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REPORT OF THE BOTANICAL DEPARTMENT.

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REPORT ON THE LOOSE SMUTS OF CEREALS.

The loose smuts are four closely allied species found on oats, wheat, and barley. Wheat is sometimes attacked by other smuts, which are, however, quite different. All the loose smuts are, as their name indicates, of a powdery nature. All attack the heads or panicles of the cereal, and usually destroy them more or less completely. They are not confined to the grain, as is the case with the stinking smut of wheat. The black powdery mass consists of the reproductive bodies called *spores*, which correspond in function to the seeds of the common plants. The vegetative portion of the parasitic fungus is wholly concealed within the tissue of the plant that is attacked. It does not cause immediate death, nor marked abnormal growth. Its presence is not easily recognized till it begins the production of its spores, forming the conspicuous black mass where the grains should have been formed.

Although the loose smut of oats is the most important, and is the only one that has been experimented with, an account will be given of the loose smuts of wheat and barley also. All of the four species described are so nearly alike, that until a few years ago they were considered but one species, to which the name *Ustilago segetum* (Bull.) Ditt., or *U. Carbo* (DC.) Tul., was applied. It has recently been shown by Jensen that the smut of oats, wheat and barley were unable to infect any of the cereals except that on which they grew. We have found a considerable difference in the manner of germination in these species, making it doubly certain that these forms are really distinct species. The importance of this fact is obvious: farmers need not fear that their oats will become infected from neighboring wheat or barley fields, and *vice versa*.

The life-history of these smuts is, as far as known, as follows: The loose spores are blown about by the wind, (or during the threshing,) and attach themselves to the grains. In the case of oats and barley, only those spores which are inside the husks are able to infect the plants to any appreciable extent. The smut being ripe during the flowering-time, the spores blown about by the wind fall upon the young grains, and are inclosed with it by the husks.

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When the seed is planted, in spring, the spores of the smut germinate and send out minute germ threads, which enter the young plant only through the first delicate leaf sheath. Only for a few days is the smut able to enter this leaf, and after the second leaf breaks through this sheath the plants are free from further infection. Assuming that the minute germ threads of the smut did enter the sheathing leaf at the proper time, the fungus develops as follows: The minute thread entering the sheathing leaf penetrates to all the parts of the stem and branches; its growth keeps pace with that of the host plant, till, at length, just before the time of flowering, the fungus forms a mass of thick threads in the young forming head, and inside of these threads the spores are produced. As the spores grow, the threads become gelatinous, and finally, when the spores are ripe, they disappear entirely, leaving a loose mass of spores.

This is essentially the course of development in all the species, though the manner of infection may vary somewhat from that here described, especially in case of the loose smuts of wheat and barley.

The following key shows in brief the characters of the different loose smuts:

1. Spores smooth, 2.
1. Spores minutely spiny, or warty, 3.
   2. Spores dark brownish in mass, contents often granular. *Ustilago Avenæ* var. *levis,* (I.)
   2. Spores black in mass, contents not granular. *Ustilago Hordei,* (III.)
3. Producing sporidia readily. *Ustilago Avenæ,* (I.)
3. Not producing sporidia readily, if at all, 4.
   4. Promycelia long, very much branched in nutrient solution; ends, however, not swollen. *Ustilago Tritici,* (II.)
   4. Promycelia shorter, sparingly branched or simple, ends of branches very often becoming swollen. *Ustilago nuda,* (IV.)

I. *Ustilago Avenæ.* Oat smut.

Spores in mass, dark dusky-brownish, variable in size, oval subglobose or elliptical in shape; epispore minutely spiny Promycelium producing in nutrient solution many sporules, little branched, but growing out readily as the cultures become exhausted, into very long germ threads; producing in water sporules and a few germ threads; spores forming a very loose mass. *Ustilago Avenæ,* var. *levis,* as above, but spores slightly darker in mass, and furnished with a smooth epispore.

II. *Ustilago Tritici.* Loose smut of wheat.

Spores in mass, dark brownish with a shade of olivaceous, rather constant in size, oval, or less often subglobose or elliptical in shape; epispore marked with minute spines or warts. Promycelia in nutrient solution much branched, and branches often many segmented, not producing sporules (?); in water producing no sporules or germ threads. Spores forming a very loose mass.

III. *Ustilago Hordei.* Covered smut of barley.
Spores in mass perfectly black, constant in size, globose or subglobose; epispore perfectly smooth. Promycelia in nutrient solution little or much branched, producing countless sporules, but not commonly germ threads; producing in water sporules but very few germ threads. Spores in mass somewhat firm.

IV. *Ustilago nuda.* Naked smut of barley.
Spores in mass dark brownish, with an olivaceous shade, rather constant, oval or less often elliptical or subglobose. Promycelia in nutrient solution not very much branched, never producing sporules, branches often swollen at tips; in water producing no sporidia, but many germ threads.

In the following pages each of these smuts is separately described; and at the end of the report is a short account of the stinking smut of wheat, and of the natural enemies of the smuts. Eight plates illustrate the smuts, and one their natural enemies. Unfortunately the plates are much too small to show all the forms obtained by germination of the spores. They must therefore be considered as showing only some of the many forms actually seen and described.

OAT SMUT, Ustilago Avence (Persoon) Jensen.

HISTORICAL.

The early authors —Pliny, Theophrastus, and others, probably knew of the oat smut, but in their writing all smuts are confused with the stinking smut of wheat, which they certainly knew. We find no further mention of oat smut till 1552, when Tragus mentioned it under the name *Ustilago,*[1] and gave a figure of it. Lobelius, in 1591, mentioned it, and gave a figure of it, under the name *Ustilago Avenæ*.[2] C. Bauhin, in 1596;[3] described it under the name *Ustilago avenaria.* Tabernæmontanus, early in the seventeenth century, mentioned it.[4] Probably all of these authors considered the smut, not as a plant, or parasite, but as a diseased condition of the host. Even Linnæus, in 1767, held the smut for infusoria,[5] under the names *Chaos Us-*tilago; and *Reticularia Ustilago*[7]*;* others, as Aymen and Girod-Chantrans, considered them small animals. Linnæus finally recognized them as plants, as did Oeder, in Flora Danica, and Bulliard, who, in 1791, described the smuts of all cereals under the general name *Reticularia segetum*[8].

1 Tragus. De stirpium Nomencl. prop. lib. III, p.666, with figure. See. F. v. Waldheim.
2 Lobelius. Icones stirpium s. plantarum tam exoticum quam indigenarum. Antverpiæ, 1591, p. 36, with figure.
C. Bauhin. Phytopinax seu enumeratio plantarum ab herbariis nostro saeculo descriptarum. Basileae, 1596, p. 52.
4 Fide Wallroth. Flora cryptogamica Germ., p. 217, No. 1672g.
5 Linné. Syst. nat. ed. XIII, Vindob,, 1767, I, p. 1327, fide De Bary.
6 Linné. Syst. nat. ed. XII, Holm, 1767., p. 1356.
7 Linné. Syst. nat. II, p. 1472, fide Streinz; ed. XIII, 1796,II, p. 1472, sec. F. v. Waldheim.
Bulliard. Histoire des champignons de la France I, p. 90, tab. 472, fig. 2.

Bonner, in 1750, Duhamel, in 1752, Tillet, in 1755, Aymen, in 1760, and Tessier, in 1783, noticed the loose smuts of cereals. Tessier speaks of the smut of oats separately.[1] Bulliard is the first botanist who gave it a distinctive name as a fungus, but his name cannot now be used, since he characterized all loose smut equally by it, and recognized no varieties. Persoon, in 1801, recognizes the smuts as fungi, and while adopting Bulliard's name for the species — *Uredo segetum* — he makes varieties on barley, wheat, and oats. The variety on oats is called *g Uredo Avence.*[2] This being the earliest scientific name used to designate the oat smut, it is here used. In 1813, Ditmar placed the loose smut of oats in the genus Ustilago, calling it *Ustilago* segetum.[3] De Candolle, in 1815, gives the same varieties as Persoon, but calls the species (to include all the loose smuts) *Uredo Carbo.* He then carefully distinguished the loose smuts from the stinking smut of wheat. *(Tilletia.)* Wallroth, in 1833,[4] still retaining the same varieties, called the species, including them, *Erysibe vera.* Phillippar called the form on oats *Uredo Carbo-Avence*[5] Tulasne, in 1847, recognized essentially the same varieties under var. *vulgaris* of *Ustilago Carbo.* The form on oats he called b *Avenacea*[6]

Recent writers have called the loose smuts of wheat, oats, barley and wild grasses indiscriminately *Ustilago segetum* (Bull.) Dittm., or Ustilago *Carbo* (DC.) Tul.; as such authors, Kühn, Fischer von Waldheim, Hoffman, Winter, Wolff Schroeter, Saccardo and others might be named. The only difference recognized by any of the writers is in the relative abundance on the different hosts. Jensen, in 1888, named the oat smut *Ustilago segetum,* var. *avenæ,*[7] and separated from it the form on wheat, var. *tritici,* and two forms on barley, var. *nuda* and var. *tecta.* In July, 1889, he recognized the form on oats as a species, "*Ustilago avence (Jensen).*"[8] The name *Avenæ, of* Persoon, was the earliest, and Jensen first put the species in the genus Ustilago; therefore the name and synonymy are as follows:

USTILAGO AVENUE (Persoon) Jensen.

1591 *Ustilago Avenæ* Lobelius, Icon. stirp., p. 36.
1596 *Ustilago Avenaria* Bauhin, Phytopinax, p. 52.
1767 *Chaos Ustilago* Linné, Syst. nat., ed. XII, II, p. 1356. p. p.[9]
1791 *Reticularia Ustilago* Linné, Syst. nat., ed. XIII, II, p.1472. p. p.
1791 *Reticularia segetum* Bulliard, Hist. des champ., I, p. 90, tab. 474. Poiret, in Encyc. méth. de bot., VI, p. 181. Withering, Bot. Arr. IV., p. 356.

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[1] Tessier. Traité sur les malades des grains, Paris, 1782, pp. 310-336, with plate. Sec. F. v. W. & De Bary.
[2] Persoon. Synopsis methodica fungorum, pars prima. Gottingae, 1801, p. 224, " Effusa fluctans."
[3] Dittmar, in Sturm Deutschlands Flora III Band, 3 Heft, S. 36, t. 33.
[4] Wallroth. Flora cryptogamica Germaniae pars posterier (Comp. F1. Germ., sectio II, tomus IV). Norimbergae, 1833, p. 217, No 1672.
[5] Phillippar. Traité organogr. et phys. — agr. sur la Carie, le Charbon, Versailles, 1837, p. 92, pl. II.
[6] R. et Ch Tulasne. Memoir sur les Ustileginées comparées aux Uredinées, in Ann. Sci. Nat., 3e série, t. VII, 1847, p. 80.
[7] J. L. Jensen. The Propagation and Prevention of Smut in Oats and Barley. In Journal of the Royal Agricultural Society of England, XXIV, s, s,, part II, p. 11.
[8] J. L. Jensen. Le Charbon des Ceréales, Copenhague, July, 1889, p. 4.
[9] p. p. = in part.

Johnston, Flora of Berwick-on-Tweed, II., p.203. Greville, Fl. Edin., p.442. p.p.

1797 *Uredo segetum* Persoon, Disp. meth. fung., p.56; Synop. meth. fung., p.224. p. p.

1801 *Uredo (Ustilago) segetum g Uredo Avenæ* Persoon, Syn. meth. fung., p. 224.

1809 *Cæoma segetum* Link, obs., I, p.4; Sp. pl. Wild., T. VI, P. II, p.1. p.p.

1813 *Ustilago segetum* [Bulliard] Dittmar, in Sturm Deutschl. Fl., III, 3, S. 67, T. 33. Fries, S. M., III, p. 518. Berkeley, in Smith's English Flora, V, pt. II, 1847, p. 374; Outl. Br. Fung., p. 335. Cooke, Micro. F. 4th ed., p. 229. Loudon, Encyclopedia of Plants, London, 1872, pp. 1044, 1045, No. 16657. P. A. Karsten, Mycologia Fennica, pars IV, in Bid rag till kännedom af Finlands natur och folk, Trettionde-forsta Häflet, p. 6, No. 1. Winter, Die Pilze, I, p. 90, Nr. 103. Oertel, Beitr. zur Fl. d. Rost. u. Brandp. Thüringens, in Deutsche Bet. Monats-schr., IV, Nr. 3, März, 1886, S. 40, No. 141. Schroeter, Die Pilze Schlesiens, I. S. 267, Nr. 418. Plowright, Br. Ured. and Ust., p. 274. De Toni, in Sacc. Syll., VII, II, p. 461, No, 1676. p. p.

1815 *Uredo Carbo g Avenæ* DeCandolle, Fl. fr., VI, p. 76.

1833 *Erysibe vera g Avenæ* Wallroth, Flora. crypt. Germ., p. 217, No. 1672.

1837 *Uredo Carbo Avenæ* Phillippar, Traité sur la carie et la charbon, p. 92, pl. 2.

1847 *Ustilago Carbo a vulgaris b Avenacea* Tulasne, Mém. sur les. Ust. comp. aux Ured., p. 80.

1871 *Ustilago Carbo* Tulasne, Cooke, Handb. Br. Fungi, II, p. 512, No. 1520. Hazslinszky, Magyarhon üszökgombái és ragyái, in Magy. tud. akad. math. és termész. közlemények, XIV, köt. 1876–7, 1.110. Fischer von Waldheim, Apergu system. des Ustilaginées, p. 12, No. 6; Gholovnev-uiya monoghraficheskei ocherk, chast II, str. 13. p. p.

1888 *Ustilago segetum* var. *Avenæ* Jensen, Om Kornsorternes Brand (Anden Meddelelse) S. 61.

1888 *Ustilago segetum* var. *avenæ* Jensen, Prop. and Prev. of Sm. in Oats and Barley, in J. R. A. S. XXIV s. s. P. II, p. 4.

