μ , emerging up to 40 μ , but rarely present; basidia simple, with 4 sterigmata, often protruded; spores hyaline, even, 9–10 \times 3–4 μ , somewhat curved.

Fructifications 3 \times 2 mm., up to 25 \times 3 mm., the margin free all around and rolled up 1–2 mm.

On fallen branches of *Acer*, *Quercus*, and other frondose species. Washington, California, and New Mexico. August to April. Rare.

S. patelliforme differs from our other *Stereums* by being of more fleshy consistency and with a waxy hymenium. In these characters it approaches *Corticium*, but it has the longitudinal arrangement of hyphae characteristic of *Stereum* and the margin becomes narrowly reflexed. These characters separate *S. patelliforme* from our other *Stereums* with the exception of *S. pubescens*, which is snow-white on the upper side with a thick covering of fine soft hairs, is more broadly reflexed, and has a somewhat radiately rugose hymenium.

Specimens examined:

Washington: Bingen, *W. N. Suksdorf*, 713, type, 752, 753, 884, 917.

California: Campo Mts., *C. D. Orcutt*, 2005, comm. by U. S. Dept. Agr. Herb.

New Mexico: Ute Park, Colfax Co., *P. C. Standley*, 14735, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 44951).

55. *S. ochraceo-flavum* Schweinitz in Peck, N. Y. State Mus. Rept. 22: 86. 1869; Morgan, Cincinnati Soc. Nat. Hist. Jour. 10: 195. 1888; Sacc. Syll. Fung. 6: 576. 1888; Masee, Linn. Soc. Bot. Jour. 27: 184. 1890. Plate 5, fig. 55.

Thelephora ochraceo-flava Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 167. 1832.

Type: in Herb. Schweinitz and Curtis Herb.

Fructification coriaceous, thin, small, effuso-reflexed, sometimes confluent along branches, often conical and attached by

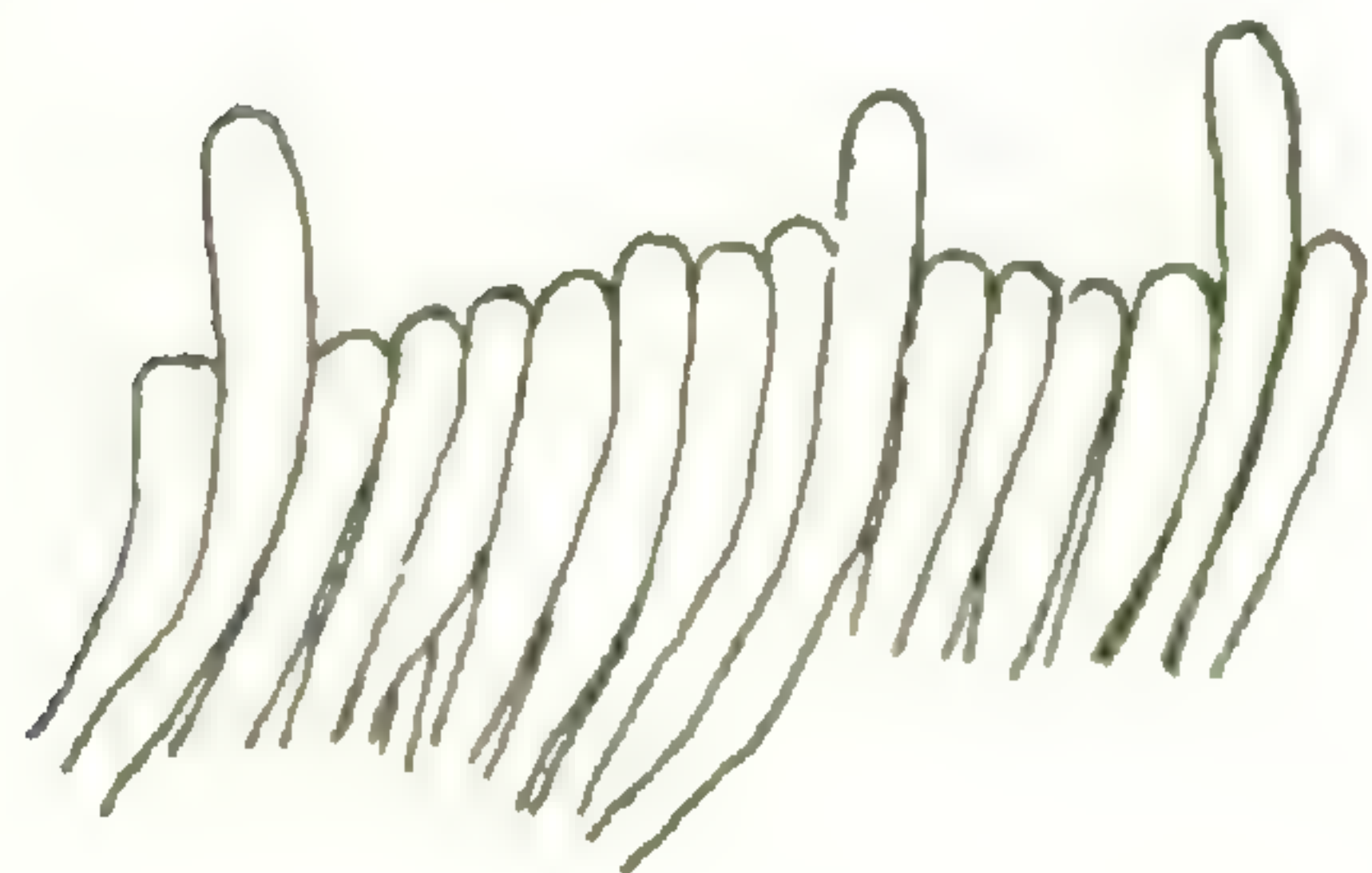


Fig. 27. *S. ochraceo-flavum*.
Hymenium showing three cystidia, $\times 488$.

one side and the umbo and sometimes only by the umbo, the upper side villose-tomentose, somewhat furrowed, white, weathering gray; in structure 200–300 μ thick below the hairy covering, with intermediate layer becoming bordered on the upper side by a denser or colored zone when old and weathered, composed of densely and longitudinally arranged, hyaline hyphae 3–4 μ in

diameter; no colored conducting organs; hymenium even, "yellow," becoming cream-buff in the herbarium; cystidia not incrusted, obtuse, $20\text{--}25 \times 4\text{--}6 \mu$, protruding up to 15 μ ; spores not found.

Reflexed portion 3–5 mm. broad, and about as long; scattered conical pilei 3–5 mm. in diameter.

On dead branches of frondose species. Canada to Mississippi and westward to Missouri, and in California and Mexico. July to May.

S. ochraceo-flavum may be recognized at sight by its small, white, conical fructifications heavily clothed with long, soft hairs and by its bright yellow hymenium. The non-incrusted cystidia afford a good distinctive microscopical character for separation of this species from very small specimens of *S. sulphuratum*. In specimens which have persisted beyond their normal season of active growth, the upper side of the intermediate layer becomes hardened and pale golden.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 17; Ell. & Ev., Fungi Col., 6; Ravenel, Fungi Am., 787; Ravenel, Fungi Car. 2: 31; de Thümen, Myc. Univ., 10.

Ontario: Ottawa, *J. Macoun*, 242.

Vermont: Middlebury, *E. A. Burt*.

Massachusetts: *D. W. Weis*, comm. by C. G. Lloyd, 145 (in Mo. Bot. Gard. Herb., 56687); Cambridge, *E. A. Burt*; Magnolia, *W. G. Farlow*.

- Connecticut: Storrs, *A. E. Moss*, comm. by P. W. Graff, 38 (in Mo. Bot. Gard. Herb., 44792).
- New York: Albany, *H. D. House* (in N. Y. State Mus. Herb., and Mo. Bot. Gard. Herb., 55209); East Galway, *E. A. Burt*; Ithaca, Cornell Univ. Herb., 219; Poughkeepsie, *W. R. Gerard*, 228, 261 (in N. Y. Bot. Gard. Herb.); Staten Island, *L. M. Underwood* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56701).
- New Jersey: Newfield, *J. B. Ellis*, in Ellis, N. Am. Fungi, 17, Ell. & Ev., Fungi Col., 6, and de Thümen, Myc. Univ., 10.
- Pennsylvania: Bethlehem, *Schweinitz*, type (in Herb. Schweinitz and in Curtis Herb.); State College, *J. F. Adams*, 8 (in Mo. Bot. Gard. Herb., 44085).
- Maryland: Seven Locks, *P. L. Ricker*, 1005; Takoma Park, *C. L. Shear*, 1119, 1240.
- Virginia: Park Lane, *W. H. Long*, 18463 (in Mo. Bot. Gard. Herb., 55101).
- North Carolina: Blowing Rock, *G. F. Atkinson*, 4316.
- South Carolina: *H. W. Ravenel*, in Ravenel, Fungi Car. 2: 31; Summerville, *C. L. Shear*, 1228.
- Georgia: Darien, *H. W. Ravenel*, in Ravenel, Fungi Am., 787; Fullerton, *P. L. Ricker*, 918.
- Florida: *C. G. Lloyd*, 4859; Hanosassa (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56688); New Smyrna, *C. G. Lloyd*, 2089; Tampa, *N. L. & E. G. Britton & J. A. Shafer*, 46 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56689).
- Alabama: Auburn, *F. S. Earle & C. F. Baker* (in Burt Herb. and Mo. Bot. Gard. Herb., 5089); Montgomery Co., *R. P. Burke*, 22 (in Mo. Bot. Gard. Herb., 12291).
- Mississippi: Ocean Springs, *F. S. Earle*, 180 (in Mo. Bot. Gard. Herb., 5090).
- Michigan: New Richmond, *C. H. Kauffman*, 87 (in Mo. Bot. Gard. Herb., 44995).
- Wisconsin: Palmyra, *Miss A. O. Stucki*, Univ. Wis. Herb., 40.
- Indiana: Millers, *E. T. & S. A. Harper*, 938.
- Tennessee: Elkmont, *C. H. Kauffman*, 59 (in Mo. Bot. Gard. Herb., 44971).
- Iowa: Decorah, *E. W. D. Holway*.

Missouri: Allenton, *Letterman*, 48 (in Mo. Bot. Gard. Herb., 5041).

Arkansas: Cass, *W. H. Long*, 19833 (in Mo. Bot. Gard. Herb., 17807).

California: Campo Seco, *W. H. Thomas*, 3 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 86690).

Mexico: Jalapa, *W. A. & E. L. Murrill*, 347, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54468); Orizaba, *J. G. Smith*, 511 (in Mo. Bot. Gard. Herb., 437).

56. *S. abietinum* Persoon, *Myc. Eur.* 1: 122. 1822 (under **** *Stereum* of *Thelephora*); Fries, *Obs. Myc.* 1: 274. 1815, and ed. 2, 1824; *Epicr.* 552. 1838; *Hym. Eur.* 643. 1874; *Sacc. Syll. Fung.* 6: 574. 1888. Plate 5, fig. 56.

Thelephora abietina Persoon, *Syn. Fung.* 573. 1801; Fries, *Syst. Myc.* 1: 442. 1821.—*Hymenochaete abietina* (Pers.) Masee, *Linn. Soc. Bot. Jour.* 27: 115. 1890.—*Thelephora striata* Schrader, *Spic. Fl. Germ.* 186. 1794.—*Stereum striatum* Schrader ex Fries, *Epicr.* 551. 1838; *Hym. Eur.* 641. 1874; *Sacc. Syll. Fung.* 6: 565. 1888.—*Lloydella striata* (Schrad.) Bresadola in Lloyd, *Myc. Writ.* 1. *Myc. Notes* 6: 51. 1901.—*Stereum glaucescens* Fries, *Hym. Eur.* 644. 1874; *Sacc. Syll. Fung.* 6: 575. 1888.—*Hymenochaete fimbriata* Ellis & Everhart, *Jour. Myc.* 1: 149. 1885; *Sacc. Syll. Fung.* 6: 599. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 113. 1890.—*Hymenochaete abnormis* Peck, *N. Y. State Mus. Rept.* 42: 126. *pl. 1. f. 13-16.* 1889; *Sacc. Syll. Fung.* 9: 227. 1891.

Illustrations: Istvanffi, *Jahrb. f. wiss. Bot.* 29: *pl. 5. f. 16, 17*; Patouillard, *Essai Tax. Hym.* 72; Peck, *N. Y. State Mus. Rept.* 42: *pl. 1. f. 13-16.*

Fructification coriaceous-spongy, dry, thick, resupinate, effused, rarely reflexed, with upper side tomentose, obscurely zonate, burnt umber, tuberculate or uneven; hymenium varying from light drab to cinereous or glaucous; in structure 400–900 μ thick, of which the intermediate layer and the hymenium together constitute 300–600 μ ; intermediate layer composed of longitudinally arranged and interwoven colored hyphae 3–3½ μ in diameter and bordered on its outer side by a darker, denser zone which connects it with the tomentose covering; hymenial

layer becoming zonate and containing numerous colored cystidia having more or less the appearance of colored conducting organs; cystidia colored, cylindric, obtuse, even, rough-walled or more or less incrustated, $90-150 \times 6-8 \mu$, protruding up to 60μ ; spores hyaline, even, flattened on one side, $9-13 \times 4-5 \mu$.

Resupinate specimens $2-8 \times 2-5$ cm., reflexed margin $3-8$ mm. broad.

On wood and logs of *Abies* and *Pinus*. New Hampshire to Washington and in Europe. June to October. Rare.

S. abietinum usually occurs resupinate, but its thick, separable, felty fructifications are suggestive of a resupinate *Stereum*, and this view is confirmed by the presence of the intermediate layer when radial, vertical sections are examined. The cinereous, pruinose surface of the hymenium due, however, to whitish, cobwebby filaments rather than powdery grains, is highly characteristic and shared only by the western *S. rugisporum*, as are also the colored cylindric cystidia. *S. rugisporum* is separated by its odor of anise, much thicker and more broadly reflexed pilei, and presence in occasional collections of colored spores imbedded in the deeper zones of the hymenium.

I have included *Hymenochaete fimbriata* among the synonyms of *S. abietinum*, but it may prove to belong with *S. rugisporum* instead.

Specimens examined:

Exsiccati: de Thümen, Myc. Univ., 1107.

Norway: Christiania, *M. N. Blytt*, type of *Stereum glaucescens* (in Herb. Fries).

Sweden: Stockholm, *L. Romell*, 29; Upsala, *C. G. Lloyd*, 08521 (in Lloyd Herb. and Mo. Bot. Gard. Herb., 55497).

Finland: Mustiala, *P. A. Karsten*, in de Thümen, Myc. Univ., 1107.

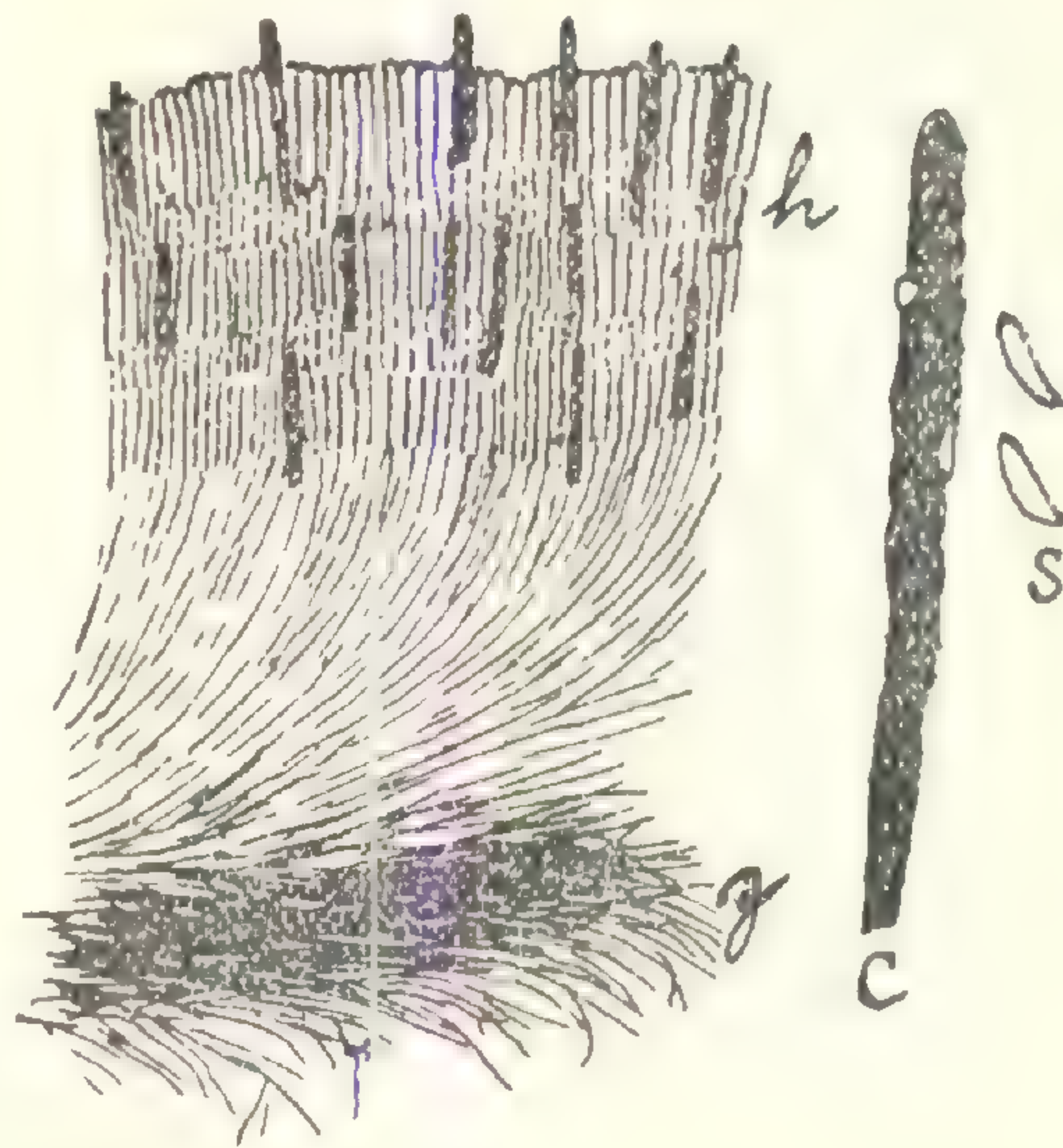


Fig. 28. *S. abietinum*. Section $\times 68$; crust-like zone, *z*; hymenium containing colored cystidia, *h*; cystidium, *c*, and spores, *s*, $\times 488$.

- Italy (?): locality not stated, *G. Bresadola*.
 New Hampshire: Crawford Notch, *L. O. Overholts & A. S. Rhoads* (in Mo. Bot. Gard. Herb., 56342); North Conway, *L. O. Overholts*, 4553 (in Mo. Bot. Gard. Herb., 55633).
 Vermont: Smugglers Notch, Mt. Mansfield, *E. A. Burt*.
 New York: Cascadeville, Adirondack Mts., *C. H. Peck*, type of *Hymenochaete abnormis* (in N. Y. State Mus. Herb.).
 Wisconsin: Madison, *M. C. Jensen*, comm. by C. J. Humphrey, 618.
 Montana: Yellowstone Park, part of type of *Hymenochaete fimbriata* from J. B. Ellis (in Kew Herb.).
 Canada: Rocky Mts., Lake O'Hara, *J. Macoun*, 2.
 Washington: Mt. Paddo, *W. N. Suksdorf*, 731.

57. *S. rugisporum* (Ell. & Ev.) Burt, n. comb.

Plate 6, fig. 58.

Hymenochaete rugispora Ellis & Everhart, Acad. Nat. Sci. Phila. Proc. 1890: 219. 1890; Sacc. Syll. Fung. 9: 228. 1891.

Type: in N. Y. Bot. Gard. Herb.

Fructification coriaceous-spongy, dry, thick, effuso-reflexed, finally umbonate along line of attachment to substratum, the

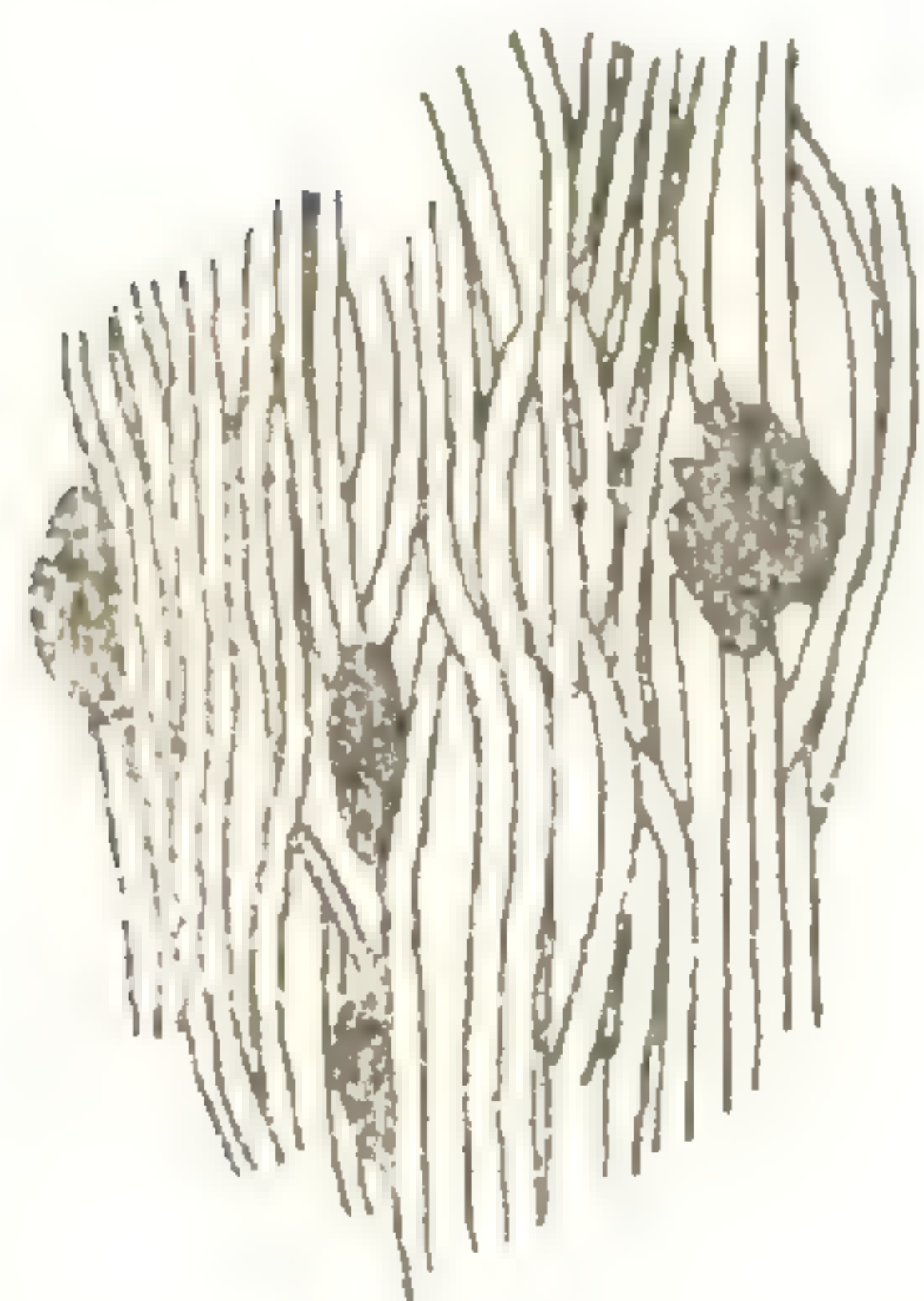


Fig. 29. *S. rugisporum*. Portion of section $\times 488$, showing colored imbedded spores.

upper side tomentose, concentrically sulcate, snuff-brown when young and remaining so on the obtuse margin, elsewhere weathering neutral gray, with an anise-like odor in the herbarium; hymenium even, light mouse-gray, becoming light drab; in structure 2–3 mm. thick, with intermediate layer and hymenium together 800–1200 μ thick and the intermediate layer connected with the loosely interwoven tomentose surface layer by a dark dense zone, the hyphae of the intermediate layer colored, 2–4 μ in diameter, longitudinally arranged and loosely interwoven, curving outward into the hymenial layer; hymenial layer becoming up to 1000 μ thick, zonate, containing colored cystidia and sometimes colored spores $7\frac{1}{2}$ –9 \times 3–3 $\frac{1}{2}$ μ , even or rough-walled; cystidia colored, cylindric, obtuse, even, rough or granule-incrusted, 100–150 \times 7–9 μ , pro-

truding up to 120 μ , starting from all parts of the hymenial layer and subhymenium; basidiospores as seen on basidia, hyaline, even, $9-13 \times 3-4\frac{1}{2}$ μ , borne 4 to a basidium.

Reflexed portions 1-4 cm. long and wide, sometimes laterally confluent for 6-8 cm.; resupinate parts of about the same dimensions.

On dead *Abies*, *Picea*, *Pinus*, and *Larix*. In Rocky Mt. states and British Columbia to Arizona. July to September.

Reflexed specimens of *S. rugisporum* may be recognized by their thick, felty, or spongy pilei, deeply concentrically sulcate, and snuff-brown or partly gray in color, with a whitish, pruinose hymenium, and an odor of anise; collections so far made indicate that this species is restricted to conifers of mountainous regions. Microscopic examination of sections shows characteristic cylindrical, colored cystidia, which in the subhymenium and the deeper zones of the hymenium are not readily distinguishable from such colored conducting organs as occur in many species of *Stereum*. There is, however, no record of bleeding from wounds of the hymenium of *S. rugisporum* and *S. abietinum*. The type specimen of *S. rugisporum* contains colored spores, usually even, but occasionally rough-walled, imbedded in the deeper zones of the hymenium; similar spores occur in some, but not all, of the collections cited below, but the collections are so similar in other characters that I regard these colored imbedded spores as an important, occasional character of the species, which will positively identify some collections.

The type of *Hymenochaete fimbriata* was collected in Yellowstone Park, Montana, on *Pinus Murrayana*; the specimen is wholly resupinate and does not show colored, imbedded spores in the preparations which I preserved. I regarded this specimen as not specifically distinct from *S. abietinum*, but the type station of *H. fimbriata* makes me uncertain as to whether the latter may not yet be demonstrated to be resupinate *S. rugisporum* instead. When so demonstrated, the specific name *fimbriatum* should be used for the species because of earlier publication.

Specimens examined:

Wyoming: Fox Park, *J. R. Weir*, 10009 (in Mo. Bot. Gard. Herb., 55788).

- Colorado: Silverton, *E. R. Hodson*, comm. by C. J. Humphrey, 1551; Tolland, *L. O. Overholts*, 1781, 2336 (in Mo. Bot. Gard. Herb., 56042, 56761); Yankee Doodle Lake, *F. J. Seaver & E. Bethel* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56729).
- Idaho: Bonanza, *G. G. Hedgcock*, comm. by C. J. Humphrey, 2168 (in Mo. Bot. Gard. Herb., 10377); Coolin, *J. R. Weir*, 11476 (in Mo. Bot. Gard. Herb., 56724); Leesburg, *F. S. Wolpert*, comm. by J. R. Weir, 7033 (in Mo. Bot. Gard. Herb., 55463); Priest River, *E. E. Hubert*, comm. by J. R. Weir, 11655 (in Mo. Bot. Gard. Herb., 56725).
- British Columbia: *J. Macoun*, 94, type (in N. Y. Bot. Gard. Herb.).
- Washington: Olympic Mts., *T. C. Frye*, 1 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56730); Seattle, *W. A. Murrill*, 130, 146 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56731, 56732) and *J. M. Grant*, 2066, comm. by C. G. Lloyd (in N. Y. Bot. Gard. Herb., 56728).
- Arizona: Agassiz, *W. H. Long*, 19445 (in Mo. Bot. Gard. Herb., 44734); Mt. Humphrey, Flagstaff, *W. H. Long*, 21306-21308, 21310 (in Mo. Bot. Gard. Herb., 54897-54899, 54901); Interior Basin, San Francisco Peaks, *W. H. Long*, 21309, 21311 (in Mo. Bot. Gard. Herb., 54900, 54902).

58. *S. ambiguum* Peck, N. Y. State Mus. Rept. 47: 145. 1894; Sacc. Syll. Fung. 11: 122. 1895. Plate 5, fig. 57.
Type: in N. Y. State Mus. Herb.

Fructifications coriaceous, dry, resupinate, effused, rarely narrowly reflexed, with the upper side tomentose, Prout's brown, the resupinate margin often brighter colored, antique brown, determinate; hymenium velvety, raw umber to Saccardo's umber when mature and thick, becoming deeply cracked in drying; in structure 600-1400 μ thick, with an intermediate layer 400-600 μ broad, composed of longitudinally interwoven, colored hyphae 3-4 μ in diameter, and with a zonate hymenial layer up to 800 μ thick containing colored incrustated cystidia in all the zones; sections darkened by KHO solution; cystidia colored, cylindric, obtuse, usually incrustated, 100-150 \times 7-12 μ , protruding up to 100 μ ; basidiospores white in spore collection,

even, $10-13 \times 3\frac{1}{2}-4\frac{1}{2} \mu$; colored spores $12 \times 3\frac{1}{2}-4 \mu$ sometimes occur in deeper zones of the hymenium.

Resupinate part 1-8 cm. long, 1-4 cm. wide, reflexed part 1-5 mm. broad in the only reflexed specimen known.

On logs of *Abies* and, perhaps, *Pinus Strobus*. Vermont and New York. June to November. Very rare.

S. ambiguum belongs in the group of species with *S. abietinum* and *S. rugisporum* on account of similarity in microscopic structure including the colored cystidia. It may be separated from both these species at sight by the color of its hymenium which is permanently umber and not at all cinereous nor glaucous. There is a difference in chemical composition also, for dilute potassic hydrate solution blackens the sections and becomes itself discolored as in the case of species of *Hymenochaete*. In fact, the general aspect of resupinate, thick, mature, deeply cracked specimens is very like that of *Hymenochaete spreta*—a species which occurs only exceptionally on a coniferous substratum. It is possible that *S. ambiguum* occurs in reflexed form in the state of Washington, for the collection cited under *S. rugisporum*, Olympic Mts., *T. C. Frye, 1*, resembles *S. ambiguum* but is not quite in perfect enough condition for confident reference here.

Specimens examined:

Vermont: Middlebury, *C. G. Lloyd, 10652* (in Lloyd Herb. and Mo. Bot. Gard. Herb., 44585); Ripton, *E. A. Burt*; Smugglers Notch, Mt. Mansfield, *E. A. Burt*.

New York: Adirondack Mts., *C. H. Peck*, type (in N. Y. State Mus. Herb.); Averyville, *C. H. Peck* (in N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb., 55699).

59. *S. umbrinum* Berk. & Curtis, Grevillea 1: 164. 1873; Wakefield, Kew Bul. 1915: 369. 1915.—Compare *Stereum umbri-*

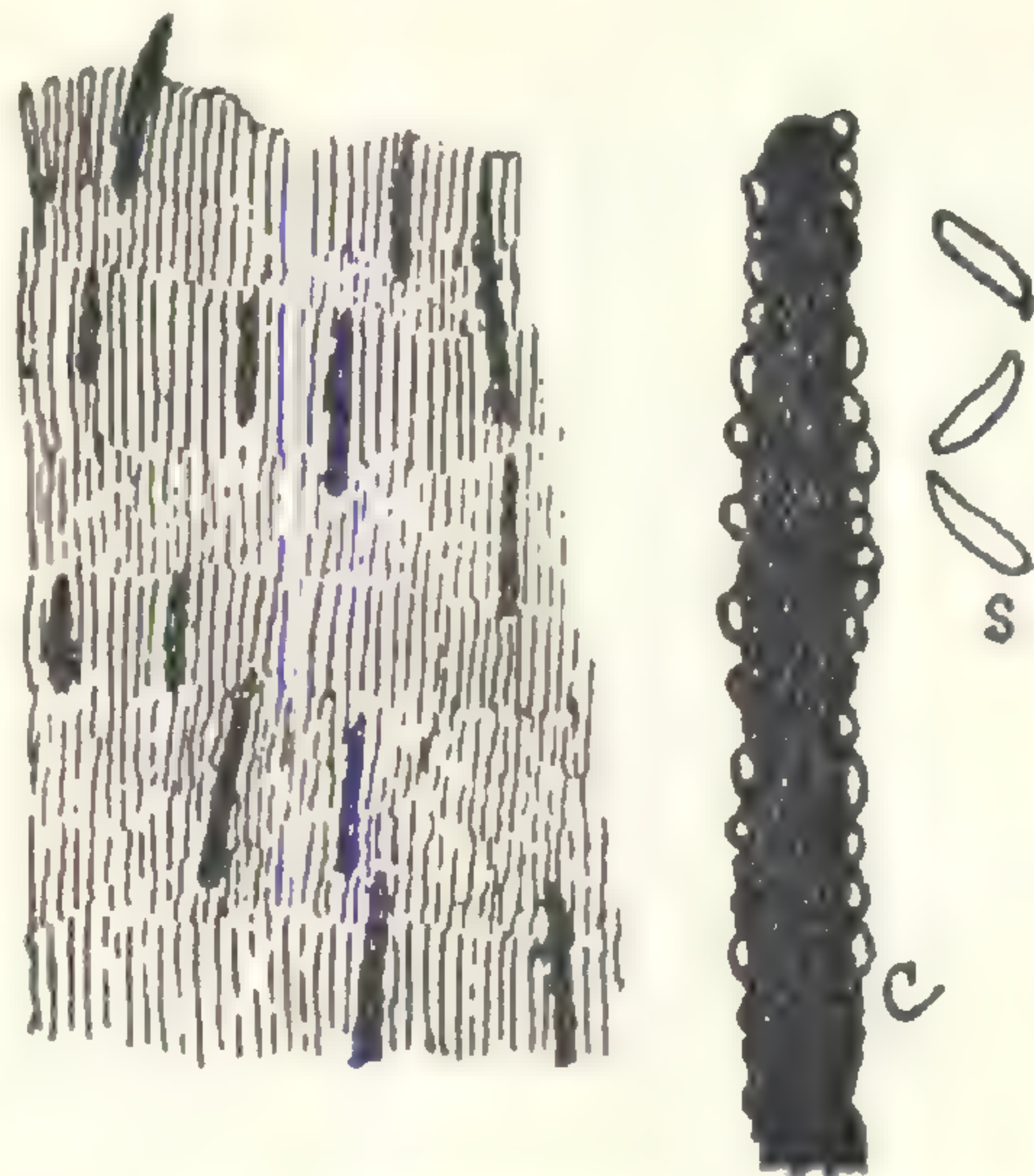


Fig. 30. *S. ambiguum*. Section of hymenial region $\times 68$; peripheral part of cystidium, *c*, and spores, *s*, $\times 650$.

num Fries in Lehmann, *Plantae Preissianae* 2: 137. 1847.
Plate 6, fig. 59.

Thelephora crassa Léveillé in Gaudichaud, *Voyage Bonite Bot.* 1: 190. *pl.* 139. *f.* 1. 1846. Not *Stereum crassum* Fries, *R. Soc. Sci. Upsal. Actis* III. 1: 111. 1851.—*Hymenochaete crassa* (Lév.) Berkeley in Cooke, *Grevillea* 8: 148. 1880; *Sacc. Syll. Fung.* 6: 597. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 114. 1890.—*H. umbrina* Berk. & Curtis in Cooke, *Grevillea* 8: 148. 1880; Morgan, *Cincinnati Soc. Nat. Hist. Jour.* 10: 198. 1888; *Sacc. Syll. Fung.* 6: 598. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 113. 1890.—*H. vinosa* (Berk.) Cooke, *Grevillea* 8: 149. 1880; *Sacc. Syll. Fung.* 6: 600. 1888.—*H. multispinulosa* Peck, *Bot. Gaz.* 7: 54. 1882; *Sacc. Syll. Fung.* 6: 600. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 108. 1890.—*H. scabriseta* Cooke in Ravenel, *Fungi Am.*, 717. 1882; Masee, *Linn. Soc. Bot. Jour.* 27: 113. *pl.* 5. *f.* 7. 1890.—*Lloydella scabriseta* (Cooke) v. Höhn. & Litsch. *K. Akad. Wiss. Wien Sitzungsber.* 115: 1580. 1906.—*Hymenochaete purpurea* Cooke & Morgan in Cooke, *Grevillea* 11: 106. 1883; Morgan, *Cincinnati Soc. Nat. Hist. Jour.* 10: 198. 1888; *Sacc. Syll. Fung.* 6: 597. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 115. 1890.—*Knieffia purpurea* (Cooke & Morg.) Bresadola, *Ann. Myc.* 1: 100. 1903.—*Peniophora intermedia* Masee, *Linn. Soc. Bot. Jour.* 25: 143. 1889; *Sacc. Syll. Fung.* 9: 238. 1891.—*Hymenochaete Kalchbrenneri* Masee, *Linn. Soc. Bot. Jour.* 27: 116. 1890; *Sacc. Syll. Fung.* 9: 230. 1891.

Illustrations: Gaudichaud, *Voyage Bonite Bot.* *pl.* 139. *f.* 1; *Linn. Soc. Bot. Jour.* 27: *pl.* 5. *f.* 7.

Type: in Kew Herb. and Curtis Herb.

Fructifications coriaceous-spongy, resupinate, effused, often becoming reflexed, light vinaceous lilac to dark lavender when young, at length brownish drab to snuff-brown, the upper surface spongy, pitted, somewhat sulcate, the reflexed margin thick, entire; hymenium even, somewhat velvety, sometimes cracking in drying, light vinaceous lilac to snuff-brown; in structure 500–1000 μ thick, composed of loosely interwoven, slightly colored hyphae $3\frac{1}{2}$ –5 μ in diameter, not forming an intermediate layer; in the subhymenial region thick-walled organs 5–6 μ in diameter, darker colored than the hyphae, originate among the

hyphae and curve outward through the hymenium as sharp-pointed cystidia, even, rough-walled, or incrustated, $100-200 \times 6-10 \mu$, protruding up to 40μ ; spores white in spore collection, even, $6 \times 3\frac{1}{2} \mu$.

Resupinate on areas 1-3 cm. in diameter, becoming laterally confluent for 10-15 cm., reflexed portion 2-5 mm. broad.

On fallen limbs of oak, hickory, and other frondose species. North Carolina to Texas and southward from Ohio and Illinois, in Arizona, West Indies, and Central America; occurs also in Poland, Cochin China, and Australia. September to February, but collected occasionally in the other months of the year.

S. umbrinum may be recognized by the purple color of young specimens which fades or changes finally to snuff-brown, although usually showing a vinaceous tinge, and by its remarkable cystidia, which, on account of their color and lack of conspicuous incrustation, verge towards setae. However, these organs are paler colored and much more elongated than undoubted setae; furthermore, sections of fructifications in which these colored cystidia are present do not immediately darken when dilute potassium hydrate is brought in contact with them, as invariably happens to sections containing true setae. It has seemed best to retain for this species the name *Stereum umbrinum* B. & C., because the type of *Stereum umbrinum* Fr., Herb. Preiss., No. 2686, collected in Australia on *Banksia Menziesii*, must be found and studied to complete the Friesian description before it can be known whether the Preiss specimen is not really a *Hymenochaete*, *Eichleriella*, *Auricularia*, or, perhaps, even identical with *S. umbrinum* B. & C., a common species in Australia. The presence of a white, intermediate layer seems to preclude the

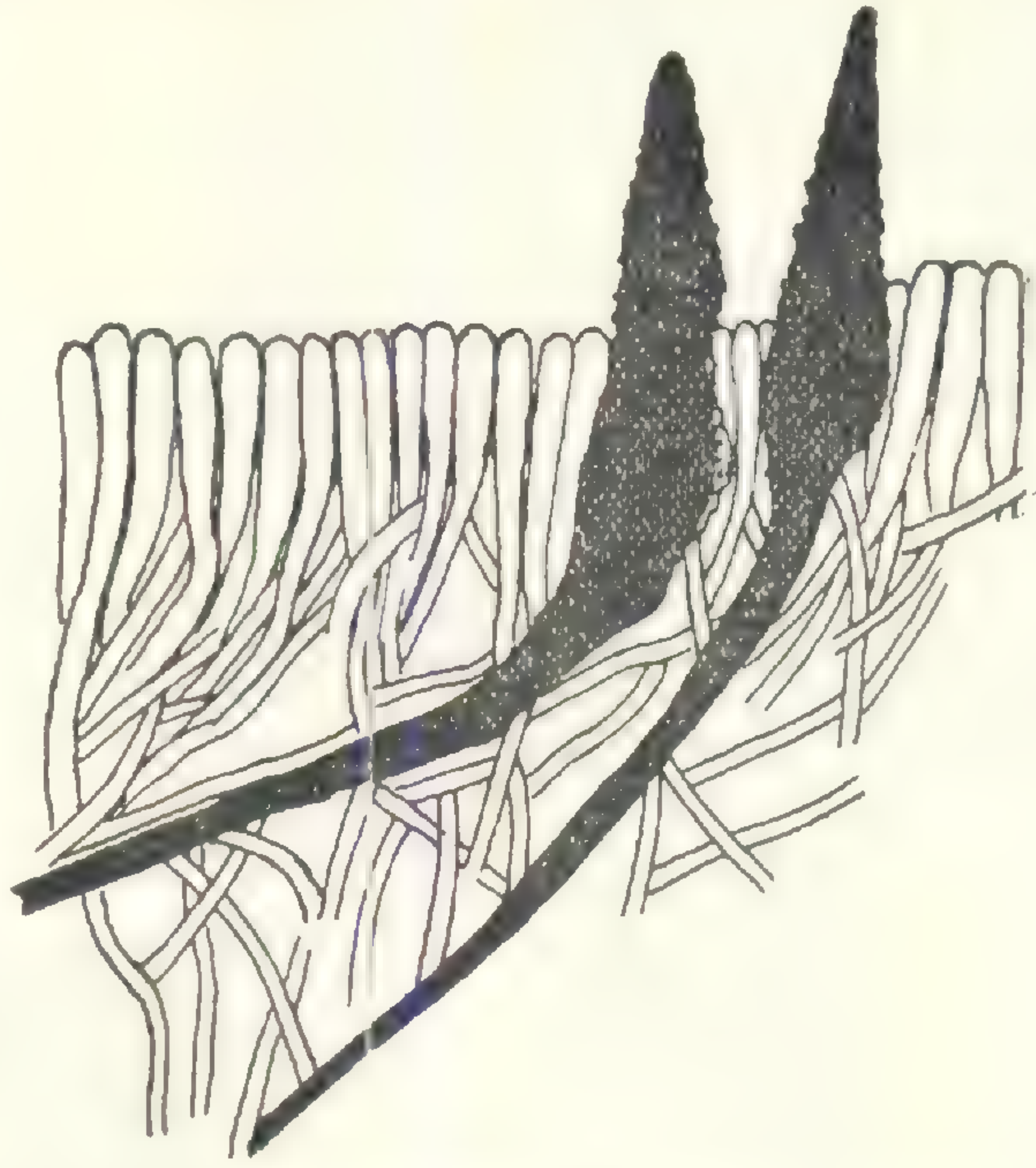


Fig. 31. *S. umbrinum*. Section of hymenial region $\times 488$, showing z, cystidia.

latter possibility. No. 2686 has not been found in the Preiss series of specimens in the Missouri Botanical Garden Herbarium; perhaps it is most likely to be found in the Stockholm collection.

Specimens examined:

- Exsiccati: Ellis, N. Am. Fungi, 606 b, under the name *Stereum papyrinum*, and 1108; Ell. & Ev., N. Am. Fungi, 2315; Ravenel, Fungi Car. 2: 36, under the name *S. papyrinum*; Ravenel, Fungi Am., 118, under the name *S. papyrinum*, the type distribution of *Peniophora intermedia*, and 445, and 717, the type distribution of *Hymenochaete scabriseta*; Rabenhorst, Fungi Eur., 3524; de Thümen, Myc. Univ., 1504, under the name *Corticium murinum*, the type distribution of *Hymenochaete Kalchbrenneri*.
- North Carolina: Asheville, *E. Bartholomew*, 5653 (in Mo. Bot. Gard. Herb., 44215); Creedmoor, *J. G. Hall*, comm. by Lloyd Herb., 10299 (in Mo. Bot. Gard. Herb., 55465).
- South Carolina: *H. W. Ravenel*, Curtis Herb., 1903, type (in Kew Herb.), and in Ravenel, Fungi Car. 2: 36; Aiken, *H. W. Ravenel*, in Ravenel, Fungi Am., 445, and *H. W. Ravenel*, 1716 (in Curtis Herb., 2308, under the name *Hymenochaete cervina*); Clemson College, *P. H. Rolfs*, 1615, 1633.
- Georgia: Darien, *H. W. Ravenel*, in Ravenel, Fungi Am., 117; Tallulah Falls, *A. B. Seymour*, comm. by W. G. Farlow, GG.
- Florida: *C. G. Lloyd*, 2134, 4857, and *W. W. Calkins*, in Ellis, N. Am. Fungi, 606 b; Eustis, *R. Thaxter*, 12 (in Farlow Herb. and Mo. Bot. Gard. Herb., 43931); Gainesville, *N. L. T. Nelson*, comm. by Lloyd Herb., 427 (in Mo. Bot. Gard. Herb., 55624), and *H. W. Ravenel*, in Ravenel, Fungi Am., 118; Green Cove Springs, *G. Martin*, in Ellis, N. Am. Fungi, 1108; New Smyrna, *C. G. Lloyd*, 192, 2122, 2134.
- Alabama: *Peters*, 770 (in Curtis Herb., under the name *S. papyrinum*); Auburn, *P. H. Mell* (in U. S. Dept. Agr. Herb. and Mo. Bot. Gard. Herb., 5106); Mobile, *E. Bartholomew*, 5751 (in Mo. Bot. Gard. Herb., 44221); Montgomery, *R. P. Burke*, 139, 150 (in Mo. Bot. Gard. Herb., 21228, 44906); Talapoosa region, *F. S. Earle & C. F. Baker* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56598).

- Louisiana: *A. B. Langlois*, comm. by *W. G. Farlow* (in *Mo. Bot. Gard. Herb.*, 44650); *St. Martinville*, *A. B. Langlois*, *A, B, C, ag*, and an *unnumbered specimen* and in *Ell. & Ev.*, *N. Am. Fungi*, 2315.
- Ohio: *A. P. Morgan*, 11, type of *Hymenochaete purpurea* (in *Kew Herb.*); *Cincinnati*, *C. G. Lloyd*, 190, and *A. P. Morgan*, comm. by *Lloyd Herb.*, 2626; *Linwood*, *C. G. Lloyd*, 2261.
- Indiana: *Greenwood*, *M. C. Jensen*, comm. by *C. J. Humphrey*, 2133 (in *Mo. Bot. Gard. Herb.*, 22825).
- Illinois: *Christopher*, *C. J. Humphrey*, 2133 (in *Mo. Bot. Gard. Herb.*, 42926); *Genesee*, *E. T. & S. A. Harper*, 824.
- Missouri: *Bismarck*, *L. O. Overholts* (in *Mo. Bot. Gard. Herb.*, 56716); *Columbia*, *B. M. Duggar*, 571; *Pacific*, *L. O. Overholts*, 3162 (in *Mo. Bot. Gard. Herb.*, 5718); *Perryville*, *C. H. Demetrio*, in *Rabenhorst, Fungi Eur.*, 3524; *Pickering*, *E. Bartholomew*, 6424 (in *Mo. Bot. Gard. Herb.*, 55194); *St. Louis*, *N. M. Glatfelter*, 1187, comm. by *N. Y. Bot. Gard. Herb.*; *Valley Park*, *E. A. Burt* (in *Mo. Bot. Gard. Herb.*, 44056, 44061).
- Arkansas: *Bigflat*, *W. H. Long*, 19858, 19895 (in *Mo. Bot. Gard. Herb.*, 8965, 8883); *Cass*, *W. H. Long*, 19832, 19905 (in *Mo. Bot. Gard. Herb.*, 8884, 8885); *Womble*, *W. H. Long*, 19821 in part, 19869 (in *Mo. Bot. Gard. Herb.*, 14650, 9142).
- Texas: *Gillespie Co.*, *C. Jermy*, 444 (in *Mo. Bot. Gard. Herb.*, 5171); *Gonzales*, *C. L. Shear*, 1229.
- Arizona: 34 near *Camp Lowell*, *C. G. Pringle*, type of *Hymenochaete multispinulosa* (in *N. Y. State Mus. Herb.* and a portion in *Burt Herb.*).
- Cuba: *C. Wright*, *Fungi Cubenses Wrightiani*, 832, comm. by *W. G. Farlow* (in *Mo. Bot. Gard. Herb.*, 43908), and *C. G. Lloyd*, 165 (in *Mo. Bot. Gard. Herb.*, 55153); *Ciego de Avila*, *Earle & Murrill*, 607, comm. by *N. Y. Bot. Gard. Herb.*; *La Magdalena*, *Earle & Baker*, 2470, comm. by *N. Y. Bot. Gard. Herb.*; *San Diego de Los Baños*, *Earle & Murrill*, 263, comm. by *N. Y. Bot. Gard. Herb.*
- Porto Rico: *Rio Piedras*, *J. A. Stevenson*, 2389 (in *Mo. Bot. Gard. Herb.*, 9441).
- Guatemala: *Secanquim*, *W. R. Maxon & R. Hay*, 3140a

Cochin China: authentic specimen of *Thelephora crassa* from Léveillé (in Kew Herb.).

Australia: *W. N. Cheesman*, comm. by E. M. Wakefield, Kew Herb. (in Mo. Bot. Gard. Herb., 44582); Victoria, *J. G. Luehmann*, in de Thümen, Myc. Univ., 1504, under the name of *Corticium murinum*, the type distribution of *Hymenochaete Kalchbrenneri*.

60. *S. papyrinum* Montagne in Ramon de la Sagra, Hist. Cuba Pl. Cell. 374. 1842; *ibid.*, folio ed., 9: 228. 1845; Syll. Crypt. 178. 1856; Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 331. 1868. Plate 6, fig. 60.

Peniophora papyrina (Mont.) Cooke, Grevillea 8: 20. pl. 124. f. 9. 1879; Sacc. Syll. Fung. 6: 641. 1888; Masee, Linn. Soc. Bot. Jour. 25: 140. 1889.—*Stereum nicaraguense* Berk. & Curtis, Am. Acad. Arts & Sci. Proc. 4: 123. 1853; Sacc. Syll. Fung. 6: 567. 1888.—*S. nicaraguae* Berk. & Curtis in Masee, Linn. Soc. Bot. Jour. 27: 183. 1890.—An *Hymenochaete pallida* Cooke & Masee, Linn. Soc. Bot. Jour. 27: 97. 1890? See Patouillard, Myc. Soc. Fr. Bul. 10: 78. 1894, and Burt, Ann. Mo. Bot. Gard. 5: 367. 1918.

Illustrations: Cooke, Grevillea 8: pl. 124. f. 9; Australian Fungi, pl. 11. f. 82.

Type: in Kew Herb.

Fructification coriaceous-papery, thin, pliant, resupinate and widely effused, sometimes reflexed, rarely umbonate sessile,



Fig. 32. *S. papyrinum*. Section of hymenium $\times 488$, showing cystidia and paraphyses. From authentic specimen.

the upper side tomentose, concentrically sulcate, drying snuff-brown, weathering to cartridge-buff, the margin entire; hymenium even, velvety, snuff-brown to Benzo-brown; in structure 500–600 μ thick exclusive of the tomentose covering, composed of longitudinally and loosely interwoven, even-walled, pale-colored hyphae 3–3½ μ in diameter, which give their color to the fructification, the intermediate layer not dense on its upper side but grading into the

tomentum; no conducting organs present; cystidia rather few and scattered, heavily and coarsely incrustated on the peripheral half, conical, $30-75 \times 12-25 \mu$, usually colored under the incrustation, confined to the hymenium; slender, flexuous paraphyses $2\frac{1}{2} \mu$ in diameter are abundant in the hymenium; spores hyaline, even, $4\frac{1}{2}-8 \times 3-4 \mu$ —but few found.