1889 *Ustilago avenæ* Jensen, Le charbon des Céréales, p. 4.

INJURIES TO THE HOST PLANT.

The oat smut resembles the loose smut of wheat and naked barley smut, in converting more or less of the head into a loose, powdery mass of spores, which are readily blown about by the wind. The smut often almost completely destroys the normal tissue of the spikelets, leaving only a black mass of spores penetrated by shreds and plates of tissue. Sometimes this tissue is so abundant as to cause the interior to have a somewhat netted appearance. More often, however, the glumes retain more or less of their normal structure, especially at the tips. At the base they are usually almost destroyed by the smut, while toward the tip the smut may break through the epidermis in isolated pustules. The smutted spikelets are at first covered with a very thin membrane, which, however, soon disappears. It has less of such a membrane than any of the loose smuts of cereals, except perhaps *Ustilago Tritici.*

In a few cases smutted heads have been collected where the smut had destroyed the grain and flowering glumes, while the large outer husks were yet entirely sound. Such a head would scarcely be seen to be smutted unless carefully examined. In plate I, fig. 3, is shown a small head with the spikelets almost completely converted into smut. Figure 2 shows a large head with the tips of the spikelets less smutted. In fig. 1 the tips of the spikelets are more or less attacked, while the top of the head is sound and produces healthy grains. The smutted heads gradually lose their smut under the influence of wind, rain and insects, and sometimes even the shreds of dead tissue fall off, leaving simply a barren stalk with no sign of grain or smut. When the glumes are not very much smutted they do not thus fall away, though they may be completely emptied of smut. The diseased plants usually appear just like healthy ones till about the time of flowering; then the smut shows itself and rapidly ripens, becomes dry and dusty long before the oats ripen. However, when a smutted hill stands somewhat alone, it is seen to have rather stouter stalks *(i. e.*, greater in diameter) than healthy stalks. Usually smutted heads grow up free from the upper leaf like healthy ones, but the smutted heads produced later than normal, and those on plants standing alone often remain partially inclosed by the sheath of the upper leaf. When this is the case the smut is almost certain to be attacked by the smut-eating beetles. Except when diseased, the smut spores always readily escape.

Such heads are not common. Almost all the heads are entirely smutted — that is, all the spikelets are attacked. Usually, also, all of the plants in a hill are attacked. This shows that the infection proceeds from the seed. The same is still further shown by the fact that although the tip of a smutted head is sometimes sound, the base is never so — proving that the infection proceeds from below upward.

The table on page 219 shows the very small per cent. of sound plants appearing in twenty-eight smutted hills growing in the field when count 13 was made (see p. 224).

No. of stalks in hill.	No. smutted.	No. healthy.
1	1	..
1	1	..
1	1	..
1	1	..
1	1	..
1	1	..
1	1	..
2	2	..
2	2	..
2	2	..
2	2	..
2	2	..
3	3	..
3	3	..
3	3	..
3	3	..
3	3	..
3	3	..
3	3	..
4	3	1
4	4	..
4	4	..
4	4	..
4	4	..
4	4	..
4	4	..
5	5	..
5	5	..
76	75	1

DIFFERENT VARIETIES ATTACKED

Usually, when grown side by side, seed of different varieties shows a different amount of smut. J. C. Arthur, in 1884,[1] gave the results of counts of oats grown on the farm of the New York Agricultural Experiment Station, at Geneva, N. Y., and found American Triumph, of 1,237 heads counted, had 10 per cent. smutted; Board of Trade, of 2,352 heads counted, had 8.5 per cent. smutted; New Australia, of 7,623 heads counted, had 9.86 per cent. smutted. Dr. Sturtevant, in 1885: says: " *Smut* was also quite prevalent, although some varieties were not affected though growing side by side with varieties badly infected The black oats were absolutely free from smut, while growing beside them on one side was the American Triumph, of which plants 10 per cent. were smutty, while on the other side grew the Board of Trade, even smuttier than the American Triumph. The two varieties most affected by smut were White Australian and Board of Trade, the former containing nearly twice as many smutty heads as any other, with the exception of Board of Trade. Those not at all affected were: Black Champion,

[1]Third Ann. Rep. N. Y. Ag. Exp. Sta. for 1884. Albany, 1885, p. 382.
[2]Bull. N. Y. Ag. Exp. Sta., quoted from Bessey, Bull. from the Iowa Ag. Coll. Dept. of Botany, 1884, p. 126.

Black Tartarian, Pringle's Excelsior Hulless, Pringle's Hybridized Hulless, Mammoth Russian, Mold's Ennobled, and Race Horse."

Arthur says[1] " the thirty varieties of oats grown in the experimental plats were very unevenly affected by smut, some having almost none, the reason for which was not apparent."

C. S. Plumb, in 1885: in an experiment to determine what influence the character of the seed had upon the progeny," planted five rows of White Australian and five of Race Horse. "The first-mentioned variety, in our 1884 test smutted very badly, while the Race Horse did not smut at all." They were synonyms, but seed was obtained from different sources. Of the 3,225 heads of White Australian produced, 294, or 9.11 per cent., were smutty. Of the 3,152 heads of Race Horse produced, 58, or 1.20 per cent., were smutty.

J. L. Jensen, in 1887, reports the following result to show the proportion of smut in twenty-three varieties of oats during three consecutive years, on the experimental farm of the Royal Agricultural School, near Copenhagen, Denmark:

SMUT IN TWENTY-THREE VARIETIES OF OATS, 1885-1887, COPENHAGEN, DENMARK,[3]

No.	NAMES OF VARIETIES.	PER CENT. OF SMUTTED HEADS.		
		1885.	1886.	1887.
1	Canada	28	30	22+
2	Berlie	1	6	9
3	White Steir Mark	1	7	12
4	Potato Oats	1	3	22
5	Oats from Scone	0	2	6
6	Swedish Cub	1	7	7
7	Forslev Oats	0	7	13
8	*Avena strigosa*	0	0	0
9	Early from Belgium	1	8	14
10	Fionie	0	6	19
11	White Three-Grained	0	0.2	4
12	Great White Tartarian	10	10	37
13	Black Steier Mark	0	9	9
14	Black Swedish	4	5	10
15	Black Tartarian	10	15	20
16	Oats from Grenaa	1	5	14
17	Early Angus	8	7	28
18	Late Angus	2	3	6
19	New Zealand	22	17	21
20	China	5	6	3
21	Blainsly	25	45	75
22	Provsti	1	3	8
23	Experimental Farm	0	4	10
	Average of 22 true oats (excluding No. 8)	5.5	9.32	16.77

[1] Arthur, I.e., p 383.
[2] Fourth Ann. Rep. N. Y. Ag. Exp. Sta, for 1885. Albany, 1886, P.128.
[3] Nye Undersögelser og Forsög over Kornsorternes Brand (Förste Meddelelse). Saertryk af Markfrökontorets Aarsberetning for 1887. S. 10; Propagation and Prevention of Smut in Oats and Barley, p. 6.

E. Bartholomew, of Rooks county, Kansas, says[1]: "The Earlier and colored varieties seemed to suffer more than the white varieties. The common white oats, and the Welcome oats (also white), seemed to suffer very little from this disease, while the Red Texas and black winter oats were affected to quite an extent."

From the experiments of Plumb and Jensen, it would seem almost conclusive that the freedom from smut of any variety is due much to the source of the seed, and that if varieties free from smut are planted adjacent to affected varieties, they will gradually become infected.

AMOUNT OF DAMAGE.

The percentage of the oat heads destroyed by the smut is, in most cases, much larger than is generally supposed, even by observant farmers. Sometimes, however, when the field is very much smutted, the large amount seen perhaps leads to an over-estimate of the amount of damage done. Yet, in fact, the amount of damage has not been realized until very recently, when careful counts have been made. As noted, J. C. Arthur in 1884 found, at Geneva, N. Y., the American Triumph 10 per cent., Board of Trade 8.5 per cent., and New Australia 9.86 per cent. smutted. He says[2]: "The appearances of smut as one passed through the field was no greater than is usually to be seen in any part of the country — at least, east of the Western plains, and the result of the count, showing a total loss of nine and one-half per cent. of smutted grain, is as much a surprise to the writer as it will doubtless be to others. The lighter oats smutted the worse. The smut appears also to bear a direct ratio to the dryness of the soil."

C. S. Plumb in 1886[3] reports the following experiment (in fuller form) with White Russian oats, grown in Geneva, N. Y.:

	Total panicles.	Smutted panicles.	Per cent. of smut.
Plat I: On dry knoll, plants of average height	2905	175	5.98
" II: Situation fairly moist and level, plants taller than the average	3108	299	7.82
" III: Situation fairly moist and level, plants of average height	2635	207	7.71
" IV: Situation in dry, hard part of field, plants smaller and shorter than the average	2253	234	10.28
Total	10901	915	8.4

Plumb says of it: "This field would have appeared very free from smut to au ordinary observer, yet the figures indicate considerable loss. Dryness of soil seems to have no special bearing in the matter of percentage of smut as both the smallest and greatest amounts occurred in parts of the field more elevated and drier than the others."

[1] In letter, July 23, 1889.
[2] Third Ann. Rep. N. Y. Ag. Exp. Sta., p. 382.
[3] C. S. Plumb. Smut in Oats in Fifth Ann. Rep. N. Y. Ag. Exp. Sta. for 1886. Elmira, N. Y., 1887, p., 125, el seg.

Another experiment is reported[1] with very smutty oats from Seneca, N. Y. The variety was American Triumph:

	Total panicles.	Smutted panicles.	Per cent. of smut.
Plat A: Retentive clay loam, plants medium height......	3186	907	28.47
" B: Soil hard, clayey loam, somewhat stony on knoll, plants below medium size....................	296	91	30.74
" C: Clayey loam, plants below medium size	362	43	11.88
" D: Average soil, clayey loam, good; plants of average height...............................	678	142	20.94
Total.....................	4522	1183	26.16

The average of the four plats, without regard to the number of plants counted, is given by Plumb as 23.21 per cent. In obtaining this the per cents. in the different rows also were averaged without regard to the number of plants in the row. This is probably the most accurate method, since there was a great variation in the number of plants counted in the different plats.

Plumb, in the same place, gives the following averages of the plats:

	Average No. panicles per plat.	Average No. smutty panicles per plat.	Average per cent. of smut per plat.
Plat A..............................	637.2	181.4	28.81
" B....................................	59.2	18.2	30.86
" C....................................	72.4	8.6	11.68
" D....................................	135.6	28.4	21.49
Average............................	226.1	59.15	23.21

He says: " The loss in the above four plats is very large, as can easily be seen by reference to the figures, even when considering Plat C, where the loss is least. Under such circumstances, where disease seems carried on from generation to generation, to the detriment of both crop and man, a vigorous attempt should be made to secure a practical remedy against such a trouble."

[1] Plumb. Smut in Oats. l. c., p. 128. Per cent. recalculated.

During 1888 and 1889 careful counts were made in the fields of oats about Manhattan, Kansas, with the following results:

COUNT 1.—Grown on a rich, rather low bottom; growth very good; June 21, 1888.

No. of heads counted....	No. smutted heads......	Per cent. of smutted heads...	Remarks.
100	16	16	Plants tall.
100	23	23	Plants tall.
100	13	13	Plants tall.
100	15	15	Plants tall.
100	13	13	Plants tall.
100	16	16	Plants short.
100	16	16	Plants short.
100	12	12	Plants short.
100	9	9	Plants short.
100	18	18	Plants short.
100	33	33	Plts. small, crowded.
1100	183	16.6	

COUNT 2.—Grown on second bench land which sloped gently; growth medium; June 21, 1888.

No. of heads counted....	No. smutted heads........	Per cent. of smutted heads........	Remarks.
100	16	16	Plants med. height.
100	17	17	Plants med. height.
100	13	13	Plants med. height.
300	46	15.3	

COUNT 3.—Grown on level creek bottom land, rich; growth good; June 21, 1888.

No. of heads counted	No. smutted heads	Per cent. of smutted heads	Remarks
300	26	8.66	Plants counted in as widely different parts of the field as possible.
300	17	5.66	
300	30	10	
100	7	7	
1000	80	8	

COUNT 4.—Grown on second bench land; growth moderate; June 22, 1888.

No. of heads counted	No. smutted heads	Per cent. of smutted heads	Remarks
100	14	14	
100	15	15	
100	25	25	
100	14	14	
100	10	10	
100	20	20	Plts. short, crowded.
100	19	19	
100	14	14	
100	26	26	
100	39	39	
100	6	6	
100	18	18	
1200	220	18.3	

COUNT 5.—Grown on rather poor upland; growth poor; July, 1888.

No. of heads counted	No. smutted heads	Per cent. of smutted heads	Remarks
53	3	5.66	One corner of this field was used in an inoculation experiment.
63	12	19.05	
162	18	11.11	
160	30	18.75	
60	4	6.66	
53	6	11.32	
96	7	7.29	
80	7	8.75	
66	13	19.69	
793	100	12.6	

COUNT 6.—Rich sandy river bottom; growth July 1, 1889.

No. of heads counted	No. smutted heads	Per cent. of smutted heads	Remarks
100	9	9	
100	5	5	
100	26	26	Near margin of field
100	6	6	
100	11	11	
100	9	9	
100	7	7	
100	2	2	
100	7	7	
100	7	7	
1000	89	8.9	

SMUT IN OATS ABOUT MANHATTAN, KANSAS—CONTINUED.

COUNT 7.—Grown same place as Count 2 of 1888; July 2, 1889.

No. of heads counted....	No. smutted heads........	Per cent. of heads smutted....	Remarks.
100	7	7	Plants counted in as widely different parts of the field as possible.
100	15	15	
100	9	9	
100	15	15	
100	6	6	
100	12	12	
100	6	6	
100	16	16	
100	14	14	
100	8	8	
1000	108	10.8	

COUNT 8.—Grown on creek bottom, same as in Count 3; July 2, 1889.

No. of heads counted....	No. smutted heads........	Per cent. of heads smutted....	Remarks.
100	3	3	
100	13	13	
100	9	9	
100	7	7	
100	8	8	
500	40	8	

COUNT 9.—Grown on same land as in Counts 3 and 8.

No. of heads counted....	No. smutted heads........	Per cent. of heads smutted....	Remarks.
106	5	4.71	
76	5	6.58	
125	3	2.40	
160	7	4.37	
163	11	6.74	
630	31	4.9	

COUNT 10.—Grown on same land as in Counts 9 and 10.

No. of heads counted....	No. smutted heads........	Per cent. of heads smutted....	Remarks.
140	8	5.71	
143	6	4.19	
165	7	4.24	
207	8	3.86	
156	16	10.25	
811	45	5.5	

COUNT 11.—Grown on same land as in Counts 8, 9, and 10.

No. of heads counted....	No. smutted heads........	Per cent. of heads smutted....	Remarks.
157	9	5.73	
173	14	8.09	
141	13	9.22	
163	13	7.93	
136	16	11.76	
770	65	8.4	

COUNT 12.—Second-bench land; growth good.

No. of heads counted....	No. smutted heads........	Per cent. of heads smutted....	Remarks.
100	7	7	
100	9	9	
100	10	10	
100	5	5	
400	31	8.8	

SMUT IN OATS ABOUT MANHATTAN, KANSAS–CONTINUED.

COUNT 13.—Rich upland; growth good; July 19, 1889.

No. of heads counted....	No. smutted heads.......	Per cent. of smutted heads.......	Remarks.
100	8	8	Whole field very smutty and unusually late.
100	10	10	
100	10	10	
100	15	15	
100	16	16	
100	17	17	
100	17	17	
100	17	17	
100	18	18	
100	26	26	
1000	154	15.4	

The following table gives in more condensed form the result of the above recorded counts:

Count.	Number of stalks counted, and character of land.	No. of smutted heads.	Per cent. of whole.
1.......	1100 bottom land..............................	183	16.6
2.......	300 second bench............................	46	15.3
3.......	1000 creek bottom............................	80	8.0
4.......	1200 second bench............................	220	18.3
5.......	793 upland..................................	100	12.6
6......	1000 sandy bottom............................	89	8.9
7.......	1000 second bench............................	108	10.8
8.......	500 creek bottom............................	40	8.0
9.......	630 creek bottom............................	31	4.9
10.......	811 creek bottom............................	45	5.5
11.......	770 creek bottom............................	65	8.4
12.......	400 second bench............................	31	8.8
13.......	1000 second bench............................	154	15.4
Total..	10504	1192	11.34+

Aside from these regular counts, made in the fields of oats about Manhattan, many more were made in connection with the experiments in preventing oat smut. Of Red Winter oats grown on untreated soil, 30,000 heads were counted, of which 3,010, or 10.03 per cent., were smutted. Of Badger Queen, out of 1,377 heads, 125, or 9.07 per cent., were smutted. Of black oats, 2,521 heads were produced, of which 470, or 18.64 per cent., were smutted.

The table from Jensen, given on page 220, shows a small percentage for some of the varieties, but a very large per cent. for others.

Jensen states that in Denmark there was an average of 8 per cent. in 1888. From these facts it will be seen, that in nearly every case where fields, or large plats of oats, were counted, a loss of over 8 per cent. was found. It is

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probable that the per cent. given for the vicinity of Manhattan for 1888 and 1889 (11 1/3) is a little too large, but it is safe to say that at least 10 per cent. –that is, ONE-TENTH OF THE CROP—is anually destroyed throughout the State.

The value of the oat crop raised in Kansas in 1888 was $12,440,908.35.[1] If 10 per cent. was destroyed by smut, this sum would represent but 90 per cent. of what the full or unsmutted crop should have been. In other words, there was a loss of $1,382,328.31 due to the smut alone. In 1889, the value of the crop was only $7,654,812.83,[2] and the loss $850,534.76. It should be remembered that this loss is almost directly from the *profit* of the crop, since it requires as much space and as much nourishment from the soil to produce a smutted head as a sound one. It costs as much for every operation in growing a smutted crop as a clean one. And finally, it may be said that if this smutted seed is used for the production of another crop, a loss of the same gigantic proportion is likely to follow; for it is a well-established fact that seed from smutted fields will produce a smutted crop, whereas clean seed from a clean field will produce a clean crop.

GEOGRAPHICAL DISTRIBUTION.

Ustilago Avenæ is found all over the world, wherever oats are grown. Apparently the disease is nearly as abundant in one locality as in another, and at any rate its injuries are found to be large wherever carefully investigated.

BOTANIC AND MICROSCOPIC CHARACTERS OF THE SMUT.

Color, shape, and size.

The spores of this species are entirely free from each other, and form a dusty mass of a dark dusky-brownish color, lacking the olivaceous tinge found in the spore mass of *Ustilago Tritici* and *Ustilago nuda.*

In shape the spores are mostly oval, but often only slightly so. Sometimes they are subglobose, and sometimes elliptical, as, for instance, fig. 43 on Plate V. Quite often the spores are more or less angular, and more often than in any other of the loose smuts the spores are irregular, or deformed. Common distortions are shown on Plate V, figs. 51, 53, and 55.

In size of spores, *Ustilago Avenæ* is the most variable of all the loose smuts. There are 5-11x4½-7µ; mostly 6–9x5-7µ, often 7–9x6–7µ. It thus seems to have the largest spores of all, but really the spores of *Ustilago Hordei* average larger, though they do not reach such an extreme length as 11µ. This may be seen by comparing the spores shown in Plate V with those in Plate VII.

Character of wall.

The wall is (as in all loose smuts) composed of two layers: the outer, deeply colored, called the *epispore*, and an inner, pallid one, called the *endospore.* These two layers can sometimes be very plainly distinguished, as in fig. 14 and 15, Plate IV. In other spores the wall, without the use of

[1] Sixth Bienn Rep. St. Bd. Agr., Kansas, 1887-8, part II, p. 19.
[2] St. Bd. Agr., Kansas, Quarterly Rep., Dec. 31, 1S89, p. 12.

special reägents, seems single, as in figs. 5, 8, 10, and 12, Plate IV; 49 and 57, Plate V. Sometimes it is very thin, again quite thick (¾-1½μ). Fischer von Waldheim[1] claims that the spores have a cuticular covering outside of the epispore, and indeed a faint line can be traced; but it is extremely difficult to see, and is not shown in the figures.

The spores are lighter on one side.

A curious fact is, that the spores of all the loose smuts are lighter colored on one side, and that they invariably germinate from this light-colored side. Previous writers do not seem to have noticed this fact, though it may very easily be observed. The light-colored portion of the spore may cover as much as one-half of the whole surface, and, again, constitute not more than one-quarter of it. Very rarely there are two opposite light areas, as in fig. 6, Plate V. In optical sections, the wall can sometimes be seen only on the dark-colored side of the spore, as in fig. 47, Plate V; and in other instances, the two layers can be seen on the dark side of the spore, while only one is visible on the light side (figs. 43 and 60, Plate V).

The epispore is spiny, or warty.

The epispore of oat smut is covered with minute elevations, or warts. They can be seen best in profile, but are also seen in optical section in many figures in Plate IV. The spines or warts are plainly seen on top, though they cannot always be recognized on the side. F. von Waldheim claims [2] that these are simply portions of the epispore less rich in water, and that they do not project at all. This, however, is sometimes not the case, as when the spines were seen plainly to project on the edge (see figs. 4, 6, and 7, Plate IV) or along the crack of a spore whose wall is being dissolved (see fig. 7, Plate V). A more probable view is, that the spines really do project somewhat, but are included more or less by the cuticle. The spines show plainest on the smooth side of the spore, since they contrast more strongly with the light background. There is, however, a small area on the light-colored side free from spines, most likely where the germ tube arises.

The contents of the spore.

The contents of the spore are homogeneous, and only very rarely granular. The spores sometimes swell up somewhat in nutrient solution, and become lighter colored. (See figs. 1 and 14, Plate V.)

Action of reagents.

The spores are variously acted upon by reagents. Potassium hydrate scarcely changes their color, but causes the endospore to swell up and appear as a thick ring. The markings can be seen plainly in profile, but scarcely at all on the edge. Glycerine obscures the markings. Acetic acid causes the epispore to swell or renders it distinctly visible without swelling, and shows markings plainly in profile. Hydrochloric acid has little effect.

[1] Fischer von Waldheim. Contr, to Biol. and Hist. of Dev. of Ustilag., in Trans. N. Y. St. Ag. Soc. for 1870, Albany, 1871, p. 323; and Sur la structure des spores dea Ustilaginées, in Bull. de la Soc. Imp. des Natur. de Moscou. 1867, I, p. 245.

[2] F. v. Waldheim. Contr., l. c., p. 223; Sur la structure, l. c., p. 243.

Nitric acid discolors the spore, and causes a general swelling and final disorganization of the spore. Schultze's macerating solution (nitric acid and potassium chlorate) rapidly destroyed the wall, attacking the light-colored side first. The contents resist decomposition longest. Chromic acid acts much the same if strong; it rapidly eats away the light side of the wall, leaving a resistant darker colored segment; at first it shows the cuticle faintly. Sulphuric acid is good to show the markings and the separation between the epospore and endospore. Chloriodide of zinc causes, after some time, the contents of the spores to assume a reddish color. It does not stain the spores readily.

GERMINATION IN WATER.

Historical.

The germination of the loose smut was first observed by Prevost,[1] who saw the spores send out a single, or very rarely a double or triple, promycelium; and saw them produce when floating on the surface of the water aigrelles, or a series of globules.

Tulasne[2] next studied the germination of the *Ust. Carbo,* and saw in old cultures that the segments of the promycelia swell at the ends, and become rounded and deeply constricted at the septa. Kühn[3] in 1868 published a full account with figures of the germination. He saw the formation of sporidia, their budding, and described the "knee-joint" fusions, and the formation of germ threads or simple germ tubes from the old segments. Fischer von Waldheim[4] observed the germination of *Ustilago Carbo* on barley and oats. He describes sporidia, but figures them only in barley smut. Wolff[5] describes quite fully the germination of *Ustilago Carbo,* presumably, in part at least, on oats. He noticed the formation of conidia, the sending out of germ threads, and the emptying of some segments, and a fusion of the segments of the same or of different promycelia by means of germ tubes.

ACCOUNT OF GERMINATIONS MADE.

In all germinations of loose smuts the spores were placed in the liquid used on slides having a central depression. These slides were then put in a perfectly dark damp chamber in an incubator.

After being in water a few hours the spores send out from the light side a small tube called the promycelium. Specimens collected at Manhattan June 2, 1889, had at the end of six hours, at 23° C., often attained a length of 16-18μ. The promycelia were always continuous, and were rather slender. Specimens collected in 1888 did not germinate so quickly. After remaining 24–27 hours the promycelium attained its full length, or nearly so,

[1] Prevost. Memoire sur la cause immediate de la carie ou charbon des blés, et de plusieurs autres maladies des plantes, et sur les preservatifs de la carie. Paris 1807, p. 29, §86.

[2] R. et. Ch. Tulasne. Memoire sur les Ustilaginées comp. aux Uredinees in Ann. sci. nat., 3e serie, t. VII, 1847, p. 33, Pl. 3 f, 10. L. R. Tulasne, Second mém. sur les Ured. et les Ust. in Ann. sci, nat. 4e serie t. II, 1854, pp. 157-158.

[3] Kühn. Krankh. der Kulturgew. 2 Aufl. 1859, S. 66-68. Taf. III, Fig. 11-21.

[4] F. v. Waldheim. Countr. to Biol., l. c., p.333 Plate V, figs. 7-15.

[5] Wolff. Der Brand des Getreides, seine Ursachen and seine Verhütung. Halle, 1874, S. 6-9. Taf. I. A., Fig. 1-20.

and had one to three septa. The promycelia were now 16–50x2-4μ, mostly 19–36x2½–3μ Quite often the segments gave rise to little protrusions on opposite sides of a septum which uniting form a knee-joint fusion. (See Plate IV, figs. 7 and 13.) More rarely at the septa sporidia were produced. No figure of mature conidia is shown in Plate IV, but in Plate V, fig. 19, is shown a form almost exactly like those found in water. These sporidia are mostly narrowly elliptical in shape, more or less pointed at the attached end. They fall off almost as soon as produced, and sometimes bud into secondary sporidia like figs. 12, 36, 9, and 42, Plate V. These sporidia are scarce, however. They are much more abundant in some cultures than in others. Already by 24 hours some of the segments become empty, especially toward the base (see Plate IV, figs. 5 and 13); also many of the promycelia are detached. After this but slight changes occur. More and more of the segments become empty, and those remaining filled swell somewhat (becoming 4-5μ. diam.). No more conidia are produced. Fusions now are somewhat common—often slender tubes arise from the spore just at the base of the promycelium and fuse with one of the upper segments, much as represented in Plate VII, figs. 43 and 45, (Ust. *Hordei.)* These slender tubes may fuse with other promycelia, or with free segments. They also arise from other parts of the promycelia, as from the spore at the base. In general, however, fusion are rare. As the segments swell their ends enlarge most and become rounded in shape, causing a deep constriction at the septum. The knee-joint fusions also open more or less—they have before this become bent in most cases. This is essentially the condition of a good culture after 48 hours. By 4 or 5 days little further changes have occurred, except that occasionally a branch or a knee-joint grows out into a long germ-thread. These are slender tubes filled with protoplasm at the tip, and with an empty many-septate basal portion. These have a continuous tip, and the empty base is shrunken. They are exactly like those shown on Plate V, figs. 28 and 29. These finally cease growing, and then all activity ceases in the culture. Sometimes the promycelia are branched, especially from near the base. (See Plate IV, figs. 1, 5, and 13.) The promycelium emerges from the spore through a small pore, which is plainly shown in optical section in Plate IV, figs. 6, 7, 9, 11, 14, and 15. Rarely in older cultures there is a slight tear in the cell-wall down from this pore.