Resupinate on under side of limbs over areas up to $25 \times 3\frac{1}{2}$ cm., and reflexed along both sides $1-2\frac{1}{2}$ cm.

On under side of fallen limbs of frondose species. Florida, West Indies, Mexico, Colombia, and Brazil. October to May. Probably common.

S. papyrinum belongs in the group with *S. umbrinum* and *S. albo-badium*; resupinate specimens of these species require examination of sectional preparations for accurate determination. The specimens which have been distributed by Ravenel and by Ellis in their exsiccati as *S. papyrinum* are *S. umbrinum*. In its reflexed stage, *S. papyrinum* is much more broadly reflexed than *S. umbrinum* and is concentrically sulcate; its cystidia are heavily incrustated and from 12 to 25μ in diameter by 30 to 75μ long, while those of *S. umbrinum* are much longer in proportion to their diameter and often can be followed from deep in the subhymenium, taper so gradually and bear so little incrustation, and are so uniformly colored that some mycologists have regarded them as setae, although they do not satisfy the definition of setae. The cystidia of *S. papyrinum* are concolorous with the hyphae under the incrustation. *S. albo-badium* has cystidia heavily incrustated but smaller than those of *S. papyrinum* and not colored.

On account of their structure, I have included in *S. papyrinum* the Cuban specimens listed by Berkeley & Curtis as *S. membranaceum*, for I find nothing to show that these specimens were ever compared with the type of the latter in Herb. Willdenow and collected on the Isle of Bourbon in the Indian Ocean; there is nothing in the original description of *S. membranaceum* to show that this may not be more closely related to *S. fasciatum* than to *S. papyrinum*. I have referred to *S. papyrinum*, as umbonate-sessile forms, the specimen from Nicaragua distributed in Smith, Central Am. Fungi, 94, and a collection from Cuba by Underwood & Earle, 1584, which are cited below; these speci-

mens have cystidia of the minimum dimensions given for the species and with less than the usual incrustation, as is the case with cystidia of the type of *S. nicaraguense*; perhaps these two specimens are *Hymenochaete pallida*.

Specimens examined:

- Exsiccati: Smith, Central Am. Fungi, 95 and 93 a and b, under the name *Stereum rufo-fulvum* (Mont.), and 94, under the name *S. purpureum*.
- Florida: Adams Key, Dade Co., *J. H. Small & C. A. Mosier*, 5364, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 71448); Miami, *W. H. Long*, 18310 (in Mo. Bot. Gard. Herb., 55442); Palm Beach, *R. Thaxter*, 16 (in Mo. Bot. Gard. Herb., 43927).
- Cuba: type, from Montagne (in Kew Herb.), and *C. Wright*, 274, and 240, both under the name *S. membranaceum* (both in Curtis Herb.); Alto Cedro, *L. M. Underwood & F. S. Earle*, 1481, 1492, 1584, comm. by N. Y. Bot. Gard. Herb.; Ceballos, *C. J. Humphrey*, 2726 (in Mo. Bot. Gard. Herb.); El Yunque Mt., Baracoa, *L. M. Underwood & F. S. Earle*, 364 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56714), and 739, 745, and 1233, comm. by N. Y. Bot. Gard. Herb.; Managua, *Earle & Murrill*, 32, comm. by N. Y. Bot. Gard. Herb.; San Diego de los Baños, *Earle & Murrill*, 264, 356, 362, 367, 380, all comm. by N. Y. Bot. Gard. Herb.
- Porto Rico: Espinosa, *J. A. Stevenson*, 2751 (in Mo. Bot. Gard. Herb., 5554).
- Jamaica: *A. E. Wight*, comm. by W. G. Farlow; Hope Gardens, *F. S. Earle*, 141, 165, 431, 494, all comm. by N. Y. Bot. Gard. Herb.; Port Maria, *F. S. Earle*, 467, comm. by N. Y. Bot. Gard. Herb.; Troy and Tyre, *W. A. Murrill & W. Harris*, 898, comm. by N. Y. Bot. Gard. Herb.; Westmoreland, *F. S. Earle*, 425A, comm. by N. Y. Bot. Gard. Herb.; San Juan, *F. S. Earle*, 62, comm. by N. Y. Bot. Gard. Herb.
- Mexico: Colima, *W. A. & E. L. Murrill*, 637, 648, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54583, 54584); Jalapa, *C. L. Smith*, in Smith, Central Am. Fungi, 93a; Orizaba, *W. A. & E. L. Murrill*, 748, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54655).

Nicaragua: *C. Wright*, 264, type of *S. nicaraguense* (in Curtis Herb.); Castillo Viejo, *C. L. Smith*, in Smith, Central Am. Fungi, 95; Ometepe, *C. L. Smith*, in Smith, Central Am. Fungi, 93b; San Juan del Norte, *C. L. Smith*, in Smith, Central Am. Fungi, 94.

Canal Zone: Gatun, *M. A. H.* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56715).

Colombia: Bonda, *C. F. Baker*, 26.

Brazil: Santo Anna da Chapada, Matto Grosso, *G. O. Malme*, 564, comm. by L. Romell.

61. *S. Earlei* Burt, n. sp.

Plate 6, fig. 61.

Type: in Burt Herb. and N. Y. Bot. Gard. Herb.

Fructification coriaceous-spongy, dry, effuso-reflexed, with the upper surface tomentose, snuff-brown, the margin entire; hymenium mouse-gray and somewhat pruinose in the older portion, snuff-brown and veined toward the margin; in structure with the intermediate layer 150 μ thick, composed of longitudinally interwoven, colored hyphae 3–4 μ in diameter, with the hymenial layer up to 200 μ thick, zoned, containing cystidia in all its portions; cystidia colored, heavily hyaline incrustated on the outer half, slender-pointed, 45–60 \times 5–12 μ , protruding up to 30 μ ; spores hyaline, even, 5–6 \times 3–3½ μ .

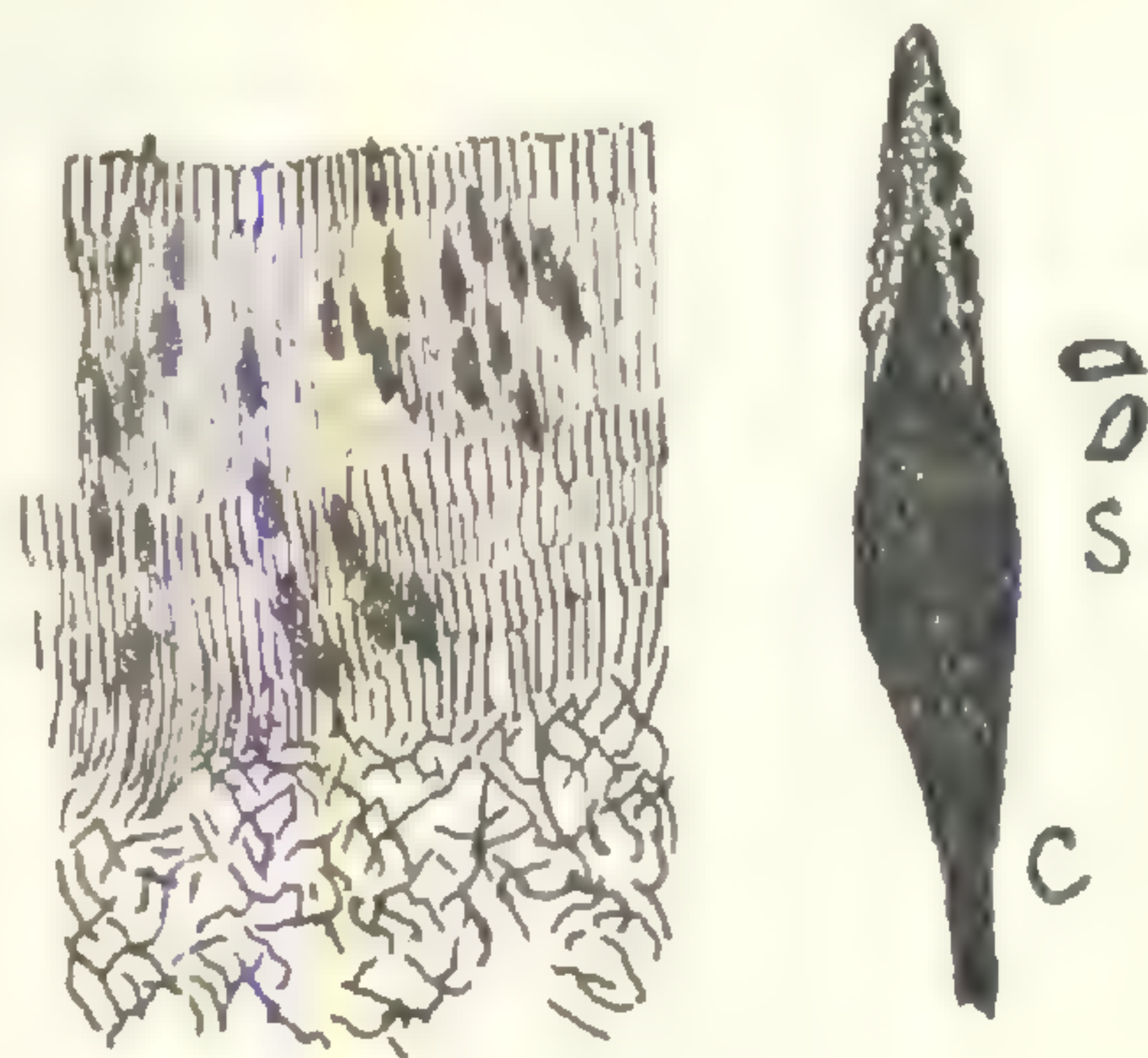


Fig. 33. *S. Earlei*. Section of type \times 68; cystidium, *c*, and spores, *s*, \times 488.

Reflexed portion up to 1 cm. broad; resupinate portion laterally confluent for 8 cm., but a strip only 1 cm. wide removed from the substratum.

In a wood pile. Hope Gardens, Jamaica. November.

Fructifications of this species have the general aspect of those of *S. papyrinum*, but are thinner, more compactly interwoven, with slenderer cystidia, and have the hymenial layer up to 200 μ thick and composed of several zones; cystidia are present in each of these zones, and those of the innermost zones do not reach to the surface of the hymenium. In *S. papyrinum*

the hymenium is a single layer of basidia, cystidia, and paraphyses. In the collector's note, the color is given as "violet purple edged with white," but colors of dried specimens are as given above.

Specimens examined:

Jamaica: Hope Gardens, *F. S. Earle*, 151, type, comm. by N. Y. Bot. Gard. Herb.

62. *S. Chailletii* Persoon, *Myc. Eur.* 1:125. 1822 (in ******Stereum* of *Thelephora*); Fries, *Epier.* 551. 1838; *Hym. Eur.* 642. 1874; *Sacc. Syll. Fung.* 6: 566. 1888; Bresadola, *I. R. Accad. Agiati Atti III.* 3: 106. 1897. Plate 6, fig. 62.

Thelephora Chailletii Pers. in Fries, *Elenchus Fung.* 1: 188. 1828.—*Xerocarpus ambiguus* Karsten, *Soc. pro Fauna et Flora Fennica Actis* 2¹: 38. 1881.—*Trichocarpus ambiguus* Karsten, *Finska Vet.-Soc. Bidrag Natur och Folk* 48: 407. 1889.—*Hymenochaete ambigua* Karsten in *Sacc. Syll. Fung.* 9: 230. 1891.—*Peniophora Atkinsonii* Ellis & Everhart, *Phila. Acad. Nat. Sci. Proc.* 1894: 324. 1894; *Sacc. Syll. Fung.* 11: 129. 1895.

Fructification coriaceous, nearly always resupinate, effused, occasionally reflexed, with upper surface tomentose, more or

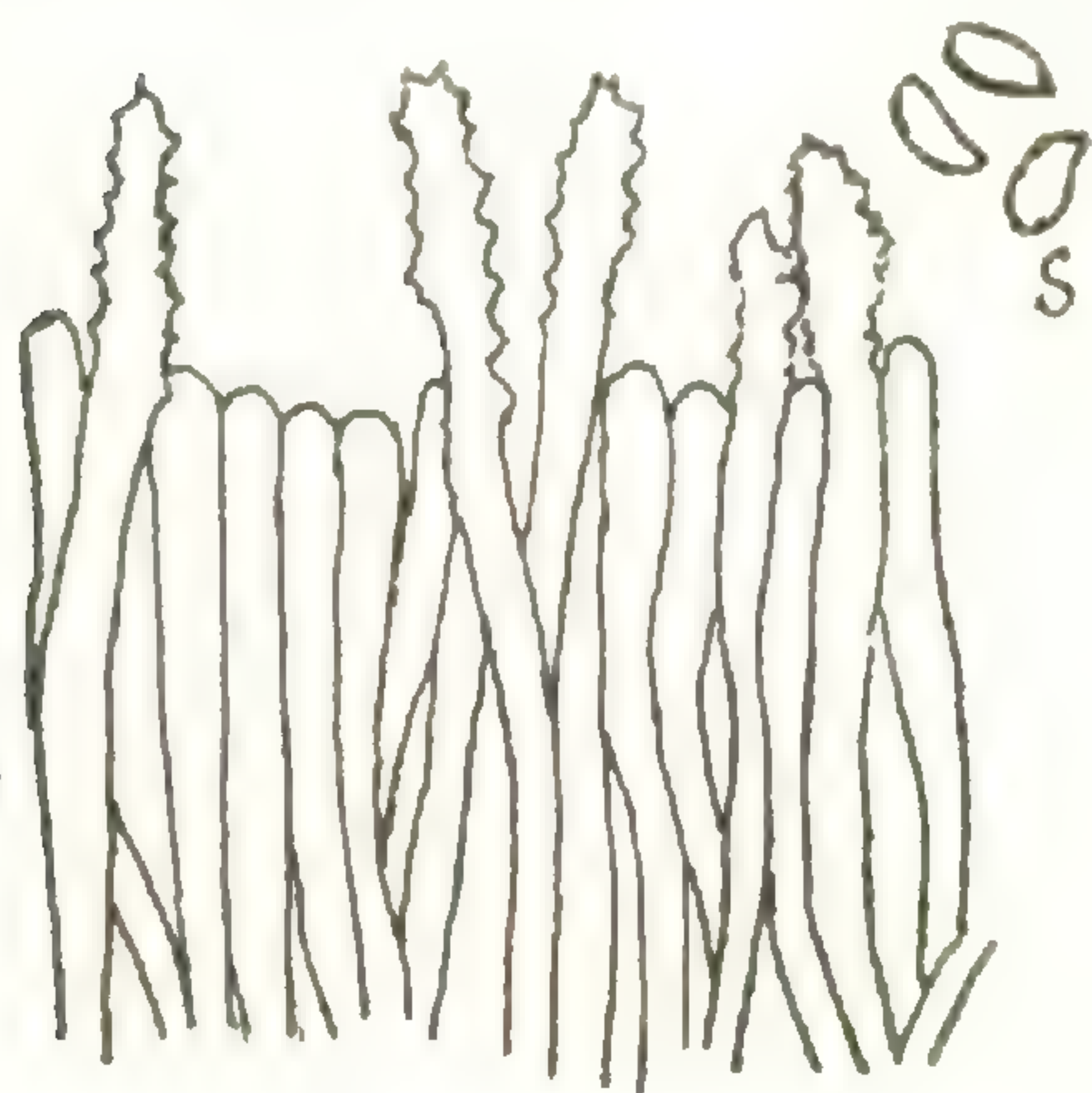


Fig. 34. *S. Chailletii*. Section of hymenium $\times 665$, showing paraphyses; spores, s.

less concentrically sulcate when well developed, hair-brown to clove-brown, the margin entire; hymenium rather uneven, not polished, avellaneous to wood-brown; in structure 300–600 μ thick, composed of somewhat longitudinally and not densely interwoven hyphae 3–4 $\frac{1}{2}$ μ in diameter, some of which are hyaline, thin-walled, and with deeply staining protoplasm, and many thick-walled, stiff, giving their color to the fructification, and

curving into the hymenium where they terminate in cystidia; cystidia slightly colored, roughened above, 50–120 \times 4–4 $\frac{1}{2}$ μ , protruding up to 20 μ , slender-pointed; spores white in spore collection, ellipsoidal, 5–6 \times 3–3 $\frac{1}{2}$ μ .

Wholly resupinate specimens $\frac{1}{2}$ –2 cm. in diameter, becoming laterally confluent over areas up to 15×2 cm.; reflexed portions 1–5 mm. broad—up to 2 cm. broad in European specimens.

On dead *Tsuga*, *Pseudotsuga*, *Abies*, *Picea*, *Larix*, *Thuja*, and *Cupressus*. Canada to New Jersey, in Wisconsin, in Idaho to British Columbia and Washington, and in New Mexico at altitude 7500 ft. Occurs also in Europe. Probably throughout the year but most collections dated July to October. Infrequent.

S. Chailletii occurs just often enough reflexed so that an observant collector will soon locate his gatherings correctly in *Stereum*. It is noteworthy by its colored cystidia of the same type as those of *S. umbrinum* but of only half the diameter of those of the latter, and by its occurrence on conifers of the species named above, and by restriction in geographic range to the northern United States and southern Canada and the Rocky Mountain plateau. The avellaneous, somewhat velvety hymenium is so uniform in appearance that when once learned this species may usually be recognized thereafter at sight.

Specimens examined:

Exsiccati: Ell. & Ev., N. Am. Fungi, 2904, under the name *Hymenochaete simulans* Ell. & Ev., n. sp., but description does not seem to have been published; Krieger, Fungi Sax., 1202.

Norway: Christiania, *M. N. Blytt*, determined by E. Fries (in Herb. Fries).

Finland: Merimason, *P. A. Karsten*, authentic specimen of *Trichocarpus ambiguus*.

Sweden: Stockholm, *L. Romell*, 24, 25, 341, all under the name *Stereum abietinum*.

France: Arnac, Aveyron, *A. Galzin*, unnumbered spec. and 17948, comm. by H. Bourdot, 7926, and unnumbered respectively.

Switzerland: Sachs, *W. Krieger*, in Krieger, Fungi Sax., 1202.

Italy? or perhaps Hungary?: locality not given, *G. Bresadola*.

Canada: Cow's Swamp, *J. Macoun*, 115; Dow's Swamp, *J. Macoun*, 249 in part.

Ontario: Ottawa, *J. Macoun*, 57.

Vermont: Ripton, *E. A. Burt*, two collections.

New York: Beaver River, Adirondack Mts., *G. F. Atkinson*, Bot. Dept. of Cornell Univ., 4607; Ithaca, *G. F. Atkinson*, 14189; Syracuse, *G. F. Atkinson*, 677, part of type of *Peniophora Atkinsonii*.

New Jersey: Newfield, *J. B. Ellis*, in *Ell. & Ev.*, N. Am. Fungi, 2904.

Wisconsin: *M. C. Jensen*, comm. by *C. J. Humphrey*, 2502 (in *Mo. Bot. Gard. Herb.*, 5060).

Idaho: Coolin, *J. R. Weir*, 11133, 11527, 11940 (in *Mo. Bot. Gard. Herb.*, 56717, 56722, 56718); Kaniksu National Forest, Priest River, *J. R. Weir*, 65, 110 (the latter in *Mo. Bot. Gard. Herb.*, 13272).

British Columbia: Kootenai Mts., near Salmo, *J. R. Weir*, 482, 510, 513 (in *Mo. Bot. Gard. Herb.*, 18282, 3771, 1739); Sidney, *J. Macoun*, 81 (in *Mo. Bot. Gard. Herb.*, 5887); Squamish, *J. Macoun*, 533 (in *Mo. Bot. Gard. Herb.*, 55186).

Washington: Bellingham, *J. R. Weir*, 7559 (in *Mo. Bot. Gard. Herb.*, 55467, 55790); Stanwood, *C. J. Humphrey*, 7358 (in *Mo. Bot. Gard. Herb.*, 20103).

New Mexico: Tejano Experiment Station, near Albuquerque, *W. H. Long & P. W. Seay*, comm. by *W. H. Long*, 21313 (in *Mo. Bot. Gard. Herb.*, 54884).

63. *S. ferreum* Berk. & Curtis, *Linn. Soc. Bot. Jour.* 10: 332. 1868; *Sacc. Syll. Fung.* 6: 586. 1888; *Massee*, *Linn. Soc. Bot. Jour.* 27: 197. 1890. Plate 6, fig. 63.

An *Stereum areolatum* Fries?

Type: in Kew Herb. and Curtis Herb.

Fructifications corky, effused, usually resupinate, sometimes becoming barely reflexed on the upper side and there drab,



Fig. 35. *S. ferreum*. Section of hymenial region of type, $\times 488$. Shows rough, colored cystidia.

nearly even; hymenium somewhat colliculose, not shining, cinnamon-drab to drab; in structure up to $1100\ \mu$ thick, with the intermediate layer $500\ \mu$ thick, bordered by a darker zone next to substratum and composed of colored, thick-walled, somewhat ascending, interwoven hyphae $3-3\frac{1}{2}\ \mu$ in diameter; hymenial layer up to $600\ \mu$ thick, containing in all parts innumerable incrusted cystidia, minutely rough, either colored throughout or colored under the incrustation, $20-25 \times 5-7\ \mu$, protruding up to $6\ \mu$; spores hyaline, even, globose, $4\ \mu$ in diameter, but few found.

Fructifications 4–8×1–2 cm., margin reflexed 1 mm.

On bark of fibrous structure of an unrecorded species. Cuba and Jamaica. Rare.

S. ferreum may be recognized by its resupinate, drab fructifications, rarely having a narrowly pileate margin, and by the thick hymenial layer containing innumerable small colored cystidia which at the surface of the hymenium have the colorless incrustation roughened. So few spores were observed that it may be they were foreign spores. *S. ferreum* is at least closely related to *S. areolatum*, a European species occurring on *Taxus*, and I have been inclined to regard it as not specifically distinct from the latter, but we do not know yet that *S. ferreum* occurs on *Taxus* or a related genus; if not a strictly tropical species but a synonym of *S. areolatum*, the lack of a northern range in eastern United States is at variance with species common to Europe and North America.

Specimens examined:

Cuba: *C. Wright*, 199, type (in Kew Herb.).

Jamaica: Cinchona, *W. A. & E. L. Murrill*, 458, comm. by N. Y. Bot. Gard. Herb.; Sir John Peak, *W. A. Murrill*, 803, comm. by N. Y. Bot. Gard. Herb.

64. *S. cinerascens* (Schw.) Masee, Linn. Soc. Bot. Jour. 27: 179. 1890. Plate 6, fig. 64.

Thelephora cinerascens Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 167. 1832.—*Hymenochaete cinerascens* (Schw.) Léveillé, Ann. Sci. Nat. Bot. III. 5: 152. 1846; Morgan, Cincinnati Soc. Nat. Hist. Jour. 10:197. 1888.—*Peniophora cinerascens* (Schw.) Sacc. in Sacc. Syll. Fung. 6: 646. 1888.—*P. Schweinitzii* Masee, Linn. Soc. Bot. Jour. 25: 145. 1889.—*Corticium aschistum* Berkeley & Curtis, Am. Acad. Arts & Sci. Proc. 4: 123. 1858.—*Peniophora Berkeleyi* Cooke, Grevillea 8: 20. pl. 122. f. 4. 1879; Sacc. Syll. Fung. 6: 642. 1888; Masee, Linn. Soc. Bot. Jour. 25: 144. 1889.—*Stereum moricola* Berkeley, Grevillea 1: 162. 1873; Sacc. Syll. Fung. 6: 567. 1888.—*Peniophora moricola* (Berk.) Masee, Linn. Soc. Bot. Jour. 25: 141. 1889.—*Stereum dissitum* Berkeley, Grevillea 1: 164. 1873.—*Peniophora dissita* (Berk.) Cooke, Grevillea 8: 150. 1880; Sacc. Syll. Fung. 6: 645. 1888; Masee, Linn. Soc.

Bot. Jour. 25: 143. 1889.—*Corticium ephesium* Berk. & Curtis, Grevillea 1: 178. 1873; Sacc. Syll. Fung. 6: 618. 1888.—*Peniophora ephesia* (Berk. & Curtis) Masee, Linn. Soc. Bot. Jour. 25: 151. 1889.—*Stereum neglectum* Peck, N. Y. State Mus. Rept. 33: 22. 1880.—*Peniophora neglecta* Peck, N. Y. State Mus. Rept. 40: 76. 1887.—*P. occidentalis* Ellis & Everhart, Torr. Bot. Club Bul. 24: 277. 1897; Sacc. Syll. Fung. 14: 224. 1900.—*Lloydella occidentalis* (Ell. & Ev.) v. Höhn. & Litsch. K. Akad. Wiss. Wien Sitzungsber. 116: 791. 1907.—*Stereum purpurascens* Lloyd, Myc. Writ. 4. Letter 53: 14. 1914.

Illustrations: Cooke, Grevillea 8: pl. 122. f. 4. 1879.

Type: in Herb. Schweinitz, Curtis Herb., and Kew Herb.

Fructifications coriaceous, often resupinate and effused, sometimes reflexed, with upper surface strigose-hairy, concentrically sulcate, warm buff to pinkish buff, weathering gray, often laterally confluent, the margin entire; hymenium minutely bristly with the cystidia, even, drying pinkish buff to drab; in structure 400–600 μ thick excluding the hairy covering, with the intermediate layer composed of longitudinally interwoven, thick-walled hyphae 4–4½ μ in diameter; cystidia large, incrustated, thick-walled, often brownish at the base, conical, 100–150 \times 12–20 μ , emerging up to 40–70 μ ; spores white in spore collection, even, 10–12 \times 6 μ , somewhat flattened on one side.

Resupinate portions 1–10 \times 1–2½ cm.; reflexed margin 2–8 mm. broad.

On logs and fallen limbs of *Ulmus*, *Tilia*, *Robinia*, *Morus*, etc. Canada to Texas, westward to California, and in Mexico, Cuba, and Brazil. Common. June to February.

Fully developed specimens of *S. cinerascens* may be recognized by their narrowly reflexed, strigose-hairy pileus and hymenium somewhat pruinose with the large, bristly, colorless cystidia. In sectional preparations, these cystidia are usually slightly colored at the base and more numerous and larger than in any other North American *Stereum*; the spores are very large also.

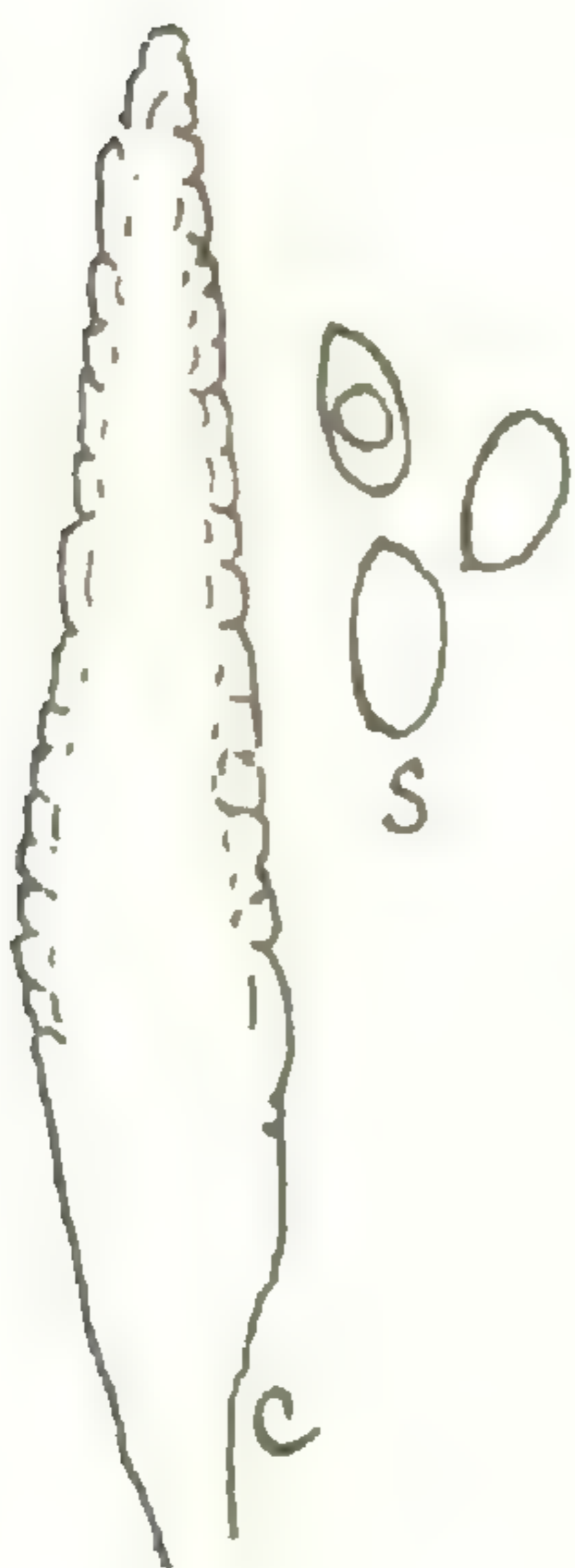


Fig. 36.
S. cinerascens.
Cystidium, c, and
spores, s, \times 488.

Wholly resupinate specimens have merely a superficial resemblance to *Peniophora*, for they are loosely attached to the substratum by the layer of loosely arranged, coarse hairs which forms the strigose covering of the upper surface of a reflexed specimen; the intermediate layer is well developed in resupinate specimens, and the cystidia and spores are the same as in reflexed specimens. It is surprising that a species so common and so marked in its microscopical characters should have seemed new so many times.

Specimens examined:

- Exsiccati: Bartholomew, *Fungi Col.*, 2337, 4648; Ell. & Ev., *N. Am. Fungi*, 2314, type distribution of *Peniophora occidentalis*; Shear, *N. Y. Fungi*, 313.
- Canada: *J. Macoun*, 45, 68, and another specimen comm. by J. B. Ellis, under the name *Peniophora occidentalis*; Lower St. Lawrence valley, *J. Macoun*, 33, 34, 79.
- Quebec: Hull, *J. Macoun*, *Nat. Hist. Surv. of Canada*, 359, and *J. Macoun*, 52; Ironsides, *J. Macoun*, 282.
- Ontario: Guelph, *J. H. Faull*, *Univ. Toronto Herb.*, 669 (in *Mo. Bot. Gard. Herb.*, 44916); Jefferson, *G. H. Graham*, *Univ. Toronto Herb.*, 673 (in *Mo. Bot. Gard. Herb.*, 44922); Ottawa, *J. Macoun*, 234; Toronto, *J. H. Faull*, *Univ. Toronto Herb.*, 651 (in *Mo. Bot. Gard. Herb.*, 44947).
- Vermont: Middlebury, *E. A. Burt*, six collections.
- Massachusetts: *W. G. Farlow*, two collections.
- New York: Alcove, *C. L. Shear*, 1312, and in Shear, *N. Y. Fungi*, 313; Cayuga Lake Basin, *G. F. Atkinson*, 3020, 8023, J; Greenbush, *C. H. Peck* (in *N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb.*, 56020); Ithaca, *C. J. Humphrey*, 261, and a specimen comm. by G. F. Atkinson, *Van Hook*, comm. by G. F. Atkinson, 7988; Knowersville, *C. H. Peck* (in *N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb.*, 55755); Syracuse, *L. M. Underwood*, 5 (in *N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.*, 56709); Verona, *C. H. Peck*, type of *Stereum neglectum* (in *N. Y. State Mus. Herb.*, and perhaps a duplicate in *Mo. Bot. Gard. Herb.*, 55754).
- Pennsylvania: Bethlehem, *Schweinitz*, type (in *Herb. Schweinitz, Curtis Herb.*, and *Kew Herb.*).
- South Carolina: *Curtis Herb.*, 5997, type of *Stereum moricola* (in *Kew Herb.*).

- Georgia: Atlanta, *E. Bartholomew*, 5694 (in Mo. Bot. Gard. Herb., 44220), and in Bartholomew, Fungi Col., 4648.
- Florida: Cocoanut Grove, *R. Thaxter*, 95 (in Mo. Bot. Gard. Herb., 43922); Miami, *W. H. Long*, 12951 (in Mo. Bot. Gard. Herb., 55102); Totten Key, *P. H. Rolfs*.
- Alabama: *Peters*, 923, type of *Corticium ephedrium*, 1004, 1007 (in Curtis Herb., 6050, 6088, and 6089 respectively, and in Kew Herb.).
- Texas: *C. Wright*, Curtis Herb., 3903, type of *Stereum dissitum* (in Kew Herb., and probably a co-type in Burt Herb., and U. S. Dept. Agr. Herb.).
- Michigan: Ann Arbor, *C. H. Kauffman*, 25; New Richmond, *C. H. Kauffman*, 64 (in Mo. Bot. Gard. Herb., 19651).
- Ohio: Cincinnati, *A. P. Morgan*, comm. by Lloyd Herb., 2590, and *A. P. & S. V. Morgan*, comm. by U. S. Dept. Agr. Herb., under the name *Hymenochaete imbricatula* as determined by Morgan; Linwood, *C. G. Lloyd*, 3553, 02835.
- Indiana: Hibernian Mills, *Whetzel & Reddick*, comm. by D. Reddick, 2.
- Minnesota: Cass Lake, *J. R. Weir*, 324 (in Mo. Bot. Gard. Herb., 6968); Clearwater Lake, *F. Weiss*, 4 (in Mo. Bot. Gard. Herb., 56634); Wright Co., *F. Weiss* (in Overholts Herb., 5367).
- Iowa: Webster, *O. M. Oleson*, 437 (in Mo. Bot. Gard. Herb., 44060); Woodbine, *C. J. Humphrey & C. W. Edgerton*, comm. by C. J. Humphrey, 6535 (in Mo. Bot. Gard. Herb., 14042).
- Missouri: Creve Coeur, *P. Spaulding* (in Mo. Bot. Gard. Herb., 5137); Upper Creve Coeur, *E. A. Burt* (in Mo. Bot. Gard. Herb., 56711).
- Arkansas: Fordyce, *C. J. Humphrey*, 5778.
- Nebraska: Lincoln, *C. L. Shear*, 1052; Pawnee City, *C. L. Shear*, 1016.
- Kansas: Louisville, *E. Bartholomew*, in Bartholomew, Fungi Col., 2337; Rooks Co., *E. Bartholomew* (in Burt Herb. and Mo. Bot. Gard. Herb., 5011).
- Montana: *F. W. Anderson*, in Ell. & Ev., N. Am. Fungi, 2314.
- California: Bear Valley, near Olema, *M. A. H.* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56591); Berkeley,

H. A. Lee, comm. by *W. A. Setchell*, 1020 (in *Mo. Bot. Gard. Herb.*, 44304).

Mexico: Xuchiles, near Cordoba, *W. A. & E. L. Murrill*, 1181, 1213, comm. by *N. Y. Bot. Gard. Herb.* (in *Mo. Bot. Gard. Herb.*, 54590, 54591).

Nicaragua: *C. Wright*, 274, type of *Corticium aschistum* and *Peniophora Berkeleyi* (in *Curtis Herb.*).

Cuba: *C. G. Lloyd*, 428 (in *Mo. Bot. Gard. Herb.*, 55157); Alto Cedro, *Earle & Murrill*, 515 (in *N. Y. Bot. Gard. Herb.* and *Mo. Bot. Gard. Herb.*, 56291); Havana, *Bro. Leon*, comm. by *J. R. Weir*, 10188 (in *Mo. Bot. Gard. Herb.*, 56216).

Jamaica: *Chester Vale*, *W. A. & E. L. Murrill*, 343, comm. by *N. Y. Bot. Gard. Herb.*

Brazil: Matto Grosso, Santa Anna da Chapada, *G. V. Malme*, 572, comm. by *L. Romell*.

65. *S. magnisporum* Burt, n. sp.

Plate 6, fig. 65.

Type: in Burt Herb.

Fructifications coriaceous-gelatinous, thin, resupinate, becoming confluent, free all around, with margin reflexed on the upper side, probably white, drying pale pinkish buff, hoary, the margin white, entire; hymenium even or with one or two broad veins, setulose with the large cystidia, drying pinkish buff; in structure 300 μ thick when dry, swelling to 1200–1500 μ thick when wet for sectioning, of gelatinous consistency, composed of loosely interwoven, hyaline hyphae 2 μ in diameter, not incrusted; hymenial layer not zonate, composed of large simple basidia 45–60 \times 15 μ , having 4 sterigmata 12 μ long, of hyaline, filiform, flexuous paraphyses 2–2½ μ in diameter, not exceeding the basidia, and of conical, incrusted cystidia 45–90 \times 12–15 μ , protruding up to 60 μ ; spores hyaline, even, 15–20 \times 12–14 μ .

Fructifications 2–6 mm. in diameter, laterally confluent for 15 mm., margin reflexed for 1–2 mm.

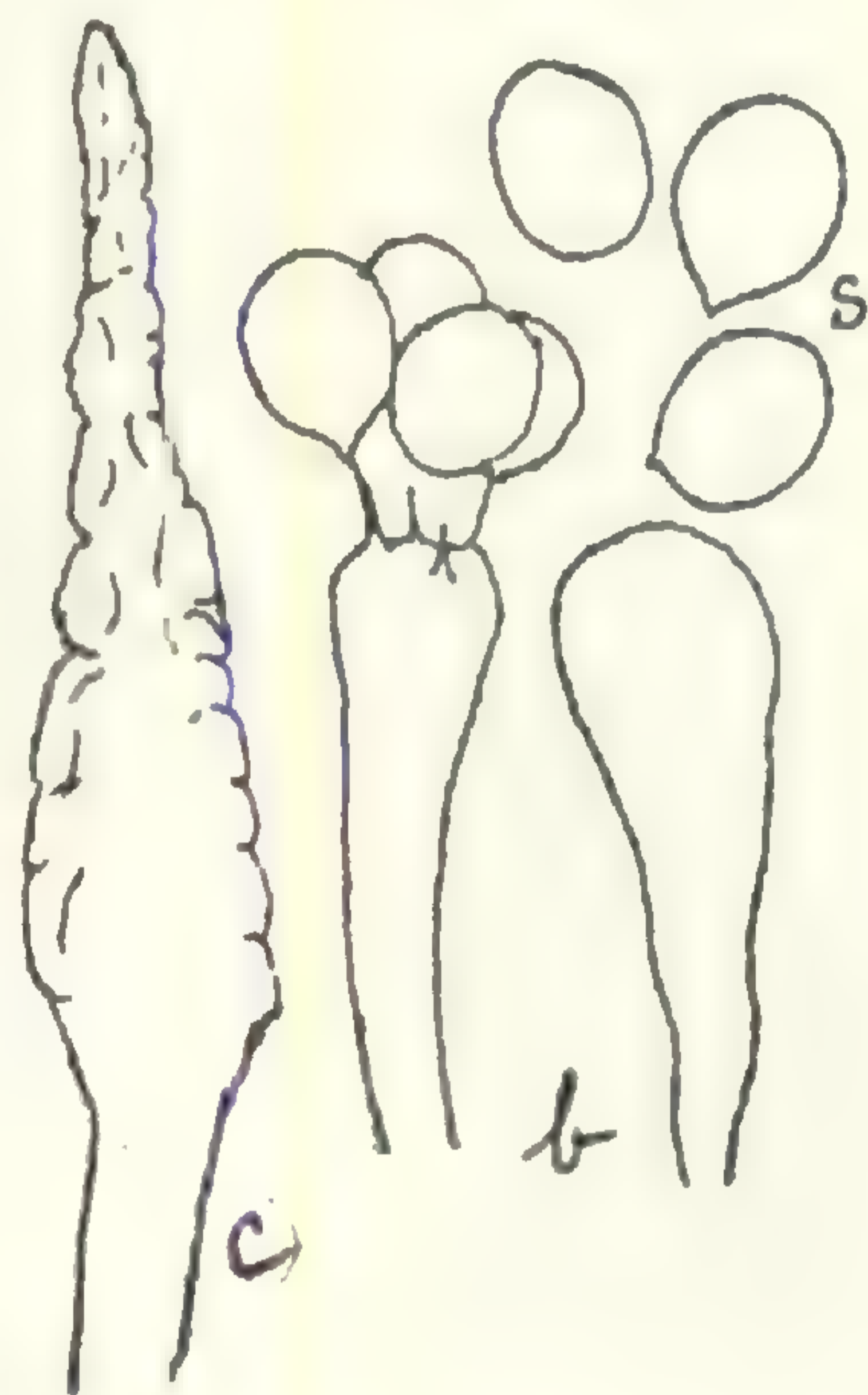


Fig. 37. *S. magnisporum*. Cystidium, *c*, basidia, *b*, and spores, *s*, \times 488. From type.

On dead limbs of a frondose species. Jamaica. December to January.

S. magnisporum may be recognized by its small, whitish fructifications, with narrowly reflexed or free margin, pale hymenium distinctly setulose with the large cystidia, and by the very large spores. The large spores and basidia show relation of *S. magnisporum* to *Aleurodiscus*, but the absence of granular matter or of any unusual character of the paraphyses leads to the belief that this species will usually be sought for among the Stereums.

Specimens examined:

Jamaica: Chester Vale, *W. A. & E. L. Merrill*, 328, type, comm. by N. Y. Bot. Gard. Herb.; Cinchona, *W. A. & E. L. Merrill*, 522, comm. by N. Y. Bot. Gard. Herb.

66. *S. spumeum* Burt, n. sp. Plate 6, fig. 66.

Corticium spumeum Berk. & Rav. in Curtis Herb. (in part); *Grevillea* 20: 13. 1891 (in part—nomen).—*C. ochroleucum*, "as resupinate ambient condition," Berk. & Curtis, *Grevillea* 1: 166. 1873, but not *Stereum ochroleucum* Fries.—Not *Corticium ochroleucum* var. *erimosum* Berk. & Curtis, *Grevillea* 1: 166. 1873.

Type: in Burt Herb.

Fructifications spongy-soft, effused, resupinate, separable, sometimes narrowly reflexed, the upper surface tomentose and becoming cartridge-buff to pinkish buff in the herbarium, the margin entire; in structure 400–1500 μ thick, composed of loosely interwoven, hyaline, thick-walled hyphae 3–4½ μ in diameter, sometimes nodose-septate, the intermediate layer not bordered on its upper side by a crust-like or colored zone; hymenium even, cream-buff to pinkish buff; no conducting organs; cystidia incrusted, 36–60 \times 9–12 μ , sometimes protruding up to 40 μ ; spores hyaline, even, 5–9 \times 3–4 μ .

Resupinate over areas 1–10 \times 1–5 cm., reflexed portion 1–4 mm. broad when present.

On bark and wood of dead beech, oak, and other frondose limbs. New York to Mexico. August to January. Rare.

S. spumeum is noteworthy by its narrowly reflexed pileus, spongy-soft throughout, and without differentiation of its sur-

face of soft, matted, interwoven hairs from the hyphae of the intermediate region, by its buff hymenium, and by its incrustated cystidia. These incrustated cystidia and different aspect of the fructifications afford sharp separation from *S. ochraceo-flavum*; *S. ochroleucum* and *S. rugosiusculum* have the general aspect of *S. spumeum* but both lack incrustated cystidia, and *S. rugosiusculum* has in its subhymenial region pyriform, vesicular organs. *S. spumeum* is so frequently resupinate or very narrowly reflexed that gatherings are likely to be referred to *Peniophora*.

Specimens examined:

New York: Hudson Falls, *S. H. Burnham*, 27 (in Mo. Bot. Gard. Herb., 54486).

Pennsylvania: *E. Michener*, 1864 (in Curtis Herb., under the name *Corticium giganteum*).

South Carolina: Aiken, on oak limbs, *H. W. Ravenel*, 1772 (in Curtis Herb., under the name *Corticium ochroleucum*, "formerly *C. spumeum*").

Louisiana: Baton Rouge, *Edgerton & Humphrey*; St. Martinville, *A. B. Langlois*, *E*, type

Mexico: Guernavaca, *W. A. & E. L. Merrill*, 405, 413, 414, 498, 503, 520, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54520-54523, 56685, 55524); Cordoba, *W. A. & E. L. Merrill*, 1214, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54592).

67. *S. erumpens* Burt, n. sp.

Plate 6, fig. 67.

Type: in Burt Herb.

Fructifications corky, rarely resupinate, usually bursting out from the inner bark as small pezizaeform, orbicular disks or cups with elevated black margins and cinereous or pallid neutral gray hymenium; these fructifications may become crowded as if confluent, and then broken up into frustules and remain attached by the under side to the substratum, or the margin on the upper side may grow outward so as to form umbonate, sessile pilei attached by the umbo and lower side, with the upper surface narrowly concentrically sulcate, mummy-brown to fuscous; hy-

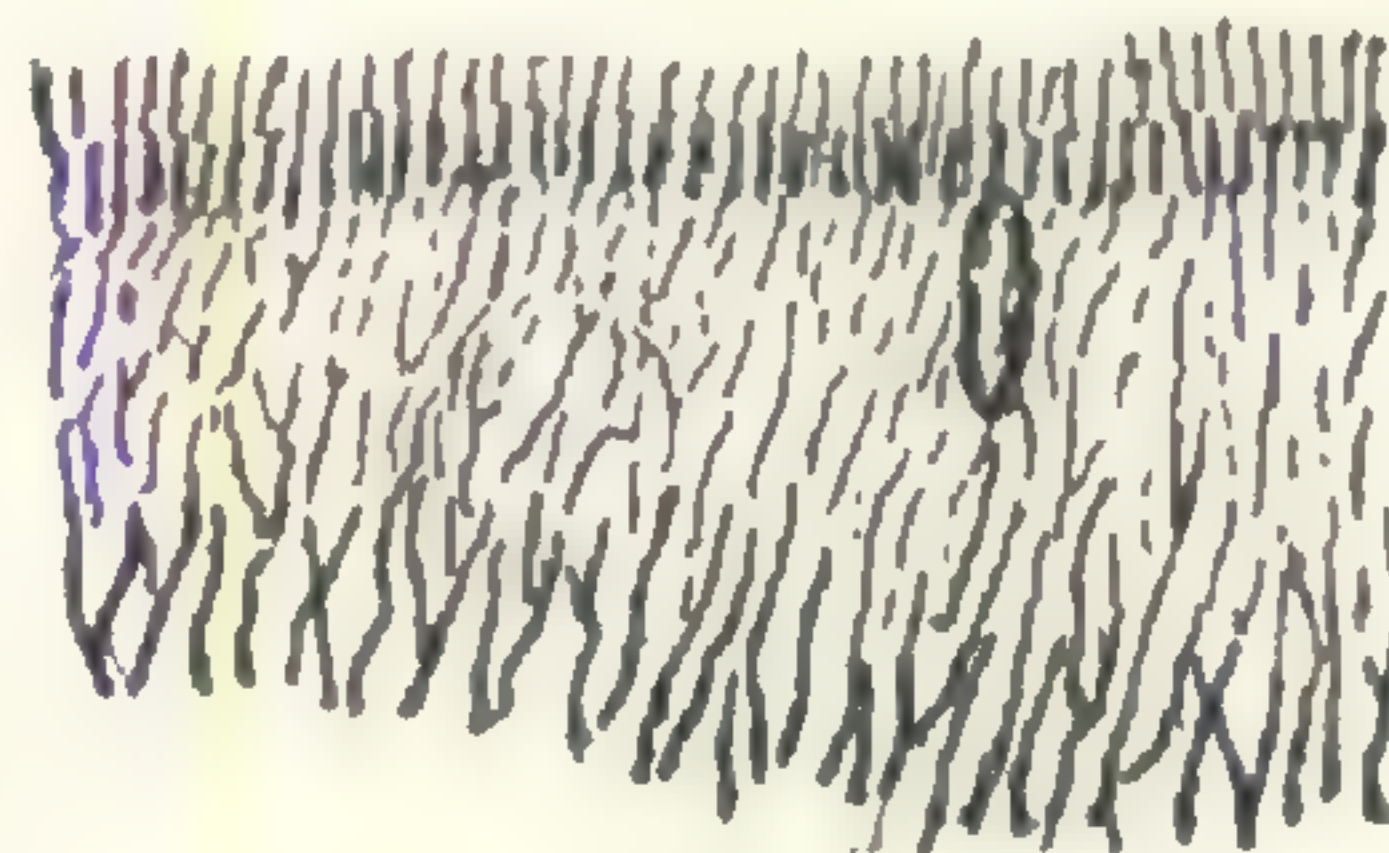


Fig. 38. *S. erumpens*.
Section of type, $\times 90$.

menium even or somewhat tubercular, pallid neutral gray; in structure 200–300 μ thick, composed of ascending, densely interwoven hyphae both colored and hyaline, the former $3\frac{1}{2}$ μ in diameter, with the tips arranged side by side in colored subhymenial zones, mark the 1–3 strata finally present; cystidia incrusted, cylindric, $30\text{--}60 \times 8\text{--}20$ μ , sometimes protruding up to 20 μ beyond the hymenium, starting from all parts of the fructification; spores hyaline, even, $5\text{--}7 \times 1\frac{1}{2}\text{--}2\frac{1}{2}$ μ .

Fructifications 1–2 $\frac{1}{2}$ mm. in diameter, reflexed 1–2 mm.

On dead limbs of alder, chestnut, willow, and other frondose species. Rhode Island to Alabama and westward to Washington and Oregon. March to January. Occasional.

S. erumpens combines the characters of *S. versiforme* and *Peniophora cinerea*; it is more constantly and distinctly reflexed than *S. versiforme*, always has a gray hymenium, and has quite a different mode of origin from the latter. In the type small blackish bodies burst out from the bark, open at the tip, disclosing whitish hymenium, and then grow to mature condition. Specimens at hand do not show how such a large resupinate fructification as that collected by E. T. and S. A. Harper, No. 819, cited below, does arise, and I may be wrong in referring the specimen to *S. erumpens*. An important microscopical detail of *S. erumpens* is the narrow olivaceous zone of colored hyphal tips at the very base of the basidia of the hymenium.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 720, under the name *Corticium quercinum* var. *scutellatum*.

Rhode Island: Lincoln, *F. W. Collins*.

New York: East Galway, *E. A. Burt*; Ithaca, *C. J. Humphrey*, 2568 (in Mo. Bot. Gard. Herb., 20784); Karner, *H. D. House* (in N. Y. State Mus. Herb. and Mo. Bot. Gard. Herb., 55210); New Scotland, *C. H. Peck* (in N. Y. State Mus. Herb., T 28, and Mo. Bot. Gard. Herb., 54658).

New Jersey: Newfield, *J. B. Ellis*, in Ellis, N. Am. Fungi, 720.

Maryland: Takoma Park, *C. L. Shear*, 959.

District of Columbia: North Takoma, *C. L. Shear*, 1043, type.

Georgia: Raleigh, *R. M. Harper*, 2037b, comm. by P. L. Ricker, and (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 42597).

Alabama: Auburn, *F. S. Earle*, 2301 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56292).

Indiana: Scottsburg, *J. R. Weir*, 5836 (in Mo. Bot. Gard. Herb., 55462).

Illinois: Glencoe, *E. T. & S. A. Harper*, 819, 937.

Arkansas: Fayetteville, *R. R. Rosen*, comm. by L. O. Overholts, 5117 (in Mo. Bot. Gard. Herb., 56358).

Montana: Missoula, *J. R. Weir*, 354 (in Mo. Bot. Gard. Herb., 9435).

Washington: Brewerton, *E. Bartholomew*, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 4939).

Oregon: Grants Pass, *J. R. Weir*, 8701 (in Mo. Bot. Gard. Herb., 36742).

68. *S. sulcatum* Burt in Peck, N. Y. State Mus. Rept. 54: 154. 1901; Lloyd, Myc. Writ. 5. Notes 44: 619. *text f. 878*. 1917. Plate 6, fig. 68.

Illustrations: Lloyd, *loc. cit.*

Type: in Burt Herb., N. Y. State Mus. Herb., and Bresadola Herb.