The germination of *Ustilago Avenæ* in water is peculiar because by reason of the rather short promycelia, very commonly detached, producing sporidia rather sparingly, and by the slightly swollen segments; also for the germ threads which grow from the promycelia in old cultures.

GERMINATION IN NUTRIENT SOLUTION.

Hallier[1] seems to have been the first to employ nutrient solutions in the study of the germinations of *Ustilago Carbo* (species not given, but probably

[1] Phytopathologie Leipzig, 1868, S. 250, 251. Taf. III, Fig. 1, 2, 4, 5.

oat smut or covered smut of barley). He used various substances, such as starch, paste, white of egg, milk, sugar, water, "and so forth." He observed and figured the abundant production of conidia and their germination into tubes, and showed the thick distorted promycelia found in rich nitrogenous. substance. He also showed the fuller expansion of the promycelium into dumb-bell shaped segments. He, however, describes the change of the promycelia into various moulds, no doubt, through impure cultures. Brefeld claims the credit for the discovery, or at any rate, application of nutrient solution for prolonged cultures of fungi.[1] At any rate, though antedated in its first application by Hallier, he was the first to successfully apply nutrient solutions to long-continued, pure cultures of smuts. He describes in 1883, in Hefenpilze I, very fully the germination and growth of oat smut in nutrient solution. He uses mostly for the purpose a decoction of manure carefully sterilized. He emphasizes especially the fact that the culture can be carried on for long periods of time through countless generations by transferring the budding sporidia to fresh nutrient solutions from time to time. Frank[2] in commenting on Brefeld's lecture, states that in his researches it was found that sugar or other carbohydrates is the great stimulus. Especially interesting was the fact, that the addition of a minimum or grape-sugar solution to a decoction of manure immediately greatly accelerated the development of the fungus into yeast-like sporidia[3].

The germination of smut spores, and of many other fungi is greatly accelerated by placing them in a solution containing nitrogenous matter, or better, a mixture of sugar and nitrogenous substances. Finding a simple decoction of manure, nutrient gelatine or solution of pepetone unsatisfactory from the difficulty in preventing the growth of contaminating bacteria and moulds, and finding also a simple sugar solution, though greatly stimulating the growth, to lack nourishing power, a combination of the two was used. The advantage of a solution of fixed and known chemical composition being very great, it was decided to avoid all decoctions, which would almost certainly vary in strength and composition. The following modification of the Cohn nutrient solution was used in nearly all the cultures, both oat smut and the other loose smuts.

Distilled water	42.385	grammes.
Cane sugar	7.000	"
Ammonium tartarate	.250	"
Potassium phosphate	.125	"
Magnesium sulphate.	.125	"
Calcium phosphate.	.125	"
	50.000	"

[1] Brefeld. Neue Unters, über Brandp. u. Brandt., II Nach. d. Klub d. Landw. z. Berlin, No. 220 S. 1.578, foot-note.

[2] Neue Unters, II. Diskussion. Nachr. d. El. Nr. 222, S. 160I.

[3] "Bei meinen desbezüglichen Versuche ergab sich, class zucker dies *stimudans* ist oder andere Koblenbydrate, was sich besonders interessant bei Mistdekokten zeigte, wo ein Minimum von hinzugesetzter chemisch-reiner Traubenzuckerlösung algbald die Entwicklung der Pilze in Form der hefenartigen Sprossung mächtig beförderte."

This solution had so much sugar that the growth of micro-organisms was largely prevented. This same large amount of sugar greatly stimulated the growth of the smuts. In the text, and in the explanation of the plates, this solution is called modified Cohn solution, or mod. Cohn sol. The cultures in nutrient solution were conducted in exactly the same manner as those in water, viz., in slides having concave centers, placed in a damp chamber in an incubator.

ACCOUNT OF THE GERMINATION IN MODIFIED COHN SOLUTION.

The spores soon germinated, and at first the promycelia appeared very much like those produced in water cultures. Soon, however, they became somewhat different. The promycelia became septate sooner than in water cultures; and soon the sporidia started to sprout out from the segments at the septa. By 24 hours the promycelia had attained a considerable length, in fact had attained nearly their full growth. At this stage they were 24-63x2½-4μ, mostly 25-55x2½-3½μ, curved, or more often, straight. Adjacent segments were very often connected by knee-joint fusions, and from many of the promycelia sporidia arose at the septa. (See Plate V, figs. 1, 3, 8, 9, 11, 12, 17, 21, 22, 25, etc.) These sporidia were somewhat larger than those obtained in water cultures, being especially wider. They were commonly about 9–11x2–3μ. They readily fall off from the promycelia and when freed, or rarely while yet attached, sprout out to form secondary sporidia. (See figs. 1, 2, 8, 9, 22, and 27.) Brefeld[1] says that in his experiments, "No promycelium was to be found without sporidia." In our cultures, however, some of the promycelia did not produce sporidia. This may be because the modified Cohn solution was less favorable for the growth of the smut than the manure solution used by Brefeld, or perhaps because of some difference in the germinative power of the smut spores used. Such differences in the germination of specimens from Canada and Kansas, used by us, were very slight, yet a much less amount of difference than that to be described under *Ustilago Hordei* would fully explain all discordance between our results and those obtained by Brefeld without assuming any marked difference in the nourishing power of the solutions used. It might be that Brefeld dealt with the form we have called var. *levis*, which was observed in every case to germinate with greater vigor than the ordinary form of the species. Prof. Brefeld describes the formation of conidia on the promycelia in the greatest profusion, and figures more conidia arising from a single promycelium than we have ever observed. However, conidia were often very abundant in our cultures, and since very many were floating free in the liquid, it was not possible to determine exactly how many had arisen from a single promycelium. Often the sporidia arising on opposite sides of a septum, crossed as shown in fig. 19; sometimes as many as four sporidia were seen sprouting from the two sides of a single septum. By 20 hours the pro-

[1] Brefeld. Hefenpilze, S. 58.

mycelia sometimes had empty cells, and in some instances the knee-joints had grown out into long tubes. Occasionally the promycelium was branched, especially from near the base. It should be stated that even by this time a considerable number of the promycelia were detached from the spore by breaking away at the base. These detached promycelia produced sporules, and behaved almost like those still attached.

The production of conidia and their budding continued till the solution began to be somewhat exhausted. Then the segments of the promycelium became slightly swollen. (Figs. 2, 4, 15, etc., Plate V.) The buckle-joints open curiously (figs. 37, 38), and the conidia become more rounded, and may sprout out into slender tubes (figs. 5, 13, 24, 32), and very often fuse by means of these. Aside from the conidia, fusions were almost wanting, excepting knee-joints. A great number of the segments of the promycelia now became empty, and the remaining ones rounded off slightly at the septa, and remained filled with granular protoplasm, or long, delicate branches ramified from the segments and bound the whole culture together. These branches are very often of the character of germ threads—that is, slender threads arising from a knee-joint fusion or from an ordinary segment. As they grow they empty the segment of its contents, which pass out to the tip of the thread, while its basal portion is left empty. As growth progresses, the protoplasm forms septa from time to time at its lower end. The tips of these germ threads are continuous, and 50-110x2½-3+½μ. The empty cell of the base nearest the tip has the same width; but when the protoplasm recedes out and this cell becomes second, it contracts so that the basal portion of such germ threads is only 1½–2½.μ in diameter.

Exactly similar germ threads are sometimes produced from conidia like those shown in figs. 28 and 29, the only difference being that these tubes, arising from segments, are in every part stouter than those from conidia. Finally, the growth of the end of the germ tubes ceases, as the solution becomes more nearly exhausted, or when they have attained a length of as much as 200-500μ. The protoplasm contracts slightly from the tip, and the whole swells slightly. This process is the end of all growth. During the rapid growth of good smut spores the culture remains almost entirely pure, but as it gets old a constantly increasing number of bacteria and moulds invade it till they probably assist materially in the final decomposition of the promycelia. If at any early stage the sporidia were transferred to fresh nutrient solutions, they budded with increased vigor, and those so produced grew and themselves budded. Brefeld studied especially this point, and cultivated the sporidia through many generations. He also found that if the sprouting promycelia were transferred to new nutrient solutions, they continued to form sporidia. "Only the want of nutrient material limits the uninterrupted formation of conidia."[1] In 1888 he re-

[1]Brefeld. Hefenpilze, S. 61.

ports the continuous cultivation of these yeast-like spores for 10 months through more than 1,000 generations[1]

INFECTION OF THE HOST PLANT.

HISTORICAL.

Early writers supposed the spores or the granules contained in them to enter the plant, since it was very soon discovered that it was the powdery mass of spores that carried the infection. After the discovery of the germination of the spores, it was supposed that the promycelium entered the plants. DeBary[2] inclined to the opinion that the smut entered the plant through the stomata or breathing pores. Kühn[3] carefully studied the infection of wheat by stinking smut, and found that the host plant was entered through the root joint[4] by the germ tubes of the parasites. F. v. Waldheim was unable to infect either oats or barley with the smut. Hoffman[5], experimenting only with barley, found the parasite entered the first root sheath. Wolff, in 1874[4a], found the smuts to enter wheat, oats and barley through the first, mostly very lightly colored, whitish or yellowish green, glossy sheath leaf which appears first, and is of cylindrical, slightly pointed form. Brefeld has carefully investigated the subject, recently, and finds that the infection of the host plant is easily accomplished by sprouting the plants, washing them, then spraying with a solution containing sporidia still budding, and then leaving the plant several days in a damp atmosphere. The infection was accomplished by means of the germ threads grown out from the sporidia, and if these threads had already been formed before the inoculation was attempted, it failed.

In the following experiments,[6] he used cultures in his nutrient solution containing the budding sporidia of oat smut.

I. The oats were in the first stages of germination. The little roots had already appeared. The plants were sprayed with the fluid containing the sporidia, and left in a damp atmosphere 10 days, at a temperature of 10° C., then sowed. Result: In ten experiments, 17–20 per cent. smutted.

II. Young germinated plants were covered with earth, except the tips of the germinated plants, which alone were sprayed with the fluid containing the sporidia, Result: In seven experiments, not more than 5 per cent. smutted.

III. Same as I, except that the germinated plants were further advanced, having the first leaf ¼-¾ in. long (½–2 cm.), but not yet broken through. Result: In eight trials, 2 per cent. smutted.

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1 Neue Unters. II. Nachr. Nr, 220, S. 1582.
2 DeBary. Die Brandpilze, S. 122.
3 Kühn. Die Krankh. der Kulturgewächse. S. 48.
4 Place of juncture of primary root with stem.
4a Wolff. Der Brand des Getreidesseine Ursachen und seine Verhütung Halle, 1874, S. 18-24, Taf. IV, fig. 1.
5 Hoffman, Ueber den Flugbrand, Sep. Abdr. aus Botanische Untersuchungen, Herausgeg. v. H. Karsten, S. 203, 204.
6 Brefeld. Neue Unters. IL Nachr. aus dem Kl. d, Landw. zu Berlin, Nr, 221, S. 1591.

IV. Same as in II, except that the plants whose tips were infected were ½-¾ in. long (½–2 cm.) Result: In three experiments, 1 per cent. smutted; in two experiments, none.

V. The germinated plants had the first leaf broken through. Result: In three trials, 1 per cent. smutted; in two others, none.

VI. Seed sown in infected earth before they had germinated. Result: In five trials 4-5 per cent. smutted.

VII. Ungerminated seed sown in an infected mixture of field soil and fresh horse dung. Result: In three trials 40–46 per cent. smutted; in three others, where the sowings had not been placed in a cool room, 27-30 per cent. smutted.

VIII. An experiment using sporidia which had been cultivated in nutrient solutions ten months, and after the exhaustion of the nutrient solution would no longer grow out into germ threads; otherwise as in I. Result: In one trial 1 per cent. smutted; in another, 2 per cent.; in two others, none.

IX. An experiment with large plants by infecting from without and in the growing point. Result: No smutted plants.

In all these nine experiments barley was treated in exactly the same way, but, being treated with oat smut instead of barley smut, remained entirely sound.

Brefeld finds the plants are free from infection after the growing leaves have pushed one centimeter through the sheath leaf. The temperature at which the trial was conducted was found to exert an important influence on the result. An experiment as in I, except at a temperature of 15° C., gave 3 per cent. smutted; when the temperature was higher, only 1–2 per cent. or none at all were smutted. He considers from VII, where the seed sown in infected manure and soil mixed gave such a large per cent. smutted, that the disease is very likely carried to the fields in the manure, and especially since the manure is often mixed with straw containing spores of the smut.

Jensen[1] denies that the spores in barn-yard manure are able to infect to any appreciable extent oats or barley. He says:[2] “While it may be quite true that barn-yard manure when applied to fields causes the crop to have more smut in it than is the case in unmanured fields, yet this arises from the manure increasing the fertility of the land, and not from the introduction of smut spores. Nor does it matter in what way the fertility is increased, whether by farm-yard or by artificial manure, or by the system of cropping, the result is the same.”

Jensen reports[2] the following observation in support of his claim: A

[1] Jensen. Nye Undersögelser og Forsög ever Kornsorternes Brand (Förste Meddelelse) Saetryk af Markfrökontorets Aarsberetning for 1887, S. 7; Smut *(Ustilago segetum)* in Oats and Barley, in Gard. Chron., vol. III, 3d series, No. 71, May 5, 1888, p. 555; Om Kornsorternes Brand (Anden Meddelels), S. 3; Prop. and Prev. of Smut, J. R. A. S. XXIV, s.s. II, p. 3; Le charbon des cëreales, p. 7; Ueber die Verhütung des Kornbrandes, S. 5.

[2] Jensen. Nye Undersög. og Forsög, S. 8; Prop. and Prev. of Smut, p. 4.

portion of a plot which had been manured for 25 years, and was every year seeded to barley, produced a considerably larger percentage of smutted ears than those other portions of the same plot where the crop was poorer from the soil either being unmanured or treated with artificial manure from which some essential part of plant-food was excluded. The manured portion was not, however, more smutted than the other plot, on which barley had been grown every fourth year for 25 years, and which had never during this time been manured with farm-yard manure, though a good crop of barley was produced, owing to the good system of cropping employed.

When manured by a compound artificial manure, the comparison was as follows:

	1885.	1886.
Barn-yard-manure plot.	42 smutted heads.	1.2 per cent, smutted.
Artificial-manure plot . .	35 " "	1.0 " "

The portion manured with farm-yard manure was a little more luxuriant.

Our experiments made in 1888 and 1889 with oats at Manhattan, showed in the manured portion a very much more vigorous growth but no increased amount of smut, even when smut had been purposely mixed in *considerable quantity with the manure when it was applied.*

Plumb, in 1885, planted oats, and with each grain of some rows placed one or more grains of smutted oats (variety Race Horse).

The following shows the result:[1]

Row 1: One grain + one grain of smut . . . . . .total panicles... 632	Smutted . . . 13	Per cent. of smut.. 2.05
Row2: " + two grains of smut.. " ...644	" ...17	" " ...2.63
Row3: " + four grains of smut... " ...554	" ...16	" " ...2.88

Jensen[2] took oats from a field where more than 40 per cent. was smutted, and washed a quantity with water to which was added fine sand. Each grain was then found on examination to have on an average 50 spores adhering to it. Portion A was thus planted. B was planted without any preparation, and on an average 8,000 spores adhered to it. C was dusted with smut, and about 40,000 spores adhered to each grain. The germinative power of the spores was tested, and it was found that each grain in A had 25 living spores on it, in B 4,000, and in C 12,000. The result was as follows:

A 25	living spores on each grain produced	29 per cent. smutted ears.
B 4000	" " "	37 " "
C 12000	" " "	36 " "

Jensen[3] has shown that the disease is produced in the crop by spores inside of the husks, and if the husks be removed the grain can be infected by simply dusting it with spores. He gives the following experiments to prove this:

1. Husks removed, spores dusted on the bare kernel . .. . . gave	33 ears	of which 4	were smutted
2. Husks removed, no spores dusted on the bare kernel . . . . . "	53 "	" 0	"
3. Husks removed, spores dusted on the outside . . . . . . "	50 "	" 0	"
4. Husks not removed, spores not dusted on the outside .. . . "	62 "	" 0	"

[1] Fourth Ann. Rep. N. Y. Ag. Exp. Sta. 1884, p. 129.
[2] Jensen. Nye Undersög. og Forsög., S. 9; Prop. and Prev. of Smut in Oats and Barley, p. 5.
[3] Jensen, Prop. and Prev. of Smut in Oats and Barley, p. 8.

The spores can, however, be carried to the grain without removing the husk if the seed is immersed in water in which spores are suspended. Jensen gave the following trial of this:

Oats dipped in spore-charged water produced... 29 per cent. smutted ears.
Oats dusted with dry spores produced . . . . 0 smutted ears.

In an experiment of ours in 1889 (plot 34; seep. 256), the untreated seed was wetted, then rolled in smut. This seemed to increase the amount of smut appreciably. The plot had, out of 3,000 heads counted, 432 heads or 14.4 per cent. smutted, while the nearest untreated plot had only 8.06 per cent. smutted.

Jensen, in Gardeners' Chronicle for April 5,1888, suggests that the infection of the plant is brought about by spores inside the husks, which lodged there when the crop was in blossom. In an experiment of ours in June, 1888, a square rod of oats just in blossom was dusted with smut spores in considerable quantity on the 20th, 22d, 25th and 27th of the month. When ripe, it was harvested and kept separate. In the spring of 1889 it was planted, together with other plots, with seed from other parts of the same field. One of the artificially infected plots (23) was 6.8 per cent. smutted, and the other was 5.36 per cent., while the untreated plot had 6.4 per cent. of smut, midway between the two artificially smutted ones. Hoffman[1] also states that attempted infection at the time of flowering was without result. It is probable that he used barley in this test, but he does not state. However, the fact that immersing the seed five minutes in hot water effectually prevents smut, (which treatment of course has no effect on the power of the spores in soil or manure to infect the plant,) proves that the infection is brought about by spores adhering to the seed. It is probable that under very favorable circumstances spores carried to the field in manure might infect the plants grown there, but in view of the results from Jensen's, and from our own experiments, the chances are probably very small.

METHODS OF TREATMENT.[2]

HISTORICAL.

I. Superstitious practices used by the Ancients.

Pliny in his Nat. Hist., book XVIII, chapter 45, says:[3] "As for mildew, that greatest curse of all to corn, if branches of laurel are fixed in the ground it will pass away from the field into the leaves of the laurel." Pliny probably uses the word mildew *(robigo)* to include the rusts and smuts of grains, and perhaps also other diseases.

[1] Hoffman, Ueber den Flugbrand, S, 202 and 203.
[2] In the following account, the methods of treatment against all common smuts are given, since they have almost all been used against the oat smut. The earlier writers usually paid most attention to the stinking smut of wheat (Tillelia).
[3] Nat. Hist. of Pliny, translated by Bostock and Riley, London, MDCCCLVI, Vol. IV, p, 58.

II. *Methods of planting, cultivation, etc.*

(a) Change of seed, etc.

Of this, Tull, writing about 1730, says:[1] " . . . there are but two remedies proposed, and these are brining, and change of seed." Again:[2] "But of the two remedies against smuttiness a proper change of seed some think most certain." The change of seed seems always to have been a favorite remedy, and even as late as 1878 it was recommended in Austria by v. Ahasbahs.[3] Of course a change of seed is a very good preventive of smuts, provided of course that the seed comes from a locality free from smut. The measure is however only temporary, since the seed gradually becomes infested with smut from surrounding fields, or especially with stinking smut of what from the soil. It is also from an injudicious change of seed that the smut is often introduced into new localities or produced in greater abundance in the old.

(b) Avoidance of certain manures.

(1) Because of their direct effect on the host plant.

Fischer v. Waldheim says:[4] "In fine, therefore, it appears to me that we have every reason to affirm that in all probability it is the excessive supply of carbon in the supporting plant that more than anything else promotes the development and the epidemic diffusion of parasitic fungi. We are, therefore, compelled to admit that unfortunately . . . by cultivation . . . we frequently produce . . . conditions favorable to a luxuriant parasitic growth." He says: "We invariably found the specimens containing *Ustilago carbo* (black rust) in greatest abundance on the oats and barley plants that were best developed." Jensen also mentions[5] that the amount of smut in oats may be increased by in any way increasing the fertility of the land. We have not in our experiments noticed any such increase in the amount of smut in the manured plots, and in the counts made in the fields about Manhattan the highest per cent. of smut would often be shown where the plants were on high land, small and crowded.

(2) Because of carrying the spores of the smut or aiding their development.

Brefeld[6] has vigorously upheld the claim that oat smut as well as other smuts may be carried in the manure and enabled to multiply enormously in it by the formation of multitudes of yeast-like sporidia. He has obtained from his experiments (see p. 234) results seeming to support this view. He strongly recommends that the use of fresh manure on grain fields

[1] Jethro Tull. The Horse-Hoeing Husbandry, London, 1829, p. 222.
[2] Tull Horse-Hoeing Husbandry, p. 224.
[3] V. Ahasbahs. Beobactungen über den Weizenbrand und den Samen Wechsel, in Oesterrisches landw. Wochenbl.. 1879. S. 145. Rev. Just. Bot. Jahresbr.. 7 Jahrg. 1879. I. S. 545 (by Sorauer).
[4] F. v. Waldheim. Remarks on the Causes of the Occurrence of Parasitic Plants upon Cultivated Cereals, in Trans. N. Y. St.. Ag. Soc. for —, p.161.
[5] Jensen. Propagation and Prevention of Smut in Oats and Barley, p. 4.
[6] Brefeld. Hetenpilze and New Unters, 11.

be avoided. Jensen, however, strongly combats this view, and claims: "The spores of smut in farmyard manure, when applied to the field, will not to any appreciable extent infect oats and barley." In our attempts to infect oats, a considerable quantity of oat smut was applied with manure to the soil in July, 1888; oats were planted in the spring of 1889, but no considerable effect of the smut and manure could be observed. In fact, the per cent. of smut on such plots was actually less than on untreated plots. (See p. 256.)

(*c*) Hastening the growth of the seed.

From the fact that infection of the host plant takes place only when the plants are very small, it has long been held that anything which increases the vigor of the seed, or in any way secures a more rapid germination, aids in preventing the smut.

Brefeld, in his infection experiments, found that while the infection was very successful when carried out at 10°C. (50°F.), it was of scarcely any effect when the temperature was over 15°C. (59°F.) (See p. 234.) Now oats are usually planted when the ground is still cold, and we might reasonably expect that if planted later, when the ground was warm, a very rapid growth would result, and, conformably to Brefeld's experiments, infection fail. In 1889 this was indeed the case. In many oat-fields about Manhattan, seed falling to the ground at harvest-time (July) caused a volunteer crop to spring up. *In every case this second crop was absolutely free from smut.* Even when the first crop had been very badly smutted, and the volunteer crop very abundant, yet the result was the same— no smutted heads. The only exception was, that rarely new stalks arose from smutted hills, and these were uniformly smutted. The plants so raised are, however, very much attacked by rusts *(Uredo of Puccinia coronata* and of *Puccinia graminus).* It might be, however, that sufficient oats for seed might be raised from a late planting. Owing to the ease with which any oats may be disinfected by Jensen's hot-water treatment, it is probable that such late seeding would not be profitable.

Tull claimed[1] that with wheat a "crop planted very early is not so apt to be smutty."

III. *Treatment of seed before planting.*

A. MECHANICALLY.

Tessier says[2] wheat "passed a great number of times through a wire sieve produces fewer corrupted ears than if sown without any treatment." Sinclair says:[3] "It is said that passing seed wheat loosely through mill-stones, so as not to injure the grain, has been found to prevent smut." A vigorous fanning of the seed has also been recommended to prevent the smut.

[1] Tull. Horse-Hoeing Husbandry, p. 226.
[2] Tessier. Result of Experiments made at Rambouillet under the King's eye relative to the distemper of wheat called the smut. In Young's Annales of Agricultural, Vol. VI, 1786, p. 206.
[3] Sinclair. Code of Agriculture. Fifth Edition. London, 1832, App., p. 59, foot-note.

Though such treatment might in part prevent the smut of wheat, it would be wholly ineffectual when applied to oats, whose grain is protected by a husk, which also incloses the spores that bring about the infection of the young seedlings.

B. CHEMICALLY.

(a) Washing the seed with solutions of various substances.

(1) Brining.

Soaking in brine is undoubtedly the oldest seed treatment against smut. Tull says:[1] " Brining of wheat, to cure or prevent smuttiness (as I have been credibly informed) was accidentally discovered about seventy years ago [about 1660[2]], in the following manner, viz.: A ship-load of wheat was sunk at Bristol in autumn, and afterwards at ebbs all taken up after it had been soaked in sea-water; but it being unfit for making of bread, a farmer sowed some of it in a field, and when it was found to grow very well the whole cargo was bought at a low price by many farmers and all of it sown in different places. At the following harvest all the wheat in England happened to be smutty except the produce of this brined seed, and that was all clean from smuttiness. This accident has been sufficient to justify the practice of brining ever since, in all the adjacent parts, and in most places in England."

(2) Brining and liming.

This practice, a modification of simple brining, was undoubtedly the most common of all known in the eighteenth century, and was everywhere practiced. It is not very much discussed in the books and periodicals of the time, but this is without doubt because of it being the universal practice of farmers. Only new or strange remedies were mentioned. There are many forms of the treatment, but in all the grain was either simply wetted in a heap or immersed completely in the brine for some time, after which the grain is limed in order to dry it.

This treatment, like simple brining, largely prevents the smut, but does not completely prevent it, unless so strong as to injure the seed considerably.

(3) Liming.

Simple liming was much used before the discovery of the value of copper compounds, and was strongly recommended by Tessier[3]. The usual form was to make a solution of the fresh lime, and put the grain in this solution.

(4) Other solutions.

Young[4] experimented against wheat smut in 1786 to 1788, and used, besides brining, and brining and liming, simple liming, soaking in lye, in arsenic, in arsenic and salt, arsenic and lye, &c., in various ways. These do

[1] Tull. Horse-Hoeing Husbandry, chap. XII, pp. 222 and 223.
[2] Sinclair. Code of Agriculture. 5th ed. App., p. 58 (foot note*).
[3] Tessier. Traité sur la Maladie des Graines; Result of Exp. made at Rambouillet. In Young's Ann. of Ag., Vol. VI, 1786, pp. 205-211.
[4] Young's Annales of Agric., Vol. VIII, 1787, pp. 409–413, and Annales of Agric,, Vol. X, 1788, pp. 131 and 132.

not, however, seem to have been in very general use, except perhaps lye or arsenic combined with lime. Soaking in urine, either fresh, or stale, and with or without the addition of other substances, was also used. Tessier[1] used in his experiments sulphate of copper, clear juice of lemon, ether, spirits of mint, alcohol, hartshorn, &c.

(5) Copper compounds.