Fructification corky, rigid, resupinate or effuso-reflexed, with the reflexed part becoming glabrous, bister, irregular, deeply and concentrically sulcate; hymenium uneven or somewhat tubercular, not polished, drying between light buff and pinkish buff, assuming a reddish color where bruised; in structure 600–1500 μ thick, with the intermediate layer bordered by a dark dense zone on its upper side, and composed of very densely and longitudinally interwoven, hyaline hyphae 3–3½ μ in diameter, the hymenial layer becoming zonate or stratose; no colored conducting organs; cystidia incrusted, 30–50 × 8–12 μ ; spores white in spore collection, even, subglobose, 4–6 × 3–5 μ .

Confluent over areas 3–15 × 1–8 cm.; reflexed margin 3–10 mm. broad.

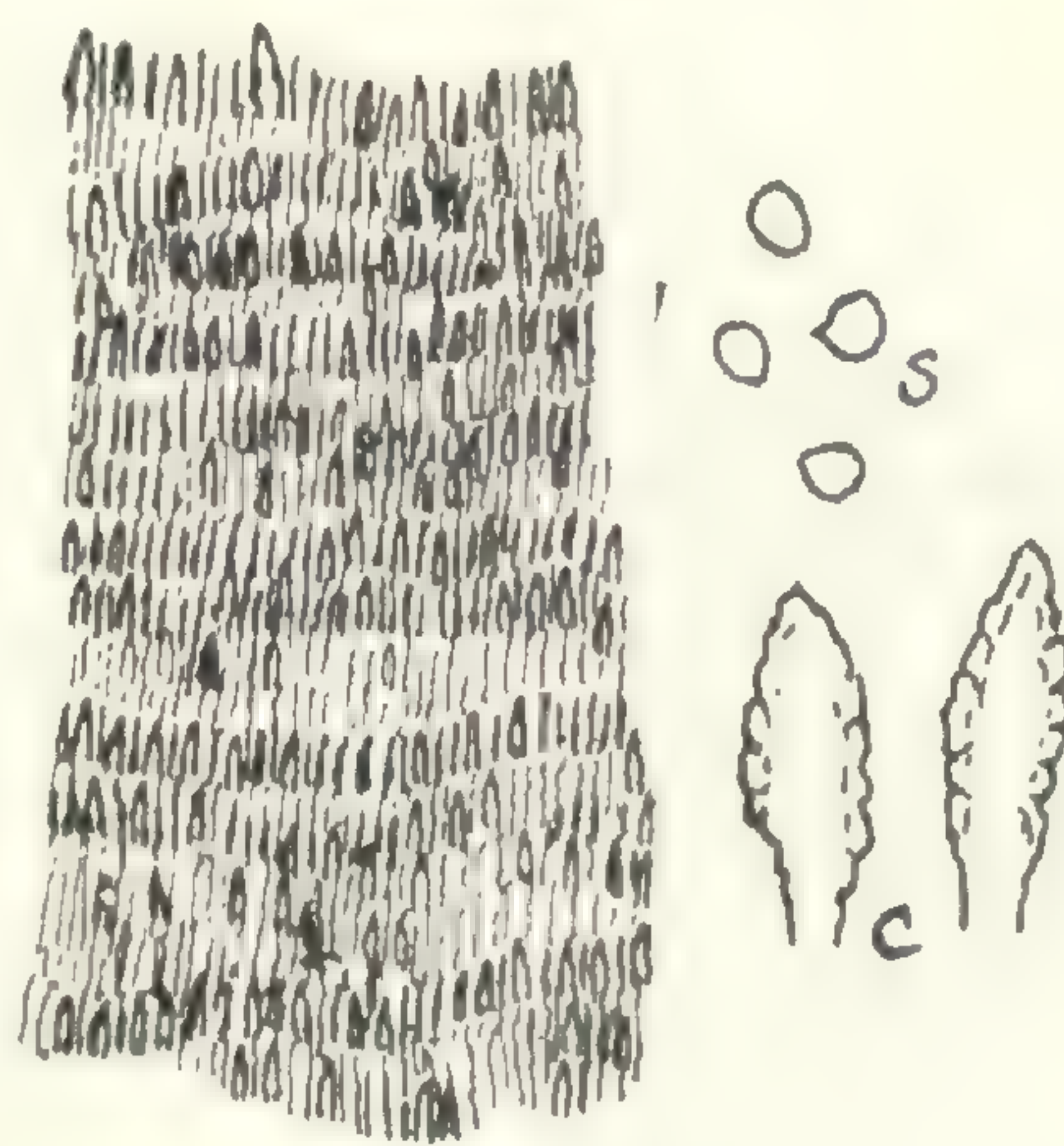


Fig. 39. *S. sulcatum*. Section of hymenial region × 90; cystidia, c, and spores, s, × 665.

On logs and stumps of *Tsuga*, *Abies*, *Picea*, *Taxodium*, *Pseudotsuga*, and *Larix*. Canada to Texas and westward to British Columbia and Washington. May to November. Frequent.

S. sulcatum may be recognized by its brown, deeply and sharply and concentrically sulcate pileus, ruddy hymenium, incrustated cystidia, and occurrence on conifers. Where the northern hemlock occurs it is usually on this species. *S. Chailletii* is found on conifers throughout the same northern geographical range, but is much thinner and does not have as large nor incrustated cystidia. In the older herbaria *S. sulcatum* is often found under the name *Stereum rugosum*, to which specimens were erroneously referred.

Specimens examined:

Exsiccati: Ell. & Ev., N. Am. Fungi, 1935, under the name *Stereum rugosum*; Ell. & Ev., Fungi Col., 217, under the name *S. rugosum*.

Canada: *J. Macoun*, 27, 32, 43; Lower St. Lawrence Valley, *J. Macoun*, 69a, 76.

Ontario: Ottawa, *J. Macoun*, 234, and in Ell. & Ev., N. Am. Fungi, 1935.

New Hampshire: North Conway, *L. O. Overholts* & *H. H. York*, comm. by *L. O. Overholts*, 5033 (in Mo. Bot. Gard. Herb., 56350).

New York: Floodwood, *E. A. Burt*, type; Ithaca, *G. F. Atkinson*, 2023, 2617, 2636, 5072, 7889, 19398, and *C. O. Smith*, comm. by *G. F. Atkinson*, 8032; North Elba, *C. H. Kauffman*, 7 (in Mo. Bot. Gard. Herb., 21821); Pompey, *L. M. Underwood*, in Ell. & Ev., Fungi Col., 217.

Louisiana: Litcher, *H. von Schrenk*, 26 (in Mo. Bot. Gard. Herb., 42637).

Texas: Houston, *H. W. Ravenel*, 113 (in U. S. Dept. Agr. Herb., under the herbarium name *Stereum tricolor*).

Wisconsin: Ladysmith, *C. J. Humphrey*, 1908 (in Mo. Bot. Gard. Herb., 42917).

West Virginia: comm. by *W. G. Farlow*.

Tennessee: Elkmont, *C. H. Kauffman*, 60 (in Mo. Bot. Gard. Herb., 16403).

Montana: Gallatin National Forest, Spring Hill, *G. G. Hedgcock*, comm. by *C. J. Humphrey*, 2164 (in Mo. Bot. Gard. Herb., 10399).

Idaho: Kaniksu National Forest, Priest River, *J. R. Weir*, 4, 29, 58, 74, 82, and 102 (the last in *Mo. Bot. Gard. Herb.*, 16029).

Canadian Rocky Mts.: Lake Louise, *J. Macoun*, 3; Lake O'Hara, *J. Macoun*, 7; Papiston Creek, *J. Macoun*, 8.

British Columbia: Yoho Valley, *J. Macoun*, 5.

Washington: Mt. Paddo, *W. N. Suksdorf*, 843, 844.

Oregon: Sumpter, *G. G. Hedgcock*, comm. by *C. J. Humphrey*, 2570 (in *Mo. Bot. Gard. Herb.*, 20460).

69. *S. subpileatum* Berk. & Curtis, *Hooker's Jour. Bot.* 1: 238. 1849; *Grevillea* 1: 163. 1873; *Sacc. Syll. Fung.* 6: 585. 1888; *Massee, Linn. Soc. Bot. Jour.* 27: 192. 1890; *Long, Jour. Agr. Res.* 5: 421. *pl.* 41. 1915. Plate 6, fig. 69.

Illustrations: *Jour. Agr. Res.* 5: *pl.* 41.

Type: in Curtis Herb. and Kew Herb.

Fructifications thick, corky, drying rigid, very hard, resupinate or effuso-reflexed, sometimes laterally confluent and attached by the umbos, with upper surface concentrically sulcate, somewhat zonate, tomentose, cinnamon-brown, the margin entire; hymenium even, light buff; in structure 800–1200 μ thick, with the intermediate layer bordered and connected with the tomentum by a denser and darker crust and bearing on the opposite side a hymenial layer which becomes multizonate; hyphae of intermediate layer colored, thick-walled, stiff, 3–3½ μ in diameter, densely and longitudinally arranged; cystidia incrusted, cylindric, 30–36 \times 7 μ , becoming colored where buried in older zones of the hymenium, at first sometimes slightly aculeate; spores hyaline, even, 4–5 \times 3 μ .

Fructifications with reflexed portion 1–6 cm. broad.

Perennial on logs of several species of *Quercus* causing a pock-

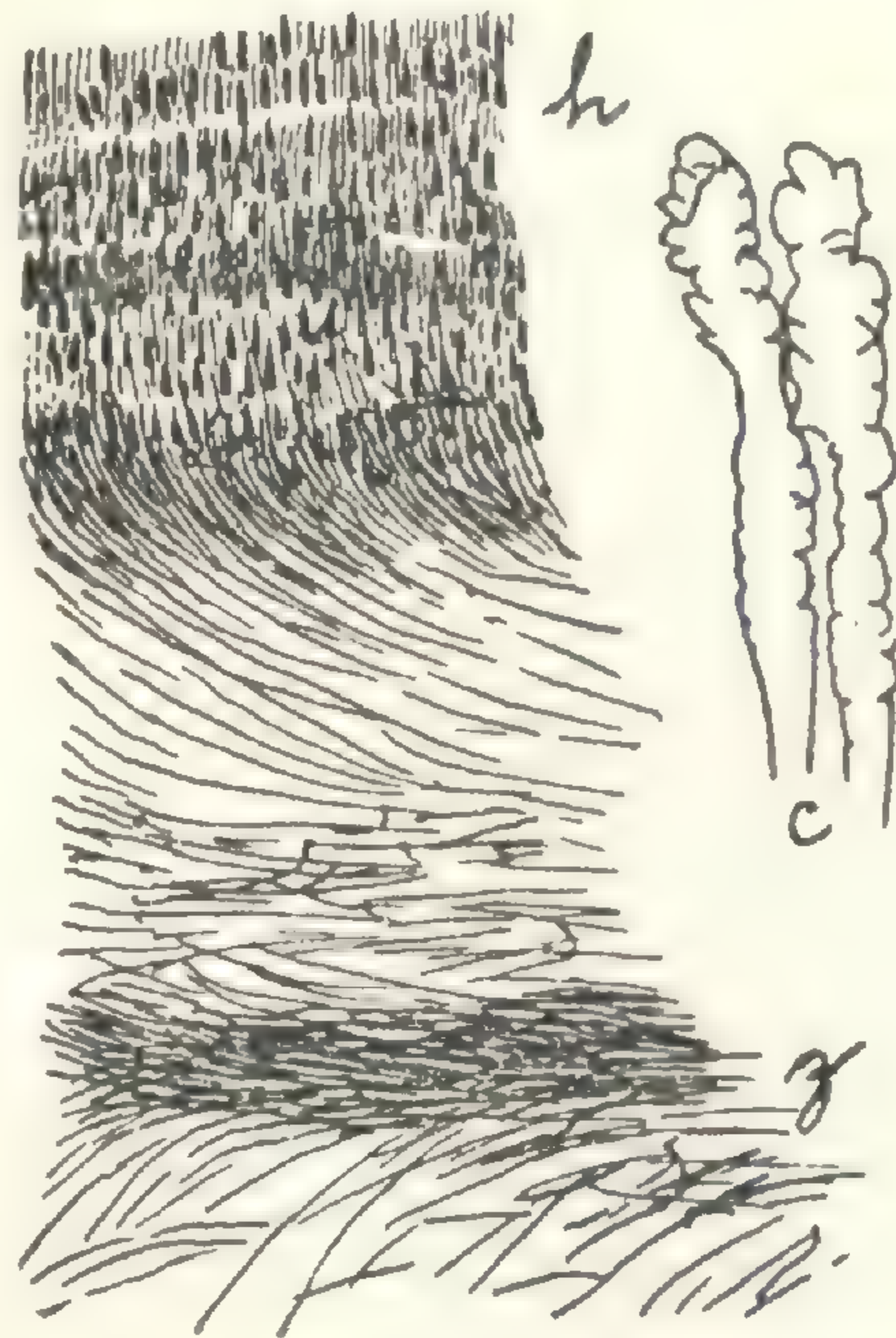


Fig. 40. *S. subpileatum*. Section \times 68; hymenium, *h*, crust-like zone, *z*, cystidia of type, *c*, \times 488.

eted or honeycomb heart rot. North Carolina and Ohio to Mexico, and in Cuba.

In general aspect *S. subpileatum* is not distinguishable from *S. sepium* and *S. insigne*; it is more commonly met with than these latter species and with them occurs on oak logs, is also tobacco-colored and sulcate above and has a whitish hymenium which differs from the other species of this group by containing cylindric, incrusted cystidia and only very rarely an occasional paraphysis with its outer portion of bottle-brush or aculeate form. Usually such paraphyses are not found in preparations of the hymenium of this species. Occasionally preparations may show young cystidia which are merely rough above or somewhat aculeate. One must not confuse *S. subpileatum* with the other species which have numerous and conspicuous bottle-brush paraphyses.

Specimens examined:

- Exsiccati: Ell. & Ev., Fungi Col., 917; Ravenel, Fungi Am., 219; Ravenel, Fungi Car. 1: 30; Smith, Cent. Am. Fungi, 146.
- North Carolina: Blowing Rock, *G. F. Atkinson*, 4183.
- South Carolina: Santee, *H. W. Ravenel*, type (in Curtis Herb., 1007); Society Hill (in Curtis Herb., 1062).
- Georgia: Vienna, *C. J. Humphrey*, 5228.
- Florida: *W. W. Calkins* (in U. S. Dept. Agr. Herb., Burt Herb., N. Y. Bot. Gard. Herb., and Mo. Bot. Gard. Herb., 56759), and in Ell. & Ev., Fungi Col., 917.
- Alabama: Auburn, *F. S. Earle & C. F. Baker* (in Burt Herb. and Mo. Bot. Gard. Herb., 5110); Montgomery Co., *R. P. Burke*, 31 (in Mo. Bot. Gard. Herb., 17137).
- Louisiana: St. Martinville, *A. B. Langlois*.
- Ohio: *A. P. Morgan* (in Lloyd Herb., 2607).
- Kentucky: Mammoth Cave, *C. G. Lloyd*, 2798.
- Missouri: Columbia, *B. M. Duggar*, 550; Marianna, *H. von Schrenk* (in Burt Herb. and Mo. Bot. Gard. Herb., 42837); Wicks, *L. O. Overholts*, 3161 (in Mo. Bot. Gard. Herb., 5713).
- Arkansas: *W. H. Long*, 12703, 18502 (in Mo. Bot. Gard. Herb., 44160, 44161).
- Texas: Jasper, *E. R. Hodson*, 325, comm. by P. L. Ricker.
- Mexico: Jalapa, *C. L. Smith*, in Smith, Cent. Am. Fungi, 146.

Cuba: *C. Wright*, 515, the *S. scytale* of *Fungi Cubenses* but not according to the type (in *Curtis Herb.*).

70. *S. sepium* Burt, n. sp.

Plate 6, fig. 70.

Type in Burt Herb.

Fructification corky, drying rigid, hard, resupinate, becoming broadly reflexed, with the upper surface concentrically sulcate, somewhat zonate, tomentose, sepia, the margin paler and entire; hymenium even, not shining, between light buff and avellaneous; in structure 600–1500 μ thick—up to 3 mm. thick in resupinate portion of Mexican specimens—, with the intermediate layer bordered and connected with the tomentum by a denser and darker zone and bearing on the opposite side a hymenial layer which becomes multizonate; hyphae of intermediate layer colored, thick-walled, densely and horizontally arranged, 3–3½ μ in diameter; cystidia incrusted, cylindric, 25–35 \times 7 μ , becoming colored where buried in the deeper zones of the hymenium; paraphyses of bottle-brush or aculeate form, numerous and conspicuous in the hymenial surface, cylindric, 12–25 \times 3–5 μ ; spores hyaline, even, 4 \times 2½ μ .

Probably resupinate over large areas, for fragments fractured on three sides are 6 cm. square; reflexed margin 2–4 cm. long, 6 cm. wide.

Under side of rotten logs of frondose species. Pennsylvania to Mexico and Colombia. Collected from July to December but probably perennial.

The few collections of *S. sepium* which have been observed have the upper surface of the pileus a little brighter colored than that of *S. subpileatum* and the hymenium more avellaneous, but I cannot certainly separate the former from the latter except by the very numerous and conspicuous bottle-brush paraphyses which are present, in addition to cystidia, in the hymenium of

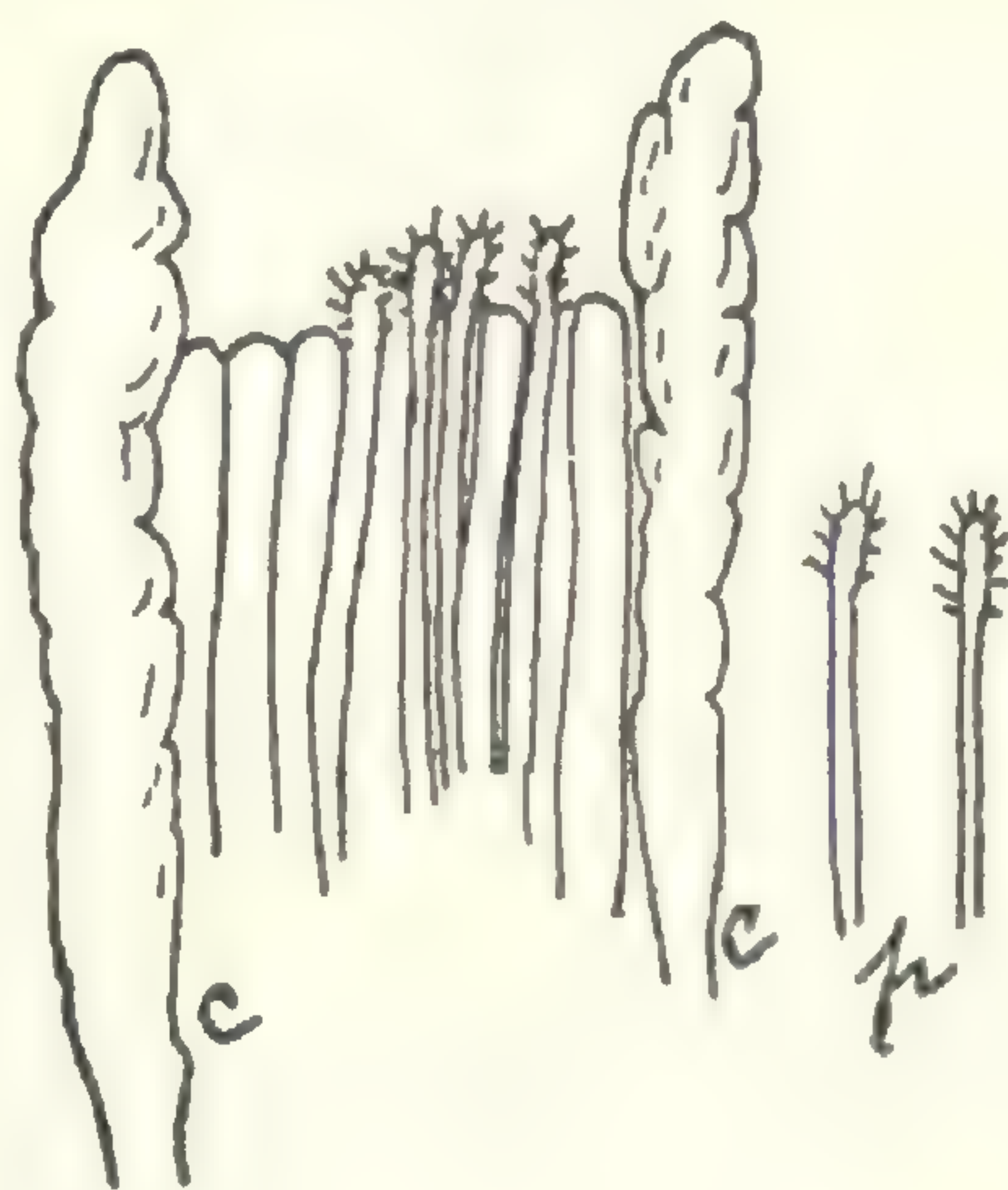


Fig. 41. *S. sepium*. Hymenium of type \times 665, showing cystidia, c, and bottle-brush paraphyses, p.

S. sepium. The specimens of Mexican collections cited below have larger size than those from the United States.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 1205, under the name *Stereum subpileatum*.

Pennsylvania: West Chester, *Everhart & Haines*, in Ellis, N. Am. Fungi, 1205.

North Carolina: Blowing Rock, *G. F. Atkinson*.

South Carolina: Clemson College, *P. H. Rolfs*, 1632.

Georgia: Vienna, *C. J. Humphrey*, 5229, type.

Mexico: Jalapa, *W. A. & E. L. Merrill*, 117, 188, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 11011, 54445), and 39 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56760).

Colombia: Bonda, *C. F. Baker*, 24, in Plants of Santa Marta, Colombia, under the name *Stereum illudens*.

71. *S. albobadium* (Schw.) Fries, *Epier.* 551. 1838; Morgan, *Cincinnati Soc. Nat. Hist. Jour.* 10: 195. 1888; Sacc. *Syll. Fung.* 6: 579. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 194. 1890. Plate 6, fig. 71.

Thelephora albobadia Schweinitz, *Naturforsch. Ges. Leipzig Schrift.* 1: 108. 1822 (in *C. Corticia*); *Am. Phil. Soc. Trans.* N. S. 4: 167. 1832; Fries, *Elenchus Fung.* 1: 189. 1828.—*T. albo-marginata* Schweinitz in Berkeley, *Hooker's London Jour. Bot.* 6: 324. 1847; *Lea's Cat. Plants Cincinnati*, 66. 1849; Sacc. *Syll. Fung.* 6: 539. 1888.—*Peniophora albo-marginata* (Schw.) Masee, *Linn. Soc. Bot. Jour.* 25: 144. 1889.—*Stereum bizonatum* Berkeley & Curtis, *Grevillea* 1: 163. 1873; Sacc. *Syll. Fung.* 6: 582. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 178. 1890.—*S. Coffearum* Berkeley & Curtis, *Linn. Soc. Bot. Jour.* 10: 332. 1868; Sacc. *Syll. Fung.* 6: 576. 1888.—*Hymenochaete paupercula* Berkeley & Curtis, *Linn. Soc. Bot. Jour.* 10: 334. 1868.—*Peniophora paupercula* (Berk. & Curtis) Cooke, *Grevillea* 8: 150. 1880; Sacc. *Syll. Fung.* 6: 645. 1888.

Type: I was unable to find the type in Herb. Schweinitz, although it was studied by Berkeley & Curtis, *Acad. Nat. Sci. Phila. Jour.* 3: 221. 1856.

Fructifications coriaceous, thin, at first resupinate, orbicular,

becoming confluent, sometimes becoming narrowly reflexed, with the upper surface villose, varying from buffy brown to Natal-brown, becoming somewhat zonate when reflexed about 5 mm., the margin entire and usually whitish; hymenium even, somewhat velvety, bister or snuff-brown, becoming light drab and somewhat pruinose with age; in structure about $500\ \mu$ thick, the intermediate layer with a darker zone on its upper side and composed of loosely, longitudinally arranged, slightly colored hyphae $3-3\frac{1}{2}\ \mu$ in diameter; hymenium $30-45\ \mu$ thick, not zonate, having incrustated cystidia $30-45 \times 8-15\ \mu$ all confined to the single-layered hymenium, protruding up to $25\ \mu$; branched, filiform paraphyses $2\ \mu$ in diameter, becoming colored, are present also in the hymenium, basidia simple, 4-spored; spores white in spore collection, even, flattened on one side, $6-11 \times 3-4\frac{1}{2}\ \mu$.

Fructifications 5-10 mm. in diameter, becoming confluent over areas 1-2 cm. wide and 3 to many cm. long, and reflexed 2-5 mm.

On dead frondose wood and fallen limbs. New York to Mexico and westward to Idaho and Arizona, in the West Indies, and reported from Brazil. Throughout the year. Common.

S. albobadium may usually be recognized by its brown, velvety hymenium with a white border; with age the hymenium tends to become more uniformly light drab or pruinose, but some small fructifications in the vicinity are likely to show the original color contrasts. This species has a wide geographic range and is somewhat variable in coloration but is very constant in microscopic structure; the branched, colored paraphyses are highly distinctive.

Specimens examined:

Exsiccati: Bartholomew, Fungi Col., 3688, 4784; Ellis, N. Am. Fungi, 15; Ravenel, Fungi Am., 221, 449; Ravenel, Fungi Car. 1: 29.

New York: Grand View, *H. von Schrenk* (in Mo. Bot. Gard.

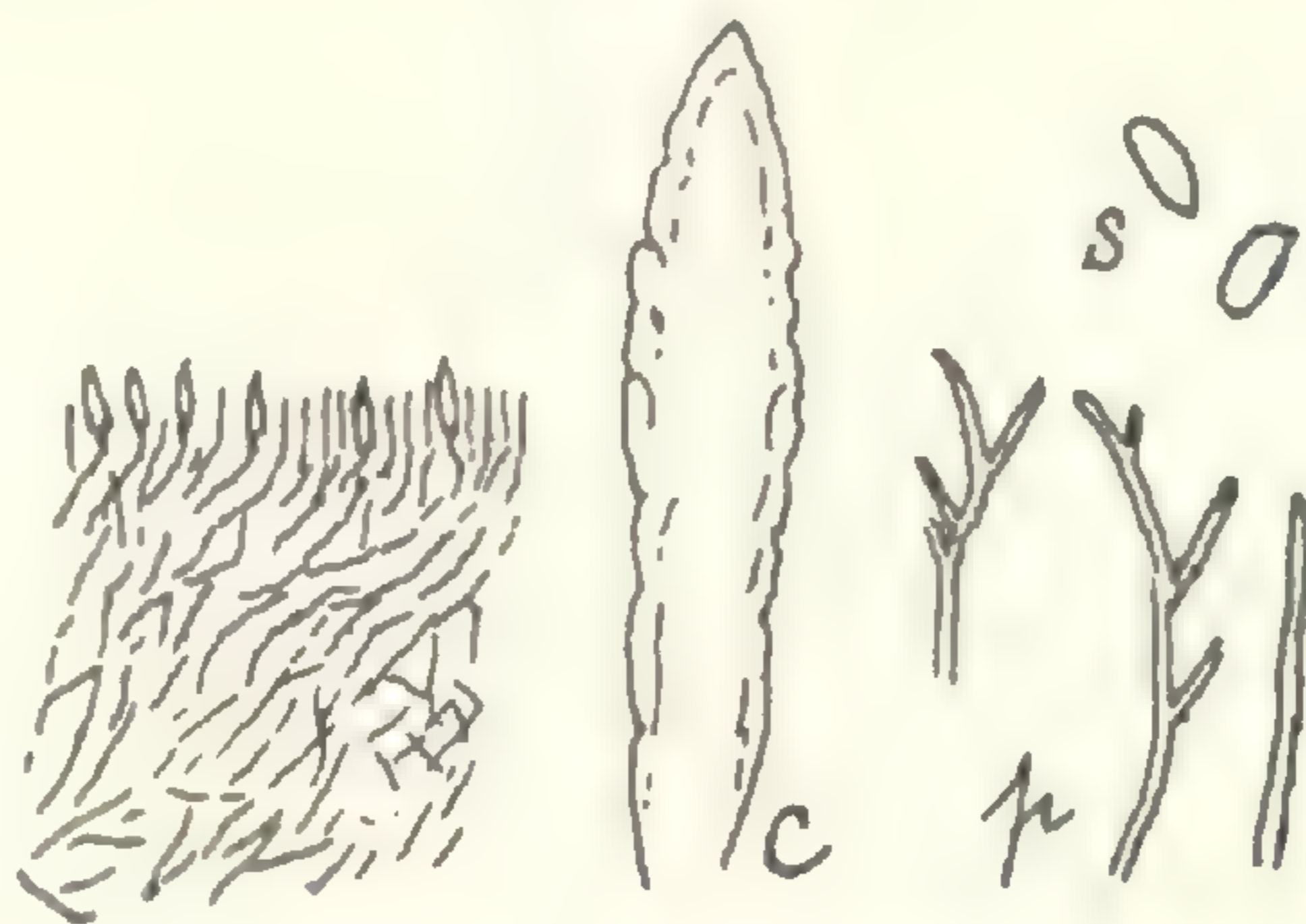


Fig. 42. *S. albobadium*. Section $\times 90$; cystidium, *c*, paraphyses, *p*, and spores, *s*, $\times 665$.

- Herb., 43009); Orient, *R. Latham* (in Mo. Bot. Gard. Herb., 16267).
- New Jersey: Newfield, *J. B. Ellis*, in *Ellis, N. Am. Fungi*, 15.
- Maryland: Plummers Island, *C. L. Shear*, 1276, 1277; Seven Locks, *P. L. Ricker*, 1007; Takoma Park, *C. L. Shear*, 1118, 1126.
- District of Columbia: Washington, *C. L. Shear*, 1263-1265, 1402.
- Virginia: Arlington Cemetery, *W. H. Long*, 12978 (in Mo. Bot. Gard. Herb., 55104).
- North Carolina: Chapel Hill, *W. C. Coker*, 3849 (in Mo. Bot. Gard. Herb., 56672).
- South Carolina: Curtis Herb., 1924, type of *Stereum bizonatum* (in Kew Herb.); *Ravenel*, in *Ravenel, Fungi Car.* 1: 29; Aiken, *H. W. Ravenel*, in *Ravenel, Fungi Am.*, 449; Clemson College, *P. H. Rolfs*, 1637; Society Hill, under the name *T. albo-marginata* (in Curtis Herb.).
- Georgia: Atlanta, *E. Bartholomew*, in *Bartholomew, Fungi Col.*, 4784; Darien, *H. W. Ravenel*, in *Ravenel, Fungi Am.*, 221.
- Florida: New Smyrna, *C. G. Lloyd*, 2089, 2104, 2132.
- Alabama: Auburn, *F. S. Earle* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56764), *F. S. Earle & C. F. Baker* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 5055, 56765, 56772), *C. R. Hudson* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 55568); *McGeher* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56766), and *L. M. Underwood*, comm. by U. S. Dept. Agr.; Fayette Co., *P. V. Siggers*, comm. by A. H. W. Povah, 16 (in Mo. Bot. Gard. Herb., 14849); Mobile, *E. Bartholomew*, 5752 (in Mo. Bot. Gard. Herb., 44257); Montgomery, *R. P. Burke*, 5, 29 (in Mo. Bot. Gard. Herb., 20914, 17071).
- Mississippi: Ocean Springs, *F. S. Earle*, 181 (in Mo. Bot. Gard. Herb., 44311).
- Louisiana: St. Martinville, *A. B. Langlois*.
- Texas: Paris, *C. L. Shear*, 1234; Quitman, *W. H. Long*, 18448, 12081 (in Mo. Bot. Gard. Herb., 55105, 55131); San Antonio, *H. von Schrenk*, also *W. H. Long*, 21217 (in Mo. Bot. Gard. Herb., 42577 and 55131 respectively).
- Ohio: *C. G. Lloyd*, 189, 594 (in Lloyd Herb.); College Hill, *C. G. Lloyd, P*; Norwood, *C. G. Lloyd*, 2810.

- Missouri: Meramec, *P. Spaulding* (in Mo. Bot. Gard. Herb., 5017); Perryville, *L. O. Overholts & R. A. Studhalter*, comm. by *L. O. Overholts*, 2723 (in Mo. Bot. Gard. Herb., 44293); Upper Creve Coeur, *E. A. Burt* (in Mo. Bot. Gard. Herb., 54861, 56768).
- Kansas: Rooks Co., *E. Bartholomew* (in Burt Herb. and Mo. Bot. Gard. Herb., 5054); Stockton, *E. Bartholomew*, in *Bartholomew, Fungi Col.*, 3688.
- Idaho: Bonner's Ferry, *J. R. Weir*, 592 (in Mo. Bot. Gard. Herb., 36746).
- Arizona: Phoenix, *W. H. Long*, 19030 (in Mo. Bot. Gard. Herb., 55106).
- New Mexico: Cienega Springs, *W. H. Long*, 21525 (in Mo. Bot. Gard. Herb., 55155); Tyom Experiment Station, *W. H. Long*, 21364, 21408 (in Mo. Bot. Gard. Herb., 55107, 55108); Tejano Experiment Station, *W. H. Long*, 21889, 21897, 21902 (in Mo. Bot. Gard. Herb., 55165–55167).
- Bermuda: *S. Brown, N. L. Britton, & F. J. Seaver*, 1244 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56273).
- Cuba: *C. Wright*, 247, type of *Stereum Coffearum* (in Curtis Herb.), and 542, type of *Hymenochaete paupercula* (in Curtis Herb.), and *C. G. Lloyd*, 423 (in Mo. Bot. Gard. Herb., 55159); Alto Cedro, *L. M. Underwood & F. S. Earle*, 1492, 1590, comm. by N. Y. Bot. Gard. Herb.; La Gloria, Camaguey, *J. A. Shafer*, 740 (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56770); Managua, *Earle & Murrill*, 11, comm. by N. Y. Bot. Gard. Herb.; Omaja, *C. J. Humphrey*, 2746 (in Mo. Bot. Gard. Herb., 14385); San Diego de los Baños, *Earle & Murrill*, 281, 302, 316, 353, comm. by N. Y. Bot. Gard. Herb.
- Porto Rico: Rio Piedras, *J. A. Stevenson*, 2424, 6272 (in Mo. Bot. Gard. Herb., 3607, 55090).
- Mexico: Jalapa, *W. A. & E. L. Murrill*, 301, 309, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54432, 54483); Motzorongo, Cordoba, *W. A. & E. L. Murrill*, 992, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54597); Orizaba, *W. A. & E. L. Murrill*, 760, 761, 766, 769, 774, 779, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54627, 54631, 54628, 54629, 54610,

54645); Tepeite Valley, Guernavaca, *W. A. & E. L. Merrill*, 408, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54544); Xuchiles, Cordoba, *W. A. & E. L. Merrill*, 1209, 1210, comm. by N. Y. Bot. Gard. Herb. (in Mo. Bot. Gard. Herb., 54598, 54599).

72. *S. heterosporum* Burt, n. sp.

Plate 6, fig. 72.

Type: in Mo. Bot. Gard. Herb.

Fructifications coriaceous, thin, resupinate, orbicular, becoming confluent, sometimes reflexed, with the upper surface villose, bister, somewhat concentrically sulcate and zonate, the margin entire, whitish; hymenium even, somewhat velvety, bister, becoming light drab and somewhat pruinose in the center with age; in structure 300–500 μ thick, the intermediate layer with a darker zone on its upper side and composed of loosely and longitudinally arranged, slightly colored hyphae 3–3½ μ in diameter, many of

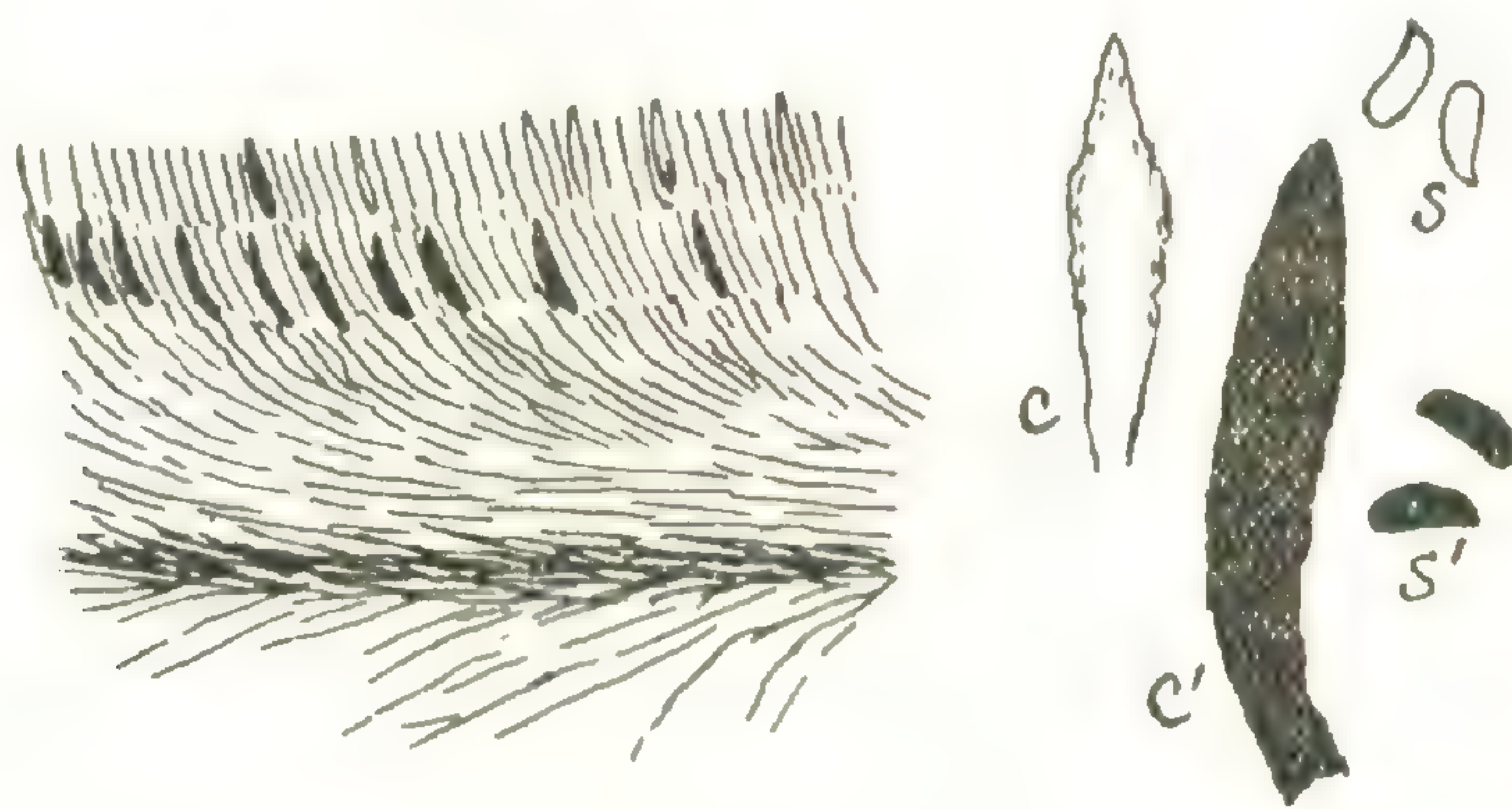


Fig. 43. *S. heterosporum*. Section $\times 90$; hyaline cystidium, *c*, colored cystidium, *c'*, hyaline spores, *s*, colored spores *s'*, $\times 665$.

which curve into the hymenium and often become there as dark-colored as conducting organs and sometimes incrustated; hymenium 70–120 μ thick, becoming more or less zonate, with cystidia incrustated starting from all parts of the layer, 30–35 \times 6–7 μ , protruding up to 15 μ , often colored under the incrustation in the deeper layers of the hymenium; paraphyses filiform, 2 μ in diameter, branched, numerous at the surface of the hymenium; basidiospores hyaline, even, 8–9 \times 3½ μ , borne 4 to a basidium; ochraceous spores of the same form and dimensions as the basidiospores often occur copiously imbedded throughout the hymenium.

Fructifications 5–10 mm. in diameter, becoming confluent over areas 1–2 cm. wide and up to 12 cm. long, and reflexed 2–7 mm.

On wood and in crevices of the bark of dead limbs and logs of *Eucalyptus*, oak, pecan, and other frondose species. Oregon to Mexico. September to April.

Resupinate specimens of *S. heterosporum* are not distinguishable in aspect from the darkest colored specimens of *S. albobadium*; all specimens of the former which have been seen so far have been bister or seal-brown, which is also the color of the upper side of the pileus. Mature specimens of *S. heterosporum* differ from those of *S. albobadium* in the much thicker zonate hymenium which has cystidia in all parts of this layer and many wholly buried below the surface; the deeper region of the hymenium is dark-colored in the type because of the abundance of dark-colored hyphal ends which are occasionally incrustated, and colored imbedded spores are as numerous as in *Stereum rugisporum*, which has nearly the same geographic range. I have not found colored imbedded spores in the collection distributed in Ell. & Ev., Fungi Col., 1116, which I refer to *S. heterosporum* on account of other distinctive characters of this species.

Specimens examined:

Exsiccati: Ell. & Ev., Fungi Col., 1116, under the name *Stereum albobadium*.

Oregon: Portland, *C. J. Humphrey*, 6125.

California: Berkeley, *C. J. Humphrey*, 5981; Campo Mts., *C. R. Orcutt*, 2007, 2008, comm. by U. S. Dept. Agr. Herb.; Compton, *A. J. McClatchie*, in Ell. & Ev., Fungi Col., 1116, and (in N. Y. Bot. Gard. Herb., Burt Herb., and Mo. Bot. Gard. Herb., 56769); Claremont, *D. L. Crawford*, 1513, comm. by L. O. Overholts, 3325 (in Mo. Bot. Gard. Herb., 21688); Santa Cruz, *Dr. Anderson*, comm. by W. G. Farlow.

Arizona: Coronado National Forest, *G. G. Hedgcock* & *W. H. Long*, comm. by C. G. Humphrey, 2562, 2563 (in Mo. Bot. Gard. Herb., 13070, 12811).

Mexico: Parral, Chihuahua, *E. O. Matthews*, 3, and 27, type (in Mo. Bot. Gard. Herb., 44282, 44420, 44106); Rosario, *E. O. Matthews* (in Mo. Bot. Gard. Herb., 44110).

73. *S. versiforme* Berk. & Curtis, *Grevillea* 1: 164. 1873; *Sacc. Syll. Fung.* 6: 580. 1888; Masee, *Linn. Soc. Bot. Jour.* 27: 193. 1890. Plate 6, fig. 73.

Peniophora Ellisii Masee, *Linn. Soc. Bot. Jour.* 25: 144. 1889; *Sacc. Syll. Fung.* 9: 237. 1891.—An *Thelephora obscura* Persoon, *Myc. Eur.* 1: 146. 1822 (in **** *Corticium*)? See *Peniophora obscura* (Pers.) Bresadola, *I. R. Accad. Agiati Atti* III. 3: 113. 1897.

Type: in Kew Herb. and Curtis Herb.

Fructifications at first thin, effused, resupinate, adnate, orbicular, becoming confluent, finally thickening, cracking, and

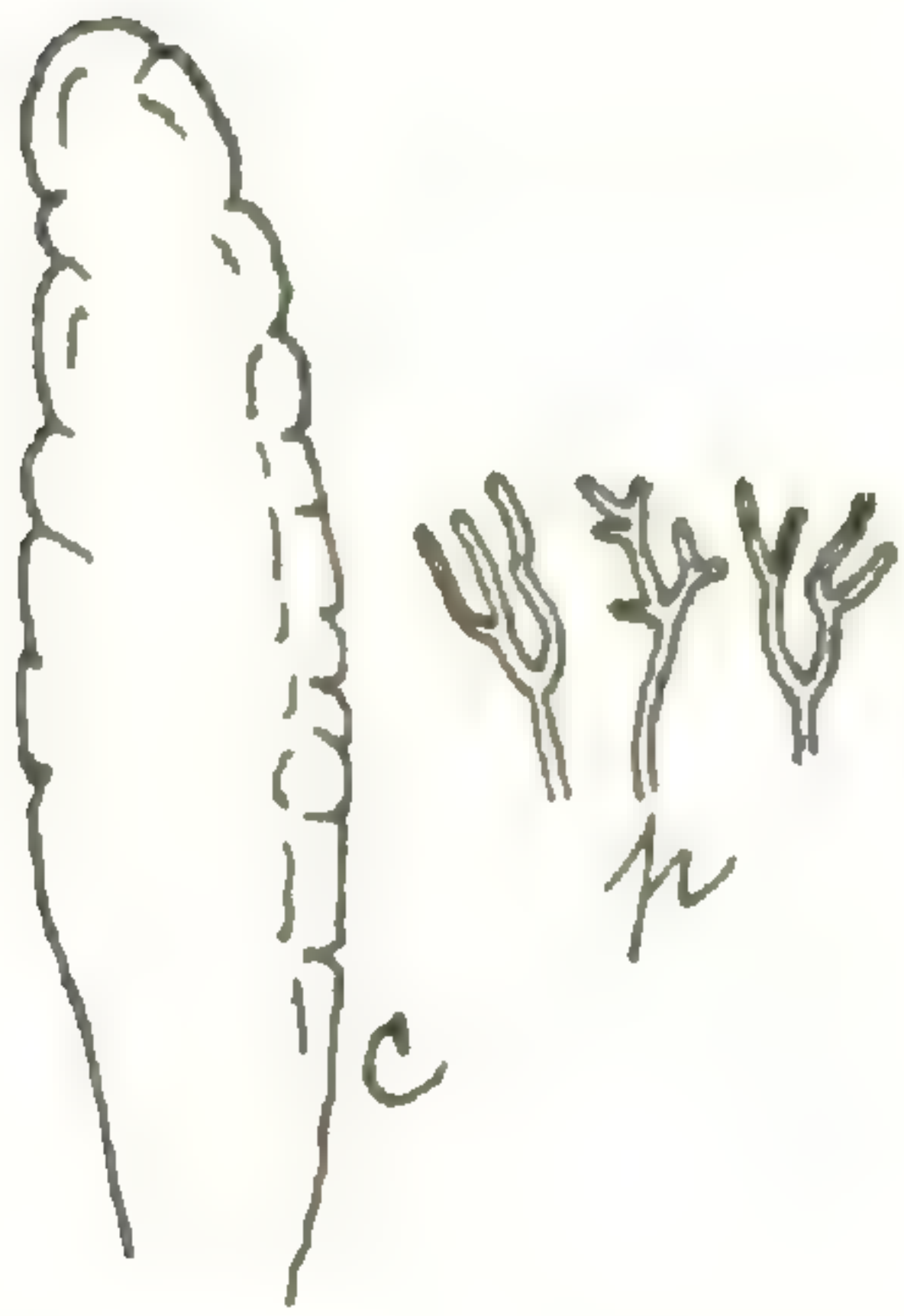


Fig. 44. *S. versiforme*. Cystidium, *c*, and paraphyses, *p*, $\times 665$.

becoming narrowly reflexed and somewhat complicate and curling away from the substratum, the upper side uneven, plicate, somewhat fuscous or blackish; hymenium velvety, Prout's brown to bister, somewhat papillate; in structure 200–400 μ thick, composed of densely arranged, ascending and interwoven hyphae, some of which are colored; hymenium usually simple but sometimes with one or two additional zones in some places, containing heavily incrustated, cylindric cystidia 45–75 \times 12–24 μ , starting in various parts of the hymenium and subhymenium, wholly buried below the surface of the hymenium or emerging up to 15 μ ; hymenial surface velvety, with very numerous colored paraphyses with bushy-branched tips; spores hyaline, even, curved, 5–7 \times 2–3 μ .

Fructifications 2–10 mm. in diameter, confluent over areas up to 7 \times 1–2 cm.; margin reflexed about 1 mm. usually, rarely up to 2 mm.

On the bark of dead limbs of oak, chestnut, birch, and other frondose species. Canada to Alabama and westward to Iowa and Arkansas. July to February. Common.

S. versiforme is distinct among the *Stereums* by its Prout's brown, velvety, or at least dull, hymenium, barely reflexed margin, and colored, bushy-branched paraphyses, among which are scattered large, incrustated cystidia. The presence of these

paraphyses, the location of the cystidia in the hymenial side of the fructification, and the velvety surface sharply separate wholly resupinate specimens of *S. versiforme* from brownish colored forms of *Peniophora cinerea*.

Peniophora obscura (Pers.) Bresadola, according to specimen collected in Hungary, communicated to me by Bresadola and compared by him with an authentic specimen of Persoon, is strikingly similar to very young and wholly resupinate specimens of *Stereum versiforme*. There is no European record that *P. obscura* ever has been observed reflexed or has shown any tendency to become reflexed. In America, *S. versiforme* is wholly resupinate only when very young and soon thickens, becomes more or less reflexed, and in well-developed specimens such as that cited below, collected by Underwood at White Plains, N. Y., has but little in common with *P. obscura*. For these reasons I believe that the name *Stereum versiforme* should be applied to American specimens until Europeans find their *Peniophora obscura* in a reflexed stage identical in its characters with *S. versiforme*.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 606, under the name *Stereum papyrinum*; Ell. & Ev., N. Am. Fungi, 3209; Ell. & Ev., Fungi Col., 611; de Thümen, Myc. Univ., 307.

Canada: *J. Macoun*, 8 in part, 70; on peach tree, *J. H. Faull* (in Mo. Bot. Gard. Herb., 55561).

Quebec: *Hylmer*, *J. Macoun*, 229.

Ontario: York Mills, *J. H. Faull*, Univ. Toronto Herb., 322 in part (in Mo. Bot. Gard. Herb., 44933).

New Hampshire: Chocorua, *W. G. Farlow* (in Mo. Bot. Gard. Herb., 55586).

Vermont: Ripton, *E. A. Burt*.

Massachusetts: Arlington Heights, *E. A. Burt*; Sharon, *A. P. D. Piguet*, comm. by *W. G. Farlow* (in Mo. Bot. Gard. Herb., 55231); Waverly, *A. B. Seymour*, T 15 (in Mo. Bot. Gard. Herb., 18098).

New York: Alcove, *C. L. Shear*, 1139, 1304, 1328; East Galway, *E. A. Burt*; Grand View, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42807); Ithaca, *Van Hook*, comm. by *G. F. Atkinson*, 8217; Karner, *H. D. House* (in N. Y. State Mus. Herb.

- and Mo. Bot. Gard. Herb., 54354, 54366); White Plains, *L. M. Underwood* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 5031).
- New Jersey: Newfield, *J. B. Ellis*, comm. by C. G. Lloyd, and in Ellis, N. Am. Fungi, 606, Ell. & Ev., N. Am. Fungi, 3209, Fungi Col., 611, and de Thümen, Myc. Univ., 307.
- Pennsylvania: *Michener*, type (in Curtis Herb., 4265, and in Kew Herb.); Bethlehem, *Schweinitz* (in Herb. Schweinitz, under the name *Thelephora amphibola* of Schw., Syn. N. Am. Fungi, No. 726, but not of Fries); Carbondale, *E. A. Burt*, two collections; State College, *C. R. Orton & L. O. Overholts*, comm. by L. O. Overholts, 2661 (in Mo. Bot. Gard. Herb., 11419); Trexlertown, *W. Herbst*, 14.
- Maryland: Glen Sligo, *C. L. Shear*, 1050, 1095; Hyattsville, *F. L. Scribner*, 90, comm. by U. S. Dept. Agr. Herb.; Takoma Park, *C. L. Shear*, 1020, 1336.
- Virginia: Fairfax, comm. by U. S. Dept. Agr. Herb.; Woodstock, *C. L. Shear*, 1196.
- South Carolina: Salem, *Schweinitz* (in Herb. Schweinitz, under the name *Thelephora bufonia* of Schw., Syn. N. Am. Fungi, No. 725, but probably not *T. bufonia* Pers., which is too imperfectly known for recognition in Europe); Summer-ville, *C. L. Shear*, 1227.
- Alabama: Auburn, *F. S. Earle* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56785, 56786), and *F. S. Earle & C. F. Baker* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56787, 56788).
- Michigan: Ann Arbor, *C. H. Kauffman*, 21 (in Mo. Bot. Gard. Herb., 9808), and *Abrams* (in N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb., 56789).
- Iowa: Woodbine, *C. J. Humphrey & C. W. Edgerton*, comm. by C. J. Humphrey, 6518 (in Mo. Bot. Gard. Herb., 20624).
- Missouri: Concordia, *C. H. Demetrio* (in Mo. Bot. Gard. Herb., 5030); Oran, *H. von Schrenk* (in Mo. Bot. Gard. Herb., 42887); St. Louis, *E. A. Burt* (in Mo. Bot. Gard. Herb., 8725); Williamsville, *B. M. Duggar*, 478, 481.
- Arkansas: Bigflat, *W. H. Long*, 19783, 19898 (in Mo. Bot. Gard. Herb., 5921, 9138); Cass, *W. H. Long*, 19800, 19827 (in Mo. Bot. Gard. Herb., 8636, 8886); Womble, *W. H. Long*,

19768, 19873, 19881 (in Mo. Bot. Gard. Herb., 9143, 8964, 5920).