According to Prevost,[2] Tessier in 1789 sowed some wheat treated with a solution of sulphate of copper, and the crop produced no smut. The experiment did not prove anything, since the untreated wheat produced only $^{1}/_{1800}$ of smutted heads. In 1807 Bénédict Prevost published a very important paper giving an account of the successful use of copper treating stinking smut of wheat. He accidentally discovered the value of copper in trying to germinate some smut spores. Some of the spores, placed in water which had been distilled in a copper vessel, failed to germinate, while the same spores placed in water which had not touched the copper, germinated as usual.[3] He then experimented with copper compounds to prevent the smut in the wheat. He used solutions of copper sulphate, copper acetate, verdigris obtained by the action of vinegar on copper, and of copper oxide. He recommends the use of a solution of 9 decagrammes of copper sulphate in 14 litres of water for every hectolitre of wheat, (about a 6-per-cent. solution.) He claims this to be a remedy superior to anything else, and to be, if properly applied, an infallible antidote. It very soon became quite widely known and practiced. Sinclair says:[4] "It may be added, that Prevost's discovery was in a great measure accidental, and that the utility of preparations from copper has long been known in Flanders." He also states[5] that Prevost uses one ounce of blue vitriol to every bushel of grain, dissolved in a wine galloon of water. The grain is stirred well with the solution, skimmed, and left stand an hour, after which it is drained; then washed in rain or pure water to prevent injury to the grain, and then dried either with or without lime. In 1858 Kühn[6] recommended a dilute solution of copper sulphate as a remedy against smuts. He used one pound of copper sulphate for every five Berlin bushels of wheat. The copper sulphate was dissolved in hot water, and then mixed with sufficient cold water to cover the grain 4 inches deep. It was left in this solution 12–14 hours, then dried. The treatment was much used in this form, and indeed is yet. The later authors use a ½-per-cent. solution by weight.

(6) Copper sulphate, with subsequent liming.

In 1873 Dreisch[7] published an account of an exhaustive series of experi-

[1] Tessier, art. Carie, p. 721. Quoted from Prevost, Mém., p. 65, § 163.

[2] Prevost. Mémoire sur la immédiate de la carie on charbon des blés et de plusieurs autres maladies des plants at sur les préservatifs de la carie. Paris, 1807, p. 65, § 163.

[3] Prevost. Mém., p. 55, § 130.

[4] Sinclair. Code of Agric., 5th cd., App., p. 62.

[5] Sinclair. l. c., App., p. 59.

[6] Kühn. Die Krankheiten der Kulturgewächse, ihre Ursachen und ihre Verhütung. Berlin, 1859, $.85-89.

[7] Dreisch, Unters. über die Einwirkung verdünntert. Kupferlös. den Kelmprocess des Weizen. Dresden, 1873.

ments upon the influence of dilute copper solutions on the germinative power of wheat. He found that even a dilute solution injured the germinative power of the wheat to an appreciable extent, and that if the wheat was soaked for a few minutes in lime water after being soaked in copper sulphate this injury was largely prevented. This practically perfected the blue-vitriol treatment, and as thus modified has been very much used. Perhaps the best form is to soak the grain 12 hours in a one-half-per-cent. solution of copper sulphate, after which it is immersed five minutes in milk of lime made by slacking lime in ten times its weight of water. This treatment is very effective against the stinking smut of wheat and covered barley smut, but it does not entirely prevent oat smut, and has little effect upon the naked barley smut.[1] According to Plowright; this and other treatments have little effect on the loose smut of wheat.

(b) Exposing the seed to the action of gases or vapors.

(1) Dissolved.

In 1879 Zoebl[3] published an account of the use of sulphurous oxide (SO_2) as a remedy for smut. He burned sulphur in a barrel half-full of water, which absorbed the SO_2 produced. Into this he put the grain and completely closed the barrel. Then the barrel was rolled, to thoroughly wet the grain, after which it stood for 3–6 hours. The grain was then dried for sowing.

(2) In gaseous form.

Tessier used ether to prevent wheat smut. It may be that some of the means used for killing grain beetles may also prove effectual against the smut. In this event the gaseous treatment might be of considerable importance. The following are worthy of trial, and most of them are now being tested: Carbon bisulphide (CS_2), chloroform ($CHCL_3$), ether $(C_2H_5)_2$,O, sulphurous acid (SO_2), and vapors of gasoline, kerosene, ammonia, and alcohol.

(c) Sowing solids with the seed.

This is practically done when the wheat is treated with a solution of any non-volatile substance, as copper sulphate, lime, &c. The solutions upon drying leave a quantity of the substance adhering to the seed. Brefeld supposes[4] that copper sulphate so adhering is of great use in treating grains to prevent smut. The substance would kill all sporules in the soil which might otherwise be able to infect the young plant. Even a very small amount of copper sulphate dissolved in the water of the soil about the seed would be able to poison the delicate sporules or their germ tubes, which, unlike the spores, are not protected by a thick wall. This fact may explain why Jensen found[5] in one of his experiments that a ¼-per-cent. copper sulphate solution reduced the per cent. of smutted heads from 36 to ½, but

[1] According to the experiments of Jensen. (See Prop. and Frey. of Smut.)
[2] Plowright. Br. Ured. and Ust., p. 102.
[3] Zoebl. Die schwefelige Saure als Mittel gegen den Steinbrand des Weizens, in Oesterr. landw. Woehenbl., 1879, Nr. 13, S. 145. Reviewed in Just, Bot. Jahresbr. 7 Jahrg. 1879, I. S. 545; Sorauer, Pfl. Krkh. 2 Aufl. II. S. 207.
[4] Brefeld. Neue Unters. II, Nachr. aus d. K1. d. Landw. zu Berl,, Nr. 222., S. 1602.
[5] Jensen. Prop. and Prev. of Smut, p.13.

only reduced the vitality of the smut spores from 20 per cent. to 5 per cent. Thaxter has recently[1] recommended sowing chemical substances, such as sulphur, or sulphide of sodium, with the seed as a remedy against onion smut *(Urocystis cepulæ* Frost). This will undoubtedly prove to be a valuable remedy against smuts (such as of onions) which remain in the soil and infect the young plants when they germinate. Brefeld supporse this to be the case with oat smut, and it certainly is to some extent the case with stinking smut of wheat.

C. PHYSICALLY.

(a) Washing in water.

Tessier says[2]: "It is the same with washing in water or with salt. These, it is true, diminish the activity of the contagious principle, but are incapable of destroying it completely."

(b) Exposure to sunshine.

Emile Laurent in 1889[3] stated that in some regions of Hainault, and particularly in the canton of Flobeck, a burning sun at the time of sowing seed diminished the chances of smut infection for grains, and particularly for wheat. He investigated the subject because of the common belief to this effect. He exposed spores of "*Ustilago Carbo*" from wheat *(Ustilago Tritici)* to the full sunlight in a glass vessel open above. Other spores were exposed to the light of the sun passed through a layer of solution of sulphate of quinine three centimeters thick. The temperature of the surrounding air did not rise above 40° C. (104° F.). After eight hours the spores exposed to the sun had lost the power of germination even in nutrient solution (unfermented beer). The spores shaded entirely from the sun germinated with great regularity. The spores sheltered from the chemical rays of the sun by the solution of sulphate of quinine did not lose their power of germinating after 16 hours of exposure to a very hot sun. The spores on the exterior of a head of smut are thus killed, while those in the interior of the head remain capable of germinating.

We have noticed in our germination of spores that sometimes the cultures grew better than other; and once in particular spores clinging to the paper in which specimens were inclosed refused to germinate, while spores obtained from the interior of smutted spikelets germinated vigorously. These facts would seem to support the statements of Laurent, since the spores clinging to the paper were undoubtedly mostly from the exterior portions of the smutted heads, and had consequently been exposed to the bright summer sun a considerable time before they were collected. This curious fact may have an effect as yet little appreciated in preventing the smut; for whenever the grain is exposed to the sun to dry, no matter what the treatment was, this disturbing influence would be felt.

[1] Thaxter, Rept. of Mycologist, in Ann. Rep. Conn, Ag. Exp. Sta. for 1889, pp. 146-158.
[2] Tessier. Result of Experiments made at Rambouillet. In Young's Ann, Agr. VI, 1787, p. 207
[3] Laurent. Influence de la luminiere sur les spores du charbon des cereales. In Bull, Soc, Bot. de Belgique, Tome 28, anné 1889, (2e) part, p. 262,

Prevost says, however[1], that alternate wetting and drying of the spores of the stinking smut of wheat, either in shadow or in sunshine, does not destroy their power of germination. He also exposed spores in liquids (water and copper sulphate) to the sun when it was so hot as to cause the temperature to rise to 56° (C.) and they did not lose their power of germinating. The subject is an interesting one, and will be further investigated.

(c) Exposure to heat.

(1) Dry heat.

x Flaming.

Wolff[2] says that the Fellahs and Moors, in order to prevent the smut, "Homari," of the sorghum and sugar cane, threw the seed through a high flame of a straw fire, thus by the sudden heat killing the spores adhering to the seed.

Haberlandt[3] describes a method of preventing the stinking smut of wheat by momentarily exposing the seed to a flame. Sorauer[4] criticises this practice, since the spores within the smutted grains are not killed.

xx Heated dry air.

Sinclair says:[5] "Kiln-drying the seed, . . . though a hazardous, is, when properly executed, a successful mode of preventing smut."

Schindler[6] found that dry heat below 80° C. did not affect the smut spores. According to Pierre,[7] this temperature injures the wheat so much that only 64 per cent. germinated. Jensen exposed oats to dry heat at 125° and at 129° F. for seven hours. This exposure had no effect upon the amount of smut.

(2) Damp heated air.

Schindler[8] found that moistened grains of stinking smut were killed by prolonged heating at 50° C. (122° F.) Jensen in 1888 [9] reported the trial of moist heat. Oats exposed for 5 hours at 127° F., caused the destruction of all smut, but also injured the seed somewhat.

(3) Hot solutions.

Tessier[10] says: "I have tried liming from 20° R. (77° F.) of heat up to 80° R. (212° F.), and I have assured myself that the diminution in the amount of smut was not by reason of the degree of heat of the liming, and that it

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[1] Prevost Mem sur la cause de la carie, p. 53, § 124.

[2] Wolf, Krankh, d. Landw Nutzpflanzen. Berlin, 1887, S. 58.

[3] Haberlandt. Einfluss des Kupfervitriols auf den Keimfahigkeit des Weizeus, in Muller's landw. Centralb., 1874, Bd. XXII S.381; Reviewed in just, Bot. Jahresbr., 2 Jahrg. 1874, S. 382; Sorauer in auf landw, Centralb., XXII Bd., S. 595.

[4] Sorauer Fremde und eigene neuere Bobactungen auf dem Gebiete der Pflanzenkrankheiten in Muller's landw., Centralbl., XXII, Jahrg. October, 1874, S. 596.

Sinclair. Code of Agric., 5 ed. app., p. 58.

Schindler. Ueb, d. Einfl, verscheid. Temp. auf d. Keimfahigk. der Steinbrandsporen inForsch. auf d. Gebiete der Ag. phys. 1880, Bd. III, Heft. III, S. 288-293. Reviewed in Bot. Centralbl., 1880, S. 929. Plowrught, Br. Ured. & Ust., p. 104; Sorauer, Pflanzenkr. 2 Aufl. 11, S. 206.

J. Isidore-Pierre, Ueb. d. Einfluss d. Warme u. d. Beizens mit Kalk u. Kupfervit. auf d. Keimfahigk. d. Weizens, in Ann. Agronomiques, II, 1876; Bied. Centralbl., 1876, X, S.362-364. Rev. just, Bot, Jahresbr. Jahrg. 1876 S. 880; Sorauer, Pflanzenkr. 2 Aufl. II, S. 206.

Schindler. Enifl. verschied. Temp., I.c.

Jensen. Prop. and Prev. of Smut, pp. 12 and 15.

Tessier. Quoted from Prevost Mem., pp. 32, § 121.

is of no consequence whether the lime be at 20° R. (77° F.), or at 60° R. (167° F.) Prevost thinks that the smut was not heated so high.[1] Sinclair[2] says, under the head *Boiling Water and Lime:* "This mixture, when properly applied, is found to be effectual. Sometimes chalk-lime, recently burnt, is put into a copper of boiling water, and as soon as the lime is dissolved, the mixture, at this degree of heat, is poured upon the wheat, previously spread upon a stone floor, and the wheat and the mixture are immediately well turned together with shovels.[3§] Sometimes the wheat, put into a common wicker basket, is dipped two or three times into a mixture of hot water and quick-lime,[3¶] and sometimes boiling water and quick-lime have been successfully used after the seed has been well washed and. skimmed." [3 ¶]

(4) *Hot water.*

Prevost[4] says he several times sowed wheat that was infected, and which was well wetted with boiling water. It did not germinate so well as wheat sown the same time without having been treated, but it always produced less smut. The next notice of a hot-water treatment was in 1887 by J. L. Jensen,[5] who, in a Danish publication, reported wonderful success with hot water as a preventive against oat and barley smut as well as against the stinking smut of wheat *(Tilletia),* and the stem smut of rye *(Uroc. occulata).* In the same year, Prilleaux, as stated by F. D. Chester[6] "recommends placing the seed in a basket lined with coarse cloth, and then dipping the same in water, heated to a temperature of 110° F., for five minutes; after which the seed is immediately dipped into cold water. The author claims that the germinating quality of the seed is not injured; on the contrary, he claims that the seed will germinate sooner." In the *Gardeners Chronicle* of May 5, 1888, Jensen states that, "the spores of Ustilago segetum of oats and barley are killed by the action of water at a temperature of 56° C, (133° F.) in the course of two or three minutes." In 1888 he published in Danish a very full account[7] of further experiments, all showing the great value of his hot-water method. In the same year he published a very full account in English in the Journal of the Royal Agricultural Society of England for 1888, Vol. XXIV, S. S. Part, pp. 1-19, entitled "The Propagation and Prevention of Smut in Oats and Barley." On p. 12 he gives the following table, showing a comparison of several methods of treatment:

1 Prevost. Mém,, p. 32, §121.
2 Sinclair. Code of Agriculture, Fifth edition. App., p. 57.
3 Sinclair. Code of Agriculture. Fifth edition. App., p. 57. §Middlesex Report, p. 207. ||Dorset Report, p. 212, ¶ Buckinghamshire Report, p. 179,
4 Prevost. Mém., p. 32, § 21.
5 J. L, Jensen, Nye Undersögelser og Forsög over Korrrsorternes Brand (Förste Meddelelse). Særtryk af Markfrokontorets Aarsberetning for 1887, Kjöpenhavn.
6 In Bull. III, Del. Ag. Exp. Sta,, Dec. 1888 last page, from Bull. Soc. Nat. Agric.,1887, XLVIII, P.549.
7 J. L. Jensen, Om Kornsorternes Brand. (Anden Meddelelse.) Kjöpenhavn, 1888, p. 72.