74. *S. insigne* Bresadola, Nuov. Gior. Bot. Ital. 23: 158. 1891; Sacc. Syll. Fung. 9: 222. 1891. Plate 6, fig. 74.

Type: authentic specimen, probably part of the type, in Burt Herb.

Fructification corky, drying rigid, hard, effuso-reflexed, the upper surface concentrically sulcate, somewhat zonate, tomentose, snuff-brown to bister, the recent growth at the margin paler; hymenium even, pinkish buff to drab-gray and pruinose; in structure 1500 μ thick, with the intermediate layer bordered and connected with the tomentum by a darker and denser zone and bearing on the opposite side a multizonate hymenium; hyphae of the intermediate layer colored, thick-walled, densely and longitudinally arranged, $3\frac{1}{2}$ μ in diameter; no cystidia; paraphyses of bottle-brush or aculeate form, numerous and conspicuous in the hymenial surface, cylindric, $25-30 \times 4-4\frac{1}{2}$ μ ; spores published by Bresadola as hyaline, even, $4-6 \times 3-3\frac{1}{2}$ μ —none found by me.

Reflexed $1\frac{1}{2}-4$ cm., laterally confluent for 9 cm. in the Florida specimen.

On oak logs. Florida, Venezuela, and Italy. February. Rare.

This species belongs in the group with *S. subpileatum* and *S. sepium* and is not distinguishable in general aspect from these species, but its hymenium contains numerous and conspicuous bottle-brush paraphyses and no cystidia, while both of the other species named have cystidia. The Venezuelan specimen cited below was determined by Berkeley as *Stereum illudens*, from which it appears distinct, for while the type of *S. illudens*, in Kew Herbarium, collected by Drummond, 158, Swan River, Australia, has bottle-brush paraphyses for its hymenial surface, it has in its subhymenium elongated, cylindric, thick-walled organs 6 μ in diameter, up to 100 μ long, a little darker colored than the surrounding hyphae and curving outward into the deeper portion of the hymenium, which is not zonate.



Fig. 45. *S. insigne*. Section of hymenium of authentic specimen $\times 665$; bottle-brush paraphyses, *p*.

Specimens examined:

Italy: Florence, *Martelli*, comm. by G. Bresadola.Florida: *C. G. Lloyd*, 4846.Venezuela: *Fendler*, 177 (in Curtis Herb.).**75. *S. durum* Burt, n. sp.**

Plate 6, fig. 75.

Type: in Smith, Central Am. Fungi, 147, copy in Mo. Bot. Gard. Herb.

Fructification very hard, orbicular, attached by the center, free or reflexed all around, concentrically sulcate, fuscous to

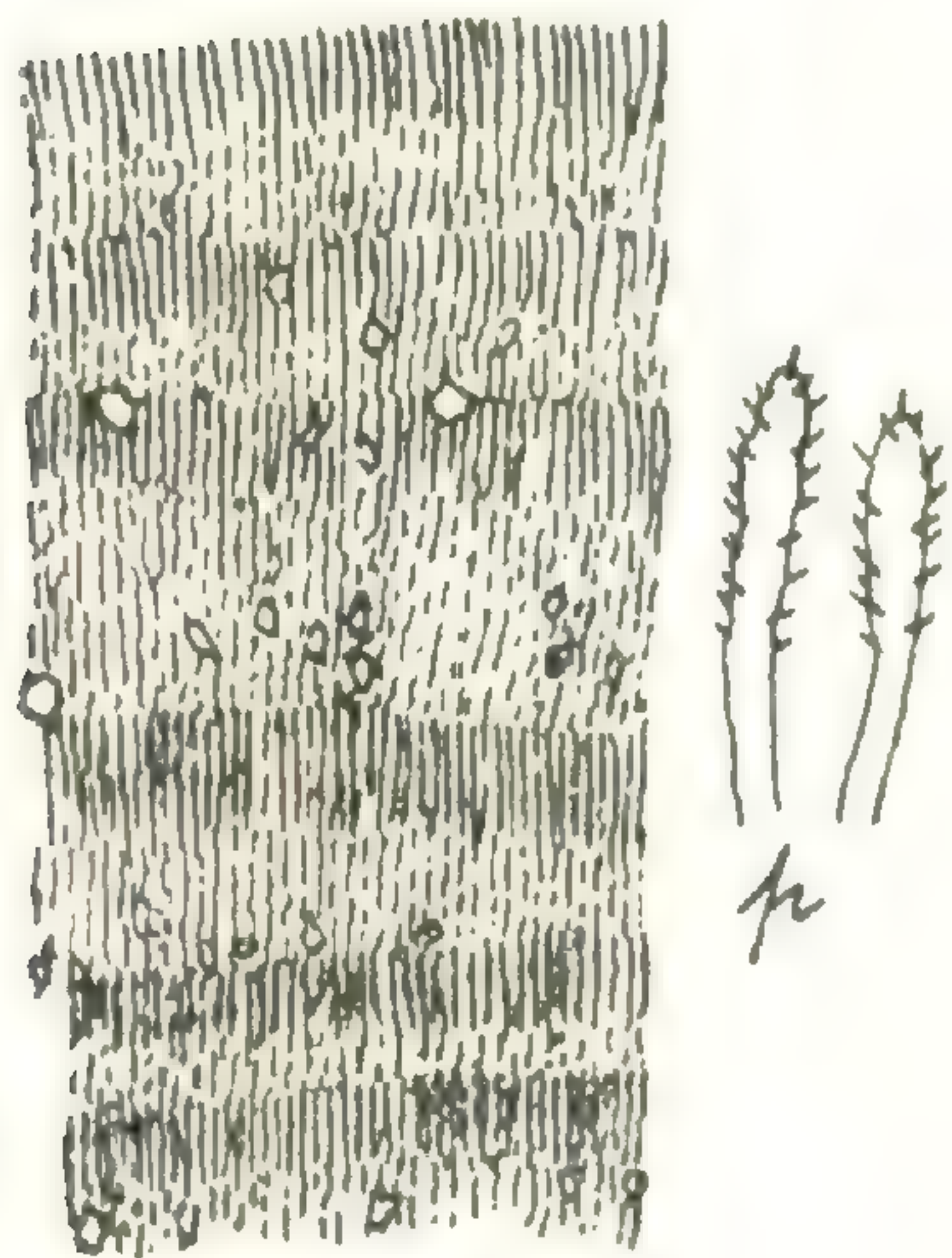


Fig. 46. *S. durum*. Section of hymenial region of type $\times 90$; bottle-brush paraphyses, *p*, $\times 665$.

bone-brown, with a horn-like crust, becoming somewhat shining; hymenium even, not shining, between pale drab-gray and tilleul-buff, somewhat pruinose; in structure 2–3 mm. thick, hazel throughout, and multizonate or stratose, containing many scattered crystals, hyphae $3\frac{1}{2}$ –4 μ in diameter; paraphyses of bottle-brush or aculeate form, numerous and conspicuous in the hymenial surface, cylindric, 12–15 \times 4–5 μ ; no cystidia; no spores found.

Fructification 3 cm. in diameter, reflexed 1 cm.

On dead wood. Mexico.

S. durum is much thicker, harder, and more rigid than *S. insigne* and

not tomentose. The microscopic structure agrees exactly with that of preparations from an authentic specimen in Kew Herbarium of *Stereum annosum*, No. 99, collected at Neilgherries, Ceylon, and should be compared with the latter when better known. For the present the development of a pileus by *S. durum*, with characters as stated, is reason for regarding this species as distinct from *S. annosum*, a resupinate species of the other side of the world.

Specimens examined:

Exsiccati: Smith, Central Am. Fungi, 147, under the name *Stereum ferreum*.

Mexico: Jalapa, *C. L. Smith*, type, in Smith, Central Am. Fungi, 147.

76. *S. frustulosum* (Pers.) Fries, Epicr. 552. 1838; Hym. Eur. 643. 1874; Morgan, Cincinnati Soc. Nat. Hist. Jour. 10: 196. 1888; Sacc. Syll. Fung. 6: 572. 1888; Masee, Linn. Soc. Bot. Jour. 27: 199. 1890. Plate 6, fig. 76.

Thelephora frustulosa Persoon, Syn. Fung. 577. 1801; Myc. Eur. 1: 134. 1822; Fries, Syst. Myc. 1: 445. 1821.—*Thelephora perdix* Hartig, Zersetzung. des Holzes, 103–108. pl. 13. 1878.

Illustrations: Cooke, Fung. Pests, pl. 20. f. 20; Hartig, loc. cit.; Masee, Dis. Cult. Plants, 397. text f. 124; Tubeuf, Dis. of Plants, 35. text f. 11, and 430. text f. 260, 261.

Fructifications woody, resupinate, tuberculose, crowded as if confluent and then broken up into frustules, sometimes grown outward from place of attachment and narrowly reflexed or with a free margin all around, the upper side black, crust-like,

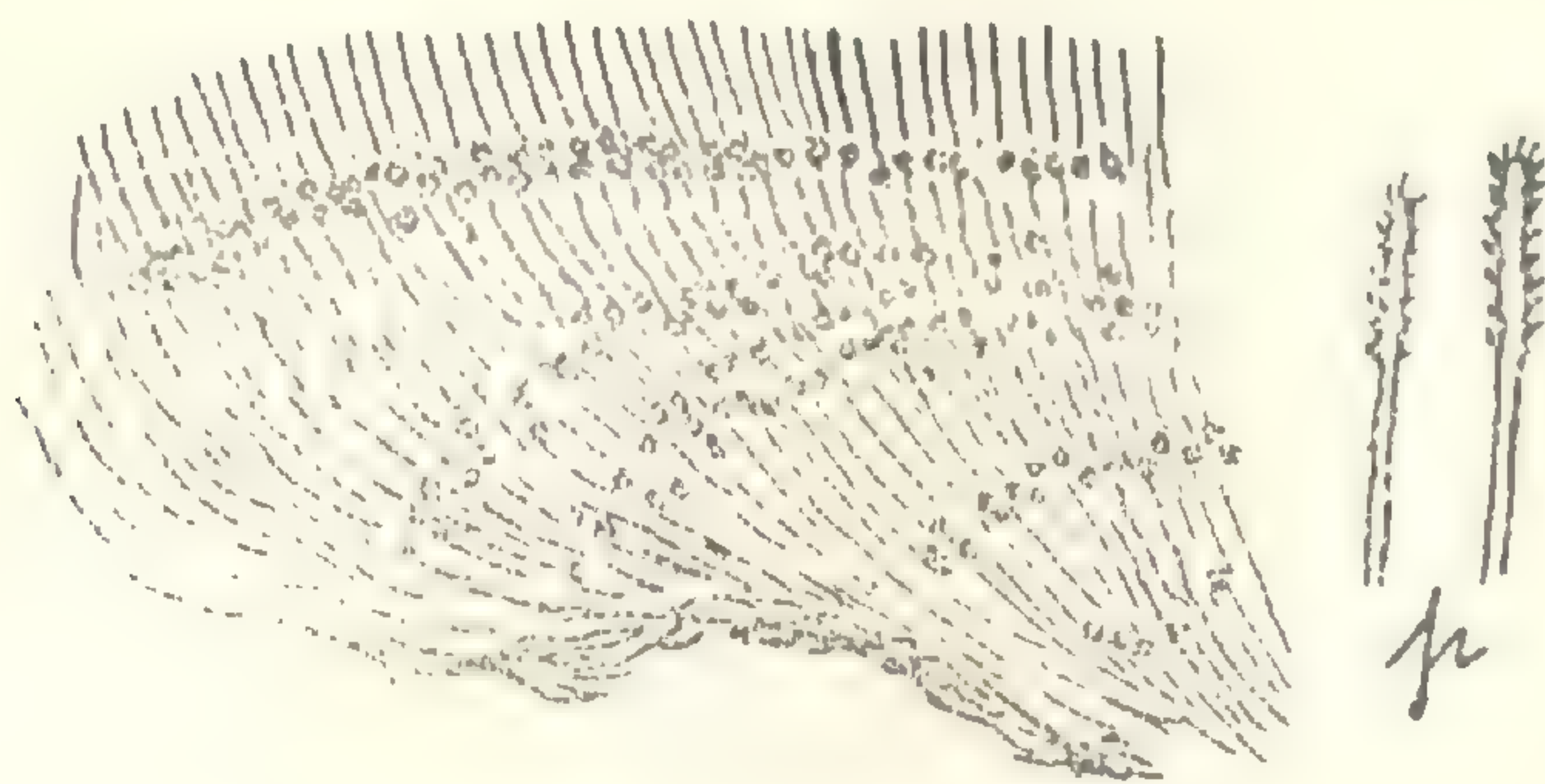


Fig. 47. *S. frustulosum*. Section $\times 45$; bottle-brush paraphyses, *p*, $\times 665$.

concentrically sulcate, glabrous; hymenium convex, pinkish buff to whitish and pruinose; in structure 800 μ or more thick, with hyphae densely arranged, radiating outward from the place of attachment and bearing a multizonate hymenium in which are great numbers of bottle-brush or aculeate paraphyses; spores hyaline, even, $5-6 \times 3-3\frac{1}{2} \mu$.

Fructifications 2–4 mm. in diameter; margin reflexed 3 mm. in the best developed specimen known to me.

On wood of oak logs and stumps in which it causes a pocketed or honey-comb rot. Canada to Texas and westward to Oregon, in Mexico and in Europe.

S. frustulosum may be recognized by its occurrence in small convex fructifications of woody consistency, crowded together

on the under side of dry and hard oak wood or on the sides of stumps. On the sides of stumps it may sometimes be found reflexed. The bottle-brush paraphyses and many-zoned hymenium are good structural characters for confirmation of the determination.

Specimens examined:

Exsiccati: Bartholomew, *Fungi Col.*, 1881, 4587; Ellis, *N. Am. Fungi*, 106; Ell. & Ev., *Fungi Col.*, 7; Ravenel, *Fungi Car.* 2: 34; de Thümen, *Myc. Univ.*, 308.

Sweden: Stockholm, *L. Romell*, 28; Upsala, *E. P. Fries* (in *Curtis Herb.*).

France: Aveyron, *A. Galzin*, 13935, comm. by H. Bourdot, 26649.

Ontario: Carleton Place, *J. Macoun*, 421 (in *Macoun Herb.*).

Vermont: Grand View Mt., *E. A. Burt*, three collections.

Massachusetts: Dedham, *Hanna*; Wellesley, *L. W. Riddle*, 14.

New York: Glasco, *P. Wilson*, 50 (in *Mo. Bot. Gard. Herb.*, 54763); Ithaca, *W. C. Muenscher*, 144 (in *Mo. Bot. Gard. Herb.*, 56601); Palisades, *P. Wilson*, 62 (in *Mo. Bot. Gard. Herb.*, 54761).

New Jersey: Alpine, *P. Wilson*, 8 (in *Mo. Bot. Gard. Herb.*, 54764); Englewood, *P. Wilson*, 60 (in *Mo. Bot. Gard. Herb.*, 54762); Hackensack Swamp, *W. H. Ballou* (in *Mo. Bot. Gard. Herb.*, 56599); Newfield, *J. B. Ellis*, in *Ellis, N. Am. Fungi*, 106, in *Ell. & Ev., Fungi Col.*, 7, and *de Thümen, Myc. Univ.*, 308.

Pennsylvania: Kittanning, *D. R. Sumstine*.

Maryland: Hyattsville, *F. L. Scribner* (in *U. S. Dept. Agr. Herb.*).

South Carolina: *H. W. Ravenel*, in *Ravenel, Fungi Car.* 2: 34; Clemson College, *P. H. Rolfs*, 1621, 1630, 1638.

Florida: Tallahassee, *E. Bartholomew*, in *Bartholomew, Fungi Col.*, 4587.

Alabama: Auburn, *F. S. Earle & C. F. Baker* (in *Mo. Bot. Gard. Herb.*, 5079); Montgomery, *R. P. Burke*, 27 (in *Mo. Bot. Gard. Herb.*, 17875).

Louisiana: *A. B. Langlois*.

Texas: Denton, *W. H. Long*, in *Bartholomew, Fungi Col.*, 1881; Galveston, *H. W. Ravenel*, 36, comm. by *U. S. Dept. Agr. Herb.*

Ohio: *C. G. Lloyd, 185* (in Lloyd Herb.); Loveland, *D. L. James* (in U. S. Dept. Agr. Herb.).

West Virginia: Paw Paw, *C. L. Shear, 1180*.

Kentucky: Crittenden, *C. G. Lloyd, 1685*.

Wisconsin: Blue Mounds, *Miss A. O. Stucki, 30*; Madison, *W. Trelease, 83* (in Mo. Bot. Gard. Herb., 44105).

Iowa: Webster Co., *O. M. Oleson, 450* (in Mo. Bot. Gard. Herb., 44062).

Missouri: Columbia, *B. M. Duggar, 443*; Creve Coeur, *P. Spaulding* (in Mo. Bot. Gard. Herb., 44103), and *E. A. Burt* (in Mo. Bot. Gard. Herb., 7861); St. Louis, *Miss C. Rumbold*; Valley Park, *E. A. Burt* (in Mo. Bot. Gard. Herb., 44058, 44063).

Nebraska: Saltillo, *C. L. Shear, 1051*.

Kansas: Bourbon Co., *A. O. Garrett, 125*.

Oregon: Portland, *J. R. Weir, 597* (in Mo. Bot. Gard. Herb., 36747).

Mexico: Tepeite Valley, Guernavaca, *W. A. & E. L. Merrill, 411* (in Mo. Bot. Gard. Herb., 54545).

U. S. Northern Pacific Expl. Exp.: Ousmia, *C. Wright, comm.* by U. S. Dept. Agr. Herb.

77. *S. roseo-carneum* (Schw.) Fries, R. Soc. Sci. Upsal. Actis III. 1: 112. 1851. Plate 6, fig. 77.

Thelephora roseo-carnea Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1: 107. 1822 (under *C. Corticia*).—*T. anthochroa* Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 168. 1832, but not *T. anthochroa* of European authors.—*Corticium lilacino-fuscum* Berkeley & Curtis, Grevillea 1: 180. 1873; Sacc. Syll. Fung. 6: 621. 1888; Masee, Linn. Soc. Bot. Jour. 27: 143. 1890.—*Stereum lilacino-fuscum* (Berk. & Curtis) Lloyd, Myc. Writ. 5. Letter 68: 8. 1919.—*S. sendaiense* Lloyd, Myc. Writ. 5. Myc. Notes 48: 680. text f. 1015. 1917.—*Corticium subrepandum* Berkeley & Cooke, Grevillea 6: 81. 1878; Sacc. Syll. Fung. 6: 608. 1888; Masee, Linn. Soc. Bot. Jour. 27: 119. 1890.

Illustrations: Lloyd, *loc. cit.*

Type: in Herb. Schweinitz, under the name *Thelephora anthochroa*.

Fructifications coriaceous-soft, thin, usually resupinate, effused,

becoming confluent, sometimes with margin barely free, rarely distinctly reflexed, with the upper surface tomentose, light buff to pinkish buff, the margin entire; hymenium even, cracking in a tessellated manner, not shining, light vinaceous purple when young, gradually changing to avellaneous when mature; in

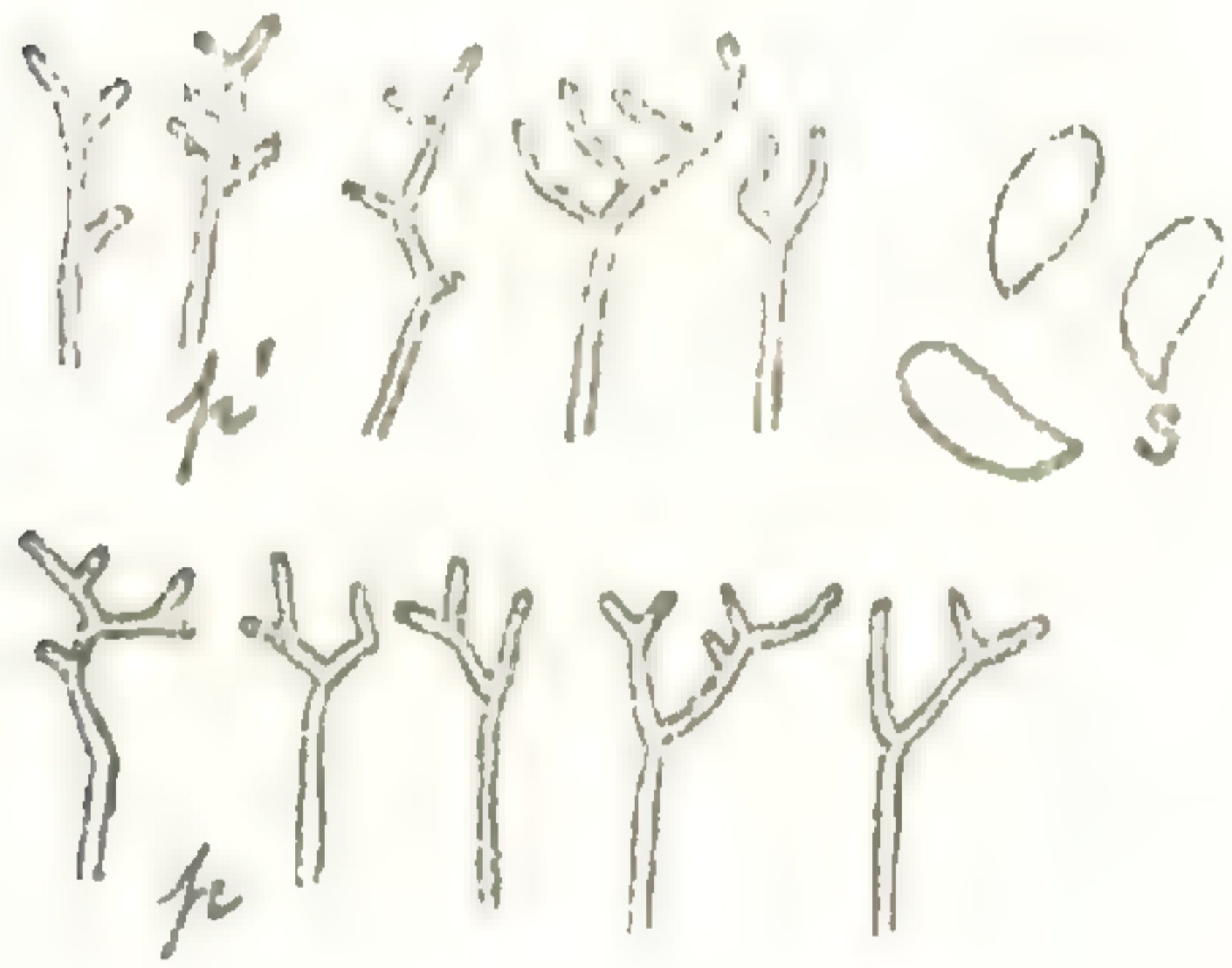


Fig. 48. *S. roseo-carneum*. Paraphyses of type, *p*; paraphyses, *p'*, of collection at Ithaca, and spores, *s*, all $\times 665$.

structure 250–300 μ thick, composed of somewhat longitudinally and loosely interwoven, hyaline, thin-walled, nodose-septate hyphae $2\frac{1}{2}$ –3 μ in diameter, not differentiated into an intermediate layer with a dark or dense bordering zone; hymenial layer simple when young, with very numerous and conspicuous, filiform paraphyses, colored above and with short-branched tips or bearing short lateral prongs on from 5–20 μ of the outer portion of the paraphysis, the

paraphyses less conspicuous when basidia appear; spores white in spore collection, even, flattened on one side, $6-9 \times 4-5 \mu$, borne 4 to a basidium on simple basidia.

At first forming little fructifications $3-5 \times 2$ mm., which become confluent over areas up to $6 \times 1\frac{1}{2}$ cm.; margin becoming free or reflexed for 1–3 mm.

On fallen limbs of frondose species. Canada to North Carolina and westward to Wisconsin, and in Brazil and Japan.

Since *S. roseo-carneum* is nearly always resupinate and does not show in sectional preparations of such specimens a distinct intermediate layer, its inclusion in the genus *Stereum* must trouble beginners. Fortunately it is a species so unique in structure that it may be determined with confidence. Most collections are likely to show more or less of the fuscous-lilac color, which is intense in young stages; the hymenium cracks and has the aspect of *Corticium evolvens* in other features than color, although of different structure; sections of *S. roseo-carneum* show in the hymenial surface filiform paraphyses branched above, as shown in the text figure. Such paraphyses are present in only one of our *Corticiums*—*Corticium roseum*. It is regrettable that the Schweinitz type was relabeled by Dr.

Michener to conform to the name used by Schweinitz in 'Synopsis North American Fungi' and the original label removed from the specimen, but Schweinitz gives in the later publication the name which he originally used.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 515 and 20, the latter under the name *Corticium incarnatum*.

Ontario: London, J. Dearness, D945 k, reflexed specimen (in Mo. Bot. Gard. Herb., 14251).

New Hampshire: Chocorua, W. G. Farlow, reflexed specimen; North Conway, L. O. Overholts, 5032, 5161—the latter reflexed (in Mo. Bot. Gard. Herb., 56348, 56349).

Vermont: Middlebury, E. A. Burt, two collections, of which one is reflexed; Ripton, E. A. Burt.

Massachusetts: reflexed specimen, comm. by C. H. Peck; Arlington Heights, reflexed specimen, E. A. Burt; Sharon, A. P. D. Piguet, comm. by W. G. Farlow.

Connecticut: C. Wright, type of *Corticium lilacino-fuscum* (in Kew Herb. and Curtis Herb., 5610).

New York: Alcove, C. L. Shear, 1001, 1002, 1004, 1072, 1321; Altamont, reflexed specimen, E. A. Burt; Brookton, W. C. Muenscher, 215 (in Mo. Bot. Gard. Herb., 56612) Cayuga Lake basin, G. F. Atkinson, 3022; East Galway, E. A. Burt; Ithaca, Van Hook, and H. S. Jackson, comm. by G. F. Atkinson, 8247 and 14396 respectively; North Elba, C. H. Kauffman, 13 (in Mo. Bot. Gard. Herb., 16987).

New Jersey: Newfield, J. B. Ellis, 2487, type of *Corticium subrepandum* (in Kew Herb.), and in Ellis, N. Am. Fungi, 20, and 515.

Pennsylvania: Spruce Creek, J. H. Faull, Univ. Toronto Herb., 312 (in Mo. Bot. Gard. Herb., 44886); State College, L. O. Overholts, 2676 (in Mo. Bot. Gard. Herb., 5946), and L. O. Overholts & C. R. Orton, comm. by L. O. Overholts, 5041, reflexed specimen (in Mo. Bot. Gard. Herb., 56359).

District of Columbia: Rock Creek, C. L. Shear, 1352; Washington, T. Pergande (in U. S. Dept. Agr. Herb.).

Virginia: Woodstock, C. L. Shear, 786, 788.

North Carolina: Salem, Schweinitz, type, under the name *Thelephora anthochroa* (in Herb. Schweinitz).

West Virginia: Fayette Co., *L. W. Nuttall*, comm. by Lloyd.
Herb.

Michigan: Ann Arbor, *C. H. Kauffman*, 13.

Indiana: Crawfordsville, *D. Reddick*, 9, 10.

Wisconsin: Palmyra, *Miss A. O. Stucki*, 48.

Brazil: Rio Grande do Sul, Hamburgerberg, *G. O. Malme*, 75,
comm. by L. Romell, 330.

Japan: *A. Yasuda*, comm. by C. G. Lloyd (in Mo. Bot. Gard.
Herb., 55214), and part of type of *Stereum sendaiense* (in
Mo. Bot. Gard. Herb., 55448); Sendai, *A. Yasuda*, reflexed
specimen (in Mo. Bot. Gard. Herb., 56247).

SPECIES IMPERFECTLY KNOWN

Thelephora aculeata Berk. & Curtis, *Grevillea* 1: 149. 1873;
Sacc. Syll. Fung. 6: 523. 1888.

The type was collected on the ground in Santee Swamp, South Carolina, in June. I had compared with the type a collection made by Professor P. H. Rolfs, on the ground, Clemson College, South Carolina, on June 18, and found this collection so similar to the type in aspect, although smaller, that I referred this specimen to *Thelephora aculeata*. I had not been able to demonstrate basidia for the type nor for the Rolfs specimen; now while working out the detailed structure of the latter specimen for publication, I find globose, longitudinally septate basidia $9\ \mu$ in diameter, and hyaline, even spores up to $9 \times 4\frac{1}{2}$ – $5\ \mu$. It seems probable that when there is opportunity to examine the type again it may be found to have similar basidia and belong in *Tremellodendron*.

Stereum arenicolum Berkeley in Masee, *Linn. Soc. Bot. Jour.* 27: 201. 1890.

“Resupinatum, effusum, crassum, rigidum, subtus tomento ferrugineo molli vestitum; hymenio levi, glabro fusco-purpurascens; sporae ellipsoideae, 7×4 – $5\ \mu$ (Berk. in Herb. n. 3822).

“On sand under trees, Vera Cruz.

“Rigid, thick, 2–3 inches across, attached to the sand and probably decayed wood by a dense ferruginous tomentum; margin sometimes slightly upraised; substance pale cinnamon.”

The above should be compared with *S. crassum*.

Stereum cuneatum Lloyd, Myc. Writ. 4. Letter 54: 7. 1916.

"Pileus cuneate, tapering to the base (2 cm. high), cut into a few fimbriate segments. Surface pale, smooth. Hymenium unilateral, pale yellow (honey yellow of Ridgway), smooth. Cystidia none. Spores globose, $3\frac{1}{2}$ –4 mic., hyaline, smooth. The plant grows densely caespitose in the earth, from a common mycelial base. It belongs in Section 7 of my recent pamphlet on Stipitate Stereums." Florida.

Perhaps the above is *S. Burtianum* or *S. tenerrimum*.

Stereum cupulatum Patouillard in Duss, Fl. Crypt. Antilles Fr. 233. 1904.

Scattered or close together, orbicular, from resupinate becoming cup-shaped, attached by a dorsal point, coriaceous, rigid, hard; external face glabrous, not zonate, brown, the margin entire or sinuate, acute; hymenium pruinose, even, concave, dull cinereous, reddish towards the border; trama compact, brown-umber; spores cylindrical-ovoid, colorless, $6 \times 3 \mu$; no cystidia.

Fructifications 6–8 mm. in diameter.

On bark of *Prunus Dussii*.—Forest of Buins-Jaunes. Duss, 212.

The above is a translation of the original description; the species seems to be very near, if at all distinct from, *Stereum vibrans*, which Patouillard did not recognize among the species of Guadeloupe.

Stereum fragile Patouillard, Soc. Myc. Fr. Bul. 16: 179. 1900; Sacc. Syll. Fung. 16: 187. 1902.

Fructification resupinate at first, becoming dimidiate, orbicular, rigid, hard, more or less incised at first, the margin erect and acute; upper surface plane, ochraceous russet, tomentose, with some reddish and nearly glabrous concentric zones; trama 1 mm. thick, whitish, compact; hymenium plane, livid, becoming purplish; cystidia abundant, fusoid, not colored, thin-walled, $40 \times 10 \mu$.

On decaying wood. Guadeloupe.

This fungus is very fragile and divides radially with great ease. Its aspect is like that of *S. fasciatum*, *S. lobatum*, etc., but

it is easily distinguished by the violaceous tint of the hymenium. I have not seen authentic specimens of *S. fragile*, but from the foregoing translation of the original description, it seems very probable that *S. fragile* may prove a synonym of *S. albobadium*, a species common in the West Indies but not recognized by Patouillard among the species of Guadeloupe.

Stereum fimbriatum Ellis, Torr. Bot. Club Bul. **6**: 133. 1877.

According to the authentic specimen from Ellis to Cooke in Kew Herb., this is a whitish, flaxy mass having no hymenium and quite indeterminable.

Stereum Galeottii Berkeley, Hooker's Jour. Bot. **3**: 15. 1851; Sacc. Syll. Fung. **6**: 574. 1888; Masee, Linn. Soc. Bot. Jour. **27**: 176. 1890.

"Umbonato-sessile, parvum, convexum, rigidum; pileo cervino velutino-tomentoso crebrissime badio-zonati; zonis hic illic glabris nitentibus; hymenio cinereo-alutaceo. Galeotti, No. 6853.

"Hab. Caripi, Spruce; Vera Cruz, Galeotti; Xalapa, Mr. Harries.

"Pileus 1½ inch broad, 1 inch long, subflabelliform, umbonato-sessile, mostly convex above, slightly undulated, thin but rigid, fawn-colored, clothed with velvety down; repeatedly zoned; zones mostly very close and narrow, frequently forming bay-brown, smooth and shining, alternating with paler fasciae. Hymenium tan-colored with a cinereous tinge.

"Undoubtedly nearly allied to *Stereum lobatum*, Kze, but a much smaller and neater species."

The type of the above should be compared with *Stereum versicolor*.

Stereum griseum Schweinitz, Naturforsch. Ges. Leipzig Schrift. **1**: 106. 1822 (under *B. Sterea* of *Thelephora*); Fries, Elenchus Fung. **1**: 179. 1828.—*Stereum porrectum* Fries, Epicr. 548. 1838; Sacc. Syll. Fung. **6**: 579. 1888.

I have been unable to find any Schweinitzian specimen of this species. It seems probable that the description was based on the old stage of *Stereum fasciatum* in which the attachment is by

umbo prolonged into stem-like form. Such fructifications occur rarely and are perplexing if not gathered in the same collection with the usual sessile fructifications.

S. ochroleucum Fries, Hym. Eur. 639. 1874; Sacc. Syll. Fung. 6: 562. 1888; Masee, Linn. Soc. Bot. Jour. 27: 184. 1890.

Corticium ochroleucum Fries, Epicr. 557. 1838.—Not *Stereum ochroleucum* Bres. Ann. Myc. 1: 91. 1903, nor Brinkmann, Westfälische Pilze, 49.

Type: authentic specimen in Kew Herb.

This species does not occur in North America and adjacent regions although reported from time to time from United States, Cuba, and Venezuela. Since I have not received under any name specimens of the true *Stereum ochroleucum* from European correspondents, this species is probably rare in Europe, and it may help toward recognition of the species to call attention to the specimen in Kew Herbarium.

The specimen is labelled:

“*Corticium ochroleucum* Fr.
Svex. Westm.
Maji — leg. Lbd.”

This specimen agrees well with the original description; its reflexed portion is $1\frac{1}{2}$ cm. broad, about $1-1\frac{1}{5}$ mm. thick as the sections show in my preparation; the consistency is soft in comparison with *S. hirsutum* and the hyphae about $2\frac{1}{2}$ mm. in diameter, granule-incrusted, and interwoven throughout the thickness of the pileus rather than parallel and longitudinally arranged side by side as in *S. hirsutum* and *S. sulphuratum*. In other words there is not the sharply marked intermediate layer which Fries regarded as an important distinctive character of the genus *Stereum*, and this is probably the reason for his originally regarding this species as a *Corticium* although broadly reflexed. There is not present a hardened crust or golden zone to mark the upper side of the intermediate region, but instead the hyphae become more loosely arranged toward the surface and become the hairy covering of that side. No cystidia, gloeocystidia, nor colored conducting organs are present; the spores are hyaline, even, $4\frac{1}{2}-5 \times 3 \mu$.

The American *Stereum spumeum* has aspect and structure very similar to *Stereum ochroleucum* Fr. but differs by having incrustated cystidia.

Stereum unicum Lloyd, Myc. Writ. 4. Stip. Stereums, 35. text f. 556. 1913.

The type is in New York State Museum under the name *Thelephora speciosa* unless relabeled to conform to the name applied by Lloyd. The type bears no basidia yet and is not determinable as to genus; it was collected in Providence, Saratoga County, New York, where I have been looking for a fertile specimen when in the original locality occasionally in the summer.

EXCLUDED SPECIES

Stereum acerinum (Pers.) Fr. is *Aleurodiscus acerinus* (Pers.) v. Höhn. & Litsch.

Stereum acerinum var. **nivosum** Berk. & Curtis is *Aleurodiscus nivosus* (B. & C.) v. Höhn. & Litsch.

Stereum calyculus Berk. & Curtis is *Craterellus calyculus* (B. & C.) Burt.

Stereum candidum Schweinitz is *Aleurodiscus candidus* (Schw.) Burt.

Stereum carolinense Cooke & Ravenel is *Sparassis spathulatus* (Schw.) Fr.

Stereum duriusculum, as determined by Patouillard in Duss, Fl. Antilles Fr. 232. 1903, is probably *Hypochnus pallescens* (Schw.) Burt, a species common in the West Indies.

Stereum Guadelupense Patouillard, Soc. Myc. Fr. Bul. 15: 201. pl. 10. f. 1. 1899. According to von Höhnel & Litschauer, K. Akad. Wiss. Wien Sitzungsber. 116: 753. 1907, this is a *Boletus* overrun by a *Sepedonium*.

Stereum Haydeni Berkeley in Masee, Linn. Soc. Bot. Jour. 27: 199. 1890.

The type, in Kew Herbarium, was collected in Ohio; it is strictly resupinate, has its hyphae loosely interwoven from hymenium to substratum, and has no characters which justify its inclusion in *Stereum* as comprehended in my work. The

hymenium is deteriorated but shows no cystidia; the species may be sought for in Ohio as a probable *Corticium*.

Stereum insolitum Lloyd, Myc. Writ. 5. Myc. Notes 47: 665. *text f. 956*. 1917, is a young specimen of *Thelephora regularis* Schw.

Through the kindness of Professor McFarland, I have examined his portion of the original specimen. Most of the spores attached to the basidia are as published by Lloyd; a few spores are $6-7 \times 5 \mu$, rough-walled and still hyaline; occasional spores in a preparation from near the base of the pileus are colored and tuberculate-irregular.

Stereum Leveillianum Berk. & Curtis is *Tremellodendron Leveillianum* (B. & C.) Burt.

Stereum Micheneri Berk. & Curtis is *Thelephora albido-brunnea* Schw.

Stereum Mancianus Sacc. & Cub. is *Aleurodiscus strumosus* (Fr.) Burt.

Stereum populneum Peck, N. Y. State Mus. Rept. 47: 145. 1894.

This is known in resupinate form only and should not be included in *Stereum*.

Stereum pruinatum Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 332. 1868.

This is known in resupinate form only and should not be included in *Stereum*.

Stereum scriblitum Berk. & Cooke, Grevillea 7: 102. 1879; Sacc. Syll. Fung. 6: 567. 1888.

The type collected by *Gerard, 171* (in Kew Herb.) was studied. This is the conidial stroma of *Ustilina vulgaris*.

Stereum seriatum Berk. & Curtis is *Aleurodiscus seriatus* (B. & C.) Burt.

Stereum spongiosum Masee is *Thelephora albido-brunnea* Schw.

Stereum strumosum Fries is *Aleurodiscus strumosus* (Fr.) Burt.

Stereum subcruentatum Berk. & Curtis, Am. Acad. Arts & Sci. Proc. 4: 123. 1858, is **Aleurodiscus subcruentatus** (Berk. & Curtis) Burt, n. comb.; now included among American species, because of collections received from California and Oregon.

Stereum triste Berk. & Curtis, Linn. Soc. Bot. Jour. **10**: 332. 1868.

This is the conidial stroma of a Pyrenomycete and shows young perithecia under the stroma in the type in Curtis Herb. Collection in Kew Herb., *C. Wright, 252*, has similar structure but did not show perithecia in my sections.

(To be continued.)

EXPLANATION OF PLATE

PLATE 2

All figures of plates 2-6 have been reproduced natural size from photographs of dried herbarium specimens unless otherwise noted.

Fig. 1. *Stereum caperatum*. Specimen collected at St. Martinville, La., by A. B. Langlois.

Fig. 2. *S. hydrophorum*. Specimen collected at Rio Mato, Venezuela, by M. A. Carriker.

Fig. 3. *S. Ravenelii*. Type distribution in Ravenel, Fungi Car. 4: 13.

Fig. 4. *S. surinamense*. Specimen collected at Consuelo, San Domingo, by N. Taylor, 12.

Fig. 5. *S. Burtianum*. Specimens collected at Amherst, Mass., by P. J. Anderson.

Fig. 6. *S. quisquiliare*. From Lloyd's illustration of the type.

Fig. 7. *S. aurantiacum*. Specimens collected at Port Antonio, Jamaica, by F. S. Earle.

Figs. 8 and 9. *S. diaphanum*. Fig. 8 from type of *S. diaphanum*, and Fig. 9 from type of *S. Willeyi*.

Fig. 10. *S. exiguum*. Type.

Fig. 11. *S. tenerrimum*. Type.

Fig. 12. *S. pergamenum*. Type distribution in Ravenel, Fungi Car. 3: 25.



BURT—THELEPHORACEAE OF NORTH AMERICA

1. STEREOUM CAPERATUM.—2. S. HYDROPHORUM.—3. S. RAVENELII.—4. S. SURINAMENSE.—
5. S. BURTIANUM.—6. S. QUISQUILIARE.—7. S. AURANTIACUM.—8-9. S. DIAPHANUM.—10. S. EXI-
GUUM.—11. S. TENERRIMUM.—12. S. PERGAMENUM.

EXPLANATION OF PLATE

PLATE 3

Figs. 13 and 14. *S. pallidum*. Fig. 13, specimen collected and determined by G. Bresadola; Fig. 14, specimen collected at Blowing Rock, N. C., by G. F. Atkinson.

Fig. 15. *S. elegans*. Specimen collected at Mayaguez, Porto Rico, by B. L. Santiago, 12.

Fig. 234. *S. decolorans*. Type.

Fig. 16. *S. radicans*. Specimen collected at Grenada, by W. E. Broadway.

Fig. 17. *S. pusiolum*. Specimen collected at Rio Piedras, Porto Rico, by J. R. Johnston, 89.

Fig. 18. *S. glabrescens*. Specimen collected at Sumidero, Cuba, by J. A. Shafer, 13906.

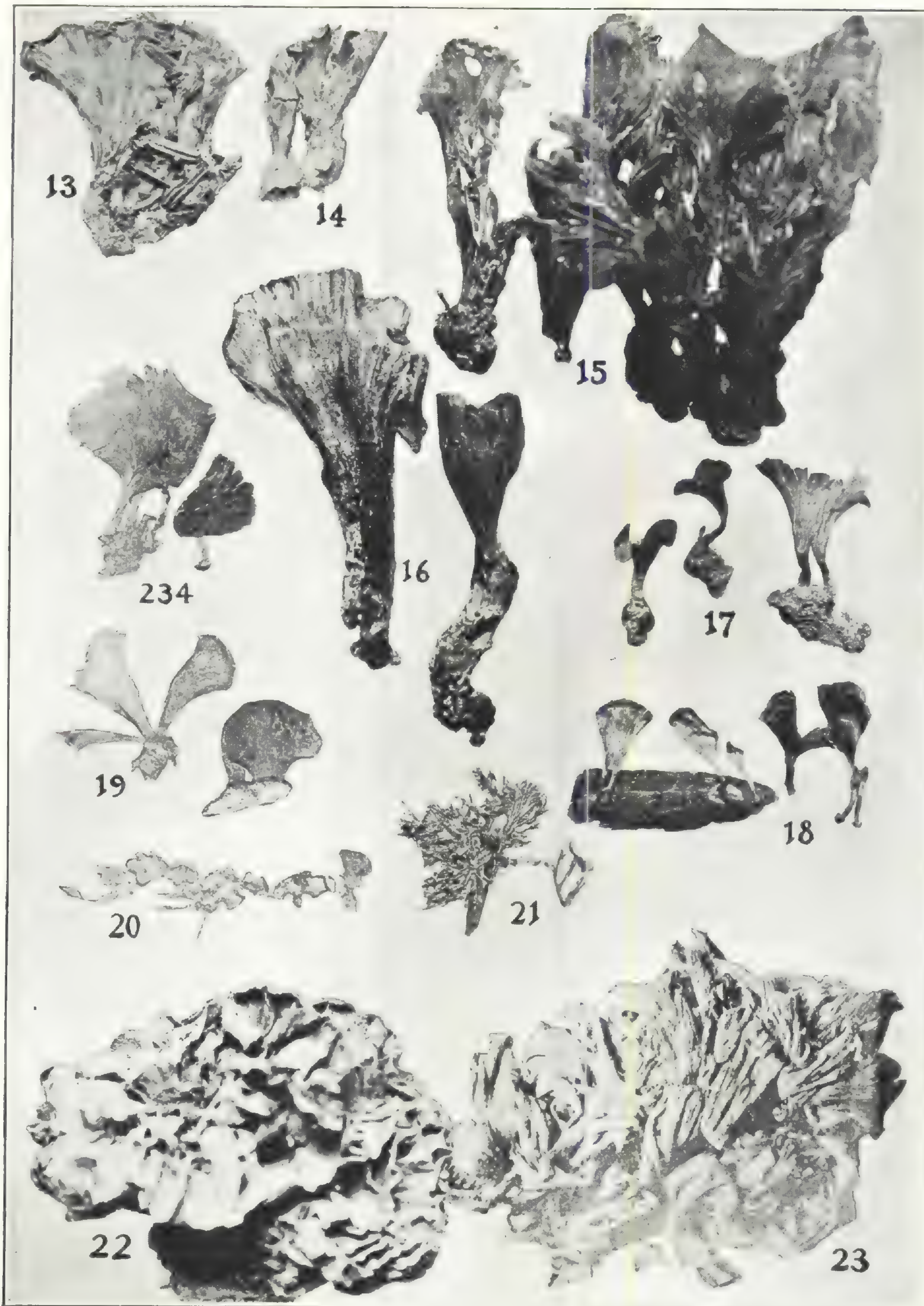
Fig. 19. *S. fissum*. Type.

Fig. 20. *S. cyphelloides*. Type.

Fig. 21. *S. Hartmanni*. Specimen collected at St. Kitt's, by N. L. Britton & J. F. Cowell.

Fig. 22. *S. craspedium*. Specimen collected in Dutch Guiana, by J. Samuels.

Fig. 23. *S. petalodes*. From C. G. Lloyd's illustration of the type.



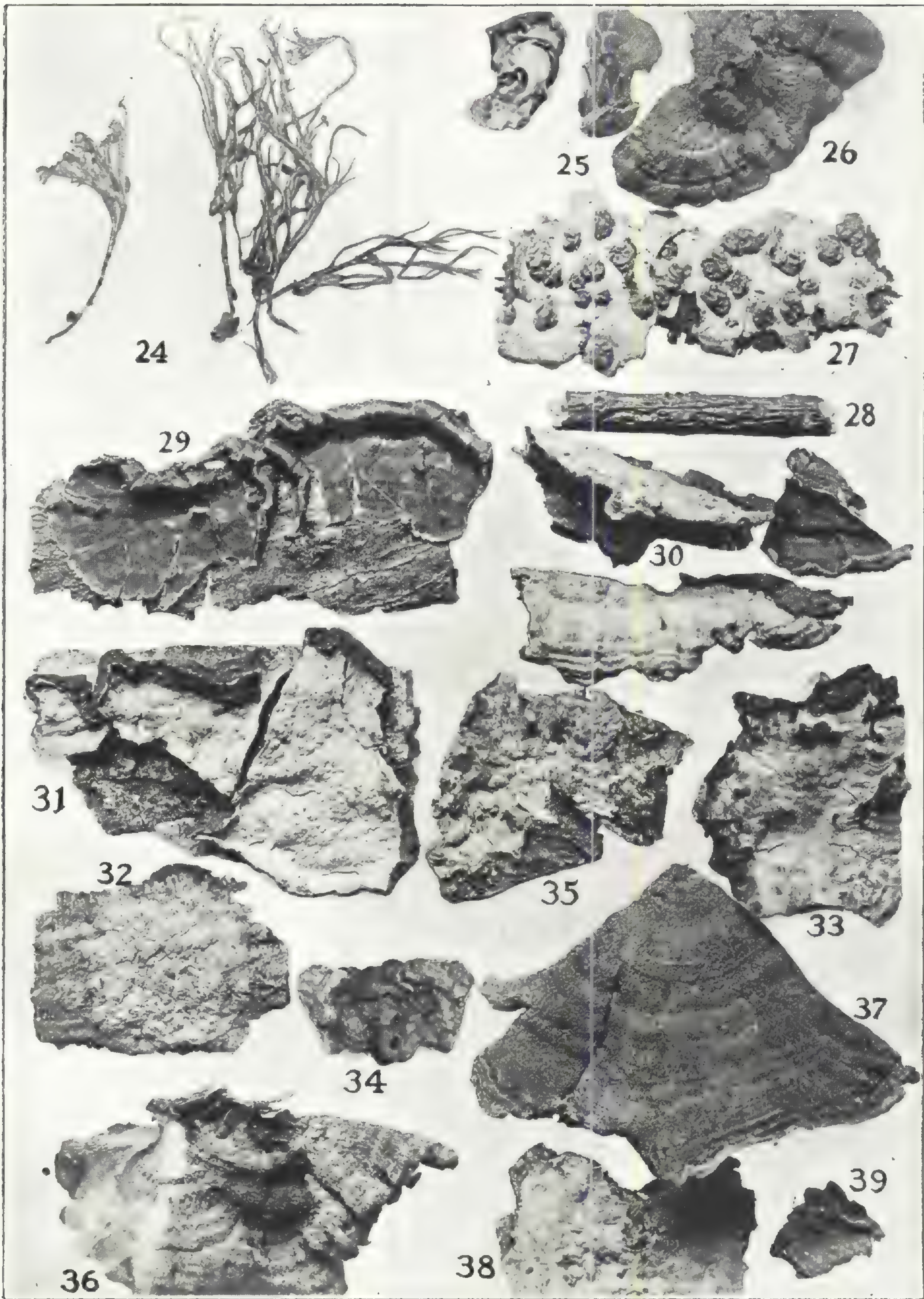
BURT—THELEPHORACEAE OF NORTH AMERICA

- 13-14. STEREOUM PALLIDUM.—15. S. ELEGANS.—234. S. DECOLORANS.—16. S. RADICANS.—17. S. PUSIOLUM.—18. S. GLABRESCENS.—19. S. FISSUM.—20. S. CYPHELLOIDES.—21. S. HARTMANNI.—22. S. CRASPIDIUM.—23. S. PETALODES

EXPLANATION OF PLATE

PLATE 4

- Fig. 24. *S. proliferum*. Type.
Fig. 25. *S. caespitosum*. Type.
Fig. 26. *S. fuscum*. Specimen collected at Middlebury, Vt., by E. A. Burt.
Fig. 27. *S. rufum*. Specimen collected at Middlebury, Vt., by E. A. Burt.
Fig. 28. *S. Pini*. Specimen collected at Chocorua, N. H., by W. G. Farlow, 37.
Fig. 29. *S. purpureum*. Specimen collected at North Ferrisburg, Vt., by E. A. Burt.
Fig. 30. *S. rugosiusculum*. Specimen collected at Creve Coeur Lake, Mo., by E. A. Burt.
Figs. 31 and 32. *S. Murrayi*. Fig 31, old reflexed specimen collected at Grand View Mt., Vt., and Fig. 32, resupinate specimen collected at Ripton, Vt., both by E. A. Burt.
Fig. 33. *S. saxitas*. Type.
Figs. 34 and 35. *S. styracifluum*. Fig. 34, type; Fig. 35, specimen collected at Auburn, Ala., by F. S. Earle & C. F. Baker.
Fig. 36. *S. gausapatum*. Specimen collected at Toronto, Canada, by T. Langton.
Fig. 37. *S. australe*. Type.
Figs. 38 and 39. *S. rugosum*. Fig. 38, specimen collected at Ithaca, N. Y. by G. F. Atkinson; Fig. 39, reflexed specimen collected in Epping Forest, England, by E. A. Burt.



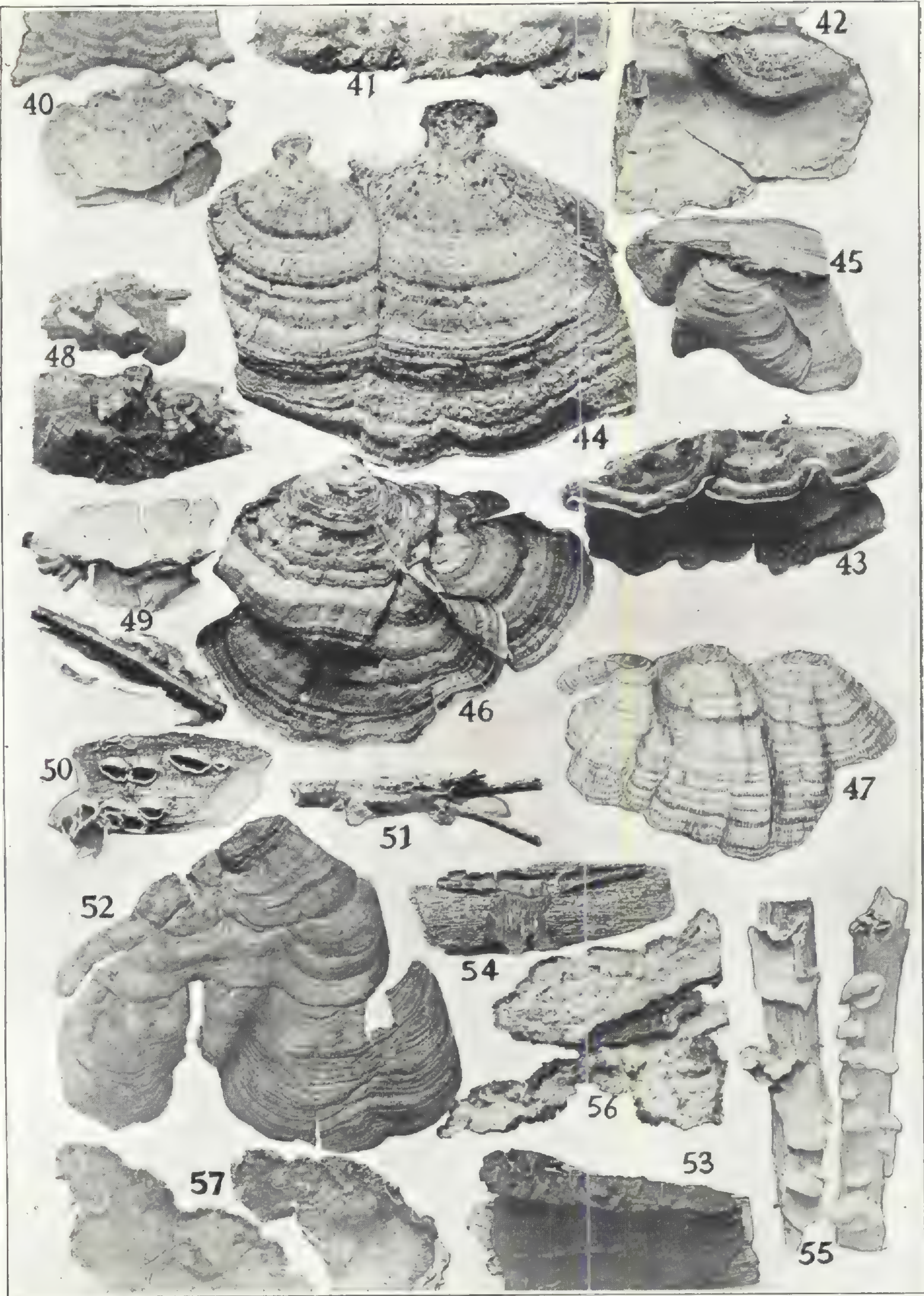
BURT—THELEPHORACEAE OF NORTH AMERICA

24. STEREOUM PROLIFERUM.—25. S. CAESPITOSUM.—26. S. FUSCUM.—27. S. RUFUM.—28. S. PINI.—
29. S. PURPUREUM.—30. S. RUGOSIUSCULUM.—31-32. S. MURRAYI.—33. S. SAXITAS.—34-35. S. STY-
RACIFLUM.—36. S. GAUSAPATUM.—37. S. AUSTRALE.—38-39. S. RUGOSUM.

EXPLANATION OF PLATE

PLATE 5

- Fig. 40. *S. sanguinolentum*. Specimen collected in Little Notch, Vt., by E. A. Burt.
- Fig. 41. *S. sulphuratum*. Specimen collected at Auburn, Ala., comm. by F. S. Earle.
- Fig. 42. *S. hirsutum*. Specimen collected at Smugglers Notch, Vt., by E. A. Burt.
- Figs. 43-45. *S. fasciatum*. Fig. 43, young effuso-reflexed stage, and Fig. 44, old stage with attachment by umbos, both collected at Middlebury, Vt., by E. A. Burt; Fig. 45, specimen collected at Formosa, Japan, by S. Kusano, II. 16.
- Fig. 46. *S. lobatum*. Specimen collected at Lake City, Fla., by P. L. Ricker, 893.
- Fig. 47. *S. versicolor*. From Berkeley's illustration of the type.
- Fig. 48. *S. rameale*. Specimen collected at Arlington, Mass., by E. A. Burt.
- Fig. 49. *S. sericeum*. Specimen collected at Middlebury, Vt., by E. A. Burt.
- Fig. 50. *S. pubescens*. Type.
- Fig. 51. *S. conicum*. Type.
- Fig. 52. *S. vibrans*. Specimen collected at Rose Hill, Jamaica, by F. S. Earle, 303.
- Fig. 53. *S. radiatum*. Specimen collected at Harraby, Ontario, by E. T. & S. A. Harper, 636.
- Fig. 54. *S. patelliforme*. Type.
- Fig. 55. *S. ochraceo-flavum*. Specimen collected at Albany, N. Y., by H. D. House.
- Fig. 56. *S. abietinum*. Specimen collected at Smugglers Notch, Vt., by E. A. Burt.
- Fig. 57. *S. ambiguum*. Specimen collected at Ripton, Vt., by E. A. Burt.



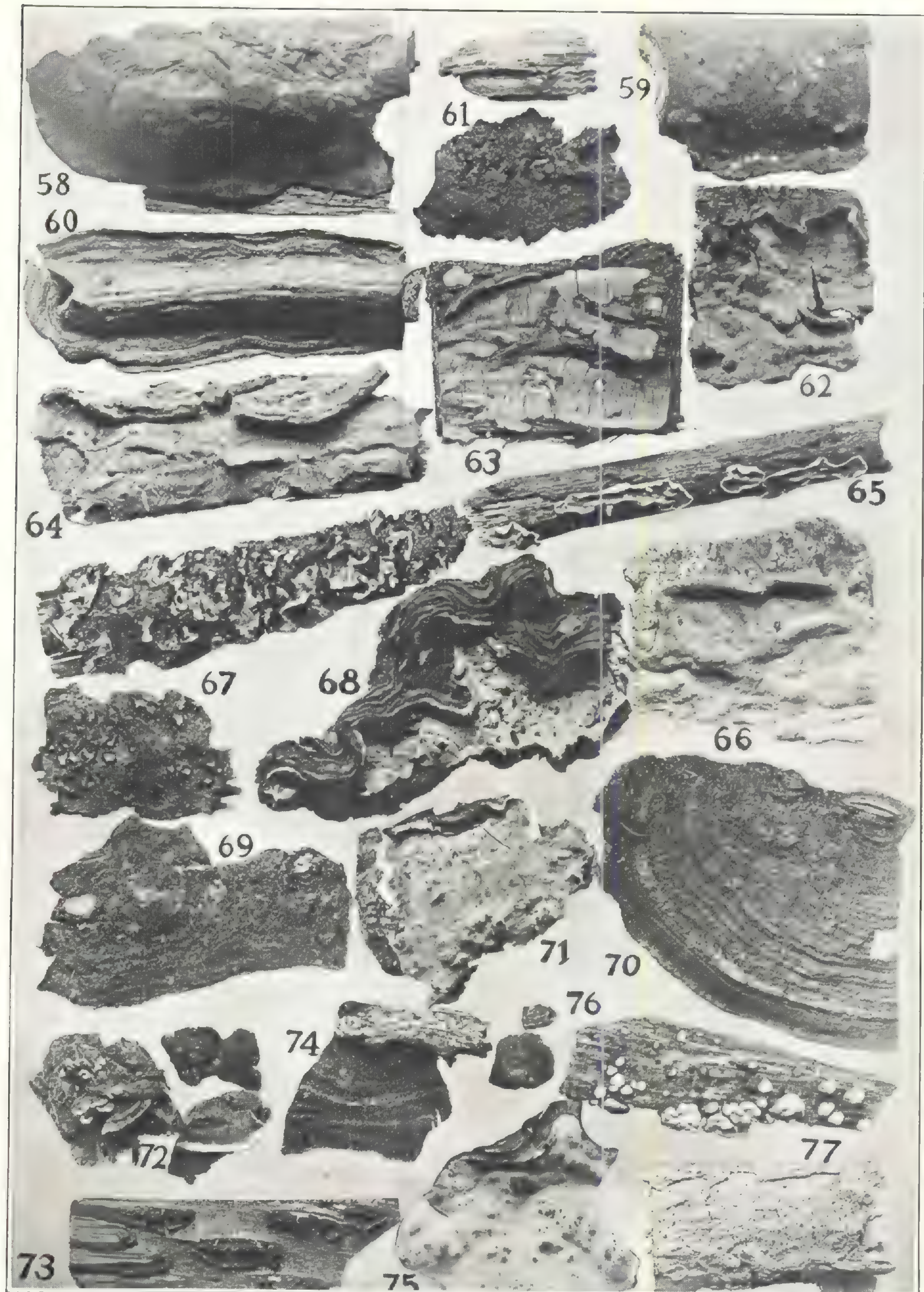
BURT—THELEPHORACEAE OF NORTH AMERICA

40. STEREOUM SANGUINOLENTUM.—41. S. SULPHURATUM.—42. S. HIRSUTUM.—43-45. S. FASCIA-
TUM.—46. S. LOBATUM.—47. S. VERSICOLOR.—48. S. RAMEALE.—49. S. SERICEUM.—50. S. PUBE-
SCENS.—51. S. CONICUM.—52. S. VIBRANS.—53. S. RADIATUM.—54. S. PATELLIFORME.—55. S.
OCHRACEO-FLAVUM.—56. S. ABIETINUM.—57. S. AMBIGUUM.

EXPLANATION OF PLATE

PLATE 6

- Fig. 58. *S. rugisporum*. Specimen collected at Flagstaff, Ariz., by W. H. Long, 21307.
- Fig. 59. *S. umbrinum*. Specimen reflexed on both sides, collected at Valley Park, Mo., by E. A. Burt.
- Fig. 60. *S. papyrinum*. Specimen on under side of a small limb and reflexed on both sides, collected at Alto Cedro, Cuba, by Underwood & Earle, 1481.
- Fig. 61. *S. Earlei*. Type.
- Fig. 62. *S. Chailletii*. Reflexed specimen collected at Albuquerque, N. M., by W. H. Long & P. W. Seay, 21313.
- Fig. 63. *S. ferreum*. Reflexed specimen collected at Cinchona, Jamaica, by W. A. & E. L. Murrill, 458.
- Fig. 64. *S. cinerascens*. Specimens collected at Middlebury, Vt., by E. A. Burt.
- Fig. 65. *S. magnisporum*. Type.
- Fig. 66. *S. spumeum*. Specimen collected at Cordoba, Mexico, by W. A. & E. L. Murrill, 1214.
- Fig. 67. *S. erumpens*. Type.
- Fig. 68. *S. sulcatum*. Type.
- Fig. 69. *S. subpileatum*. Specimen collected at St. Martinville, La., by A. B. Langlois.
- Fig. 70. *S. sepium*. Type.
- Fig. 71. *S. albobadium*. Specimen collected at Seven Locks, Md., by P. L. Ricker, 1007.
- Fig. 72. *S. heterosporum*. Type.
- Fig. 73. *S. versiforme*. Specimen collected at White Plains, N. Y. by L. M. Underwood.
- Fig. 74. *S. insigne*. Specimen collected in Florida by C. G. Lloyd, 4846.
- Fig. 75. *S. durum*. Type.
- Fig. 76. *S. frustulosum*. Specimens collected at Creve Coeur, Mo., by E. A. Burt.
- Fig. 77. *S. roseo-carneum*. Specimen collected at Arlington Heights, Mass., by E. A. Burt.



BURT—THELEPHORACEAE OF NORTH AMERICA

58. STEREOUM RUGISPORUM.—59. S. UMBRINUM.—60. S. PAPYRINUM.—61. S. EARLEI.—62. S. CHAILLETH.—63. S. FERREUM.—64. S. CINERASCENS.—65. S. MAGNISPORUM.—66. S. SPUMEUM.—67. S. ERUMPENS.—68. S. SULCATUM.—69. S. SUBPILEATUM.—70. S. SEPIUM.—71. S. ALBOBADIUM.—72. S. HETEROSPORUM.—73. S. VERSIFORME.—74. S. INSIGNE.—75. S. DURUM.—76. S. FRUSTULOSUM.—77. S. ROSEO-CARNEUM.

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STUDIES IN THE PHYSIOLOGY OF THE FUNGI XI. BACTERIAL INHIBITION BY METABOLIC PRODUCTS WILLIAM H. CHAMBERS •

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Washington University*

Considerable work has been done on the early phases of growth of bacteria in liquid media. Rahn ('06), Coplans ('07), Penfold ('14), Chesney ('16), Salter ('19), and others have shown quite definitely the factors involved in the lag phase of growth preceding the phase of logarithmic increase. They have demonstrated that the lag can be eliminated if the transfers are made during the period of logarithmic increase, but that certain factors such as difference in temperature, composition of the medium, or the age of the culture will produce a latent period immediately following the transfer.

Data on the later growth periods of bacteria are less extensive. Based on the total number of viable bacteria in the culture, the growth curve can be traced roughly as follows: It rises abruptly at first, which is the phase of logarithmic increase, then ascends more gradually until the peak is reached, and finally descends until the culture is sterile. The influence of inhibitory factors is most clearly seen in the later periods, those following the phase of logarithmic increase, the study of which is of fundamental and practical importance both in killing pathogenic bacteria, that is, hastening the decline in the growth curve, and in prolonging the life of useful cultures, suspending this decline. In the work presented here, emphasis is placed on the later periods of growth and on the influence of the products of a growing culture on the path of the growth curve.

LITERATURE

The literature on the subject of the inhibition of bacteria in culture by their own metabolic products is widely scattered, and the investigational work in this phase of growth studies is very meager. The entire subject is often dismissed with some such statement as "the organisms are finally killed by their own products."

From time to time different investigators have sought to determine if there is a special metabolic product, enzymatic in nature, which inhibits the growth of the organism producing it. One of the earliest publications on this subject appeared by Eijkmann ('04). He grew *Bacillus coli* in gelatin at 37° C., treated it in different ways, and then solidified and reinoculated the gelatin. He concluded that *Bacillus coli* in gelatin produced a diffusible, thermolabile substance which would not pass through a porcelain filter and which inhibited growth of *Bacillus coli* and other organisms, for treatment with ether, subjection to heat, or filtration through a porcelain filter removed some inhibiting substance and permitted a streak growth on the solidified gelatin.

The following year Conradi and Kurpjuweit ('05,'05^a) extended the work of Eijkmann, finding the same action in bouillon. They called the substance "autotoxin" and applied the theory to the germicidal action found in feces. They reported that the "autotoxin" of *Bacillus coli* was killed by boiling but was virulent up to a dilution of 1:3200 in a 10-hour culture, and that the heated stool filtrate from a paratyphoid patient would support growth of the same *Bacillus paratyphosis* in a 1:50 dilution, but the unheated filtrate only in a 1:400 dilution. Rolly ('06), Passini ('06), and Manteufel ('07) disputed the findings of Eijkmann, also those of Conradi and Kurpjuweit, and held that the existence of inhibitory substances had not yet been proved. Rolly could not repeat the work of Conradi and Kurpjuweit with the same results but found that the filtered half of a 20-hour bouillon culture gave better growth than the cooked half. Manteufel claimed that the loss of necessary food material from the media explained some of the results attributed to "autotoxin." Kruse ('10) summarized these reports and

explained the death of organisms in culture as probably due rather to the exhaustion of the media and the accumulation of well-known metabolic products than to an "autotoxin." He suggested the possibility of the exhaustion of the media and the accumulation of products causing the death of a few of the weaker individuals, which become self-digested, thereby releasing previously formed "autotoxin." Acids and alkalis are reported by him as inhibitory agents, although bouillon in which pneumococci had grown would not support a second growth even on readjusting the reaction.

In connection with some work on the latent period of growth, Chesney ('16) found that pneumococci in plain broth showed marked inhibition 24 hours after inoculation, the number of bacteria decreasing rapidly to zero, but if after 96 hours a portion of the bouillon was filtered through a porcelain filter and reinoculated, no inhibition was evident, indicating that the inhibitory substance was killed or attenuated in 3 days at 37° C.

It is apparent from the literature cited above that results are conflicting concerning the production of an enzymatic "autotoxin," and while the reports favoring the existence of such a product are not conclusive, no other satisfactory explanation for the observed reactions has been demonstrated.

Recent literature has indirectly contributed considerable of value concerning the relationship of acid and alkali to growth and death of bacteria, through the more general use, since 1916, of the hydrogen ion concentration as an expression of acidity of media. Winslow and Lochridge ('06), working on *Bacillus coli* and *Bacillus typhosus*, stated that the toxic effect of inorganic acids, HCl and H₂SO₄, corresponded to their dissociation, but with organic acids, acetic and benzoic, the undissociated molecule was also important, for results did not correspond to the dissociation of the acids. Michaelis ('14) advanced the idea that organisms produce acid to a certain concentration, which he found to be P_H 5.0 with *Bacillus coli* in lactose bouillon, and that they automatically protect themselves against harmful amounts.

Since that time a great deal has been published on final or limiting hydrogen ion concentrations for different organisms,

but only a very little on the effect on growth of changes in hydrogen ion concentration during growth. Clark ('15) determined the final P_H of 16 cultures of *Bacillus coli* in 1 per cent dextrose medium as P_H 4.67–5.16, and Clark and Lubs ('15) in constructing their media for differentiating the members of the colon-aerogenes group showed that a reversion of reaction toward the alkaline may take place, depending on the dextrose, but they did not show the relationship between reversion of reaction and growth. Itano ('16) reported that with *Bacillus subtilis*, *Streptococcus erysipelatus*, and *Streptococcus lacticus* in plain broth, acid was formed in alkaline media and alkali in the acid media, thus bringing the P_H to a certain definite hydrogen ion concentration. Fred and Loomis ('17) showed a wide range of reaction for *Bacillus radiccicola*, obtaining good growth between P_H 3.9 and 11.1. They also demonstrated that the hydrogen ion concentration approaches the neutral point during growth. Shohl and Janney ('17) found that P_H 4.6–5.0 was inhibitory for *Bacillus coli* in urine. Ayers, Johnson, and Davis ('18) added streptococci to the list of organisms whose final P_H was demonstrated. They separated the pathogenic from the non-pathogenic forms on the basis of limiting hydrogen ion concentration, the former reaching P_H 5.4–6.0 and the latter P_H 4.6–4.7.

The work of Ayers and Rupp ('18) on simultaneous acid and alkali fermentations showed some interesting P_H curves. They found in a .5 per cent dextrose medium that *Bacillus coli* produced acid to P_H 4.8 but that *Bacillus aerogenes* produced less initial acid and the reaction reverted to P_H 6.5. From quantitative determinations of dextrose and of formic, acetic, lactic, and succinic acids, they explained the reversion of *Bacillus aerogenes* as a fermentation of the organic acids, mostly formic and acetic, to carbonates. With the alkali-forming milk bacteria, they showed alkaline fermentation of citrate, acid fermentation of dextrose, and a practically neutral reaction from the simultaneous fermentation of the citrate and dextrose. Gillespie ('18) found *Actinomyces chromogenus* gave a poor growth at P_H 4.8–5.2 and decreased the hydrogen ion concentration of the media during growth. Wyeth ('18) showed with *Bacillus coli* in glucose bouillon that the final P_H varied with

the initial P_H ; i. e., P_H 7.11 progressed to P_H 5.70 and P_H 4.96 went to P_H 4.68. He also showed a difference in critical P_H according to the acid used, whether hydrochloric, acetic, or lactic acid. Wyeth ('19) extended his previous work and found in 2 per cent peptone that an initial range of P_H 4.29–9.37 gave a final range after 216 hours of P_H 5.92–8.55, and that with an initial P_H above 8.48 the production of acid exceeded that of alkali and the reaction approached P_H 8.48. Indole formation was completely inhibited by dextrose, partially by sucrose, and not at all by starch. Avery and Cullen ('19) used the final hydrogen ion concentration to separate strains of *Streptococcus hemolyticus*; 124 human strains attained a final P_H of 4.8–5.3, while 40 dairy strains reached P_H 4.3–4.5.

Considerable work has recently appeared on the pneumococcus. Cullen and Chesney ('18) showed the relation of the growth of pneumococcus in plain broth to hydrogen ion concentration. The bacteria increased to 420,000,000 per cc. in 13.8 hours and then decreased to 160 per cc. in 96 hours. The hydrogen ion concentration increased from P_H 7.70 to P_H 7.03,¹ but these investigators expressed the opinion that the increase in hydrogen ion concentration is not the sole cause of the cessation of growth. Avery and Cullen ('19^a) showed some interesting reactions of pneumococcus to carbohydrates. One per cent of maltose, saccharose, lactose, galactose, raffinose, dextrose, or inulin produced a final P_H of about 5.0. With .4 per cent dextrose, as high an hydrogen ion concentration was attained in 48 hours as with 1 or 2 per cent dextrose. Pneumococcus differed from *Bacillus coli* in that it produced acid in plain broth, and growth ceased at about P_H 7.0. When this culture was readjusted to P_H 7.8 and reinoculated, no growth occurred unless carbohydrate was added, yet the filtrate from a dextrose culture at P_H 5.2 if readjusted to P_H 5.8, 7.0, or 8.0 would again return to P_H 5.2. Growth could only be initiated within certain limits, in carbohydrate media P_H 8.3–6.8 and in plain broth P_H 8.1–7.0. They concluded that the exhaustion of fermentable carbohydrate is only one of the many

¹ To avoid confusion, attention is called to the distinction between the concentration of the hydrogen ions and the symbolic P_H . A numerical increase in hydrogen ions is expressed as a decrease in terms of P_H .

factors involved in the complex phenomenon of growth inhibition.

Lord and Nye ('19) have demonstrated the relation of time to inhibitory action of hydrogen ion concentration with pneumococcus. They found that *Pneumococcus* Type I was killed in 1 hour at P_H 4.5-4.7, in 3 hours at P_H 5.3, and in 6 hours at P_H 6.15, but survived 6 hours at P_H 6.35, and that between P_H 6.8 and P_H 5.1 there was a direct relation between the P_H and the time required for the death of the pneumococcus. In mixtures of equal quantities of emulsions of washed pneumococci and buffer solutions of different hydrogen ion concentrations they observed very little dissolution of the bacterial cells between P_H 8.0 and P_H 7.0 or between P_H 5.0 and P_H 4.0, but noticed almost complete dissolution in the zone of P_H 6.5-5.5.

Bunker ('19) published the results of investigations of *Bacillus diphtheriae* extending over several years. The hydrogen ion curves in sugar-free and in 1 per cent dextrose media agree very closely with those of *Bacillus coli* in the experimental work of this report. He also showed that toxin was only produced within a rather narrow hydrogen ion range, P_H 7.8-8.25. The best growth, measured by pellicle formation, was obtained when the initial reaction was P_H 7.3-7.5. Cohen and Clark ('19) investigated the effect of hydrogen ion concentration on the rate of growth of different organisms during the early part of the growth curve, the period of logarithmic increase. Cultures were inoculated into media adjusted over a wide range of varying initial hydrogen ion concentrations, and observed for the first 10 hours of growth. In general, the different organisms reacted similarly. The most marked effect of the hydrogen ion concentration on early growth was found near the critical acid and alkali zones. They reported that with *Bacillus coli* fermentative activity was checked in 1 per cent dextrose bouillon at P_H 5.0, but that growth in plain bouillon was checked at P_H 5.7. They noted evidence of inhibition which obscured their results, but they did not study the inhibitory factors; however, it was found that the period of lag was more pronounced in alkaline than in acid media.

Recent contributions from Besson, Ranque, and Senez ('19), while they do not involve hydrogen ion concentration, advance

some new ideas on sugar relations and fermentation. They worked with *Bacillus coli* in bouillon containing varying amounts of dextrose. With less than .4 per cent dextrose the sugar was all removed in 24 hours and the cultures were viable after 10 days, while with .4 per cent or over the cultures were sterile in 6 days. They reported that fermentation with gas commenced at the time multiplication of the organisms ceased, that acid production started at the same time, and that more than one-half the total acid is produced in 1 hour.

From the literature reviewed it would appear that a correlation of growth curves and P_H curves, with frequent observations during growth, rather than a study of final hydrogen ion concentration, would add to our knowledge of metabolic changes in hydrogen ion concentration and of inhibition during growth.

TECHNIQUE

The experimental work was planned on the basis of a correlation of the growth of the bacteria with the changes in the hydrogen ion concentration of the media produced during growth. The technique was uniform throughout to make all results comparable. Cultures were grown in Florence flasks of 500, 1000, and 2000 cc. capacity, filled to one-half their capacities for the initial volume of media to insure a uniform and maximum surface. The basic bouillon for all the cultures, designated plain bouillon through the text, consisted of 2.5 per cent bacto-beef and 1 per cent bacto-peptone made up with distilled water according to the Digestive Ferments Company circular of December, 1916. This plain bouillon forms the basis for the different dextrose media, with a few exceptions which are noted in the data.

A culture of *Bacillus coli*, culture FG, kindly furnished from the Dairy Division, United States Department of Agriculture, was used throughout the experimental work with one exception, in which *Bacillus aerogenes*, culture VE from the same laboratory, was substituted.

To avoid the lag phase, transfers from stock agar were grown through two successive cultures of plain bouillon, and the inoculation was made from the second culture between 6 and 10 hours, during its period of logarithmic increase. A uniform tempera-

TABLE I
GROWTH AND HYDROGEN ION CONCENTRATION OF BACILLUS COLI IN
PLAIN AND 1 PER CENT DEXTROSE BOUILLON AT 30° C.

Hours	1 Plain bouillon		2 Plain bouillon and 1% dextrose	
	Bacteria per cc.	P _H	Bacteria per cc.	P _H
0	54,000	7.1	55,000	7.1
12	175,000,000	6.8	268,000,000	5.3
20			281,000,000	5.1
24	320,000,000	7.2	214,000,000	4.9
36	538,000,000	7.5	220,000,000	4.8
48	609,000,000	7.6	189,000,000	4.8
72	450,000,000	7.7	119,000,000	4.8
96	459,000,000	7.8	14,500,000	4.9
120	293,000,000	7.9	11,100	4.9
144	250,000,000	8.1	0	4.9
168	151,000,000	8.1		
192	156,000,000	8.3		
234	125,000,000	8.2		
276	115,000,000	8.3		
348	89,000,000	8.3		
492	69,000,000	8.3		
612	71,000,000	8.3		
1284	53,000,000	8.5		
1800	7,500,000	8.7		

ture of 30° C. was maintained for all cultures throughout the work.

The changes in growth and hydrogen ion concentration in each culture were followed by removing, under aseptic conditions, a 3-cc. sample at 12- or 24-hour intervals, after the flasks had been rotated briskly 30 times to mix the contents thoroughly. One cc. was diluted and plated in triplicate in agar composed of plain bouillon to which 1 per cent dextrose and 1.5 per cent granular agar had been added. The hydrogen ion concentration was determined from the remaining 2 cc. according to the colorimetric method of Clark and Lubs ('17), using the micro-colorimeter described by Duggar ('19). The hydrogen ion concentration is expressed in P_H, or the reciprocal values of Sørensen now in general biological use. Plates were counted after an incubation of 72 hours at 30° C.

Bacteria per cc.

(Logs.)

10.0

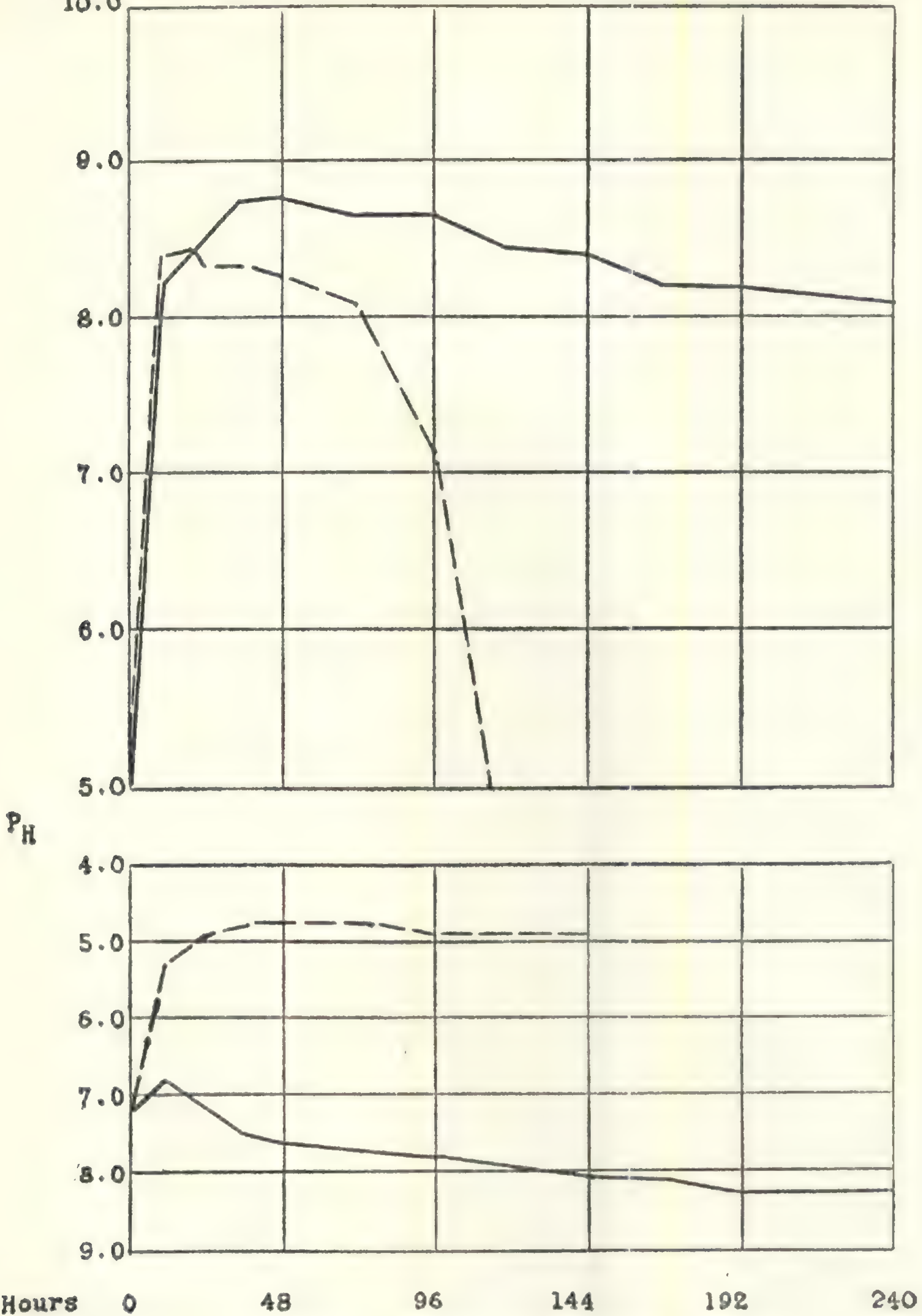


Fig. 1. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C.

———— plain bouillon.

- - - - - 1 per cent dextrose bouillon.

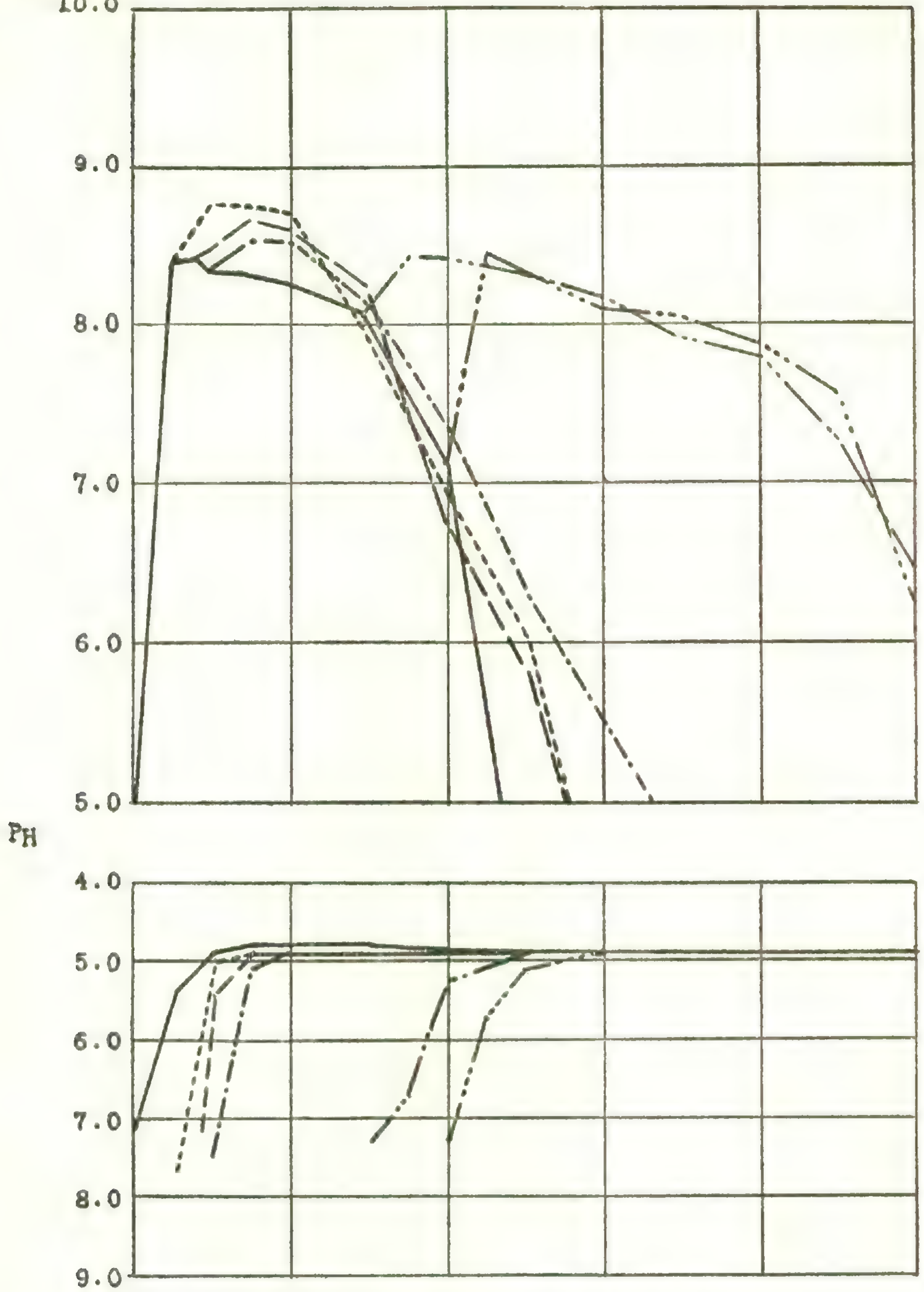
EXPERIMENTAL DATA

As a starting point for the experimental work and as a basis for comparison of inhibitory action, one culture in plain bouillon and one culture in this bouillon with 1 per cent dextrose added were inoculated with equal numbers of *Bacillus coli* from the same culture. The resulting growth (expressed in numbers of bacteria per cc.), and the hydrogen ion concentration of the media (expressed in P_H) are recorded in table 1. The comparison is more strikingly shown in fig. 1, in which the growth curves are plotted from the logarithms of numbers of bacteria per cc. as given in table 1. A comparison of the hydrogen ion curves shows a rapid production of acid from dextrose, attaining P_H 4.8 in 36 hours, but a slower production of alkali in the plain bouillon with the exception of the short acid break at the beginning of the curve. Growth in the dextrose bouillon is more rapid in 12 hours than in the plain bouillon but the maximum is reached in 20 hours, 281,000,000 bacteria per cc. when the P_H is 5.1, and the decline is then very abrupt, terminating in sterility of the culture in 144 hours. In the plain bouillon, the maximum is reached in 48 hours, 609,000,000 bacteria per cc., with a P_H of 7.6. However, after 75 days, although a P_H of 8.7 is attained, there are still 7,500,000 viable bacteria per cc. in the culture. Apparently, then, the more intense inhibition is found in the dextrose rather than in the plain bouillon.

If a bacterial "autotoxin," or any inhibitory action such as Chesney found with pneumococcus in plain broth, is produced by *Bacillus coli*, it would seem, from the results given in table 1, to be associated with the dextrose bouillon and not with the plain bouillon. A series of cultures in a 1 per cent dextrose medium were observed for the purpose of determining any variation in inhibitory action during growth and death. The results are given in table II and illustrated in fig. 2. Flask 1, the parent culture, contained the same 1 per cent dextrose bouillon as Culture 2 of table 1. Subcultures of 200 cc. each were removed from the parent cultures at the times indicated, commencing before the point of maximum growth was reached and covering a range well into the period of rapid death. The reaction of the subcultures was readjusted to approximately neutral with sterile N/1 NaOH to eliminate the acidity factor,

Bacteria per cc.

(Logs.)
10.0



Hours 0 48 96 144 192 240

Fig. 2. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C., 1 per cent dextrose bouillon, subcultured at intervals.

- parent culture.
- Subculture 1.
- - - - - Subculture 2.
- Subculture 3.
- Subculture 4.
- Subculture 5.

and the subcultures were then observed as new cultures. The points of maximum growth for the different subcultures in order are 557,000,000, 428,000,000, 342,000,000, 264,000,000, and 274,000,000 bacteria per cc., so that the subcultures fall in a regular series of decreasing maximum growths, with the exception of Culture 4 whose maximum might have occurred unobserved between 84 and 96 hours. There is nothing distinctive in the changes in hydrogen ion concentration, each subculture producing acid to P_H 4.9 in 24 to 36 hours. It would seem, then, from this series of subcultures that some factor besides hydrogen ion concentration caused an inhibition of the growth, increasing with the age of the culture.

To determine the influence of the exhaustion of the medium as a factor in the inhibitory action shown in fig. 2, another similar series was observed. Four subcultures of 200 cc. each were removed from a parent culture at 96 hours and treated in different ways. All were readjusted to approximately neutral with N/1 NaOH. In addition 50 cc. of plain bouillon condensed 5 times was added to No. 2 (200 cc.), making a total volume of 250 cc. No. 3 received 50 cc. of the condensed bouillon and 1 per cent dextrose. No. 4 received the same nutrients as No. 3 and was then sterilized for 15 minutes at 120° C. to kill any "autotoxin" or inhibitory enzymatic substance, and reinoculated as a new culture. The results are contained in table III and fig. 3. The changes in hydrogen ion concentration are very uniform, falling on almost the same line, an increase until P_H 4.9 is reached in 48 hours. The exhaustion of the medium is shown, however, by the increased growth both in the culture with the bouillon replenished and in the replenished bouillon with dextrose added. The addition of dextrose shows almost no advantage over the addition of concentrated bouillon alone, so that dextrose is not considered an important factor at this time. Acid production from P_H 7.3 to 4.9 in Subcultures 1 and 2 where the dextrose was not replenished shows that all the dextrose had not been fermented in the parent culture at 96 hours. The maximum in Subculture 3 (table III) of 545,000,000 bacteria per cc. compares very favorably with 557,000,000 in Subculture 1 of table II, so that it would appear that the exhaustion of the nutrients contained in the plain bouillon was a very im-

Bacteria per cc.
(Logs.)

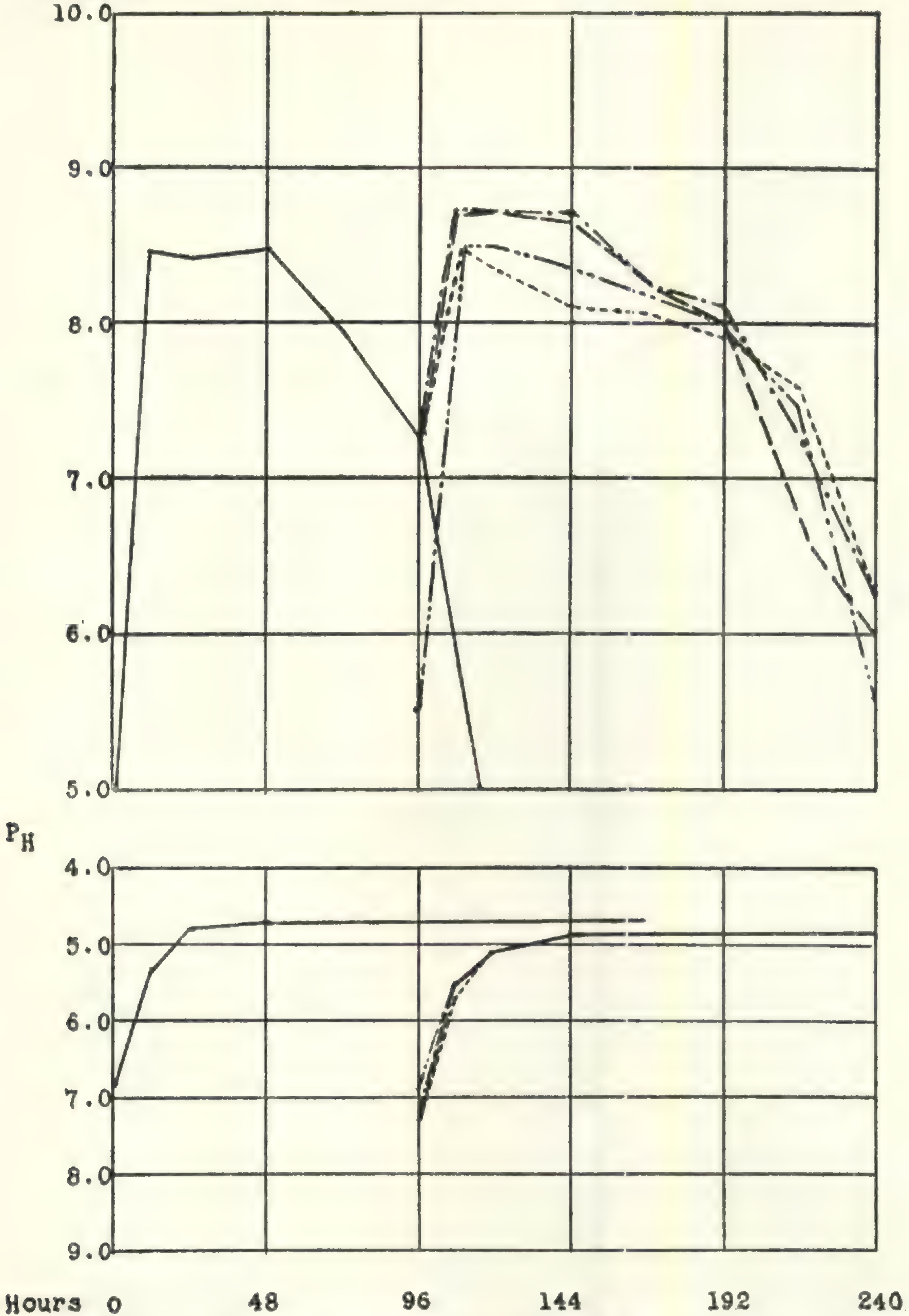


Fig. 3. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C., 1 per cent dextrose bouillon, subcultures with added nutrients.

- parent culture.
- Subculture 1.
- - - - - Subculture 2.
- . - . - Subculture 3.
- Subculture 4.

portant factor in causing the increasing inhibitory action up to 96 hours. Subculture 4, with the same added nutrients as Subculture 3 but sterilized and reinoculated, did not attain the growth of Subculture 3, probably because of the small inoculation. However, the fact that the sterilized subculture did not surpass the unsterilized would indicate that in the parent culture or in the other subcultures the inhibition was not due to a substance which could be killed by sterilizing.

Some investigators have reported that the inhibitory action disappeared on standing and that a good growth was attained upon reinoculation, although the acidity was unaltered. To check this with *Bacillus coli*, 3 to 5 days after the cultures reported in table III became sterile, Subcultures 1, 3, and 4 were mixed together and divided into three equal 200-cc. portions, designated Cultures A, B, and C. Culture A was unchanged; Culture B was sterilized 15 minutes at 120° C.; and Culture C was readjusted to P_H 7.3. All were inoculated from the same culture of *Bacillus coli* with approximately 275,000 bacteria per cc. The growth and hydrogen ion concentration changes are recorded in table IV and fig. 4. Where unaltered, the hydrogen ion concentration in Cultures A and B is P_H 5.1 at inoculation, progressing to P_H 4.9 in a short time. Death of the bacteria occurs shortly, with very little difference between the sterilized and unsterilized cultures. In Culture C, unsterilized but with acidity corrected to P_H 7.3, growth and formation of acid occur similar to that in a new culture. Normal growth when the acidity was adjusted to neutral and no growth when it was not, both in the sterilized and unsterilized cultures, would indicate that no thermolabile substance which disappears on standing was present and that the hydrogen ion concentration of the medium was the important inhibitory factor.

The combined results expressed in the four tables might be summarized as follows: Inhibition to the point of death occurred only in dextrose bouillon in conjunction with acid formation, and not in plain bouillon with alkali formation. A slight inhibitory action was found in dextrose bouillon, increasing with the age of the culture up to 96 hours, which was not attributable to acid but which probably was due to a diminution of the nutrients in the medium. No indication was found of an in-

TABLE IV

GROWTH AND HYDROGEN ION CONCENTRATION OF BACILLUS COLI AT 30° C., DEXTROSE BOUILLON, REINOCULATED

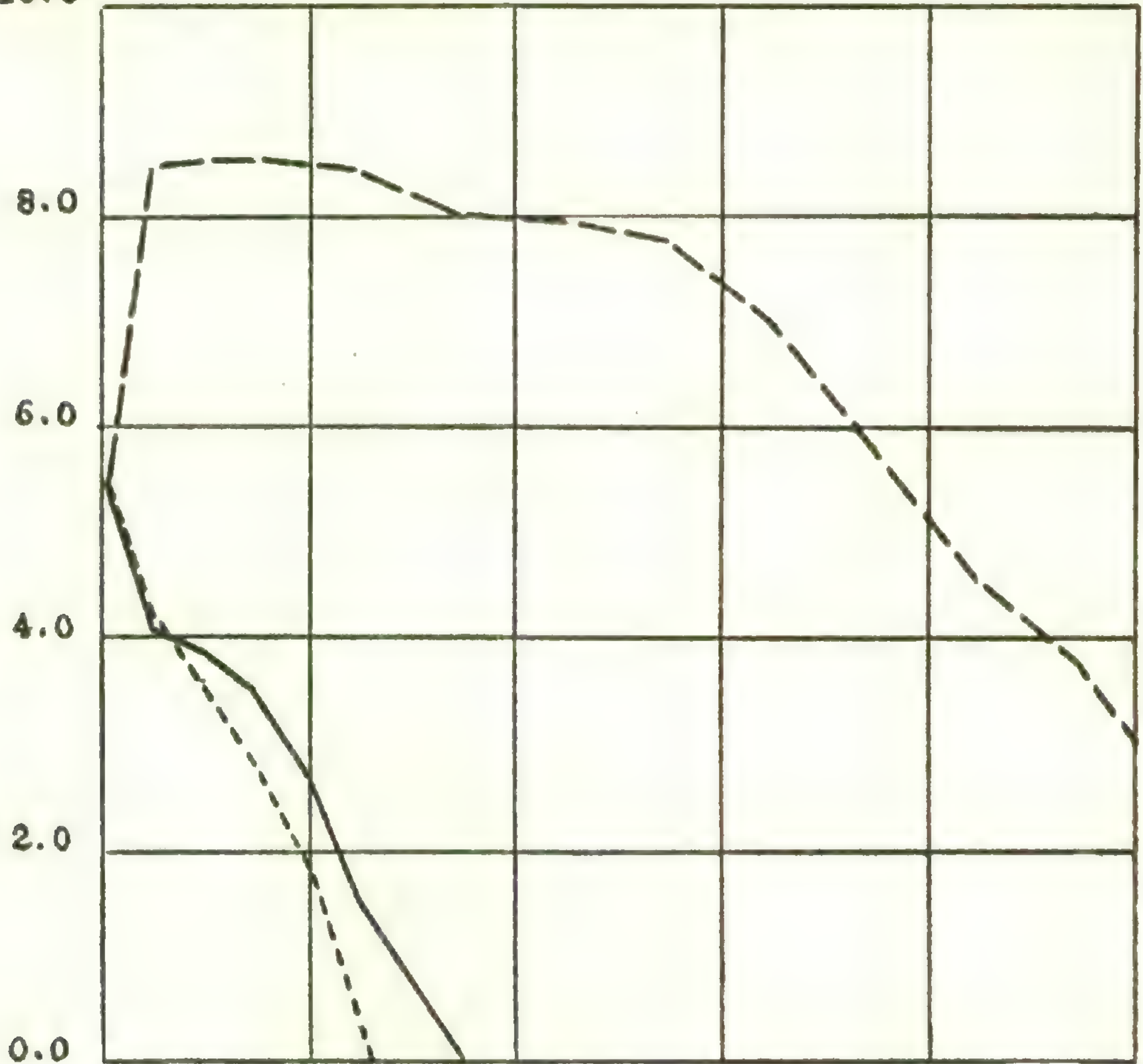
Culture	A		B		C	
Treatment	None		Sterilized		Acidity adjusted	
Hours	Bacteria per cc.	P _H	Bacteria per cc.	P _H	Bacteria per cc.	P _H
0	275,000	5.1	286,000	5.1	261,000	7.3
12	11,400	5.0	15,200	4.9	280,000,000	5.5
24	7,200	5.0	3,800	4.9	320,000,000	5.5
36	3,600	4.9	650	4.9	340,000,000	5.3
48	530	4.9	75	4.9		
60	30	4.9	2	4.9	264,000,000	5.1
84	0	4.9	0	4.9	104,000,000	5.1
108					89,000,000	5.1
132					57,000,000	5.1
156					9,500,000	5.1
180					660,000	5.1
204					36,600	5.1
228					5,400	5.1
252					280	5.1
300					0	5.1

hibitory substance which was destroyed by sterilization or inactivated on standing. The evidence of these results is against an "autotoxin" theory and points toward the hydrogen ion concentration as the predominating inhibitory factor in the experiments cited.