RESULTS OF DISINFECTION EXPERIMENTS WITH OATS.

No.	MODE OF DISINFECTION.	Smutted ears in the crop..........	Germinative power of spores in seed....	Estimation of quality of crop at the beginning of July; scale, 1—5.
		Per ct.	*Per ct.*	
1	*Undressed*	36	20	5 Very good.
2	½ Per cent. sulphate of copper..	½	5	4 Good.
3	1 P. c. sulphate of copper......	0	0	1 Very bad.
4	1 P. c. sulphate of copper with 4 p. c. quicklime.....	½	?	4½ Good; almost good as No. 1.
5	⅔ P. c. English sulphuric acid...	13	1 or 2	4 Good.
6	1 P. c. English sulphuric acid...	2	?	3 Moderate.
7	1¼ P. c. English sulphuric acid..	¼	?	3 Moderate.
8	1½ P. c. English sulphuric acid..	0	0	2 Bad.
9	4 P. c. quicklime and 2 p. c. salt..	9	4	4 Good.
10	Dry heat, 122° F., for 7 hours...	36	20	4½ Good; almost good as No. 1.
11	Dry heat, 129° F., for 7 hours...	34	?	4½ Good; almost good as No. 1.
12	Moist heat, 127° F., for 5 hours..	0	0	3 Moderate.
13	Warm water, 127° F., for 5 min's..	½	½	5 Very good.
14	Warm water, 133° F., for 5 min's..	0	0	5 Very good.

In July, 1889, he published a pamphlet *Le. Charbon des Céréles, in* French, giving concise directions for applying his method. Early in 1890[1] he published in German another account of his method. We have already given an account of it in Bulletin No. 8, Experiment Station, Kansas State Agricultural College, October, 1889: "Preliminary Report on Smut in Oats," pp. 94 and 95. Substantially the same is here reproduced:

TREATMENT RECOMMENDED.

The Jensen Hot - Water Treatment.

The hot-water treatment consists in immersing the seed, which is supposed to be infected with smut, for a few minutes in scalding water. The temperature must be such as to kill the smut spores, and the immersion must not be prolonged so that the heat would injure the germ or embryo concealed within the seed-coats. If the water is at a temperature of 132° F., the spores will be killed, and yet the immersion, if not continued beyond fifteen minutes at least, will not in the least injure the seed. The smut spores will possibly be killed by five minutes immersion. An eight- to

[1]Jensen, Ueber die Verhüting des Kornbrandes, Kjöpenhavn.

twelve-minute immersion however is recommended.* The temperature must be allowed to vary but little from 132°; in no case rising higher than 135°, nor falling below 130°. To preserve these conditions when treating large quantities of seed, the following suggestions are offered:

Provide two large vessels, as two kettles over a fire, or boilers on a cook stove; the first containing warm water (say 110°-120°), the second containing scalding water (132°).

The first is for the purpose of warming the seed preparatory to dipping it into the second. Unless this precaution is taken, it will be difficult or impossible to keep the water in the second vessel at a proper temperature. The seed to be treated must be placed, a half-bushel or more at a time, in a vessel that will allow free entrance and exit of water on all sides. For this purpose a bushel basket made of heavy wire could be used, over which stretch wire netting, say twelve meshes to the inch; or an iron frame could be made at a trifling cost, over which the wire netting could be stretched. This would allow the water to pass freely, and yet prevent the passage of the seed. A lid or cover should also be provided, otherwise the portion of seed that tends to float will escape from the wire basket. Now dip the basket of seed in the first vessel; after a moment lift it, and when the water has for the most part escaped (requiring an exceedingly short time) plunge it into the water again, repeating the operation several times. The object of the lifting and plunging, to which might be added also a rotary motion, is to bring every grain in contact with the hot water. Less than a minute is required for this preparatory treatment, after which plunge the basket of seed into the second vessel. If the thermometer indicates that the temperature of the water is falling, pour in hot water until it is elevated to 132°. If it should rise higher than 132°, add small quantities of cold water. This will doubtless be the most effectual method of keeping the proper temperature, and requires only the addition of two small vessels—one for cold and the other for boiling water. The basket of seed should, very shortly after its immersion, be lifted, and then plunged and agitated in the manner described above, and the operation should be repeated several times. In this way only will every grain of the seed be brought and kept in contact with water that is at the temperature necessary for killing the smut spores. When the basket is lifted finally from the scalding water, it must be plunged into cold water, or cold water must be thrown over it, in order to cool it quickly. The seed should then be spread out to dry, but the drying need not be thorough unless the seed is to be stored some time before planting.

EXPERIMENTS WITH TREATED SEED AND TREATED SOIL.

Through the kindness of Mr. J. F. Swingle, we were enabled to plant prepared seed on the edge of an oat-field planted with the same variety un-

*Experiments are under way to determine the minimum time of immersion and the most favorable temperature of the water.

treated. A strip about forty rods long, and one rod wide, was planted with common winter oats— one-third treated with iron sulphate,* one-third with hot water,† and one-third untreated. The seed was sown broadcast, and harrowed in. The land was a rich creek-bottom. The oats were sown on March 16. came up equally well, and on July 2 were harvested. Little difference could be seen between the plots until they headed out. The following diagram shows the relative positions of the plots:

Count 11. (8.44 per cent. smutted.)	Count 10. (5.54 per cent. smutted.)	Count 9. (4.9 per cent. smutted.)
III. (8.11 per cent. smutted.) Seed untreated.	II. (0 per cent. smutted.) Heated Water 15 minutes, at 132° F.	I. (4.67 per cent. smutted.) Iron sulphate; 18 hours in a $1\frac{1}{4}$ lbs. to 1 gal. sol.

Just before cutting, the per cent. of smut was obtained by count, both in the plots and in the adjacent portion of the field. The results of the count are given above, in the diagram of the experiment. Not a single smutted head could be found in Plot H, treated according to Jensen's hot-water method; but the iron sulphate had little or no effect.

When the oats were harvested, the self-binder was run through the middle of Plots I, II, and III, and as the machine was entirely inside of the plots, a cut of the full width (4 ft. 8 in.) was insured. A strip exactly 100 feet long was cut from each plot, and care was taken to secure all of the grain. On July 18 it was threshed, with the result shown in the following table:

TABLE SHOWING THE YIELD IN POUNDS OF GRAIN AND STRAW IN PLOTS I-III.

Plot I	29½	18½
Plot II	44¾	21 ¾
Plot III	28¾	18¼

With the yield of grain and straw in III as 100, the comparison is as follows:

TABLE SHOWING COMPARATIVE YIELD OF PLOTS I-III, WITH III AS 100.

	Straw.	Grain.
Plot III	100	100
Plot II	$155\frac{3}{5}$	$119\frac{1}{5}$
Plot I	$102\frac{5}{8}$	$101\frac{3}{8}$

*Soaked 18 hours in a solution of 11/4 pounds to 6 gallons of water.
† Treated as described above, p.

It will be seen that Plot II yielded 55 3/5 per cent. more straw, and 19 1/5 per cent. more grain, than No. III; while No. I was almost exactly the same as No. III, the difference being about equal to the difference in the per cent. of smut. It is impossible to account for the great superiority of Plot II over the others, unless, besides killing the smut, the Jensen treatment also caused the seed to germinate better.

It is an interesting, and, perhaps, very important fact, that Jensen[1] has found a similar increase in the yield over and above the amount of smut destroyed both in barley and oats. The following shows the comparative yield in two experiments conducted with barley in 1888; the figures indicate kilos per hectare[2]:

	I.	II.	Average.
Treated with warm water	2,307	4,107	3,207
Untreated	1,978	4,022	3,000

The loss from smut was 4 per cent., but the yield was increased nearly 7 per cent. Similar experiments with oats gave[2]:

	I.	II.	Average.
Jensen treatment	1,265	3,178	2,222
Untreated	1,210	3,038	2,124

The loss from smut was only about ¼ per cent., but the yield was increased nearly 5 per cent.

Another experiment was performed on upland soil, as follows: On March 21, 1889, twelve plots, each eighteen feet square, were planted. The accompanying diagram shows the arrangement of the plots.

[1] Jensen. Udbytteformerelsen ved Varmvands Methoden, Kjöp., 1890; Jensen, Ueber die Verhüting des Kornbrandes, Kjöp., 890, p. 3.
[2] Jensen. Ueber die Verhüting des Kornbrandes, Kjöp., 1890, p. 3.

1. Seed untreated, and soil untreated. *(11.1 per cent. Smut.)*	7. Seed as 1, and soil manured and smutted. *(9.1 per cent. Smut.)*
2. Seed treated with $CuSo_4$, (4 oz. to 1 gal.); soil untreated. *(2 per cent. Smut.)*	8. Seed as 2; soil manured and smutted. *(1.73 per cent. Smut.)*
3. Seed treated with hot water (132°), soil untreated. *(0 per cent. Smut.)*	9. Seed as 3; soil manured and smutted. *(0 per cent, Smut.)*
4. Seed untreated, soil untreated. *(11 per cent. Smut.)*	10. Seed as 4; soil smutted, not manured. *(8.63 per cent. Smut.)*
5. Seed treated with $CuSo_4$, (4 oz. to 1 gal.); soil untreated. *(1 per cent. Smut)*	11. Seed as 5; soil smutted, not manured. *(0 per cent. Smut.)*
6. Seed treated with hot water (132°), soil untreated. *(0 per cent. Smut.)*	12. Seed as 6; soil smutted, not manured. *(0 per cent. Smut.)*

On August 7, 1888, the land occupied by Plots 7, 8 and 9, was manured with stable manure, and all the plots from 7 to 12 inclusive were inoculated with smut. The smut had been collected in July, 1888, while the oats were yet standing. A smutted head was put on at least every square foot of ground. Then all the plots from 7 to 12 inclusive were at once plowed. Just before seeding, in March, 1889, all the plots from 1 to 12 inclusive were again plowed.* The prepared seed was sown with a drill. Red winter oats from the Farm Department were used. The seed used in Plots 2, 8, 5 and 11 was prepared by soaking 18 hours in a solution of copper sulphate of the strength of 4 oz. to 1 gal. of water. The seed used in Plots 3, 9, 6 and 12 was treated by the Jensen hot-water method before described. The other plots were untreated. The oats in the plots planted with seed treated with copper sulphate did not come up well, and the plants that appeared were not very health. On July 9 and 10, 1889, three thousand (3,000) heads were counted in each plot, with the result which follows:

PLOT l.—Of 3,000 heads 333 were smutted, or 11.1 per cent. The stand was good.

PLOT 2.—Of 3,000 heads 60 were smutted, or 2 per cent. All these, however, were along the edge adjoining Plot 1, and were probably from a few smutted grains left in the drill after planting Plots 1 and 7. The stand was very poor.

PLOT 3.—Of 3,000 heads not one was smutted. The stand was very good, and the plants looked vigorous.

PLOT 4.—Of 3,000 heads 330 were smutted, or 11 per cent, Almost exactly the per cent. found in the similar plot 1.

PLOT 5.—Of 3,000 heads 3 were smutted, or .1 per cent. The stand, &c., was as in Plot 2.

PLOT 6.—Of 3,000 heads not one was smutted. Stand, &c., as in Plot 3.

PLOT 7.—Of 3,000 heads 273 were smutted, or 9.1 per cent. Though grown on smutted and manured soil, the per cent. of smut was less than in Plot 1 adjoining. The stand was good; the growth was very rank.

PLOT 8.—Of 3,000 heads 52 were smutted, or 1.73 per cent. These smutted heads adjoined Plot 7, and are to be explained as in case of Plot 2. Stand was poor, but growth was rank.

PLOT 9.—Of 3,000 heads none were smutted, showing that not a single kernel was infected from the soil. The growth was rank, and the stand good.

PLOT 10.—Of 3,000 heads 259 were smutted, or 8.63 per cent.; less than the adjacent Plot 4 on unsmutted soil. The growth, &c., was as in Plot 4.

PLOT 11.—Of 3,000 heads none smutted. Stand was, as in Plot 5, very poor.

PLOT 12.—Of 3,000 heads none were smutted.

* By inadvertency, the land occupied by all the plots was plowed a second time the last week in October, 1888.

This experiment seemed to show:

1. Treatment of the seed with hot water by the Jensen method completely prevented the smut in every case, and improved rather than diminished the germinating power of the seed and the vigor of the plants.

2. Treatment with a solution of copper sulphate, 4 ounces to 1 gallon for 18 hours, prevented the smut, but greatly injured the seed.

3. Soil treated with manure and smut the previous August, and also soil simply smutted at the same time, actually gave a less per cent. of smut than untreated soil. This result is unexplainable, unless it can be referred to the immediate plowing which the other plots did not receive.

Another series of plots adjoining Nos. 1–12 were planted on March 23, 1889. The accompanying diagram shows the arrangement of the plots. Plot 13 was just below 12 and 6.