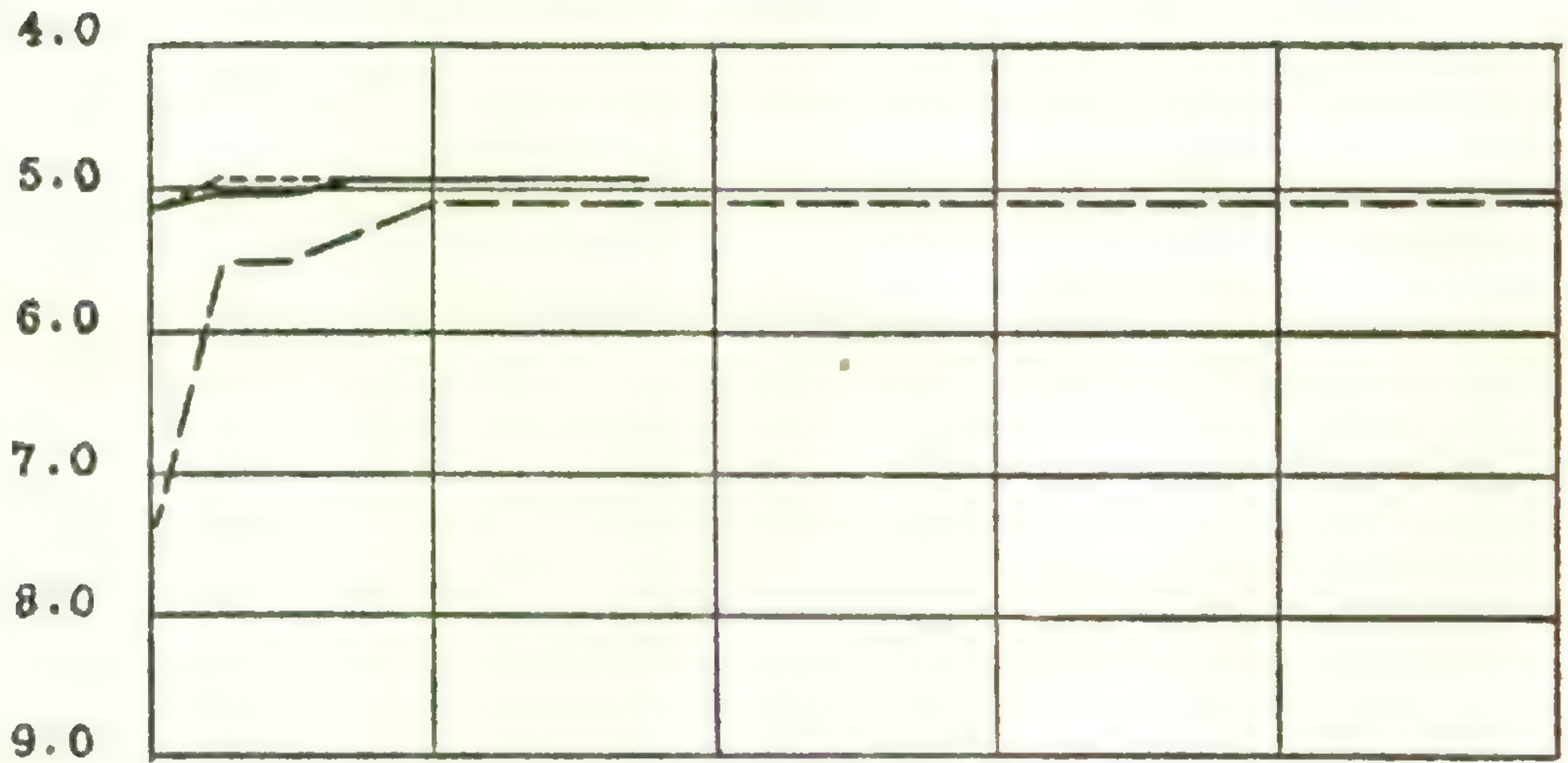
The balance of the experimental work concerns the relation of hydrogen ion concentration to inhibition. To counteract the influence of acid and alkali produced during growth, and thus to study their action by comparison, two cultures were observed in which the acid or alkali formed was neutralized at frequent intervals. The media used was the same as that reported in table 1, one culture of plain bouillon and the other of 1 per cent dextrose bouillon, 500 cc. each in 1000-cc. flasks. The acid produced in the dextrose culture was neutralized at 12-hour intervals by the addition of N/1 NaOH and the hy-

Bacteria per cc.

(Logs.)
10.0



PH



Hours 0 48 96 144 192 240

Fig. 4. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C., dextrose bouillon, reinoculated.

- Culture A, untreated.
- Culture B, sterilized.
- - - - - Culture C, acidity adjusted.

TABLE V
GROWTH AND HYDROGEN ION CONCENTRATION OF BACILLUS COLI AT
30° C., PLAIN AND 1 PER CENT DEXTROSE BOUILLON,
NEUTRALIZED AT INTERVALS

Hours	1 Plain bouillon			2 1% Dextrose bouillon		
	Bacteria per cc.	Cc. of N/5 HCl added	P _H	Bacteria per cc.	Cc. of N/1 NaOH and N/5 HCl added	P _H
0	57,000		7.1	54,000	N/1 NaOH	7.1
12	184,000,000		7.0	259,000,000		5.3
14					4.0	6.5
24	391,000,000		7.3	347,000,000		5.1
26		3	6.9		6.3	7.1
36	552,000,000		7.4	507,000,000		5.1
38		5	7.0		6.5	6.9
48	660,000,000		7.3	612,000,000		5.1
50		5	6.7		7.0	7.0
60			7.1			5.3
62		3	6.7		7.0	6.7
72	631,000,000		7.1	692,000,000		5.7
74		3	6.7		7.0	7.3
96	684,000,000		7.2	728,000,000		7.5
98		3	6.8		N/5 HCl 3.0	7.3
120	696,000,000		7.3	532,000,000		7.3
122		3	6.7		3.0	7.3
144	680,000,000		7.3	455,000,000		7.5
146		3	6.9		16.0	6.9
168	570,000,000		7.2	487,000,000		7.5
192	693,000,000		7.1	618,000,000		7.3
234	437,000,000		7.3	885,000,000		7.5
236		3	6.9		15.0	7.0
276	450,000,000		7.1	794,000,000		7.6
278		4	6.8		20.0	7.1
348	327,000,000		7.1	608,000,000		7.7
350		3	6.5		25.0	6.7
492	256,000,000		7.1	441,000,000		8.1

drogen ion concentration was determined before and after each addition. The plain bouillon was treated similarly, correcting the alkali with N/5 HCl. The growth in bacteria per cc., the hydrogen ion concentration and the cc. of acid or alkali added

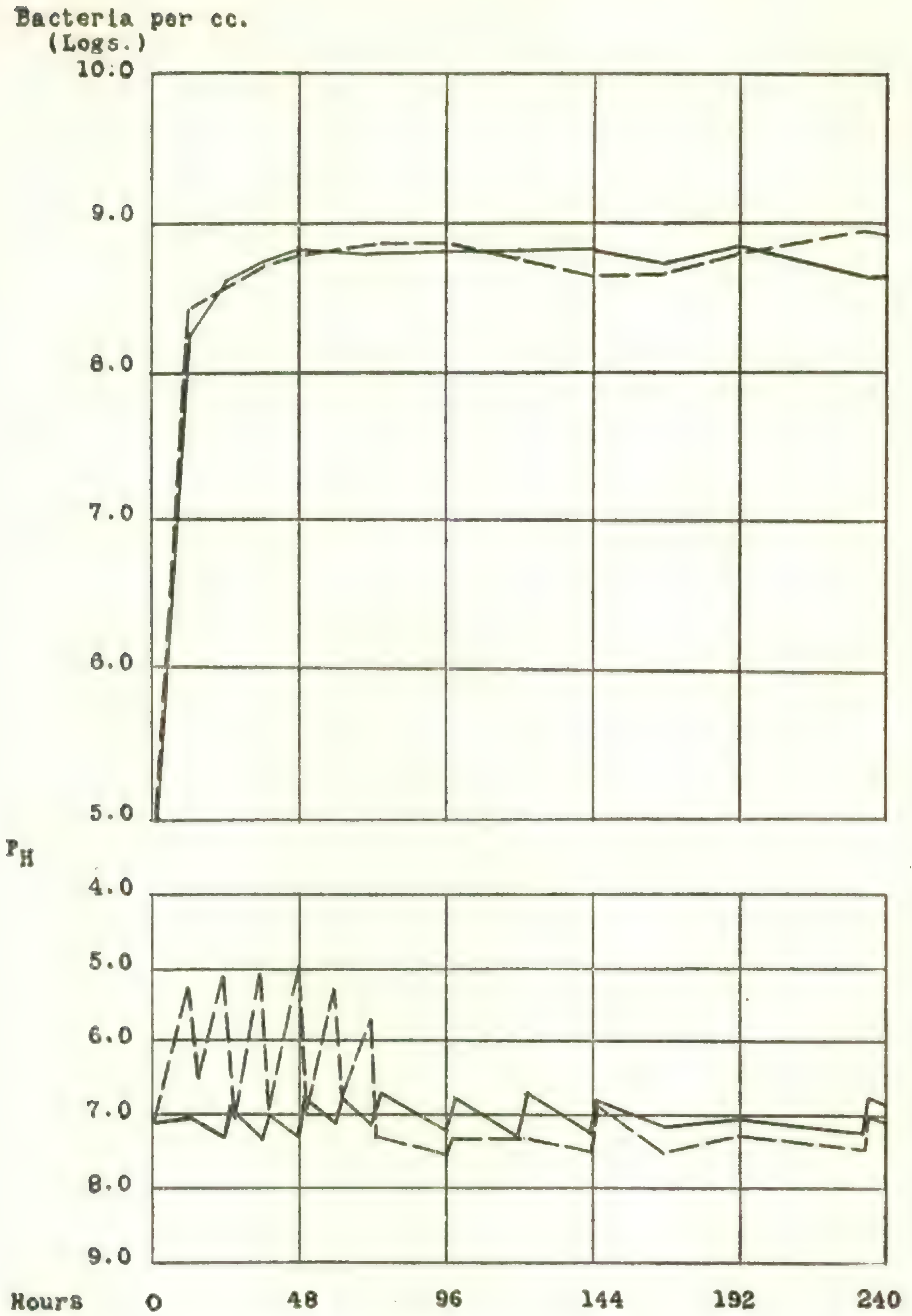


Fig. 5. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C., plain and 1 per cent dextrose bouillon, neutralized at intervals.

———— plain bouillon.
- - - - 1 per cent dextrose bouillon.

are given in table v. A more striking representation of the changes in the concentration of the hydrogen ions is shown in the curves in fig. 5. Growth in both cultures is practically parallel, with the dextrose culture reaching the highest point—885,000,000 per cc. at 234 hours. From a comparison of these growth curves with those of fig. 1, it is quite evident that neutralizing the acid or alkali prolongs the growth at a higher level.

The P_H curve for the dextrose culture shows an abundant production of acid, going as high as P_H 5.1 several times. Between 72 and 96 hours, however, the formation changed to alkali, and N/5 HCl was added to neutralize. Table v shows that 37.8 cc. of N/1 NaOH were required to neutralize the acid from 1 per cent dextrose and that in the same time, 96 hours, 19 cc. of N/5 HCl were used in neutralizing the alkali in the plain bouillon, giving a ratio of 189 to 19, or approximately 10 to 1. Theoretically, then, one-tenth of the dextrose, or .1 per cent dextrose, would furnish just enough acid in 96 hours to neutralize the alkali formed in plain bouillon, and would hold at neutral the hydrogen ion concentration of a growing culture which was fermenting dextrose, if the dextrose were added in small amounts at frequent intervals.

On this basis a culture was started in plain bouillon. The amounts of dextrose added, the growth, and the P_H values are given in table vi and illustrated in fig. 6. By 72 hours the hydrogen ion concentration had demonstrated that the theoretical amount, .025 per cent of dextrose every 24 hours, did not furnish sufficient acid to neutralize the alkali, so the amount of dextrose was increased and the intervals between additions shortened to meet the needs of the culture. The reaction, with each addition of sugar, depends on the acid fermentation of the sugar and a subsequent alkali formation, as illustrated by the P_H curves between 48 and 72 hours and between 96 and 108 hours. This alkali formation was reversed by the addition of more sugar at the proper time. Although the theoretical calculation was upset by the increased growth, the P_H curve demonstrates that it was possible to hold the hydrogen ion concentration within a very narrow zone around the neutral point. The growth was very rapid, reaching 1,550,000,000 bacteria per cc. at 48 hours, or $2\frac{1}{2}$ times as many bacteria as Culture 2,

TABLE VI
GROWTH AND HYDROGEN ION CONCENTRATION OF BACILLUS COLI AT 30° C., DEXTROSE ADDED AT INTERVALS

Hours	Bacteria per cc.	pH	Cc. of 12.5% dextrose added	% Dextrose in 500 cc. of medium	Hours	Bacteria per cc.	pH	Cc. of 12.5% dextrose added	% Dextrose in 500 cc. of medium
0	309,000	7.1	1.0	.025	252	2,850,000,000	7.0	1.2	.03
12	363,000,000	6.4	1.0	.025	264	1,700,000,000	6.7	2.4	.06
24	923,000,000	7.0	1.0	.025	288	2,014,000,000	6.7	2.2	.055
36	1,360,000,000	6.9	1.0	.025	312	1,840,000,000	6.7	2.0	.05
48	1,550,000,000	7.1	1.0	.025	336	1,705,000,000	6.6	1.0	.025
60	1,400,000,000	7.0	1.0	.025	360	2,650,000,000	6.7	1.5	.0375
72	1,512,000,000	7.3	1.0	.0375	384	1,705,000,000	7.0	1.8	.045
84	1,230,000,000	7.3	1.5	.05	408	2,650,000,000	7.0	1.5	.0375
96	1,550,000,000	7.3	2.0	.025	432	1,675,000,000	7.1	1.6	.04
104		6.7	1.0	.0375	480	2,100,000,000	7.3	2.0	.05
108		7.0	1.5	.03	504	1,500,000,000	7.2	1.0	.025
120	2,250,000,000	7.3	2.0	.025	532	2,300,000,000	7.2	1.5	.0375
132		6.8	1.0	.03	552	2,650,000,000	7.1	1.6	.04
144	3,125,000,000	7.0	1.5	.025	564	1,675,000,000	6.5	1.6	.04
156	3,200,000,000	6.7	1.0	.0375	576	1,705,000,000	7.0	2.0	.05
168	3,750,000,000	7.0	1.3	.025	600	2,650,000,000	7.1	2.0	.05
180		6.9	1.2	.03	648	1,500,000,000	7.3	2.0	.05
192	3,250,000,000	6.9	1.2	.03	672	2,100,000,000	7.0	2.0	.05
204		6.9	1.1	.0275	720	2,300,000,000	7.2	2.0	.05
216	3,425,000,000	7.0	1.2	.03	744	1,500,000,000	6.7	1.0	.025
228		7.0	1.2	.03	768	2,650,000,000	6.7	1.0	.025
240	2,650,000,000	7.0	1.2	.03	816		7.1	1.3	.0325
					840		7.0	1.2	.03

Bacteria per cc.
(Logs.)

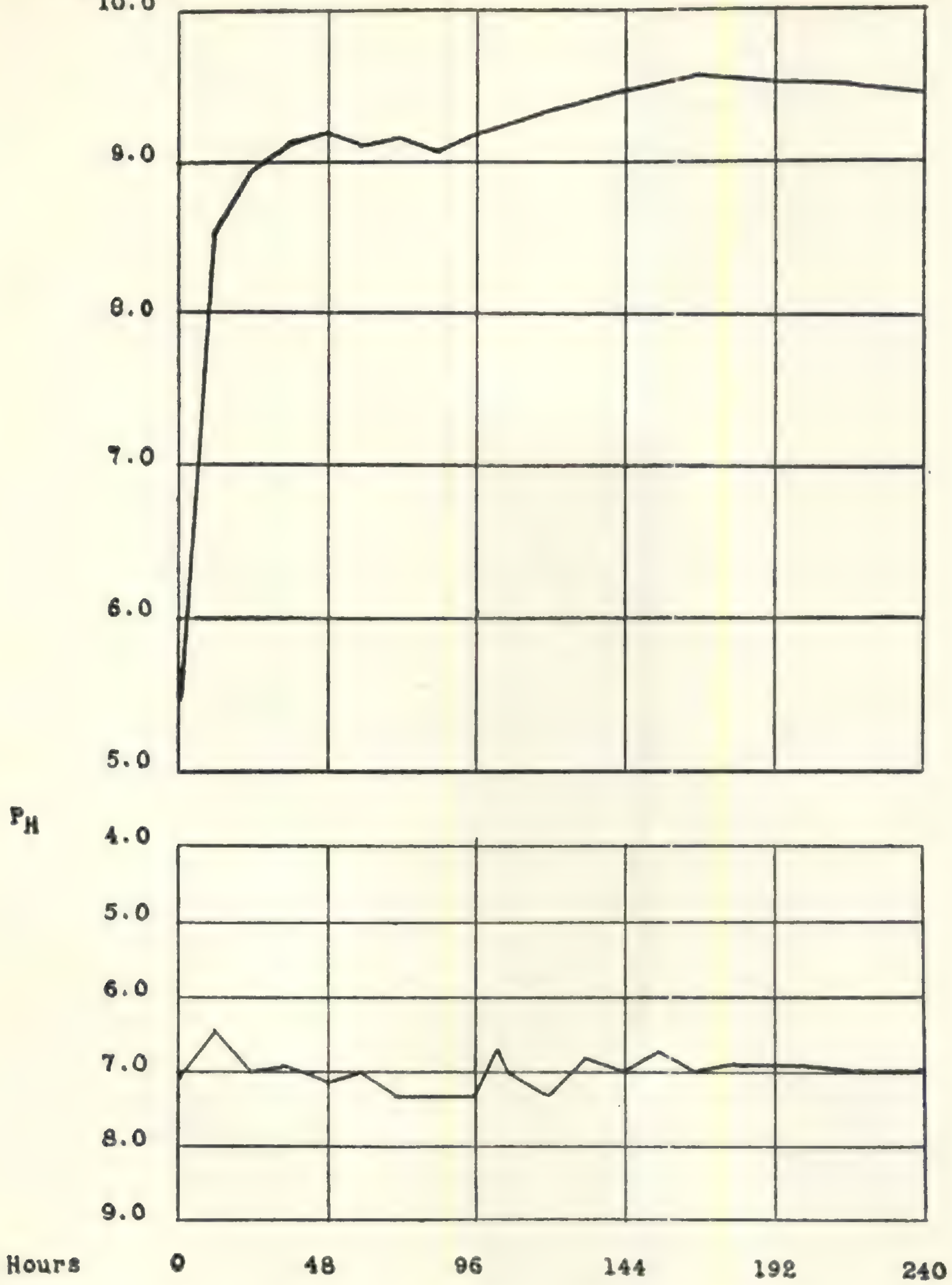


Fig. 6. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C., dextrose added at intervals.

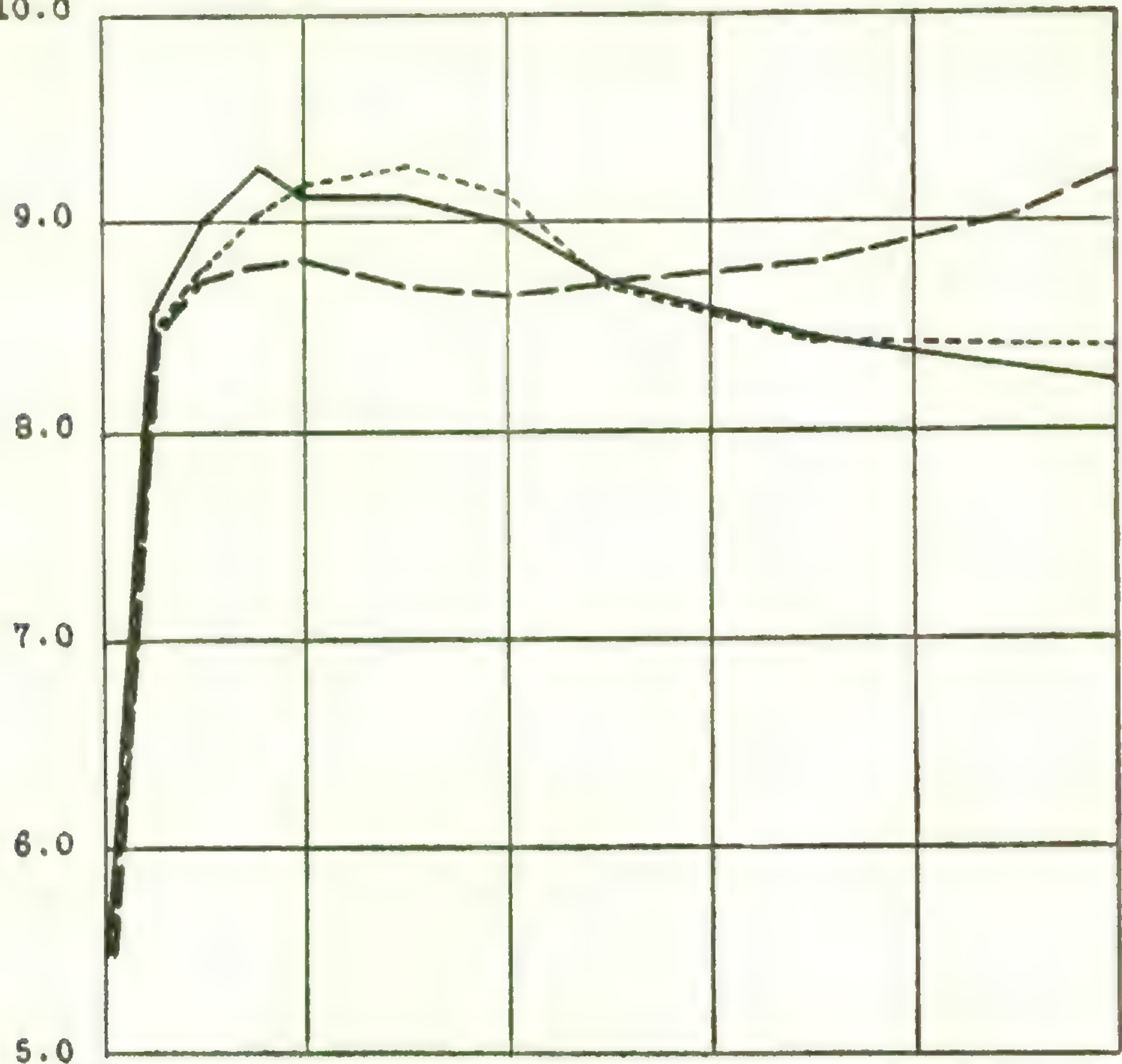
table v, produced in the same period of growth. Probably this increased growth explains the more rapid utilization of the dextrose than was calculated. The maximum growth was attained at 168 hours—3,750,000,000 bacteria per cc. Thus this culture showed the least inhibition of any of the experimental cultures and serves as a standard for comparison with the others.

To study more in detail the effect of small amounts of acid, a series of cultures was observed in which the only individual variation was in the initial amount of dextrose. To 250 cc. of plain bouillon in each of five 500-cc. flasks were added respectively .05, .1, .15, .2, and .3 per cent of dextrose, and all were inoculated from the same culture tube of *Bacillus coli*. The growth and changes in P_H are presented in table VII. The cultures are numbered, as indicated in the table, from 1 to 5 in order of increasing amounts of dextrose. Cultures 2, 4, and 5 are plotted in fig. 7 as representative of the series. The P_H curves show that acid was produced in each culture and that the amount of acid formed corresponded to the amount of dextrose provided. The cultures formed a regular series of increasing acidities. Following the acid production there was a reversion of the reaction toward alkalinity which was quite rapid in the first four cultures but slower in Culture 5, where a P_H of 5.1 was maintained from 24 to 96 hours. Comparing the growth curves of the five cultures during the period from inoculation to 48 hours, it is seen that Culture 2 makes the best growth and that Cultures 3, 4, and 5 follow in order. It would appear, then, that .1 per cent of dextrose or less is stimulative in effect and that there is no acid injury from a short exposure to P_H 5.9 (Culture 2). There is, however, some acid inhibition from a P_H of 5.5 (Cultures 3 and 4) and quite a marked inhibition—sufficient to cause some decrease in numbers—from 3 days' exposure to P_H 5.1 (Culture 5). In each case the growth curve ascended as the P_H curve descended toward the alkaline side. The maximum growth was approximately the same for all the cultures—1,400,000,000 to 1,800,000,000 bacteria per cc.—and was reached when the hydrogen ion concentration fell in a zone between P_H 7.0 and 7.6. At the point of maximum growth the hydrogen ion concentrations for the cultures in order were

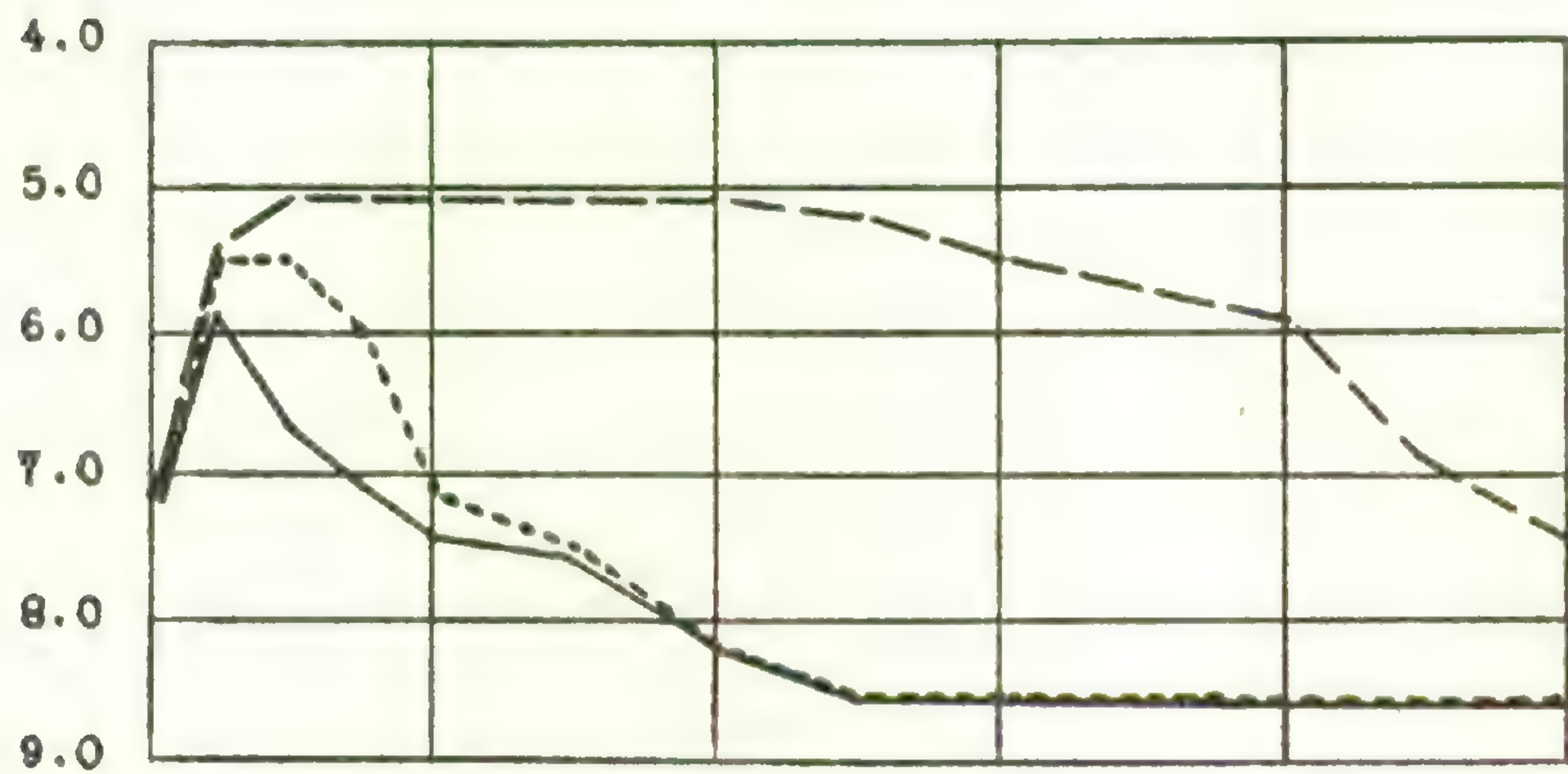
TABLE VII
GROWTH AND HYDROGEN ION CONCENTRATION OF BACILLUS COLI AT 30° C., VARIATION IN INITIAL DEXTROSE

Cultures	1	2	3	4	5	
Dextrose	.05%	.10%	.15%	.20%	.30%	
Hours	Bacteria per cc.	Bacteria per cc.	Bacteria per cc.	Bacteria per cc.	Bacteria per cc.	p _H
0	300,000	340,000	325,000	335,000	270,000	7.1
12	392,000,000	399,000,000	321,000,000	329,000,000	333,000,000	5.5
24	992,000,000	1,060,000,000	881,000,000	593,000,000	529,000,000	5.5
36	1,392,000,000	1,768,000,000	1,200,000,000	1,132,000,000	624,000,000	6.0
48	1,376,000,000	1,330,000,000	1,292,000,000	1,496,000,000	648,000,000	7.1
72	1,360,000,000	1,360,000,000	1,680,000,000	1,824,000,000	512,000,000	7.5
96	853,000,000	960,000,000	1,270,000,000	1,350,000,000	454,000,000	8.2
120	516,000,000	520,000,000	672,000,000	472,000,000	516,000,000	8.4
144						8.5
168	295,000,000	275,000,000	243,000,000	248,000,000	635,000,000	8.5
192						8.5
216						8.5
240	166,000,000	169,000,000	160,000,000	224,000,000	1,055,000,000	8.5
288					1,655,000,000	7.4
336					948,000,000	8.1
360					252,000,000	8.5

Bacteria per cc.
(Logs.)
10.0



PH



Hours

0 48 96 144 192 240

Fig. 7. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C., variation in initial dextrose.

- .1 per cent dextrose.
- - - - .2 per cent dextrose.
- · - · .3 per cent dextrose.

P_H 7.3, 7.1, 7.6, 7.5, and 7.4. The relation between growth curves and P_H curves, fig. 7, would indicate that *Bacillus coli* is more sensitive to alkali than to acid and that amounts of alkali or acid considerably less than the fatal dose become prominent factors in inhibiting growth.

Supplementing the preceding table, table VIII gives the results of growth of *Bacillus coli* in 1 per cent, 2.5 per cent, and 5 per cent dextrose media. A synthetic bouillon was used for these cultures consisting of .5 per cent asparagin, .5 per cent K_2HPO_4 , and the dextrose as indicated. The growth and hydrogen ion concentration curves are plotted in fig. 8 on the same basis as the curves in all the other figures. As might be expected, the action in general corresponded to that of Culture 2, fig. 1, which was grown in 1 per cent dextrose. Both the growth and P_H curves showed a small lag at the beginning in 2.5 per cent dextrose and a greater one with some decrease in growth in 5 per cent dextrose. Following the initial lag, the cultures produced the usual growth, acid fermentation, and death. A slightly greater acid production occurred in the 5 per cent dextrose, for the hydrogen ion concentration went to P_H 4.7. The data of tables VII and VIII show that in cultures of *Bacillus coli* sufficient acid to kill the organisms was formed from 1 per cent or more of dextrose, while .15 to .3 per cent supplied only enough acid to inhibit the growth, and .1 per cent exerted a stimulative action. Thus the amount of dextrose present seems to regulate the reaction, which is a strong factor in growth and inhibition.

In connection with the reversion of reaction, the growth and inhibition of *Bacillus aerogenes* are of interest. One culture of plain bouillon and one culture of plain bouillon plus 1 per cent dextrose were inoculated with *Bacillus aerogenes*; the growth and hydrogen ion concentration changes are recorded in table IX and fig. 9. Both the growth and hydrogen ion concentration were very similar to those of *Bacillus coli* from the time of inoculation up to 96 hours. As fig. 9 illustrates, at 96 hours the abrupt descent of the growth curve was checked at 7,600,000 bacteria per cc. The slight drop to 5,000,000 bacteria per cc. in the next 48 hours was followed by a second rise which culminated in a maximum of 1,017,000,000 bacteria per cc. at 696 hours.

TABLE VIII
GROWTH AND HYDROGEN ION CONCENTRATION OF BACILLUS COLI AT
30° C., VARIATION IN INITIAL DEXTROSE IN
ASPARAGIN BOUILLON

Cultures	1		2		3	
Dextrose	1.0%		2.5%		5.0%	
Hours	Bacteria per cc.	P _H	Bacteria per cc.	P _H	Bacteria per cc.	P _H
0	45,000	6.6	63,000	6.4	46,000	6.4
12	5,450,000	6.6	100,000	6.4	60,000	6.3
16	46,500,000	6.5	80,000	6.3	60,000	6.2
20	326,000,000	5.7	80,000	5.8	60,000	5.9
24	350,000,000	5.5	145,000	5.7	25,200	5.9
36	464,000,000	5.4	17,000,000	5.8	8,400	5.9
48	416,000,000	4.9	345,000,000	5.6	57,600	5.8
60	280,000,000	4.9	384,000,000	4.9	1,700,000	5.7
72	178,000,000	5.3	323,000,000	4.9	40,000,000	5.7
84	108,000,000	5.3	348,000,000	4.9	170,000,000	5.1
96	51,000,000	5.3	320,000,000	4.9	270,000,000	4.9
108	28,000,000	5.3	180,000,000	4.9	260,000,000	4.9
120	1,800,000	5.3	187,000,000	4.9	380,000,000	4.7
132	2,800,000	5.3	120,000,000	4.9	224,000,000	4.7
144	200,000		31,000,000		142,000,000	4.7
156	18,400	5.3	24,000,000	4.9	161,000,000	4.9
168	1,000	5.3	6,000,000	5.2	158,000,000	5.1
180	346	5.3	2,000,000	5.2	132,000,000	5.1
192	144	5.3	360,000	5.0	102,000,000	4.9
204	93		62,000		104,000,000	
216			391	5.2	54,000,000	5.3
240					21,000,000	5.3
264					9,900,000	5.0
300					900	5.0

Some points of interest in the P_H curves are that the high point, P_H 4.7, at 120 hours, did not occur during the period of greatest decrease in growth, that the P_H held at 4.9 for a considerable period after the second increase in growth began, and that the hydrogen ion concentration at the time when the maximum growth was reached was P_H 7.1. In plain bouillon there was no essential difference in growth or changes in hydrogen ion

Bacteria per cc.
(Logs.)
9.0

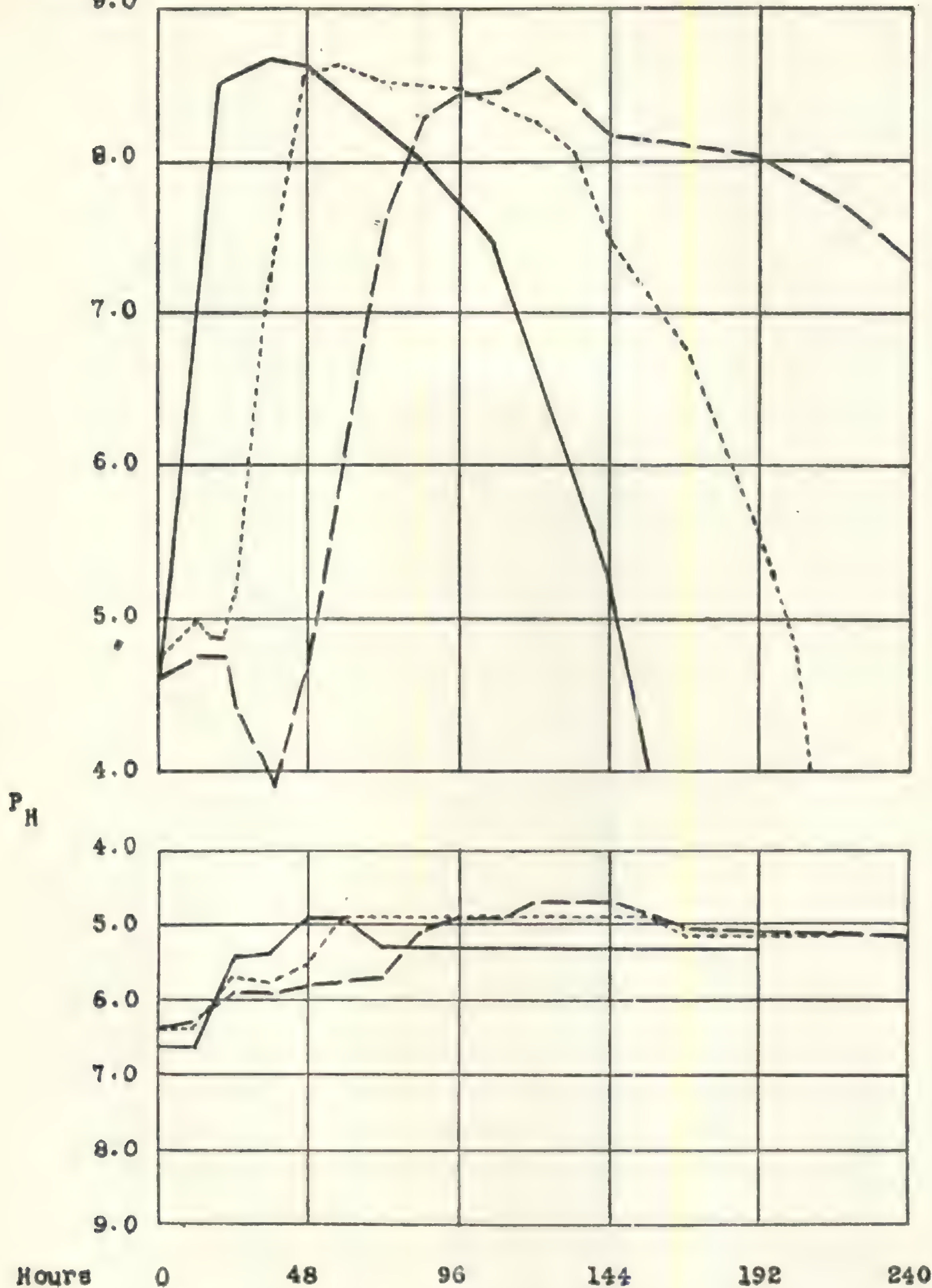


Fig. 8. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C., variation in initial dextrose in asparagin bouillon.

- 1.0 per cent dextrose.
- 2.5 per cent dextrose.
- · - · - 5.0 per cent dextrose.

TABLE IX
GROWTH AND HYDROGEN ION CONCENTRATION OF BACILLUS AEROGENES AT 30° C., PLAIN AND 1 PER CENT DEXTROSE BOUILLON

Hours	1 Plain bouillon		2 Plain bouillon and 1% dextrose	
	Bacteria per cc.	P _H	Bacteria per cc.	P _H
0	98,000	6.9	94,000	6.9
12	171,000,000	6.9	272,000,000	5.5
24	236,000,000	7.0	300,000,000	4.9
48	306,000,000	7.4	139,000,000	4.8
72	455,000,000	7.8	27,000,000	4.8
96	307,000,000	8.1	7,600,000	4.8
120	169,000,000	8.3	6,300,000	4.7
144		8.3	5,000,000	4.9
168	162,000,000	8.3	10,000,000	4.9
192	121,000,000	8.3	23,000,000	4.9
216	108,000,000	8.3	38,000,000	4.9
264			125,000,000	4.9
312			211,000,000	4.9
360			539,000,000	5.8
408	37,000,000	8.3	815,000,000	6.6
456	44,000,000	8.5	836,000,000	6.9
504			761,000,000	6.9
552	36,000,000	8.6	775,000,000	6.9
624	20,000,000	8.7	927,000,000	6.9
696	22,000,000	8.7	1,017,000,000	7.1
864	8,640,000	8.7	690,000,000	7.3
1032	2,520,000	8.7	643,000,000	7.0
1200	7,830,000	8.7	485,000,000	7.6

concentration between *Bacillus coli* (table I, Culture 1) and *Bacillus aerogenes* (table IX, Culture 1). There is a similarity in growth of *Bacillus coli* in .3 per cent dextrose and *Bacillus aerogenes* in 1 per cent dextrose, the difference between the organisms apparently being in the greater resistance of *Bacillus aerogenes* to acid.

While the experimental data reported above have emphasized the importance of the H and OH ions as factors in inhibition, these ions do not represent the only products of metabolism which might be considered as inhibitory to growth. Ayers and

Bacteria per cc.
(Logs.)
10.0

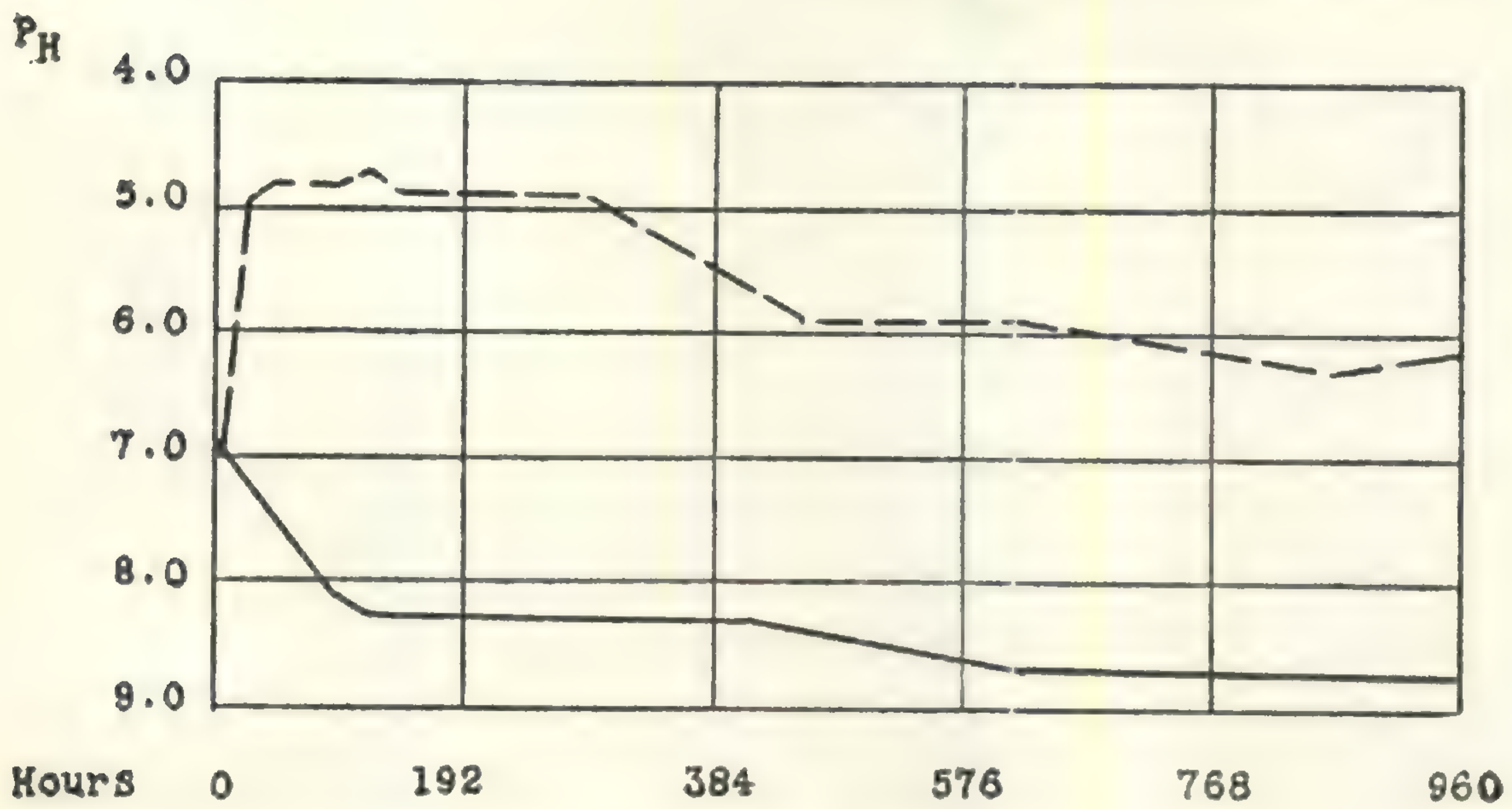
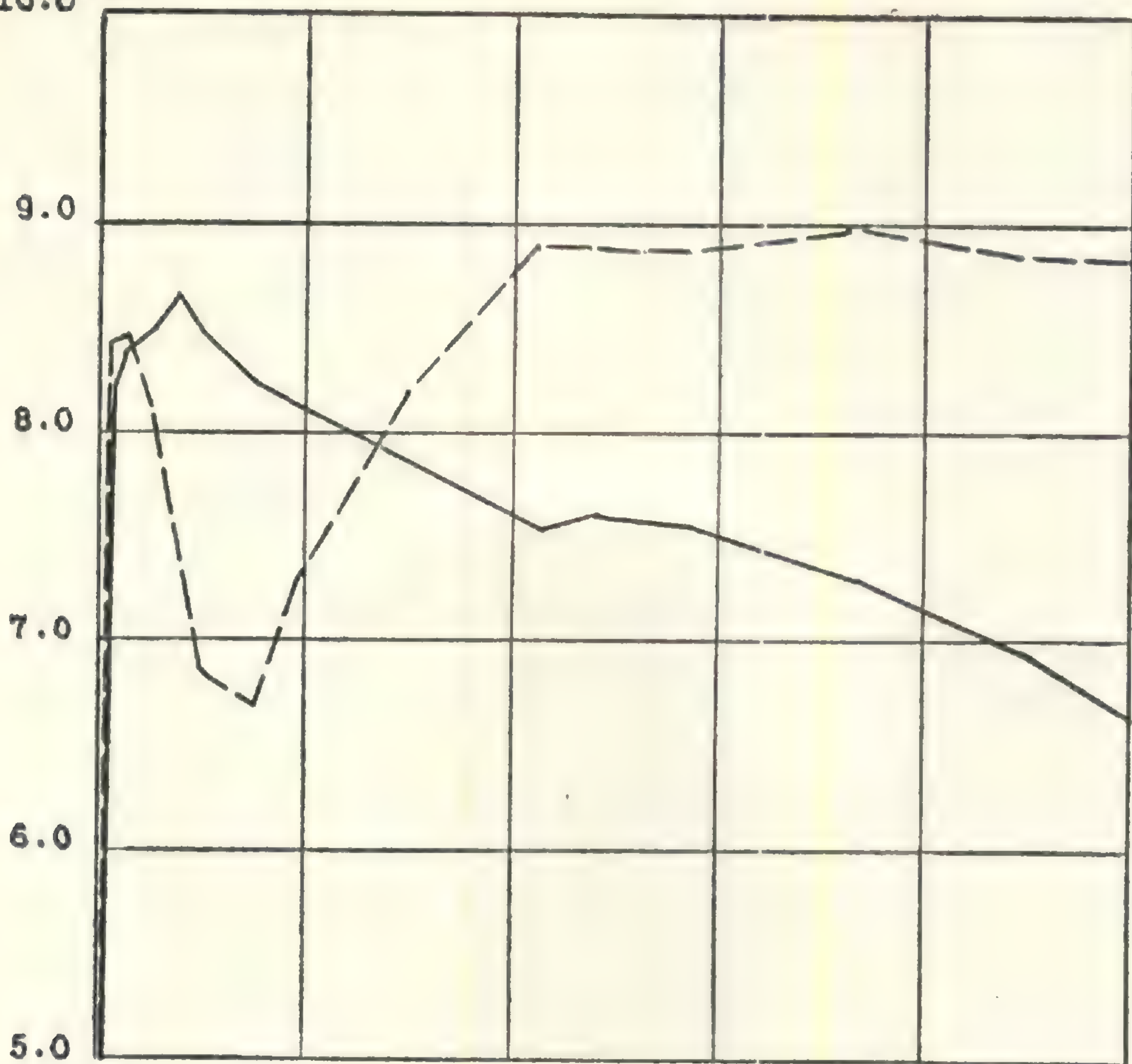


Fig. 9. Growth and hydrogen ion concentration of *Bacillus aerogenes* at 30° C.

———— plain bouillon.
----- 1 per cent dextrose bouillon.

Rupp have made quantitative determinations of formic, acetic, lactic, and succinic acids from *Bacillus coli* in a dextrose bouillon, and Wyeth, and Cohen and Clark have shown that the critical hydrogen ion concentration varies with the different acids, hydrochloric, acetic, and lactic, indicating that the anions of the acids or perhaps the undissociated molecules, as Winslow and Lochridge suggested, are also concerned in inhibition. Most of the work on the inhibitory effect of different acids has been based on inoculation of media of different P_H values obtained by using different acids, and the inhibition has been determined according to the presence or absence of growth after a certain interval. Such a method does not take into consideration milder phases of inhibition which are not severe enough to cause the death of the organisms. To illustrate this phase and to indicate some of the relations of the hydrogen ion factor to the other factors, the results of an experiment are presented in table x and fig. 10. Culture 1 was grown in 1 per cent dextrose bouillon, and Culture 2 in plain bouillon to which sterile N/5 HCl was added, as indicated in table x, in an attempt to simulate in plain bouillon the P_H curve of a culture fermenting dextrose bouillon, such as Culture 1. As seen from fig. 10, the culture produced alkali continually so that it was only possible by frequent additions of acid to hold the P_H in a zone around P_H 4.8, the greatest hydrogen ion concentration which Culture 1 attained. The growth curve, fig. 10, shows marked acid inhibition with almost no further increase in growth after the first addition of acid at 14 hours. There is practically no difference in the growth curves of the two cultures up to 72 hours, but from that point they separate widely, for death occurs shortly in the dextrose media and growth in Culture 2 does not go below 26,000,000 bacteria per cc. Thus a hydrogen ion concentration of P_H 4.8-4.9 when produced by the acid fermentation of dextrose was fatal, while that of P_H 4.7-5.1 from HCl was only strongly inhibitory, indicating that the other metabolic products of dextrose fermentation, such as acetate or lactate ions, evidently enter as factors in causing the death of the culture.

TABLE X
GROWTH AND HYDROGEN ION CONCENTRATION OF *BACILLUS COLI* AT
30° C., 1 PER CENT DEXTROSE BOUILLON AND PLAIN
BOUILLON + HCl AT INTERVALS

Hours	1 1% dextrose bouillon		2 Plain bouillon + HCl		
	Bacteria per cc.	P _H	Bacteria per cc.	Cc. of N/5 HCl added	P _H
0	55,000	7.1	57,000		7.1
12	268,000,000	5.3	179,000,000		6.7
14				15	5.2
20	281,000,000	5.1			
24	214,000,000	4.9	178,000,000		5.3
26				4	5.0
36	220,000,000	4.8	197,000,000		5.2
38				5	4.9
48	189,000,000	4.8	175,000,000		5.1
50				5	4.7
60					4.9
72	119,000,000	4.8	116,000,000		5.0
74				3	4.7
96	14,500,000	4.9	77,000,000		4.9
120	11,100	4.9	96,000,000		5.3
122				3	4.9
144	0	4.9	55,000,000		5.1
146				2	4.9
168			26,000,000		4.9
192			60,000,000		5.1
194				2	4.9
234			74,000,000		4.9
276			144,000,000		5.3
278				4	4.9
348			148,000,000		5.1
350				3	4.8
492			95,000,000		4.9
612			73,000,000		5.1

DISCUSSION

For a discussion of the combined results embodied in the experimental data presented, the inhibitory products of metabolism of *Bacillus coli* are divided under four topics: "auto-toxins"; H ions; OH ions; and products of dextrose fermentation other than those directly related to changes in H ion concentration.

Bacteria per cc.
(Logs.)

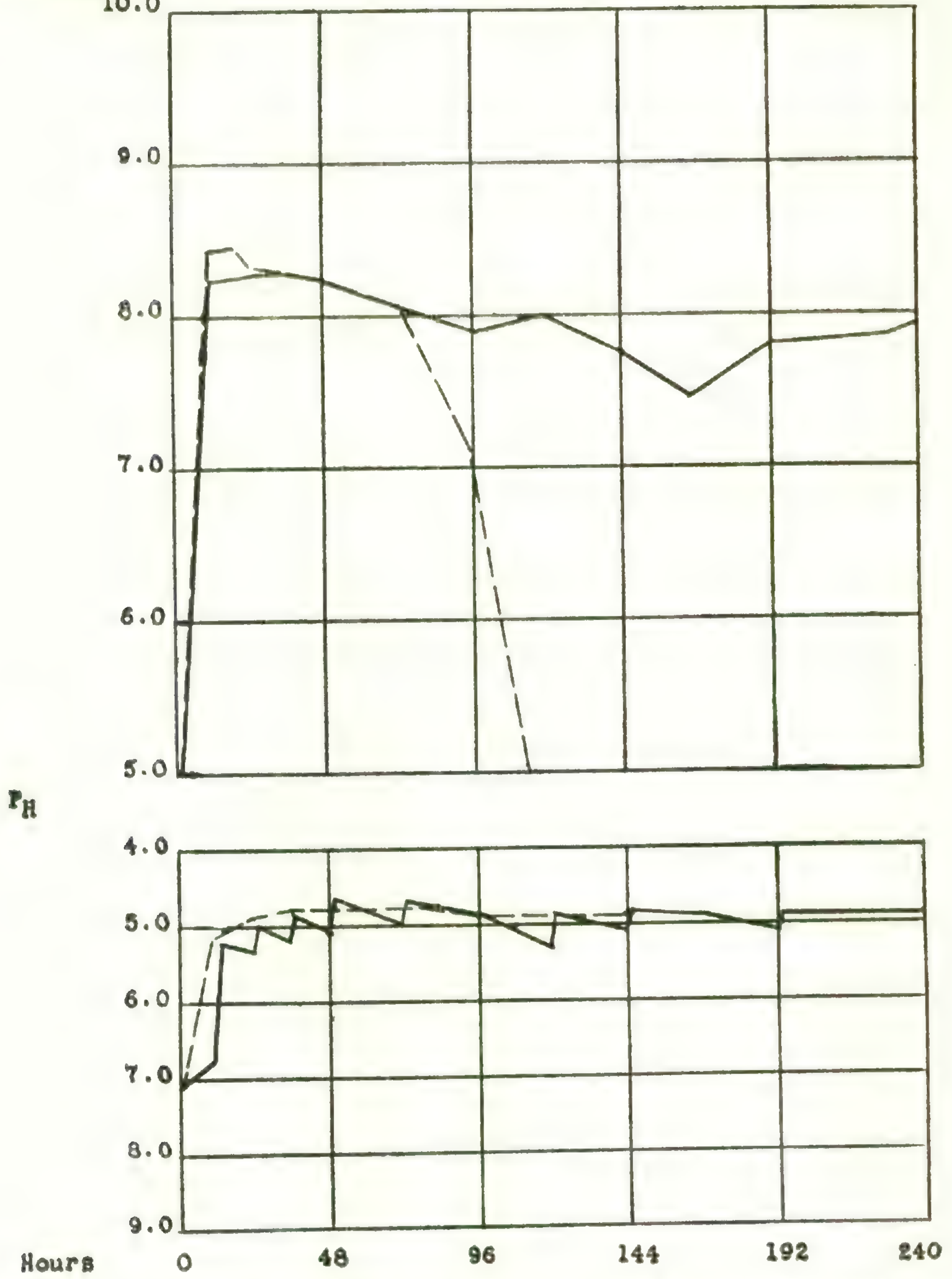


Fig. 10. Growth and hydrogen ion concentration of *Bacillus coli* at 30° C.
 ————— plain bouillon + HCl at intervals.
 - - - - - 1 per cent dextrose bouillon.

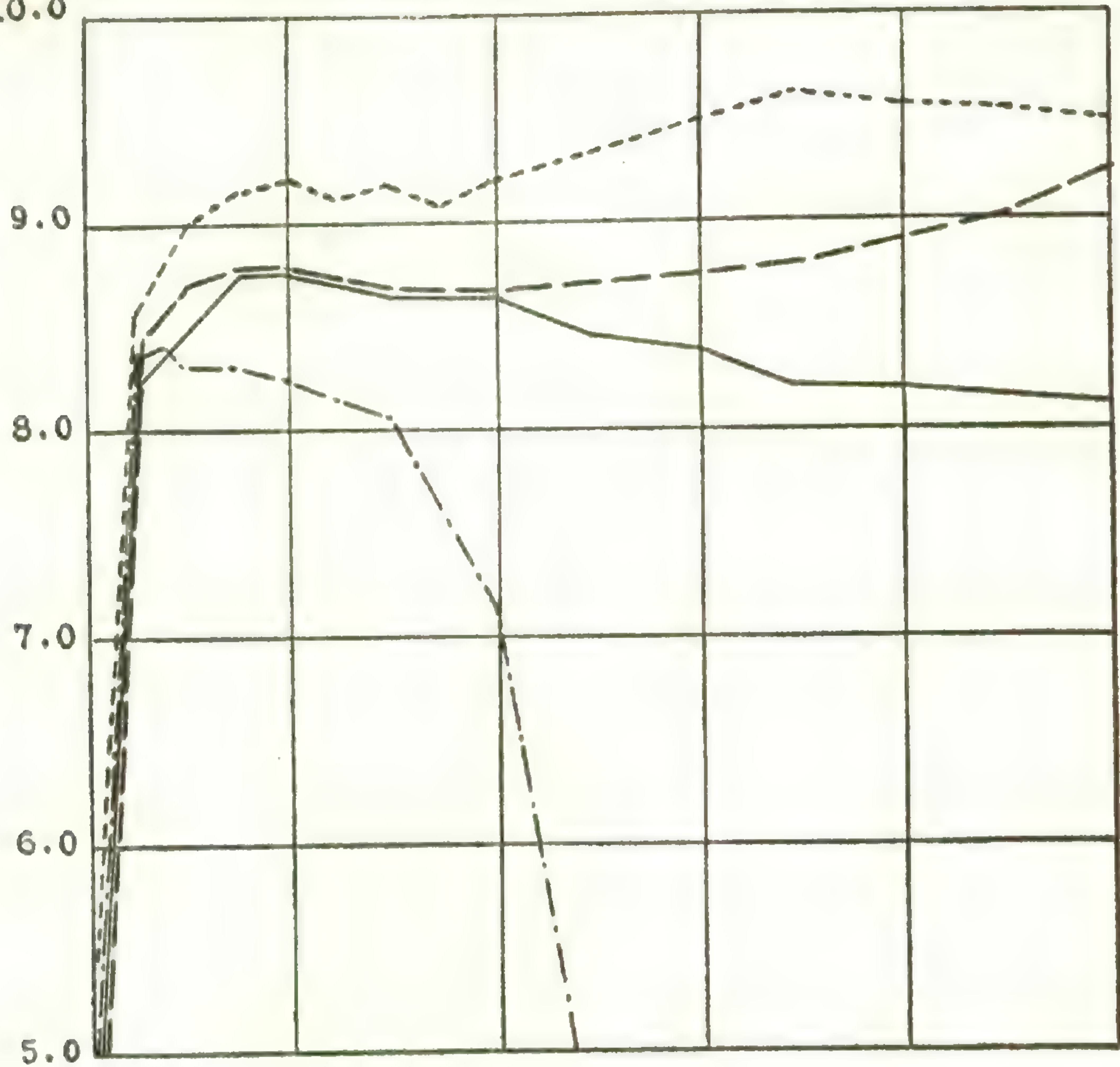
It appears improbable that *Bacillus coli*, grown under the conditions of the experiments reported, produces any "autotoxin" or special inhibitory substance such as Eijkmann and others claimed. The results given in tables II and III indicate that the slight inhibition increasing with the age of the culture is probably associated with a diminution in nutrients. No thermolabile product could be detected which would inhibit growth if the hydrogen ion concentration were corrected. It is difficult to reconcile the production of an enzymatic inhibiting substance with such growth as appears in figs. 1 and 6, especially as death did not occur in these cultures. In plain bouillon, fig. 1, the culture was viable after 75 days; and in dextrose bouillon, fig. 6, with the hydrogen ion factor controlled, growth attained 3,750,000,000 bacteria per cc. in 7 days, and there were still present over 2,000,000,000 bacteria per cc. after 840 hours. In addition there was no indication in the cultures in which death occurred that death could be attributed to an "autotoxin."

There is a direct relation between hydrogen ion concentration and inhibition. If the acid is formed from the fermentation of dextrose, with *Bacillus coli*, fig. 7 and table VII, there is no indication of acid inhibition at P_H 5.9 if maintained for only a short time. Some inhibition is apparent at P_H 5.5 which increases with the time that the culture is exposed to this P_H . There is a marked inhibition from an exposure of 72 hours to P_H 5.1, fig. 7, but it is insufficient to cause death. Fig. 4, however, shows that a prolonged hydrogen ion concentration of P_H 5.1 is lethal, and in every case throughout the experimental work a P_H of 4.9, when produced by acid fermentation of dextrose, proves fatal, figs. 1, 2, 3, 4, and 8.

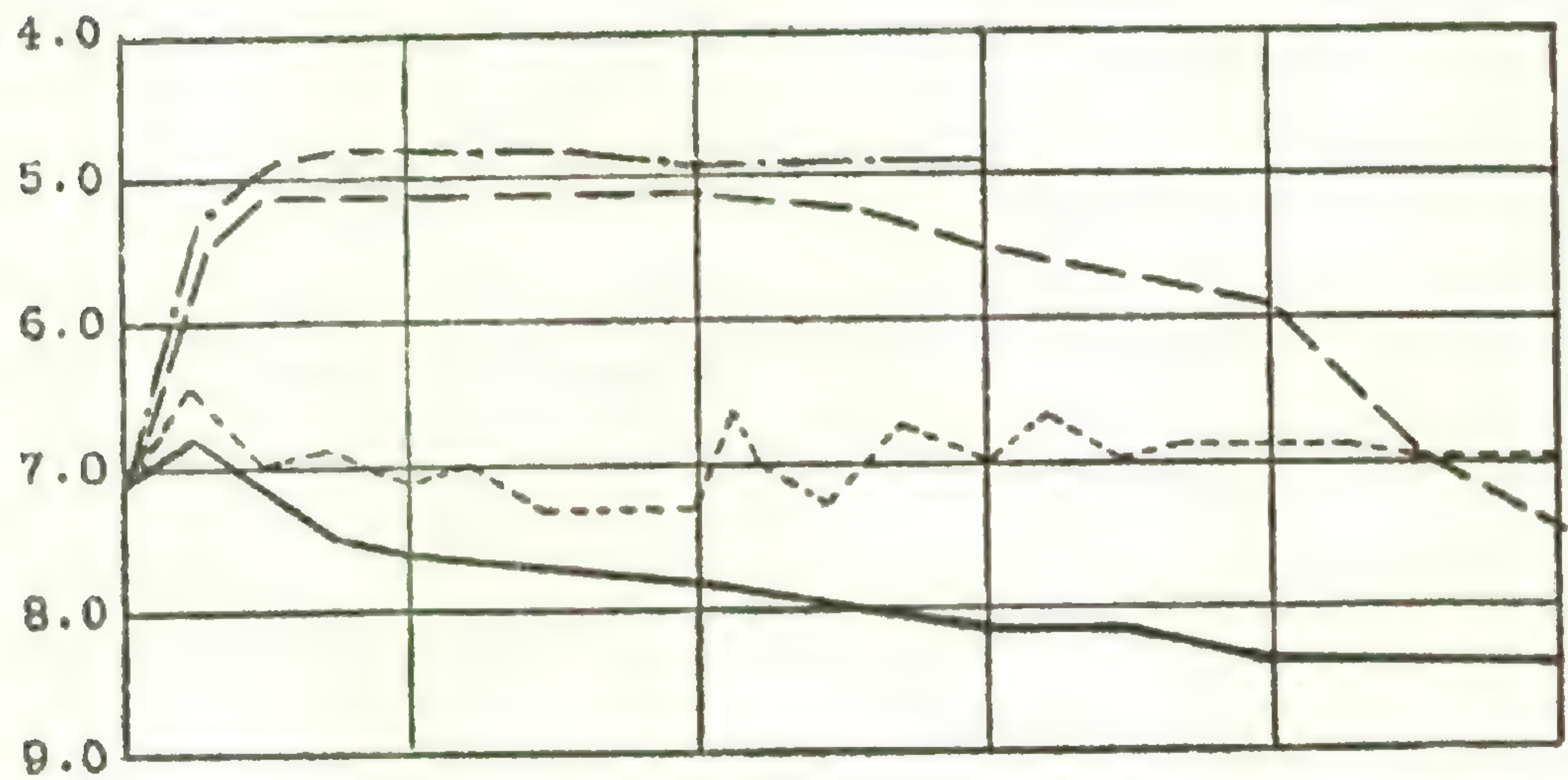
To illustrate the relationship between hydrogen ion concentration and growth, four curves from figs. 1, 6, and 7 are assembled in fig. 11. The highest growth curve, No. 2, is attained in the culture in which the P_H remains practically neutral; the P_H of 5.1, No. 3, produces an intermediate growth; and the slight difference in hydrogen ion concentration between P_H 5.1, No. 3, and 4.9, No. 4, is fatal.

The OH ions also prove to be inhibitory according to the plain bouillon growth curve in fig. 11. An alkalinity corre-

Bacteria per cc.
(Logs.)
10.0



P_H



Hours 0 48 96 144 192 240

Fig. 11. Relation of growth to hydrogen ion concentration of *Bacillus coli* at 30° C.

- No. 1 ————— plain bouillon.
- No. 2 - - - - - dextrose added at intervals.
- No. 3 - · - · - · .3 per cent dextrose.
- No. 4 · · · · · 1 per cent dextrose.

sponding to P_H 7.6–7.8 is comparable in toxicity with an acidity of P_H 5.1. *Bacillus coli* seems more sensitive to small amounts of alkali than to small amounts of acid, for in the reversions of reaction in fig. 7, inhibition is evident shortly after crossing the neutral line, about P_H 7.1–7.6. In a freshly inoculated culture without dextrose, fig. 7, inhibition is first noted about P_H 7.5. While the hydroxyl ions appear more toxic to *Bacillus coli* in less concentration than the hydrogen ions, they do not seem to be fatal in greater concentration, for death of the culture was not observed on the alkaline side, although one culture containing $CaCO_3$, which is not reported in the data, carried the P_H to 9.5.

The importance of the factors other than H or OH ions which may enter into the inhibition or killing of a culture of *Bacillus coli* is not overlooked, but it should not be over-emphasized. For example, in a 1 per cent dextrose bouillon culture, such as is shown in fig. 1 or 10, in addition to the H ions, the anions, formate, acetate, lactate, and succinate, are formed (Ayers and Rupp, '18), probably other anions, and also the undissociated acids. These add their inhibitory action to that of the H ions in producing death at P_H 4.9, illustrated by fig. 10. The best growth curve, however, fig. 11, has only the hydrogen ion concentration controlled and in reality ferments much more dextrose than the 1 per cent dextrose culture of fig. 10. The former culture ferments a total of over 1.36 per cent and none of the products are removed from the culture, while the latter does not ferment all of the 1 per cent dextrose furnished. It seems possible that the metabolic products other than the H ions are not sufficiently inhibitory to influence greatly the growth until the hydrogen ion concentration approaches the acid limit, but toward the critical acid zone their effect becomes noticeable.

The growth curves as a whole do not agree exactly with the life phases presented by Buchanan ('18). In fact, the diversity of growths produced by varying the hydrogen ion concentration, as illustrated by fig. 11, is so great that one curve can express the growth of *Bacillus coli* in bouillon only when quite definite limitations of conditions are imposed. In a growing culture of an organism like *Bacillus coli* which produces acid from dextrose and alkali in plain bouillon, growth can be con-

trolled to a certain extent by the hydrogen ion concentration, which can in turn be controlled by the amount of dextrose furnished. The initial amount of dextrose determines the amount of acid produced or the maximum hydrogen ion concentration attained. The work of Clark and Lubs, Besson, Ranque and Senez, and the experimental data presented here give a rather definite idea of the action of *Bacillus coli* according to the amount of dextrose in the medium. With .3 per cent or less of dextrose, insufficient acid is produced to kill the organisms; .4 per cent or more is sufficient dextrose to produce acid to P_H 4.9 or better, and the culture becomes sterile in 6 days or less. An amount of dextrose not accurately determined, but between .3 and .4 per cent, probably depending to some extent on the buffer in the medium, should produce just enough acid, between P_H 5.1 and P_H 4.9, depending on the time of exposure, to kill the culture. If insufficient acid to kill the culture is produced, as from .3 per cent or less of dextrose, a reversion of reaction takes place, which Ayers and Rupp have explained with *Bacillus aerogenes* as the formation of alkaline carbonates from the organic acids, especially from the formic and acetic acids. There is a similarity in reaction and in growth curves between *Bacillus aerogenes* and *Bacillus coli*, the main difference appearing to be in the greater acid resistance of *Bacillus aerogenes*. Growth in the cultures where reversion of reaction takes place seems to be typical. One-tenth per cent of dextrose provides a stimulation to growth, but greater amounts produce some evidence of acid inhibition, followed by an increase in growth with the reversion of the reaction and alkaline inhibition between P_H 7.0 and 7.6. The least inhibition is found in a culture in which the hydrogen ion concentration is held in a narrow zone around the neutral point—probably P_H 6.0–7.0 is the best—by adding small amounts of dextrose at frequent intervals. Thus, with *Bacillus coli*, hydrogen ion concentration and growth within limits can be manipulated by the dextrose furnished. The growth curves emphasize not only the value of the initial reaction and composition of the medium, but also the importance in physiological studies of following the changes in hydrogen ion concentration which the growing bacteria produce in their substrates.

SUMMARY

Growth and death of *Bacillus coli* in the culture bouillon of these experiments does not follow a constant curve but is dependent on the hydrogen ion concentration of the medium.

The hydrogen ion concentration of a growing culture of *Bacillus coli* is controlled by the composition of the medium, and particularly by the amount of fermentable carbohydrate present.

The maximum count, determined by the plate method, in the culture with the hydrogen ion concentration controlled is 3,750,000,000 bacteria per cc., as contrasted with a maximum of 281,000,000 bacteria per cc. in the 1 per cent dextrose bouillon with the hydrogen ion concentration uncontrolled.

No investigation was made of the limiting influence of other factors, such as aëration, on the maximum number of bacteria per cc. in the culture where the hydrogen ion concentration was controlled.

No metabolic product of the nature of an "autotoxin" could be found.

Of the products of metabolism, acid is the most inhibitory, checking growth slightly at P_H 5.5 and increasing in intensity to a lethal concentration between P_H 5.1 and 4.9.

The first inhibition on the alkaline side is noted between P_H 7.0 and 7.6, depending on the age of the culture and other factors. P_H 7.6 is comparable in inhibitory action to P_H 5.1. In an asparagin- $CaCO_3$ bouillon, P_H 9.5 is not fatal.

The inhibitory action of the metabolic products of dextrose other than the hydrogen ions is only evident near the critical acid concentration.

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THE NUTRITIVE VALUE OF THE FOOD RESERVE IN COTYLEDONS

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Considerable work has been done in respect to determining the capacity for growth of immature and mature seed-plant embryos separated from the endosperm or from the cotyledons. Yet this work seems to have been of comparatively little significance in ascertaining whether, under any conditions of germination and growth, these natural food reserves may be partially or completely substituted for in establishing the seedling with normal vigor in the soil or in the usual culture solutions. Reference will be made later to some of the more important literature bearing on the questions to be presented in this paper. The data here reported are, however, preliminary and intended primarily to give the results of some experiments (1) demonstrating, in those cases where the cotyledons serve as a food reserve, the striking importance of these seed-leaves in comparison with certain organic substances as a source of food for the normal and vigorous establishment of the young plant under cultural conditions, and (2) suggesting the possibility that carbohydrate or hydrocarbon food material stored outside the embryo, as in the case of corn, may be of far less significance.

Doubtless the assumption has been quite generally made that in the case of peas, beans, and other plants in which the cotyledons furnish practically the entire food reserve these seed-leaves may constitute the chief source of organic food until the first green leaves are developed. It has seemed to the writer that interesting physiological problems might be approached through a critical study of the early food reserves, and preliminary tests with Canada field peas confirmed this assumption. Accordingly, the first series of experiments with Canada field peas and with field corn were made merely to determine quantitatively the extent to which the excision of the cotyledons, or of the food supply stored outside of the embryo and the scutellum, influenced normal growth.

In the case of the Canada field peas the seed were germinated on paraffined wire mesh over tap water, and growth was permitted to proceed in diffuse light until the plumules were well established with unfolding green leaves. Solution cultures were then made in the usual way as especially described in an earlier paper (Duggar, '19). All cultures were therefore arranged in duplicate in tumblers holding about 250 cc., and the seedlings were inserted through holes in paraffined paper covers (peas), or through notches in the corks (corn). Seedlings of uniform size were selected and all cultures were placed in the greenhouse, freely and equally exposed to sunlight. A mineral nutrient solution, designated in the paper referred to above as solution B, was employed. It should be observed that this solution contains not merely all essential ions, including NO_3 , but contains these in favorable proportions and concentrations for the promotion of excellent growth. The date of the beginning of the experiment was taken as that on which the cultures were exposed in the greenhouse. At intervals of a day or more apart, the cotyledons of successive pairs of cultures were cut away so as to determine their influence on growth, and the time of excision of the last pair represented the practical exhaustion of these food reserves. In the case of corn the young plantlet with attached scutellum was carefully dissected out from the endosperm, an operation which may be effected with very little difficulty after germination begins. In all other respects the corn cultures were treated in precisely the same manner as the peas. The total green weights of all cultures are given in table 1, and the appearance of the peas at the end of the period of observation, 24 days, is shown by pl. 7.

From the results with peas it is clear that for a growth interval of 24 days the removal of the cotyledons after the second day induces a marked depression in the growth rate, and this depression is increasingly less, until, when the removal of the cotyledons occurs after 7 days, the amount of growth is very nearly the same as in the control, with cotyledons intact. Duplication of this experiment with some modifications in the interval led to the conviction that under the conditions the cotyledons are practically exhausted in somewhat less than 10 days. It might be pointed out that the removal of the coty-



DUGGAR—FOOD RESERVE IN COTYLEDONS
(Canada field peas, see table 1)

TABLE I
THE EFFECTS OF THE RESERVE FOOD SUPPLY ON THE GROWTH OF SEEDLINGS

Cult. no.	Field corn, 10 plants, average of duplicate cultures		Canada field peas, 10 plants, average of duplicate cultures		
	Time of excision of endosperm	Total green wt., grams	Cult. no.	Time of excision of cotyledons	Total green wt., grams
1	After 2 days	32.72	1	After 2 days	5.75
2	After 5 days	30.18	2	After 3 days	10.12
3	After 7 days	34.02	3	After 4 days	17.70
4	After 8 days	30.11	4	After 5 days	19.82
5	After 9 days	36.11	5	After 7 days	24.30
6	After 10 days	36.98	6	Control, uncut	25.51

ledons was done in all cases with the greatest care, so that no injury to the seedling would result. The excision was made at a point beyond the stalk of the cotyledons. In the case of corn the results are a little irregular. Nevertheless, there is the suggestion that the removal of the main carbohydrate food supply is not so important a factor in depressing the growth of the young plant. From subsequent incidental experiments I am convinced that there is some effect, but it is neither so marked as in the case of the peas nor does it seem to be so permanent, that is, the effect is not so striking during the further development of the plant.

During the summer of 1919¹ an attempt was made to substitute for the loss of the cotyledons in the case of the peas by the addition of certain organic nitrogen-containing nutrients, and especially by the addition of glycocoll, alanin, sodium asparaginate, and sodium nucleinate. These experiments were carried out under the most favorable conditions for the growth

¹This series of experiments and other supplementary studies not yet concluded were carried out at the Coastal Laboratory of the Carnegie Institution of Washington, Carmel, California, and the writer takes this occasion to acknowledge his indebtedness to the Director of Botanical Research, Doctor D. T. MacDougal, for placing at his disposal the facilities of the laboratory and for his cordial coöperation.

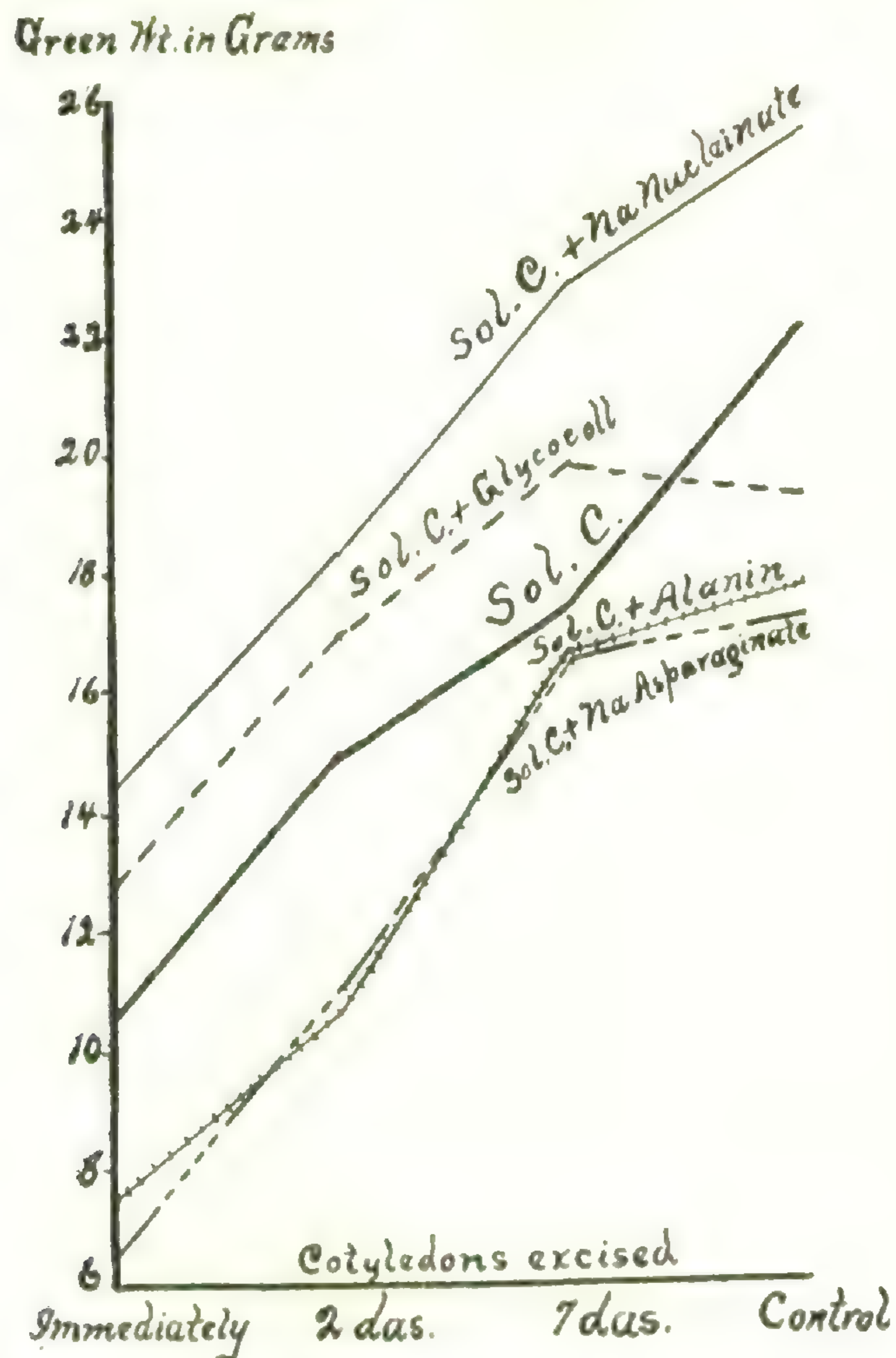


Fig. 1. Green weight quantities of Canada field peas in various solutions as affected by cotyledon excision.

of peas, at a mean temperature of about 15.6°C . The technique was the same as above described, but the use of organic substances in the solutions made it desirable to renew the solutions every 3 or 4 days in order to reduce or control bacterial action. The complete results are shown in table II, and in fig. 1. It will ultimately be necessary to extend the use of organic substances and to repeat this work under pure culture conditions. In fact, a small series of experiments in this direction has already been performed, but inasmuch as these are to constitute a part of a more extended study I will confine myself here to a brief discussion of the data presented below.

In general it will be seen that whatever the medium employed as a nutrient solution the removal of the cotyledons is shown by marked depression in the growth rate. The mineral nutrient solution employed in this case is that which I have in a previous

TABLE II

THE EFFECTS OF THE EXCISION OF THE COTYLEDONS UPON THE GROWTH OF CANADA FIELD PEAS

Cult. no.	Culture medium	Time of excision	Total gr. wt.	Gr. wt. of tops	Gr. wt. of roots	Per cent rel. to cor. cult., sol. C*	Per cent rel. to cult. 4
			10 plants, weight in grams				
1	Solution C	Immediately	10.26	4.97	5.29	100	46
2		After 2 days	14.90	8.75	6.15	100	67
3		After 7 days	17.50	11.64	5.86	100	79
4		Control, uncut	22.11	14.40	7.71	100	100
5	Solution C	Immediately	12.28	7.38	4.90	120	56
6	+	After 2 days	16.90	10.40	6.50	113	76
7	glycocoll	After 7 days	19.81	13.93	5.88	113	90
8	(M/100)	Control, uncut	19.29	13.45	5.84	87	87
9	Solution C	Immediately	6.57	3.92	2.65	64	30
10	+ sodium	After 2 days	11.04	6.68	4.36	74	50
11	asparaginate	After 7 days	16.44	10.09	6.35	94	74
12	(M/100)	Control, uncut	17.26	11.52	5.74	78	78
13	Solution C	Immediately	7.53	4.62	2.91	73	34
14	+	After 2 days	10.69	6.92	3.77	72	48
15	alanin	After 7 days	16.56	10.45	6.11	95	75
16	(M/100)	Control, uncut	17.86	12.00	5.86	81	81
17	Solution C	Immediately	14.38	7.29	7.09	140	65
18	+ sodium	After 2 days	18.32	10.13	8.19	123	83
19	nucleinate	After 7 days	22.85	14.57	8.28	131	103
20	($\frac{1}{10}$ per cent)	Control, uncut	25.43	15.09	10.34	115	115

* Per cent relative to corresponding culture, with respect to the time of excision of cotyledons, in the unmodified solution C.

paper (Duggar, '20) called solution C, which is one of the "best" combinations developed by Livingston and Tottingham ('18), and this solution has been shown to contain a favorable concentration of potassium nitrate for the growth of wheat and peas. Nevertheless, in spite of the fact that at the time of the excision of the cotyledons (even in those excised after only 2 days) there was considerable green leaf tissue in the seedlings, still the growth was weak, and at the end of 24 days the plants weighed less than one-half the control. The addition of glycocoll and of sodium nucleinate increased the growth quantities materially in the corresponding cultures, while the addition of sodium asparaginate or alanin was slightly depressing. The depressing

action, however, may have been due to a small amount of bacterial decomposition products. Even in the presence of sodium nucleinate, as in culture 17, the amount of growth when the cotyledons were excised after 2 days is much less than in the control (cotyledons uncut) in solution C, culture 4. The data seem to indicate that no proper nutrient substitute for the cotyledons has been found in these organic substances. Some additional experiments in which sugar was used in connection with nitrogen-containing substances have not served to change materially the conclusions which may be drawn. In other experiments urea and nucleic acid were used, but neither of these has been as favorable as sodium nucleinate or glycocoll. It is true, however, that sodium nucleinate has increased more than any other compound thus far used the growth quantities in the cultures lacking cotyledons.

The importance of the cotyledons in the vigorous development of the seedling is an ancient observation. Bonnet (1754) demonstrated that beans and buckwheat grew less rapidly when the cotyledons were cut off, and more important still, he observed the persisting effect of this early difference, stating the matter in the following words: "La meme différence, ou une différence analogue, a subsisté entre ces Plantes pendant toute la durée de l'accroissement. Il a toujours été facile de distinguer les unes des autres."

Sachs ('59) observed the same fact a century later while devoting more attention to the physiology of absorption and nutrition. Discussing numerous experiments designed to determine the interdependence of organs and tissues in the embryo, Van Tieghem ('73) refers incidentally to the problem here discussed.

While Schmid ('94), Hannig ('04), and Smith ('07) have contributed many interesting observations regarding the nutrition of the embryo and the capacity of different parts to develop or regenerate, these facts do not closely relate to the present investigation. Dubard and Urbain ('13), however, emphasize the favorable effects of the endosperm of certain grains in the early stages of germination. They directed their work primarily toward determining the capacity of the embryos to develop in the absence of the endosperm.

Recently Andronescu ('19) has sought to determine the importance of the endosperm and scutella in *Zea Mays* and at the same time he has endeavored to find a substitute for these, also to follow in heredity any effects observed. While demonstrating that normal plants develop without endosperm, his use of the term normal is a relative one, and he concludes with the statement, "We cannot deny, however, that the presence of endosperms is beneficial in the process of germination, as well as in the further development of the plants."

The writer proposes to continue these investigations with plants grown under sterile conditions in the hope of determining more definitely the nature of the special nutrient or growth-inducing substance furnished by the cotyledons. At present one of several explanations for the failure to substitute readily for the cotyledons may be given: (1) it is conceivable that a combination of organic nutrients including several amino acids may be necessary for normal growth; (2) that penetration of organic substances may be slow and difficult; and (3) that the cotyledons may contain a vitamine requisite for the vigorous development of the plant. In any case the results so far obtained, as well as the observations of other investigators, indicate that the depression of growth accompanying the excision of the cotyledons is marked in the case of peas and other plants with fleshy seed-leaves, and that the influence of excision extends throughout the growth period of the plants.¹

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¹ Since this paper was written there has appeared another article of considerable interest dealing with the effect of the endosperm upon the growth of the embryo (Urbain, A., Influence des matières de réserve de l'albumen de la graine sur le développement de l'embryon. *Rev. Gén. Bot.* **32**: 125-139, 165-191. *24 fig.* 1920.). In addition to careful observations on the effects of the excision of the endosperm on the development of a number of plants, a careful comparative study was made of internal structure.

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TITRATION CURVES OF CERTAIN LIQUID CULTURE MEDIA

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A study of the growth of various fungi and of the germination of various fungous spores with reference to H-ion concentration has involved a determination of the titration curves of several culture media. It is the purpose of this paper to present briefly the data obtained with these nutrient solutions, which have been the basis of subsequent work in this laboratory.

The formulae for the media employed are as follows:

Beet decoction.—Prepared according to the method outlined by Duggar, Severy, and Schmitz ('17). This consists essentially of 370.4 gms. of sugar beets per liter of distilled water, autoclaved at 15 pounds for one hour, and then filtered.

Czapek's solution.— $\text{MgSO}_4 + 7 \text{H}_2\text{O}$, .5 gm.; KH_2PO_4 , 1.0 gm.; KCl , .5 gm.; NaNO_3 , 2.0 gms.; FeSO_4 , .01 gm.; cane sugar, 30.0 gms.; distilled H_2O , 1000 cc. (Zeller, Schmitz, and Duggar, '19).

Peptone solution.—Twenty gms. bacto-peptone in 1000 cc. H_2O .

Pfeffer's solution.— KH_2PO_4 , 5.0 gms.; $\text{MgSO}_4 + 7 \text{H}_2\text{O}$, 2.5 gms.; NH_4NO_3 , 10.0 gms.; FeSO_4 , trace; cane sugar, 50.0 gms.; distilled H_2O , 1000 cc. (Pfeffer, '95).

Richards' solution.— KH_2PO_4 , .5 gm.; KNO_3 , 4.0 gms.; $\text{MgSO}_4 + 7 \text{H}_2\text{O}$, .5 gm.; NH_4NO_3 , 10.0 gms.; FeSO_4 , trace; cane sugar, 30.0 gms.; distilled H_2O , 1000 cc. (Richards, '97). This formula differs from that of the original by a reduction in the amount of MgSO_4 . The amount of precipitate produced in the more alkaline solutions was found to depend largely upon the amount of magnesium present, and, since it is important to keep the amounts of the constituents in the solutions as nearly equal as possible while varying the H-ion concentration, it seemed desirable to reduce the amount of MgSO_4 to .5 gm. per liter. Such

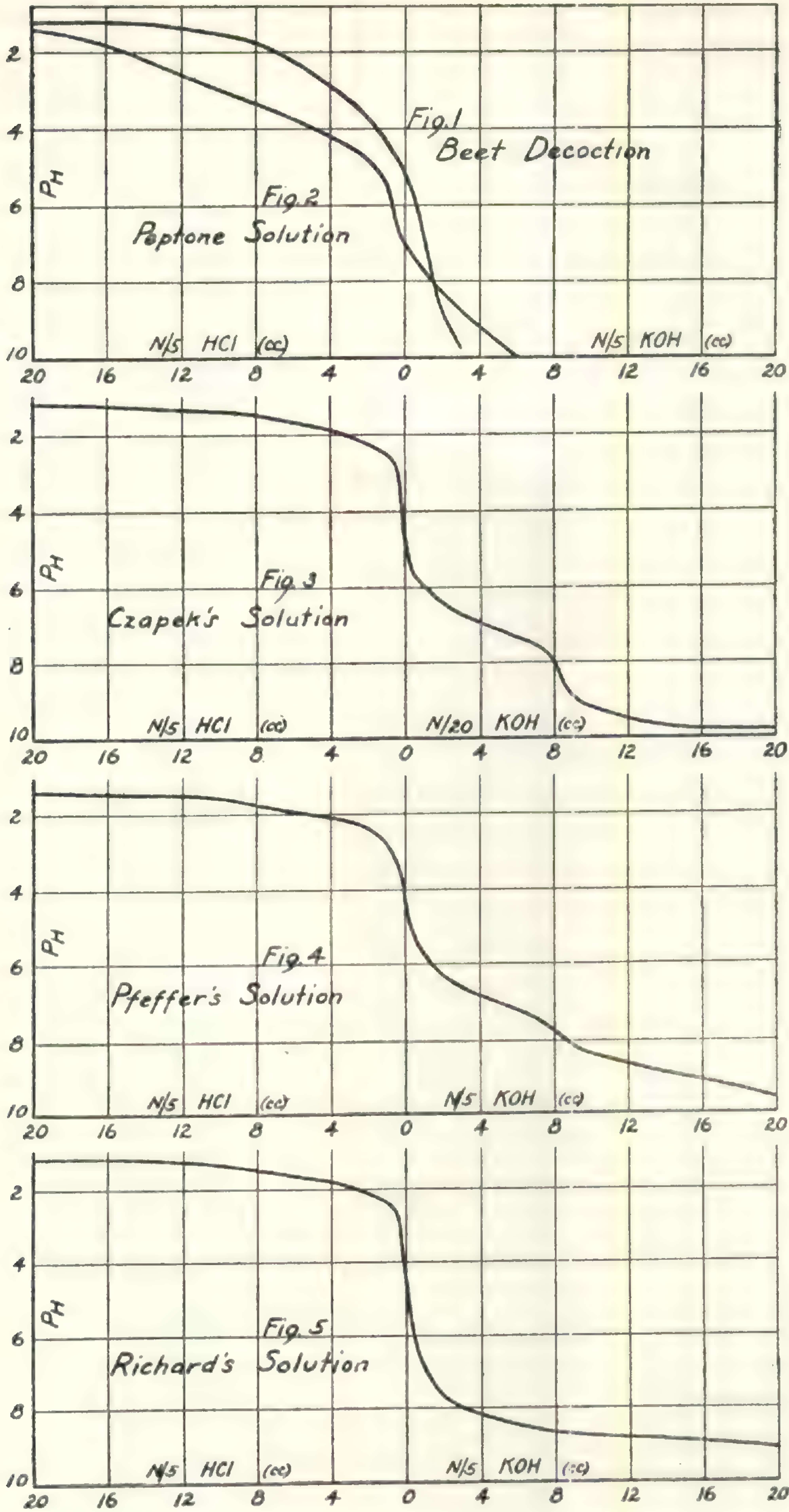
a reduction has been found by Duggar (unpublished data) to have no appreciable effect upon the growth of fungi.

The nutrient solutions were all prepared by adding 600 cc., instead of 1000 cc., of distilled water. This method allowed dilutions of the various solutions by additions of regulated amounts of acid or alkali and water for the adjustment of various H-ion concentrations without affecting materially the concentrations of the nutrient salts or constituents.

It is possible to obtain a wide range in the H-ion concentrations of the solutions by adding an alkali and a mineral acid in successively increasing quantities. The addition of the mono-, the di-, or the tri-basic potassium phosphate as suggested by Zeller, Schmitz, and Duggar ('19) was found to give results within a certain range, but additions in too large amounts were necessary to produce extreme concentrations. Therefore, since such a decided variation in the composition of the nutrient solutions undoubtedly would have existed, it seemed undesirable to adopt this method in the experiments under investigation.

From preliminary experimentation relative to the adjustment of H-ion concentration in media of alkaline reactions, the most satisfactory results were obtained by using N/5 KOH, and an alkali of this strength has been employed in all of the experiments except in the case of Czapek's solution. Here, the buffer action was less than that in the other nutrient solutions, consequently N/20 concentration was more conveniently and accurately applicable. In all the experiments, however, N/5 HCl was favorable for varying the reactions on the acid side. In the case of Czapek's solution, the reactions were also varied by means of N/1 H_3PO_4 and N/20 NaOH. These results so nearly paralleled those obtained with the above acid and alkali that it was deemed unnecessary to continue this aspect of the experiment with the other nutrient solutions.

Inasmuch as it is generally admitted that sugars readily react with acid or alkali when heated under pressure, the nutrient solutions and the acid and the alkali were sterilized separately. Thirty cc. of the nutrient solution together with the desired amount of water, as indicated in the tables, were put into small flasks, plugged, and sterilized. After cooling, the



cultures were removed to a culture chamber, and definite amounts of sterile acid and alkali were added by means of sterile graduated pipettes. The final volume of each culture was 50 cc. and represented a dilution of the constituents comparable with that in the original nutrient solutions. The solutions were allowed to stand for 24 hours in order to reach a state of equilibrium, and, at the expiration of this period, H-ion determinations were made according to the colorimetric method of Clark and Lubs ('17), all determinations being made at room temperature. (See figs. 1-5 and tables I-II).

Due to the presence of color in the beet decoction and in the peptone solution, it was necessary to use a colorimeter for the H-ion determinations. A Duboscq type was used in this particular work, the detailed method of which has been described by Duggar ('19).

In all of the mineral salt solutions, a certain amount of precipitate occurred upon the addition of alkali, the amount increasing with increase of added alkali. No such phenomenon was evidenced in the alkaline cultures of the beet decoction or of the peptone solution. The precipitation referred to commenced with culture No. 29 in Pfeffer's solution, No. 27 in Richards' solution, and very faintly in No. 23 of Czapek's solution. On the other hand, there was no precipitation whatever in the acid cultures of any of the various media.

As the reaction of the beet decoction passed from acid to alkaline, there was noted a decided color change from pale yellow to amber, and a slight cloudiness was perceptible beginning with culture No. 42.

The titration curve obtained with 2 per cent bacto-peptone agrees closely with the curves obtained by Clark and Lubs ('17) with Witte peptone, falling, as one would expect, between the curves representing concentrations of 1 and 5 per cent.

The initial P_H of the original culture solutions varied, variations of several tenths not being infrequent despite the most careful technique during preparation and the use of highest purity chemicals. Since the highest purity mono-basic potassium phosphate obtainable had a very high acidity due to the impurities present, the salt was recrystallized until the Sørensen coefficient of P_H 4.529 for a 1/15 molecular solution was obtained.

TABLE I
TITRATION DATA FOR VARIOUS LIQUID MEDIA

No.	Solution (cc.)	N/5 HCl (cc.)	N/5 KOH (cc.)	Dist. H ₂ O (cc.)	Total (cc.)	Hydrogen ion concentration, P _H			
						Beet decoction	Rich- ards	Pep- tone	Pfeffer
1	30	20.00		00.00	50	1.2	1.2	1.4	1.4
2	30	15.00		05.00	50	1.2	1.2	2.0	1.5
3	30	10.00		10.00	50	1.6	1.4	3.0	1.5
4	30	9.50		10.50	50		1.4		1.6
5	30	9.00		11.00	50	1.7	1.5	3.2	1.7
6	30	8.50		11.50	50		1.5		1.7
7	30	8.00		12.00	50	1.9	1.5	3.4	1.8
8	30	7.50		12.50	50		1.6		1.8
9	30	7.00		13.00	50	2.1	1.6	3.6	1.9
10	30	6.50		13.50	50		1.6		1.9
11	30	6.00		14.00	50	2.3	1.7	3.8	1.9
12	30	5.50		14.50	50		1.7		2.0
13	30	5.00		15.00	50	2.6	1.7	4.0	2.1
14	30	4.50		15.50	50		1.8		2.1
15	30	4.00		16.00	50	3.1	1.8	4.2	2.1
16	30	3.50		16.50	50		2.0		2.3
17	30	3.00		17.00	50	3.4	2.0	4.4	2.3
18	30	2.50		17.50	50	3.6			2.3
19	30	2.00		18.00	50	3.8	2.2	4.9	2.4
20	30	1.50		18.50	50				2.7
21	30	1.00		19.00	50	4.4	2.4	5.4	2.8
22	30	.75		19.25	50	4.5			
23	30	.50		19.50	50	4.8	2.8	6.4	3.2
24	30	.25		19.75	50	5.0			
25	30	0.00		20.00	50	5.2	4.6	7.0	4.3
26	30		.25	19.75	50	5.4			
27	30		.50	19.50	50	5.6		7.4	5.3
28	30		.75	19.25	50	6.4			
29	30		1.00	19.00	50	7.0	7.0	7.8	5.6
30	30		1.50	18.50	50		7.5		6.2
31	30		2.00	18.00	50	8.8	7.7	8.2	6.3
32	30		2.50	17.50	50		7.9		6.4
33	30		3.00	17.00	50	9.8	8.1	8.8	6.6
34	30		3.50	16.50	50		8.2		6.6
35	30		4.00	16.00	50	10.0+	8.2	9.2	6.8
36	30		4.50	15.50	50		8.3		6.9
37	30		5.00	15.00	50		8.3	9.6	7.0
38	30		5.50	14.50	50		8.4		7.1
39	30		6.00	14.00	50		8.5	10.0	7.2
40	30		6.50	13.50	50		8.6		7.3
41	30		7.00	13.00	50		8.6	10.0	7.4
42	30		7.50	12.50	50		8.7		7.6
43	30		8.00	12.00	50		8.7	10.0+	7.8
44	30		8.50	11.50	50		8.7		8.0
45	30		9.00	11.00	50		8.7	10.0+	8.2
46	30		9.50	10.50	50		8.7		8.3
47	30		10.00	10.00	50		8.8	10.0+	8.4
48	30		15.00	5.00	50		8.9		9.0
49	30		20.00	0.00	50		9.1		9.6

TABLE II
TITRATION DATA FOR CZAPEK'S SOLUTION

No.	Czapek sol. (cc.)	Acid (cc.)	Alkali (cc.)	Dist. H ₂ O (cc.)	Total cc.	H-ion concentration, P _H	
						N/5 HCl N/20 KOH	N/1 H ₃ PO ₄ N/20 NaOH
1	30	20.00		0.00	50	1.2	
2	30	15.00		5.00	50	1.3	
3	30	10.00		10.00	50	1.4	1.6
4	30	9.50		10.50	50	1.4	1.6
5	30	9.00		11.00	50	1.5	1.6
6	30	8.50		11.50	50	1.5	1.7
7	30	8.00		12.00	50	1.5	1.7
8	30	7.50		12.50	50	1.6	1.7
9	30	7.00		13.00	50	1.6	1.7
10	30	6.50		13.50	50	1.6	1.8
11	30	6.00		14.00	50	1.7	1.8
12	30	5.50		14.50	50	1.7	1.8
13	30	5.00		15.00	50	1.8	1.9
14	30	4.50		15.50	50	1.9	1.9
15	30	4.00		16.00	50	1.9	2.0
16	30	3.50		16.50	50	2.0	2.0
17	30	3.00		17.00	50	2.1	2.1
18	30	2.50		17.50	50	2.2	2.2
19	30	2.00		18.00	50	2.3	2.3
20	30	1.50		18.50	50	2.4	2.3
21	30	1.00		19.00	50	2.5	2.4
22	30	.50		19.50	50	2.9	2.6
23	30	0.00		20.00	50	4.7	4.4
24	30		.50	19.50	50	5.7	5.6
25	30		1.00	19.00	50	6.0	5.9
26	30		1.50	18.50	50	6.2	6.2
27	30		2.00	18.00	50	6.4	6.3
28	30		2.50	17.50	50	6.6	6.5
29	30		3.00	17.00	50	6.7	6.6
30	30		3.50	16.50	50	6.8	6.8
31	30		4.00	16.00	50	6.9	6.8
32	30		4.50	15.50	50	7.0	7.0
33	30		5.00	15.00	50	7.1	7.1
34	30		5.50	14.50	50	7.2	7.2
35	30		6.00	14.00	50	7.4	7.4
36	30		6.50	13.50	50	7.5	7.6
37	30		7.00	13.00	50	7.6	7.7
38	30		7.50	12.50	50	7.7	7.9
39	30		8.00	12.00	50	8.0	8.2
40	30		8.50	11.50	50	8.6	8.6
41	30		9.00	11.00	50	8.9	8.7
42	30		9.50	10.50	50	9.1	9.0
43	30		10.00	10.00	50	9.2	9.2
44	30		15.00	5.00	50	9.8	
45	30		20.00	0.00	50	9.8	

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THE USE OF "INSOLUBLE" SALTS IN BALANCED SOLUTIONS FOR SEED PLANTS

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In this paper it is proposed to give the results of several series of experiments designed primarily to determine the possible value of certain relatively insoluble salts in furnishing the necessary ions for the growth of seed plants. By means of such salts it will also be attempted to secure favorable combinations of the necessary ions. Throughout this discussion "insoluble" may be used in a very general sense, to include many salts soluble only to a comparatively slight degree, or with difficulty soluble, in water at from 15 to 25° C.

It is well known that in the soil a relatively small part of the salts ordinarily designated mineral nutrients is present in soluble form. There is, in general, a very considerable reserve or "unavailable" supply of the less readily soluble salts of such elements as K, Ca, Mg, Fe, S, and P. Nitrates are generally present only in low concentration and the surplus nitrogen supply is usually in the form of organic compounds. It has seemed to the writer eminently desirable to determine, therefore, if a favorable nutrient solution for seed plants may not be arranged from combinations of some of these insoluble salts, thus in some measure imitating the chemical relations in the soil.

In favor of this endeavor it might be argued that should this prove possible it would only be necessary to add to the culture vessel a surplus of the substances required. A small amount of that added would go into solution immediately and when an equilibrium were attained the absorption of any ions by the root would be compensated for by further solution of the substances furnishing these ions, and thus the equilibrium might be maintained and the concentration kept fairly constant over considerable intervals. Obviously, it would be impracticable to furnish nitrate as an insoluble compound, since the nitrates of

the bases required are all soluble to a high degree. If, therefore, nitrogen is furnished as NO_3 , the salt furnishing this ion would necessarily be added periodically, and to this extent the concentration would change from day to day. Relatively insoluble salts of ammonium are obtainable, however, such as MgNH_4PO_4 , and this salt has been employed in some of the experiments.

In the various experiments which have thus far been undertaken the sources of Ca are as follows: $\text{CaSO}_4+2\text{H}_2\text{O}$, CaCO_3 , $\text{Ca}_3(\text{PO}_4)_2$, and $\text{CaHPO}_4+2\text{H}_2\text{O}$; of Mg: $\text{MgSO}_4+7\text{H}_2\text{O}$, MgCO_3 , $\text{Mg}_3(\text{PO}_4)_2+8\text{H}_2\text{O}$, and $\text{MgNH}_4\text{PO}_4+6\text{H}_2\text{O}$; of K: KNO_3 and K_3PO_4 ; of Fe: $\text{FePO}_4+4\text{H}_2\text{O}$, $\text{FeC}_2\text{O}_4+2\text{H}_2\text{O}$, ferric citrate, and "soluble ferric phosphate." Certain other salts which might have been employed to advantage were not available at the time.

Among the more soluble of the salts included in this category are $\text{CaSO}_4+2\text{H}_2\text{O}$ having a solubility of 0.241 and 0.222 in 100 parts of water at 0° and at 100° C. respectively, and among the more insoluble salts are $\text{FePO}_4+4\text{H}_2\text{O}$ and CaCO_3 . One of the chief reasons for burdening the experiments with such a variety of substances may be found in the fact of their diverse solubilities; and inasmuch as the antagonistic relations of the ions in respect to the plant require consideration and are involved with osmotic and nutritive relations, such a variety of combinations was necessary in order to feel assured that some of the results obtained might be among the most favorable that such types of combinations could yield.

It is obvious that at no instant is the exact concentration of any salt known in such combinations, except approximately, in cases where soluble salts were added. However, the total concentration is readily determinable, likewise the electrolytic conductivity of the solution. One may also estimate the partial concentrations. When soluble salts are employed in nutrient solutions, the proportion of the ions is disturbed from the moment that the roots are introduced, and there is a progressive decrease in concentration until the solution is renewed. Likewise the differences in the proportion of the ions, determined, of course, by the differential absorption rates, are not continually reestablished by any form of "reserve." It would, of course,

be possible to effect a circulation of fresh nutrient solutions where soluble salts are employed, but any operation of this nature would be impracticable in most of our experimental work. After all, the problem is to obtain a combination of salts favorable to a high degree which may be employed in practically any type of experiment where the desire is to maintain the plant under satisfactory physiological conditions. If the labor involved is great in the one case and small in the other the one involving the less labor will, of course, be selected as the more practicable.

Before describing in detail the methods and experiments to be discussed it should be pointed out that the nutrient solution developed by Crone ('03) and considered by him to have certain advantages over the Pfeffer solution, contained, in addition to KNO_3 , MgSO_4 , and CaSO_4 , ferrous phosphate and tribasic calcium phosphate. The two salts last mentioned are, of course, relatively insoluble and were used by Crone with the idea of diminishing the chlorosis which he attributed to the excess of soluble phosphate and the low content of iron. Later, however, Benecke ('09) was unable to substantiate the claims made by Crone as to the benefits to be derived from the type of solution which the latter had formulated.

The experiments on which the data in table I are based were carried out in the experimental greenhouse at the Missouri Botanical Garden during April, 1920. The methods employed were in fairly close accord with those previously described. Glass tumblers of 250 cc. capacity were used with 240 cc. of nutrient solution. To these containers were fitted corks 7.5 cm. in diameter and 0.7 cm. in thickness, arranged with holes for the insertion of the roots of the seedlings, and with an extra hole to facilitate the addition of water lost by transpiration. The seedlings were germinated over water, and in order to insure the greatest possible uniformity in size a selection of these was made when the shoots were about 2 cm. in height. Each cork was held in position by a stout rubber band passing around the tumbler lengthwise. The tumblers were covered as usual to protect the roots from the light, and the cultures were then freely and equally exposed on a lattice bench in the greenhouse. The variety of wheat employed throughout was the Pacific Coast Blue Stem,

supplied by the Plant Introduction Garden of the Bureau of Plant Industry, Chico, California. The corn was a standard field strain of yellow Dent.

The results shown in tables II and III¹ were obtained at Carmel, California, during July and August of the same year. At Carmel the cultures were arranged on lattice tables in the open. The average temperature was about 15.6° C. and the average daily evaporation from a standard spherical porous cup at-mometer about 15 cc. Table II represents cultures prepared exactly as in table I except that glass beakers, of the same capacity, were used instead of tumblers. The data in table III are from experiments closely paralleling those represented by table II except that in the former the containers used were one-quart preserving jars (Economy style). This type of jar proved most convenient in this work, since the mouth of the jar is large, taking the same corks as used in the tumblers and beakers. Moreover, the spring clips which accompany these jars afford a handy method of fastening the cork to the jar so that the seedlings are not readily disturbed. The use of the larger containers in this case explains the larger quantities of salts or solutions employed, and, of course, vessels of this capacity permit the experiments to be continued over a longer period of time.

Inasmuch as certain cultures in each of these series contained not only a full mineral "nutrient" solution but also some citrate, it seemed well to arrange all the solutions and then let them stand two days in case some evidence of fermentation might develop. This occurred in certain cases especially in the second and third series, but afterwards cleared up. The significance of this will be discussed in a later paper in which the physical characteristics of nutrient solutions in general will receive special consideration.

In all cases where readily soluble salts were used in these experiments the initial quantities in the different series varied considerably, as also the quantities added from time to time,

¹ This work was done at the Coastal Laboratory of the Carnegie Institution of Washington. The writer is pleased to make acknowledgment of the facilities and coöperation extended by Doctor D. T. MacDougal, Director of Botanical Research, and of the courtesies of other members of the staff.

and these facts are brought out in the special explanations given in connection with the particular tables.

In table I there are given in the second and third columns (under "concentration," I and II) the quantities of the salts used, these being expressed in grams of the pure salt or in cc. of a standard stock solution. The concentration numbers occur again in the fifth column, indicating to which concentration the data in the remaining columns refer. When given in grams, the quantities indicated were used in 240 cc. of water, and no change of these constituents was made throughout the interval of growth.

The quantities given in cc. also require explanation. KNO_3 : the stock solution employed for every culture in which this salt occurs except No. 15 contains 35 grams KNO_3 in 1000 cc. of water, and the use of 10 cc. per culture of 240 cc. gives a concentration of this salt in the culture solution approximately three times as great as in solution B (No. 15 in this table). It is approximately two-thirds as strong as the concentration of KNO_3 in one of the "best" cultures of Livingston and Tottingham ('18), that is, R_6C_1 , referred to in my earlier paper (Duggar, '20) as solution C. Moreover, in the two cultures (No. 12 and No. 14) in which $\text{Mg}(\text{NO}_3)_2$ or NaNO_3 was substituted for KNO_3 , the strength of the solution was such as to afford a quantity of NO_3 equivalent to that of the KNO_3 in all cultures except No. 15. MgSO_4 : the stock solution, 12 grams in 1000 cc. of water, is the same as that used in solution B (No. 15 of this series). The concentration of soluble ferric phosphate is likewise made the same as in solution B (No. 15 of this table). The control solution in this series is solution B, No. 15 of the table, previously described in detail, as noted above. Additions of 10 cc. of KNO_3 were made to each culture (240 cc.) containing this salt at intervals of 7 days, and at the same time the solution in No. 15 (solution B, control) was renewed.

A glance at table I, and more especially a study of fig. 1 (wheat), indicates that the differences between the two "concentrations" or strengths of solutions are within the probable limits of variation commonly found in duplicate cultures. The average of the two similar control cultures in solution B (No. 15) is exceeded by No. 2. The latter culture differs from the control

TABLE I

GROWTH OF WHEAT AND CORN IN SOLUTIONS OF RELATIVELY INSOLUBLE SALTS. THE GROWTH QUANTITIES REPRESENT, FOR WHEAT, 10 PLANTS, AND FOR CORN, 8 PLANTS; PERIOD OF CULTURE, 21 DAYS

Cult. No.	Concentration		Salts used	Total gr. wt. gms.	Kind of plant	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II						Init.	Fin.
1	.125 gm.	.25 gm.	CaSO ₄ +2H ₂ O Mg ₃ (PO ₄) ₂ +8H ₂ O FePO ₄ +4H ₂ O KNO ₃	I 10.20	Wheat	5.70	4.50	6.9	7.5
	.125 gm.	.50 gm.		II 14.00	Wheat	8.60	5.40	6.9	7.5
	.125 gm.	.25 gm.		I 35.90	Corn	24.20	11.70	6.9	8.4
	10 cc.	10 cc.		II 33.60	Corn	25.20	8.40	6.9	7.3
2	.125 gm.	.25 gm.	CaSO ₄ +2H ₂ O Mg ₃ (PO ₄) ₂ +8H ₂ O Sol. ferric phosphate , KNO ₃	I 17.10	Wheat	10.10	7.00	7.0	8.5
	.125 gm.	.50 gm.		II 17.80	Wheat	10.50	7.30	7.0	7.5
	40 cc.	40 cc.		I 35.85	Corn	25.70	10.15	7.0	8.3
	10 cc.	10 cc.		II 35.95	Corn	26.95	9.00	7.0	7.4
3	.25 gm.	.50 gm.	CaCO ₃ MgSO ₄ +7H ₂ O FePO ₄ +4H ₂ O KNO ₃	I 10.40	Wheat	5.50	4.90	7.2	7.7
	10 cc.	10 cc.		II 8.45	Wheat	5.10	3.35	7.2	7.4
	.125 gm.	.25 gm.		I 35.40	Corn	22.45	12.95	7.2	7.2
	10 cc.	10 cc.		II 35.25	Corn	26.10	9.15	7.2	7.4
4	.25 gm.	.50 gm.	CaCO ₃ MgSO ₄ +7H ₂ O Sol. ferric phosphate KNO ₃	I 15.00	Wheat	8.10	6.90	7.3	8.3
	10 cc.	10 cc.		II 12.40	Wheat	7.60	4.80	7.3	7.5
	40 cc.	40 cc.		I 41.85	Corn	27.25	14.60	7.3	7.3
	10 cc.	10 cc.		II 36.10	Corn	25.15	10.95	7.3	7.4
5	.125 gm.	.25 gm.	CaSO ₄ +2H ₂ O MgCO ₃ FePO ₄ +4H ₂ O KNO ₃	I 8.80	Wheat	5.50	3.30	8.5	7.3
	.125 gm.	.25 gm.		II 8.80	Wheat	5.00	3.80	8.0	8.6
	.125 gm.	.25 gm.		I 32.50	Corn	23.85	8.65	8.5	8.5
	10 cc.	10 cc.		II 31.85	Corn	23.10	8.75	8.0	8.5

TABLE I—Continued

Cult. No.	Concentration		Salts used	Total gr. wt. gms.	Kind of plant	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II						Init.	Fin.
6	.125 gm.	.25 gm.	CaSO ₄ +2H ₂ O MgCO ₃ Sol. ferric phosphate KNO ₃	I 12.00	Wheat	7.60	4.40	8.3	8.7
	.125 gm.	.25 gm.		II 9.70	Wheat	5.90	3.80	7.9	8.7
	40 cc.	40 cc.		I 38.10	Corn	26.30	11.80	8.3	8.4
	10 cc.	10 cc.		II 34.85	Corn	25.90	8.95	7.9	8.8
7	.125 gm.	.25 gm.	CaHPO ₄ +2H ₂ O MgSO ₄ +7H ₂ O FePO ₄ +4H ₂ O KNO ₃	I 12.80	Wheat	6.80	6.60	6.4	8.5
	10 cc.	10 cc.		II 11.45	Wheat	7.20	4.25	6.3	8.3
	.125 gm.	.25 gm.		I 34.06	Corn	23.37	10.69	6.4	8.5
	10 cc.	10 cc.		II 41.45	Corn	28.70	12.75	6.3	7.4
8	.125 gm.	.25 gm.	CaHPO ₄ +2H ₂ O MgSO ₄ +7H ₂ O Sol. ferric phosphate KNO ₃	I 15.60	Wheat	9.00	6.60	6.8	8.8
	10 cc.	10 cc.		II 14.10	Wheat	8.90	5.20	6.6	8.3
	40 cc.	40 cc.		I 38.29	Corn	26.17	12.17	6.8	8.5
	10 cc.	10 cc.		II 41.90	Corn	27.40	14.50	6.6	8.1
9	.125 gm.	.25 gm.	CaHPO ₄ +2H ₂ O MgSO ₄ +7H ₂ O FeC ₂ O ₄ +2H ₂ O KNO ₃	I 8.10	Wheat	4.20	3.90	5.5	7.5
	10 cc.	10 cc.		II 8.00	Wheat	4.05	3.95	5.3	7.2
	.125 gm.	.25 gm.		I 25.55	Corn	17.95	7.60	5.5	8.5
	10 cc.	10 cc.		II 26.25	Corn	18.35	7.90	5.3	8.3
10	.25 gm.	.50 gm.	MgNH ₄ PO ₄ +6H ₂ O CaSO ₄ +2H ₂ O Sol. ferric phosphate KNO ₃	I 14.00	Wheat	8.90	5.10	7.3	7.4
	.125 gm.	.25 gm.		II 15.90	Wheat	10.90	5.00	7.2	7.2
	40 cc.	40 cc.		I 34.15	Corn	22.45	11.70	7.3	8.3
	10 cc.	10 cc.		II 35.45	Corn	25.80	9.65	7.2	7.4

TABLE I—Continued

Cult. No.	Concentration		Salts used	Total gr. wt. gms.	Kind of plant	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II						Init.	Fin.
11	.25 gm.	.50 gm.	MgNH ₄ PO ₄ +6H ₂ O CaSO ₄ +2H ₂ O FePO ₄ +4H ₂ O KNO ₃	I 7.00	Wheat	4.70	2.30	7.1	7.4
	.125 gm.	.25 gm.		II 7.10	Wheat	4.90	2.20	7.1	7.4
	.125 gm.	.25 gm.		I 31.60	Corn	24.00	7.60	7.1	7.6
	10 cc.	10 cc.		II 34.63	Corn	27.53	7.10	7.1	7.3
12	.25 gm.	.50 gm.	K ₃ PO ₄ CaSO ₄ +2H ₂ O FePO ₄ +4H ₂ O Mg(NO ₃) ₂ +6H ₂ O	I 4.60	Wheat	2.80	1.80	7.2	7.3
	.125 gm.	.25 gm.		II 2.61	Wheat	1.61	1.00	7.4	7.4
	.125 gm.	.50 gm.		I 17.65	Corn	13.80	3.85	7.2	8.5
	10 cc.	10 cc.		II 16.80	Corn	12.60	4.20	7.4	7.5
13	.25 gm.	.50 gm.	K ₃ PO ₄ CaSO ₄ +2H ₂ O FeC ₂ O ₄ +2H ₂ O MgNH ₄ PO ₄ +6H ₂ O	I 5.67	Wheat	3.89	1.78	8.6	7.6
	.125 gm.	.25 gm.		II 5.33	Wheat	3.72	1.61	8.6	7.6
	.125 gm.	.25 gm.		I 25.55	Corn	19.15	6.40	8.6	8.6
	.25 gm.	.50 gm.		II 26.70	Corn	20.30	6.40	8.6	7.4
14	.25 gm.	.50 gm.	K ₃ PO ₄ CaSO ₄ +2H ₂ O FePO ₄ +4H ₂ O MgNH ₄ PO ₄ +6H ₂ O NaNO ₃	I 2.15	Wheat	1.60	.55	9.0+	8.2
	.125 gm.	.25 gm.		II —	Wheat	—	—	9.0+	8.3
	.125 gm.	.25 gm.		I 14.90	Corn	11.50	2.40	9.0+	8.4
	.25 gm.	.50 gm.		II 12.90	Corn	8.45	4.45	9.0+	8.4
15	30 cc.	30 cc.	CaSO ₄ +2H ₂ O MgSO ₄ +7H ₂ O Sol. ferric phosphate KNO ₃	I 14.70	Wheat	7.80	6.90	6.9	7.3
	10 cc.	10 cc.		II 17.35	Wheat	9.75	7.60	6.9	7.6
	40 cc.	40 cc.		I 30.60	Corn	20.50	10.10	6.9	7.5
	10 cc.	10 cc.		II 25.40	Corn	17.80	7.60	6.9	7.2

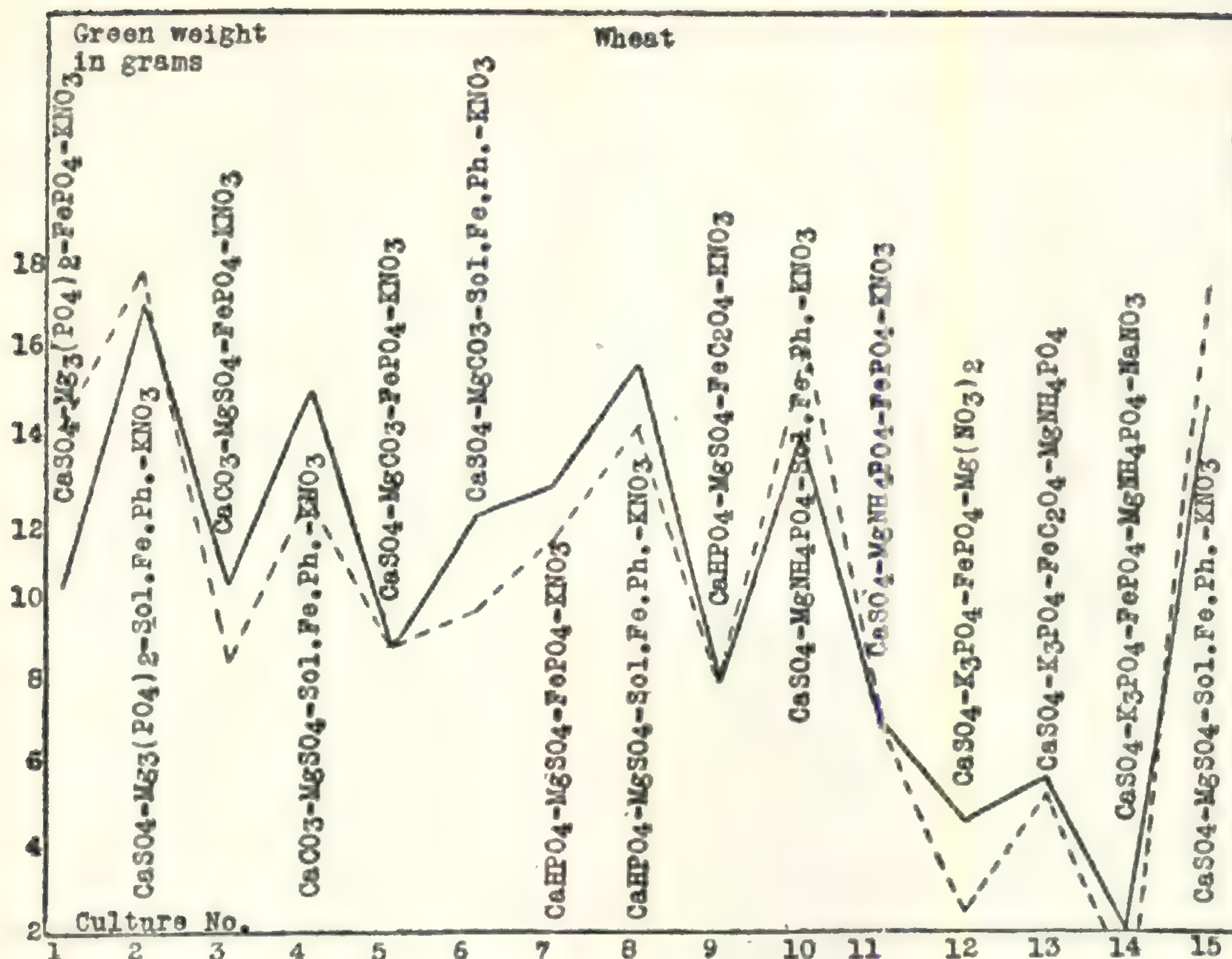


Fig. 1. Yield of wheat in solutions of relatively insoluble salts. Continuous line is concentration I and broken line concentration II (see table I).

(1) in the excess of CaSO₄ (solid phase present), (2) in the substitution of the "insoluble" tribasic magnesium phosphate for the soluble MgSO₄, and (3) in the greater content of KNO₃. It will be noticed also that cultures 4, 8, and 10 approach the value of the control, and all of these contain the soluble ferric phosphate, combined with various calcium and magnesium compounds. No culture containing either K₃PO₄ or iron oxalate has yielded satisfactorily. Similarly, MgCO₃ in the combinations employed would seem to be less depressing than K₃PO₄ but still unfavorable. Among the cultures mentioned as giving the higher yields no striking peculiarity was noted except in the case of No. 10, in which there was pronounced tillering at a relatively early period.

With corn many cultures are ahead of the control, No. 15, and those in advance are again generally the cultures containing soluble ferric phosphate, though the differences between the pairs containing FePO₄ and the salt of iron just mentioned

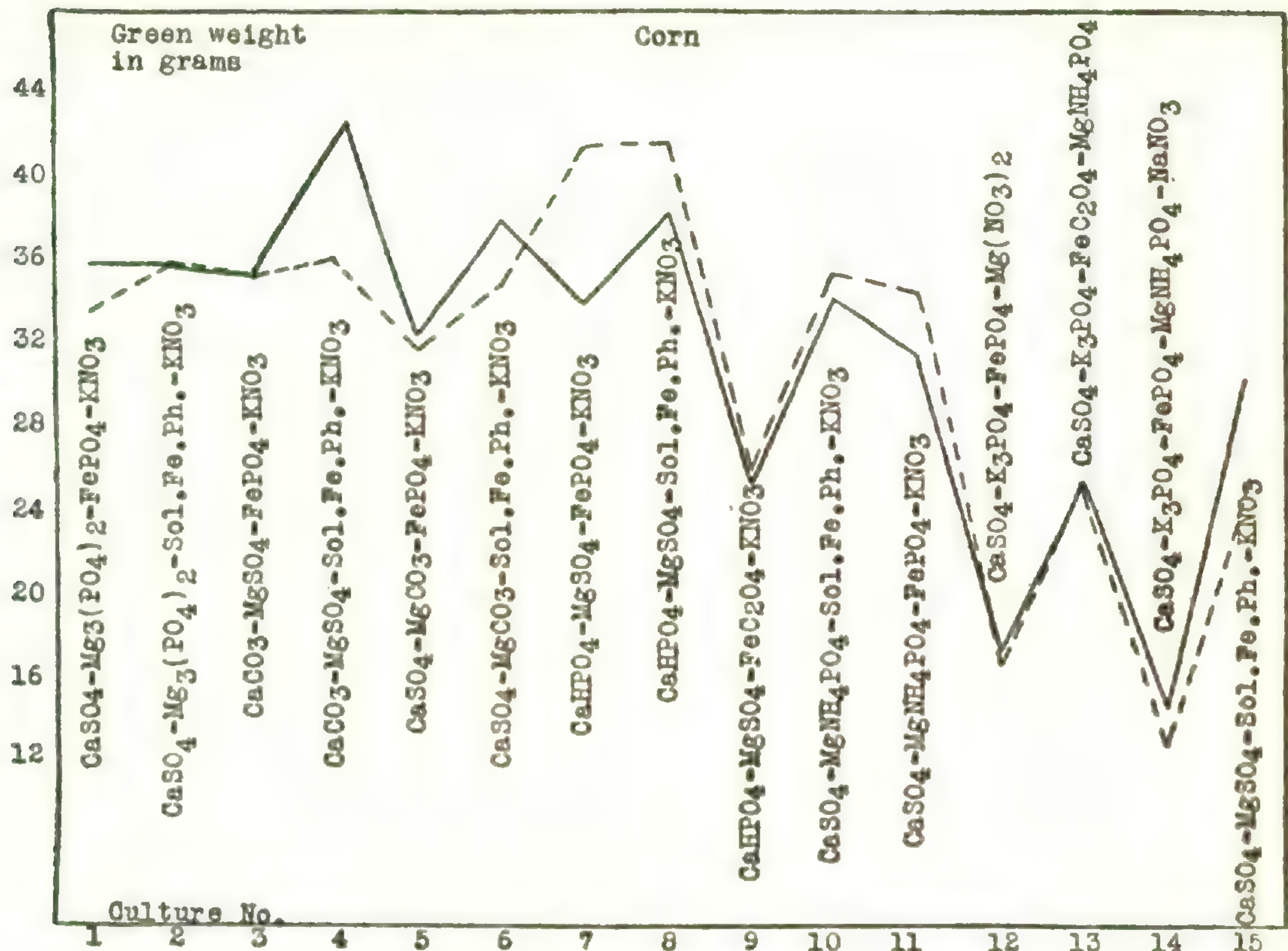


Fig. 2. Yield of corn in solutions of relatively insoluble salts. Continuous line is concentration I and broken line concentration II (see table I).

are not so striking as with wheat. Nor is it to be assumed that this relation will necessarily hold under all conditions. Moreover, corn, notably resistant to Mg salts, does not exhibit some of the antagonistic effects evident in the case of wheat. No. 11 showed pronounced chlorosis, followed, but to a somewhat less extent, by Nos. 7, 1, 12, 10, 13, and 14. Nos. 2-6, 8, and 15 were normal in appearance, while No. 9 was intensely green.

Difference in "concentration" in the first series was wholly in respect to a variation in the quantity of the relatively insoluble salts; but inasmuch as a considerable amount of the insoluble residue remained in each culture at the close of the experiment it would seem improbable that any difference in the amount of the solid phase would affect the yields. Accordingly, in the series carried out at Carmel, table II and fig. 3, it will be seen that the following are practically the only ways in which the "concentrations" are varied: (1) in column "II" the quantity of KNO_3 is one-half the amount used in column "I," and (2) in column "III," while the amount of nitrate remains

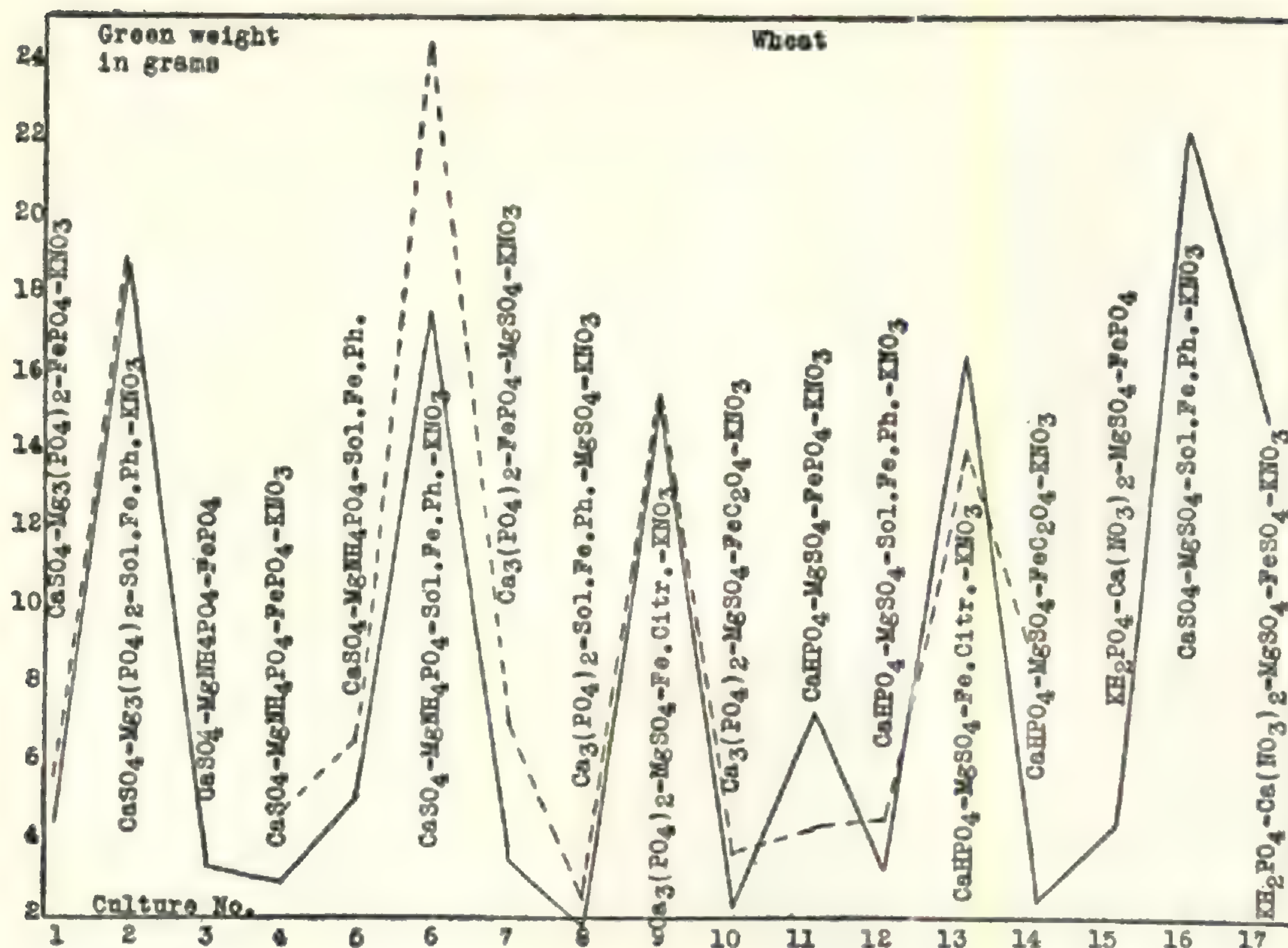


Fig. 3. Yield of wheat in solutions of relatively insoluble salts. Continuous line is concentration I and broken line concentration II (see table II).

as in "I," the quantity of the iron salt is reduced to one-half. The concentration of KNO_3 was the same as in the experiments given in table I. The stock solution of MgSO_4 contained 41.932 grams of the salt in 1 liter of water, so that 10 cc. per culture of 240 cc. gave a solution two-thirds as strong in MgSO_4 as the R_6C_1 of Livingston and Tottingham ('18). In almost every instance where the growth quantities are small the lower concentrations of the potassium nitrate and of the magnesium sulphate have a tendency within the same culture number to promote the greater growth. In this series the best culture containing insoluble salts is No. 6 (CaSO_4 [solid phase present], MgNH_4PO_4 , soluble ferric phosphate, and KNO_3), followed closely by culture 2, the latter being the same that proved so satisfactory in the previous series.

As will be pointed out later, the more insoluble calcium salts give the higher yields when in combination with relatively insoluble salts of magnesium. This is true except in certain cases where iron citrate enters into the combination. In certain cul-

TABLE II
 GROWTH OF WHEAT IN SOLUTIONS OF RELATIVELY INSOLUBLE SALTS. THE GROWTH QUANTITIES REPRESENT
 6 PLANTS: PERIOD OF CULTURE, 30 DAYS; CULTURE VOLUME, 240 CC.

Cult. No.	Concentration			Salts used	Total gr. wt. gms.	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II	III					Init.	Fin.
1	.125 gm.	.125 gm.		CaSO ₄ +2H ₂ O Mg ₃ (PO ₄) ₂ +8H ₂ O FePO ₄ +4H ₂ O KNO ₃	I 4.49 II 5.77	2.62 3.61	1.87 2.16	6.6 —	7.7 7.7
	.25 gm.	.25 gm.							
	.125 gm.	.125 gm.							
	10 cc.	5 cc.							
2	.125 gm.	.125 gm.		CaSO ₄ +2H ₂ O Mg ₃ (PO ₄) ₂ +8H ₂ O Sol. ferric phosphate KNO ₃	I 18.76 II 18.77	12.76 12.98	6.00 5.79	6.8 —	8.0 8.0
	.25 gm.	.25 gm.							
	.25 gm.	.25 gm.							
	10 cc.	5 cc.							
3	.125 gm.			CaSO ₄ +2H ₂ O MgNH ₄ PO ₄ +6H ₂ O FePO ₄ +4H ₂ O	I 3.37	1.35	2.02	7.3	6.5
	.125 gm.								
	.125 gm.								
4	.125 gm.	.125 gm.		CaSO ₄ +2H ₂ O MgNH ₄ PO ₄ +6H ₂ O FePO ₄ +4H ₂ O KNO ₃	I 2.86 II 4.77	1.73 2.95	1.13 1.82	7.4 —	7.6 8.0
	.125 gm.	.125 gm.							
	.125 gm.	.125 gm.							
	10 cc.	5 cc.							
5	.125 gm.	.125 gm.		CaSO ₄ +2H ₂ O MgNH ₄ PO ₄ +6H ₂ O Sol. ferric phosphate	I 5.11 II 6.63	2.40 3.02	2.71 3.61	6.3 —	7.3 6.9
	.125 gm.	.125 gm.							
	.25 gm.	.125 gm.							

TABLE II—Continued

Cult. No.	Concentration			Salts used	Total gr. wt. gms.	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II	III					Init.	Fin.
6	.125 gm.	.125 gm.		CaSO ₄ +2H ₂ O MgNH ₄ PO ₄ +6H ₂ O Sol. ferric phosphate KNO ₃	I 17.58 II 24.50	12.55 16.45	5.03 8.05	6.3 —	8.0 8.0
	.25 gm.	.25 gm.							
	.25 gm.	5 cc.							
	10 cc.								
7	.25 gm.	.25 gm.		Ca ₃ (PO ₄) ₂ FePO ₄ +4H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 3.56 II 7.09	2.20 4.49	1.36 2.60	6.4 6.4	7.8 7.9
	.125 gm.	.125 gm.							
	10 cc.	5 cc.							
	10 cc.	5 cc.							
8	.25 gm.	.25 gm.	.25 gm.	Ca ₃ (PO ₄) ₂ Sol. ferric phosphate MgSO ₄ +7H ₂ O KNO ₃	I 1.68 II 2.60 II 1.68	.98 1.75 .99	.70 .85 .69	6.2 6.0 —	8.0 8.0 7.8
	.25 gm.	.25 gm.	.125 gm.						
	10 cc.	5 cc.	10 cc.						
	10 cc.	5 cc.	10 cc.						
9	.25 gm.	.25 gm.	.25 gm.	Ca ₃ (PO ₄) ₂ Ferric citrate MgSO ₄ +7H ₂ O KNO ₃	I 15.26 II 15.60 III 8.88	9.58 10.36 5.25	5.68 5.24 3.63	5.8 5.7 —	8.0 8.0 7.9
	.25 gm.	.25 gm.	.125 gm.						
	10 cc.	5 cc.	10 cc.						
	10 cc.	5 cc.	10 cc.						
10	.25 gm.	.25 gm.	.25 gm.	Ca ₃ (PO ₄) ₂ FeC ₂ O ₄ +2H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 2.27 II 3.76 III 2.01	1.42 2.36 1.30	.85 1.40 .71	5.8 5.8 —	7.7 7.8 8.0
	.125 gm.	.125 gm.	.0625 gm.						
	10 cc.	5 cc.	10 cc.						
	10 cc.	5 cc.	10 cc.						

TABLE II—Continued

Cult. No.	Concentration			Salts used	Total gr. wt. gms.	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II	III					Init.	Fin.
11	.125 gm.	.125 gm.		CaHPO ₄ +2H ₂ O FePO ₄ +4H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 7.22 II 4.43	4.62 2.97	2.60 1.46	6.4 6.6	8.0 8.0
	.125 gm.	.125 gm.							
	10 cc.	5 cc.							
	10 cc.	5 cc.							
12	.125 gm.	.125 gm.	.125 gm.	CaHPO ₄ +2H ₂ O Sol. ferric phosphate MgSO ₄ +7H ₂ O KNO ₃	I 3.25 II 4.61 III 6.08	2.18 2.80 3.73	1.07 1.81 2.35	5.6 5.6 —	7.8 7.9 8.0
	.25 gm.	.25 gm.	.125 gm.						
	10 cc.	5 cc.	10 cc.						
	10 cc.	5 cc.	10 cc.						
13	.125 gm.	.125 gm.	.125 gm.	CaHPO ₄ +2H ₂ O Ferric citrate MgSO ₄ +7H ₂ O KNO ₃	I 16.41 II 13.96 III 17.85	11.36 9.60 12.67	5.05 4.36 5.18	5.8 5.8 —	8.0 7.9 8.0
	.25 gm.	.25 gm.	.125 gm.						
	10 cc.	5 cc.	10 cc.						
	10 cc.	5 cc.	10 cc.						
14	.125 gm.	.125 gm.	.125 gm.	CaHPO ₄ +2H ₂ O FeC ₂ O ₄ +2H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 2.41 II 8.43 III 4.71	1.46 4.77 2.70	.95 3.66 2.01	5.6 5.6 —	7.6 8.0 7.6
	.125 gm.	.125 gm.	.0625 gm.						
	10 cc.	5 cc.	10 cc.						
	10 cc.	5 cc.	10 cc.						
15				Solution A	4.56	2.87	1.69	—	5.2
16				Solution B	22.20	13.62	8.58	—	7.6
17				Tottingham's sol.	14.49	9.95	4.54	—	6.4

tures where the magnesium salt is the more soluble, Nos. 8-13, the more favorable action of ferric citrate as contrasted with the soluble ferric phosphate and FePO_4 in these cultures with wheat is clearly shown. With the exceptions noted the favorable influence of soluble ferric phosphate in the solution is evident, especially in Nos. 2 and 6, as also, of course, in solution B.

The Tottingham solution was exceeded by 5 combinations. The Shive solution, solution A (No. 15) was unsatisfactory in this series, since after being set up it was found that the acidity was much higher than usual. In these experiments, however, no recrystallization of the salts employed was carried out and no corrections for acidity were made.

The six cultures giving the higher yields (Nos. 2, 6, 9, 13, 16, and 17) were all green and healthy in appearance. Cultures 3 and 5, without KNO_3 , were characterized by marked attenuation; No. 14 exhibited excessive greening; and Nos. 7 and 15 were abnormally stocky in general appearance.

As stated previously, the experiments shown in table III and in fig. 4 were also obtained at Carmel. The experiments were set up on July 10, using wheat as a test plant and employing quart jars as containers. For cultures 1-20 the same stock solutions of KNO_3 and MgSO_4 as described for table II were used. The results are not in entire agreement with those given in table II. This may be accounted for in part by the use of the larger containers and also in part by differences in weather conditions. During the progress of the experiments here discussed, there were several days of comparatively warm weather without fog, inducing high evaporation rates. It is well to note also that a slight mishap to culture 2, which was found upset one morning, may be responsible in some measure for the low yield of this culture.

Renewals of the solutions in the control cultures (Nos. 21-23) were made about every 10 days. Additional amounts of KNO_3 , 20 cc. in the case of all cultures in column "I" and 10 cc. in the case of column "II," were added on July 24 and August 6. No additional MgSO_4 was added to the cultures receiving this salt until August 6, when 10 cc. were given each of those receiving this salt in column "I," and 5 cc. for similar cultures in column "II." With the larger amount of nitrate employed, cul-

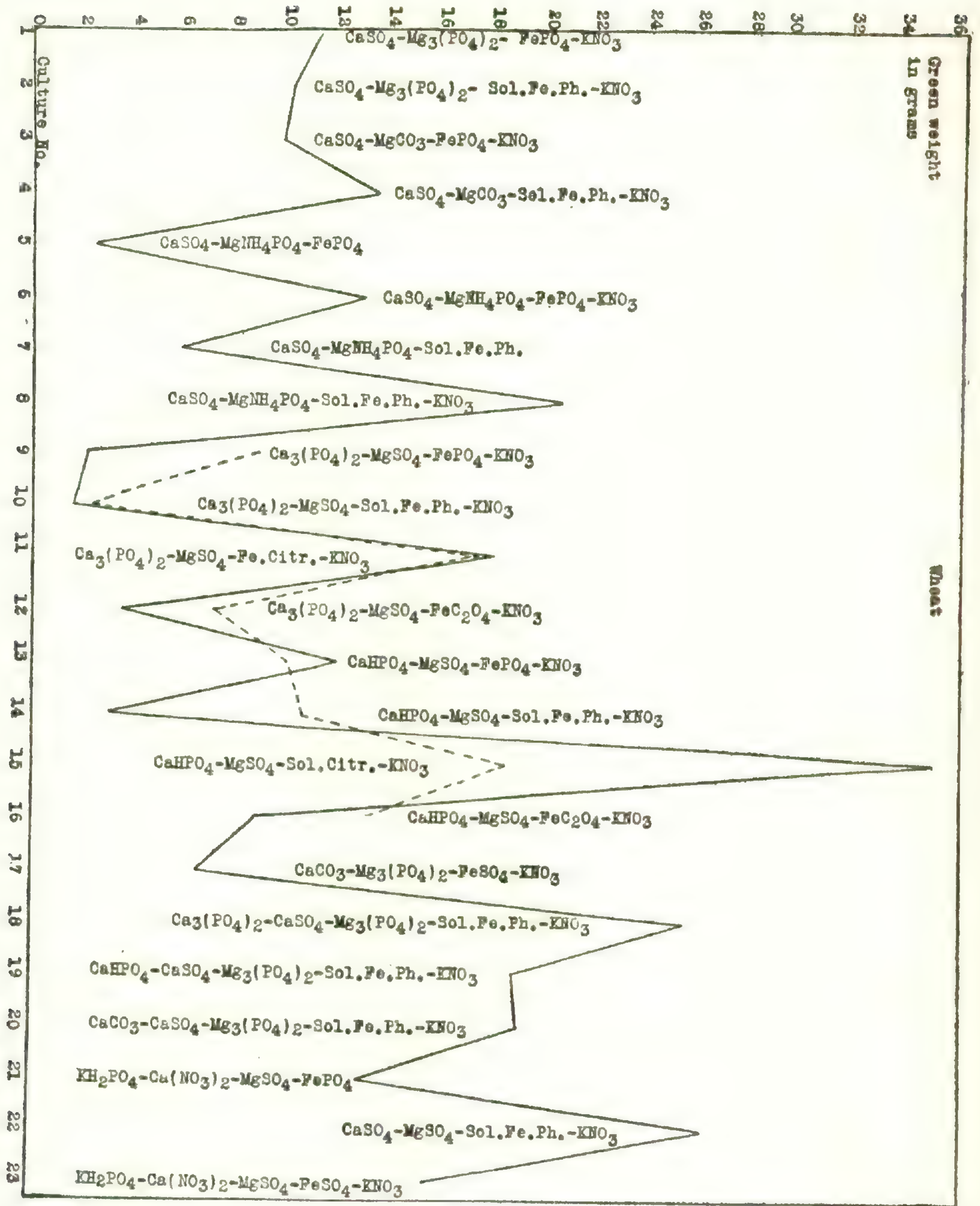


Fig. 4. Yield of wheat in solutions of relatively insoluble salts. Continuous line is concentration I and broken line concentration II (see table III).

ture 15 (CaHPO_4 , MgSO_4 , ferric citrate, and KNO_3) is best, followed by one of the controls, solution B, and this in turn is very closely followed by Nos. 18, 8, 20, 19, and 11. Cultures 11 and 15 confirm the previous experience that the ferric citrate effects a high degree of balance in cases where the magnesium salt is more soluble than the calcium salt used; and neither the soluble ferric phosphate nor the FePO_4 can replace it in this respect where wheat is the test plant (compare with the cultures above mentioned Nos. 9, 10, 13, and 14).

With due consideration of the causes already mentioned the value of the soluble ferric phosphate in the culture media is confirmed, and the importance of ferric citrate established in certain combinations. No experiments thus far made have thrown any special light on the nature of the benefit derived in these cases from the soluble ferric phosphate or the iron citrate. In both cases, however, within the range of reaction involved in the studies here reported, suspension films consisting in part at least of ferric hydroxide are thrown down. The writer is now endeavoring to determine if floating particles of this type, or a substance in the colloidal state may possibly be of importance in the absorption and distribution of the ions. I have previously mentioned this possibility (Duggar, '20, p. 42) while referring especially to certain experiments of Bonazzi and of Allen on the culture of microorganisms.

SUMMARY

The value of certain relatively insoluble salts as sources of the necessary ions for the growth of seed plants has been tested in a variety of combinations covering by no means, however, the entire range of possibility.

It is argued that in certain types of work many advantages may accrue from the use of combinations of insoluble salts, because of (1) the tendency to maintain a constant concentration of the various ions furnished, and also because (2) no renewal of the solution (except as to the addition of NO_3) is required from day to day.

As sources of Ca, Mg, Fe, PO_4 , SO_4 , many insoluble salts have been tested, but no salt of this type is procurable as a practical source of NO_3 , so that in most experiments this ion is furnished by KNO_3 .

TABLE III

GROWTH OF WHEAT IN SOLUTIONS OF RELATIVELY INSOLUBLE SALTS. THE GROWTH QUANTITIES REPRESENT 8 PLANTS: PERIOD OF CULTURE, 40 DAYS; VOLUME OF CULTURE SOLUTION, 890 cc.

Cult. No.	Concentration		Salts used	Total gr. wt. gms.	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II					Init.	Fin.
1	.5 gm. .5 gm. 1.0 gm. 40 cc.		CaSO ₄ +2H ₂ O FePO ₄ +4H ₂ O Mg ₃ (PO ₄) ₂ +8H ₂ O KNO ₃	I 11.20	6.58	4.62	7.0	7.8
2	.5 gm. 1.0 gm. 1.0 gm. 40 cc.		CaSO ₄ +2H ₂ O Sol. ferric phosphate Mg ₃ (PO ₄) ₂ +8H ₂ O KNO ₃	I 10.20	6.01	4.19	8.0	7.9
3	.5 gm. .5 gm. .5 gm. 40 cc.		CaSO ₄ +2H ₂ O FePO ₄ +4H ₂ O MgCO ₃ KNO ₃	I 9.86	5.79	4.07	9.0	7.6
4	.5 gm. 1.0 gm. .5 gm. 40 cc.		CaSO ₄ +2H ₂ O Sol. ferric phosphate MgCO ₃ KNO ₃	I 13.47	8.85	4.62	8.8	8.0
5	.5 gm. .5 gm. .5 gm.		CaSO ₄ +2H ₂ O FePO ₄ +4H ₂ O MgNH ₄ PO ₄ +6H ₂ O	I 2.40	1.42	.98	7.1	6.4
6	.5 gm. .5 gm. .5 gm. 40 cc.		CaSO ₄ +2H ₂ O FePO ₄ +4H ₂ O MgNH ₄ PO ₄ +6H ₂ O KNO ₃	I 12.90	7.72	5.18	6.9	7.4
7	.5 gm. 1.0 gm. .5 gm.		CaSO ₄ +2H ₂ O Sol. ferric phosphate MgNH ₄ PO ₄ +6H ₂ O	I 5.85	2.62	3.23	7.3	7.3
8	.5 gm. 1.0 gm. .5 gm. 40 cc.		CaSO ₄ +2H ₂ O Sol. ferric phosphate MgNH ₄ PO ₄ +6H ₂ O KNO ₃	I 20.72	12.05	8.67	8.1	7.2
9	1.0 gm. .5 gm. 40 cc. 40 cc.	1.0 gm. .5 gm. 20 cc. 20 cc.	Ca ₃ (PO ₄) ₂ FePO ₄ +4H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 2.08 II 8.83	1.28 5.77	.80 3.06	—	7.6 7.4
10	1.0 gm. 1.0 gm. 40 cc. 40 cc.	1.0 gm. 1.0 gm. 20 cc. 20 cc.	Ca ₃ (PO ₄) ₂ Sol. ferric phosphate MgSO ₄ +7H ₂ O KNO ₃	I 1.64 II 2.32	1.11 1.72	.53 .60	8.0	7.7 7.7

TABLE III—Continued

Cult. No.	Concentration		Salts used	Total gr. wt. gms.	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II					Init.	Fin.
11	1.0 gm.	1.0 gm.	Ca ₃ (PO ₄) ₂ Ferric citrate MgSO ₄ +7H ₂ O KNO ₃	I 18.02 II 17.31	11.97 9.86	6.05 7.45	8.3	7.9 8.0
	1.0 gm.	1.0 gm.						
	40 cc.	20 cc.						
	40 cc.	20 cc.						
12	1.0 gm.	1.0 gm.	Ca ₃ (PO ₄) ₂ FeC ₂ O ₄ +2H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 3.48 II 7.12	2.12 3.67	1.36 3.45	6.2	7.5 7.6
	.5 gm.	.5 gm.						
	40 cc.	20 cc.						
	40 cc.	20 cc.						
13	.5 gm.	.5 gm.	CaHPO ₄ +2H ₂ O FePO ₄ +4H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 11.87 II 10.00	7.72 6.83	4.15 3.17	6.6	7.6 7.5
	.5 gm.	.5 gm.						
	40 cc.	20 cc.						
	40 cc.	20 cc.						
14	.5 gm.	.5 gm.	CaHPO ₄ +2H ₂ O Sol. ferric phosphate MgSO ₄ +7H ₂ O KNO ₃	I 2.97 II 10.67	2.07 7.19	.90 3.48	7.9	7.9 7.8
	1.0 gm.	1.0 gm.						
	40 cc.	20 cc.						
	40 cc.	20 cc.						
15	.5 gm.	.5 gm.	CaHPO ₄ +2H ₂ O Ferric citrate MgSO ₄ +7H ₂ O KNO ₃	I 35.30 II 18.55	22.63 11.13	12.67 7.42	8.1 7.3	8.0 7.9
	1.0 gm.	1.0 gm.						
	40 cc.	20 cc.						
	40 cc.	20 cc.						
16	.5 gm.	.5 gm.	CaHPO ₄ +2H ₂ O FeC ₂ O ₄ +2H ₂ O MgSO ₄ +7H ₂ O KNO ₃	I 8.80 II 13.14	5.99 3.09	2.81 6.00	6.7	7.9 7.8
	.5 gm.	.5 gm.						
	40 cc.	20 cc.						
	40 cc.	20 cc.						
17	1.0 gm.		CaCO ₃ FeSO ₄ Mg ₃ (PO ₄) ₂ +8H ₂ O KNO ₃	I 6.52	4.20	2.32	7.8	7.9
	trace							
	.5 gm.							
	40 cc.							
18	1.0 gm.	1.0 gm.	Ca ₃ (PO ₄) ₂ CaSO ₄ +2H ₂ O Sol. ferric phosphate Mg ₃ (PO ₄) ₂ +8H ₂ O KNO ₃	I 25.55	16.82	8.73	8.0	7.9
	.5 gm.	.5 gm.						
	1.0 gm.	1.0 gm.						
	.5 gm.	.5 gm.						
	40 cc.	20 cc.						
19	.5 gm.		CaHPO ₄ +2H ₂ O CaSO ₄ +2H ₂ O Sol. ferric phosphate Mg ₃ (PO ₄) ₂ +8H ₂ O KNO ₃	I 18.99	12.58	6.41	7.8	8.0
	.5 gm.							
	1.0 gm.							
	.5 gm.							
	40 cc.							

TABLE III—Continued

Cult. No.	Concentration		Salts used	Total gr. wt. gms.	Gr. wt. tops gms.	Gr. wt. roots gms.	P _H	
	I	II					Init.	Fin.
20	1.0 gm. .5 gm. 1.0 gm. .5 gm. 40 cc.		CaCO ₃ CaSO ₄ +2H ₂ O Sol. ferric phosphate Mg ₃ (PO ₄) ₂ +8H ₂ O KNO ₃	I 19.15	12.50	6.65	8.0	7.9
21			Solution A	12.90	7.92	4.98	4.1	5.7
22			Solution B	26.23	15.16	11.07	6.6	7.7
23			Tottingham's sol.	15.55	9.20	6.35	5.8	6.4

A relatively insoluble source of NH₄ (MgNH₄PO₄) has been found unsatisfactory as a source of nitrogen with the test plants used.

In each of three series of cultures in which wheat or wheat and corn were used, one or more of the combinations containing two or more insoluble salts exceeded the growth in the best control culture employed. The best control culture contained CaSO₄, MgSO₄, soluble ferric phosphate, and KNO₃. Cultures exceeding the control contained in the several series the following combinations of salts: I, CaSO₄ (solid phase present), Mg₃(PO₄)₂, soluble ferric phosphate, and KNO₃; II, CaSO₄ (solid phase present), MgNH₄PO₄, soluble ferric phosphate, and KNO₃; III, CaHPO₄, MgSO₄, ferric citrate, and KNO₃.

In all series, with the test plants mentioned, a group of cultures approached very closely the yields of the best combinations, and in all cases in such best combinations the calcium salt is relatively more soluble than the magnesium salt, except in certain combinations into which ferric citrate enters.

Soluble ferric phosphate has proved a valuable constituent in the culture medium in a variety of combinations. In certain

cases ferric citrate has proved equally valuable. Certain fermentation processes may occur in cultures in which these compounds are employed and a further study of the influence of those changes is necessary.

Except in the cultures containing K_2PO_4 or $MgCO_3$, the hydrogen-ion concentration of all combinations used in the three series here reported ranges from 5.6 to 8.0, and after the growth of test plants there is usually a shift in the P_H toward alkalinity or greater alkalinity.

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New scientific names of plants and the final members of new combinations are printed in **bold face** type; synonyms and page numbers having reference to figures and plates, in *italic*; and previously published scientific names and all other matter, in ordinary type.

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