The variety used was Red Winter, except where otherwise mentioned. The seed of alternate plots was untreated. A garden hand-drill was used in planting, but the stand was uneven, necessitating a thinning-out of some of the dense bunches. In some of the plots the stand was very poor, owing to the injurious effects of the treatment on the seed. On May 28 the weeds were hoed out of all the plots that needed weeding. The rows were rather wide apart, and could be easily hoed without disturbing the grain. All of the plots were about 22 feet long, and most of them were about 6 feet wide, and had 6 rows. Nos. 29, 30 and 32, 33 had only 3 rows, and were of half the width, and No. 34 had 10 rows, and was correspondingly wider. The soil in all cases was without treatment of any kind, except that occupied by No. 13, which had been artificially smutted at the same time and in the same manner as that occupied by plots 10–12. The land was plowed August 8, 1888, October, 1888, and March, 1889. The diagrams on the following pages show the position and shape of the plots.

13. Untreated; soil smutted (the only one). *(9.26 per cent. Smutted.)*
14. Seed treated with hot water as in Plot 11. *(0 per cent. Smutted.)*
15. Copper sulphate (4 oz. to 1 gal.), 18 hours. *(0 per cent. Smutted.)*
16. Untreated. *(8.4 per cent. Smutted.)*
17. Lime and soap (excess of lime) 18 hours. *(0.73 per cent Smutted.)*
18. Untreated. *(11.33 per cent. Smutted.)*
19. Lime and soap (less soap) 18 hours. *(2.16 per cent. Smutted.)*
20. Untreated. *(10.23 per cent. Smutted.)*

21. Five per cent. lye, 18 hours. *(.0006 per cent. Smutted.)*
22. Untreated. *(9.83 per cent. Smutted.)*
23. Same as 25, but untreated. WINTER OATS. *(6.8 per cent. Smutted.)*
24. Untreated. RED WINTER. *(9.46 per cent. Smutted.)*
25. Artificially smutted when in bloom. WINTER OATS. *(6.43 per cent. Smutted.)*
26. Untreated. RED WINTER. *(9.13 per cent. Smutted.)*
27. Same as 23, like 25, but untreated. WINTER OATS. *(5.43 per cent. Smutted.)*
28. Untreated. RED WINTER. *(10.76 per cent. Smutted.*

29. Three per cent. sulphuric acid. BLACK OATS. *(1.70 per cent. Smutted.)*
30. Ten per cent. sulphuric acid. BLACK OATS. *(7.61 per cent. Smutted.*
31. Untreated. RED WINTER. *(9.24 per. cent. Smutted.)*
32. Untreated. BADGER QUEEN. *(9.07 per cent. Smutted.)*
33. Untreated. BLACK OATS. *(18.64 per cent. Smutted.)*
34. Smutted by moistening the seed and rolling in smut just before planting. RED WINTER. *(14.4 per cent. Smutted.)*

PLOT 13.—Seed untreated—soil smutted, same as in Plot 10 above. Of 3,000 heads counted 278 were smutted, or 9.2 per cent. of the whole.

PLOT 14.—Planted with seed treated with hot water, as for Plots 3, 6, 9 and 12 above. Soil (as for all the following) untreated. Of 3,000 heads counted none were smutted.

PLOT 15.—Seed treated with copper sulphate (40z. to 1 gal.) for 18 hours, as in Plots 25, 3 and 11 above. Of 1908 heads none were smutted. The plants were evidently much injured by the treatment.

PLOT 16.—Untreated. Of 3,000 heads 252 were smutted, or 8.4 per cent.

PLOT 17.—Seed treated by being immersed in a solution of lime and castile soap (with excess of undissolved lime) for 18 hours. Of 3,000 heads 22, or .73 per cent., were smutted. The stand was quite good.

PLOT 18.—Untreated. Of 3,000 heads counted 340 were smutted, or 11.3 per cent. of all.

PLOT 19.—Planted with seed treated the same as in Plot 17, except that the quantity of solid lime was less, and that of undissolved soap was greater. Of 3,000 heads 65 were smutted, or 2.16 per cent.

PLOT 20.—Untreated. Of 3,000 heads 307 were smutted, being 10.2 per cent. of the whole.

PLOT 21.—Seed soaked 18 hours in a 5-per-cent. solution of concentrated lye. All of the panicles produced were counted, namely 2,918, and of these but two were smutted (.0007 per cent.). The seed injured by the treatment. The two smutted were without doubt from an untreated seed, since they grew just where the drill started after planting untreated seed.

PLOT 22.—Untreated. Of 3,000 heads, 295 were smutted, or 9.8 per cent.

PLOT 23.—The seed, winter oats, but not the same as the preceding, was obtained from the field where count 5 (giving 12.6 per cent. smutted heads) was made. When the plots were in bloom, in 1888, fresh smut was dusted over them repeatedly with a view of infecting the seed more thoroughly; but of 3,000 heads counted in this plot, only 204, or 6.8 per cent., were smutted. (See Plot 27.)

PLOT 24.—Red Winter; untreated. Of 3,000 heads counted, 284, or 9.4 per cent., were smutted.

PLOT 25.—Seed from same field as that used in Plots 23 and 27, but *not* artificially smutted. Of 3,000 heads counted, 193, or 6.4 per cent., were smutted.

PLOT 26.—Red Winter; untreated. Of 3,000 heads counted, 274 were smutted, being 9.13 per cent. of all.

PLOT 27.—Seed the same as in Plot 23. Of 3,000 heads, 163, or 5.43 per cent., were smutted.

As will be seen on comparison with Plots 23 and 25, the per cent. of smutted heads in the plots planted with artificially smutted heads was in No. 23 larger and in 27 smaller than in No. 25 planted with untreated seed from the same field. In this case the attempted artificial inoculation was entirely without effect.

PLOT 28.—Red Winter; untreated. Of 3,000 heads 323, or 10.76 per cent., were smutted.

PLOT 29.—(3 rows.) Planted with black oats which had been soaked 18 hours in a 3-per-cent. solution of sulphuric acid. Of the 1,409 heads produced, 24, or only 1.7 per cent., were smutted. The plants were somewhat injured by the treatment.

PLOT 30.—(3 rows.) Seed same as in Plot 29, but was treated with 10-per-cent. solution of sulphuric acid. The seed was much injured by this treatment, and only 761 heads were produced. Of these none were smutted.

PLOT 31.—Red Winter; untreated. Of 3,000 heads 272, or 9.24 per cent., were smutted.

PLOT 32.—(3 rows.) Planted with Badger Queen; untreated. Of 1,377 heads produced, 125, or 9.07 per cent., were smutted.

PLOT 33.—(3 rows.) Planted with black oats, as Plots 29 and 30, but seed untreated. Of 2521 heads 470, or 18.64 per cent., were smutted.

PLOT 34.—(10 rows.) Planted with untreated Red Winter, artificially smutted just before planting by moistening the seeds and dusting them with smut. Of 3,000 heads counted 432 were smutted, or 14.4 per cent. To be of value this experiment should have been tried with seed treated with hot water, so that any smut obtained would be from that applied to the seeds when planted. As it was, there seemed to be an increase in the per cent. over the other plots of untreated Red Winter.

The experiments seemed to show, so far as the results of a single year can be relied upon:

1. Artificially dusting smut on the plants when they were in blossom had no appreciable effect. (See Plots 23, 25, and 27.)

2. Artificially dusting the untreated seed with smut seemed to increase the per cent. of smut slightly. (See Plot 34.)

3. Treatment with lime and castile soap solution (with excess of lime) prevented smut almost entirely. It injured the seed but slightly. (See Plot 17.)

4. Treatment with lime and castile soap solution (with excess of soap) reduced the smut much, though not so much as the treatment with excess of lime, and like that injured the seed but little. (See Plot 19.)

5. Treatment with 5-per-cent. lye solution prevented all smut, but injured seed considerably.

6. Treatment with 3-per-cent. sulphuric acid solution prevented much of the smut, but considerably injured the seed; while treatment with a 10-per-cent. solution greatly injured the seed and completely prevented the smut.

8. The per cent. of smut varied somewhat in different plots from the same seed, and much more in different varieties.

This is clearly shown in the tables on the following pages, which give the detailed counts of all the plots from 1 to 34.

PER CENT. OF SMUT IN DIFFERENT PLOTS.

PLOT 1.		PLOT 2.		PLOT 3.		PLOT 4.		PLOT 5.		PLOT 6.		PLOT 7.	
Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....
100	9	100	0	100	0	100	14	100	0	100	0	100	12
100	8	100	0	100	0	100	20	100	0	100	0	100	10
100	8	100	0	100	0	100	14	100	0	100	0	100	10
100	8	100	0	100	0	100	14	100	0	100	0	100	8
100	14	100	0	100	0	100	19	100	0	100	0	100	4
100	15	100	0	100	0	100	11	100	0	100	0	100	9
100	6	100	0	100	0	100	5	100	3	100	0	100	4
100	20	100	0	100	0	100	4	100	0	100	0	100	9
100	18	100	0	100	0	100	4	100	0	100	0	100	10
100	20	100	0	100	0	100	16	100	0	100	0	100	8
100	10	100	1	100	0	100	12	100	0	100	0	100	12
100	9	100	1	100	0	100	6	100	0	100	0	100	9
100	11	100	0	100	0	100	11	100	0	100	0	100	16
100	13	100	7	100	0	100	6	100	0	100	0	100	14
100	9	100	12	100	0	100	10	100	0	100	0	100	9
100	12	100	0	100	0	100	8	100	0	100	0	100	4
100	12	100	0	100	0	100	5	100	0	100	0	100	12
100	11	100	9	100	0	100	13	100	0	100	0	100	3
100	6	100	6	100	0	100	7	100	0	100	0	100	15
100	14	100	0	100	0	100	10	100	0	100	0	100	8
100	7	100	0	100	0	100	9	100	0	100	0	100	10
100	8	100	7	100	0	100	7	100	0	100	0	100	10
100	7	100	11	100	0	100	10	100	0	100	0	100	7
100	11	100	8	100	0	100	10	100	0	100	0	100	15
100	11	100	0	100	0	100	19	100	0	100	0	100	11
100	9	100	0	100	0	100	20	100	0	100	0	100	0
100	15	100	0	100	0	100	11	100	0	100	0	100	13
100	16	100	0	100	0	100	14	100	0	100	0	100	8
100	6	100	0	100	0	100	10	100	0	100	0	100	7
100	10	100	0	100	0	100	11	100	0	100	0	100	6
3000	11.1	3000	0.02	3000	0	3000	11	3000	0.001	3000	0	3000	9.1

PLOT 8.		PLOT 9.		PLOT 10.		PLOT 11.		PLOT 12.		PLOT 13.		PLOT 14.	
Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....
100	9	100	0	100	5	100	0	100	0	100	9	100	0
100	3	100	0	100	5	100	0	100	0	100	5	100	0
100	10	100	0	100	5	100	0	100	0	100	11	100	0
100	0	100	0	100	14	100	0	100	0	100	12	100	0
100	0	100	0	100	6	100	0	100	0	100	7	100	0
100	6	100	0	100	15	100	0	100	0	100	10	100	0
100	0	100	0	100	4	100	0	100	0	100	11	100	0
100	1	100	0	100	7	100	0	100	0	100	4	100	0
100	2	100	0	100	9	100	0	100	0	100	10	100	0
100	3	100	0	100	15	100	0	100	0	100	2	100	0
100	5	100	0	100	12	100	0	100	0	100	4	100	0
100	0	100	0	100	13	100	0	100	0	100	3	100	0
100	12	100	0	100	9	100	0	100	0	100	5	100	0
100	1	100	0	100	8	100	0	100	0	100	13	100	0
100	0	100	0	100	5	100	0	100	0	100	12	100	0
100	0	100	0	100	4	100	0	100	0	100	13	100	0
100	0	100	0	100	19	100	0	100	0	100	15	100	0
100	0	100	0	100	9	100	0	100	0	100	13	100	0
100	0	100	0	100	10	100	0	100	0	100	11	100	0
100	0	100	0	100	11	100	0	100	0	100	17	100	0
100	0	100	0	100	7	100	0	100	0	100	9	100	0
100	0	100	0	100	10	100	0	100	0	100	13	100	0
100	0	100	0	100	18	100	0	100	0	100	6	100	0
100	0	100	0	100	10	100	0	100	0	100	7	100	0
100	0	100	0	100	9	100	0	100	0	100	8	100	0
100	0	100	0	100	6	100	0	100	0	100	7	100	0
100	0	100	0	100	7	100	0	100	0	100	10	100	0
100	0	100	0	100	1	100	0	100	0	100	6	100	0
100	0	100	0	100	3	100	0	100	0	100	10	100	0
100	0	100	0	100	3	100	0	100	0	100	10	100	0
3000	1.73	3000	0	3000	8.63	3000	0	3000	0	3000	9.26	3000	0

PER CENT. OF SMUT IN DIFFERENT PLOTS—CONTINUED.

PLOT 15.		PLOT 16.		PLOT 17.		PLOT 18.		PLOT 19.		PLOT 20.		PLOT 21.	
Heads counted..	Smutted heads . ..	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....
100	0	100	13	100	1	100	1	100	1	100	5	100	0
100	0	100	2	100	1	100	12	100	2	100	8	100	0
100	0	100	2	100	0	100	21	100	2	100	6	100	0
100	0	100	12	100	1	100	15	100	3	100	8	100	0
100	0	100	6	100	1	100	16	100	4	100	11	100	0
100	0	100	13	100	1	100	6	100	2	100	6	100	0
100	0	100	11	100	0	100	9	100	2	100	16	100	0
100	0	100	22	100	0	100	11	100	2	100	13	100	0
100	0	100	8	100	0	100	17	100	1	100	8	100	0
100	0	100	9	100	3	100	8	100	1	100	15	100	0
100	0	100	4	100	0	100	12	100	2	100	13	100	0
100	0	100	8	100	0	100	13	100	1	100	11	100	0
100	0	100	7	100	2	100	11	100	9	100	7	100	0
100	0	100	20	100	1	100	21	100	1	100	9	100	0
100	0	100	5	100	0	100	9	100	5	100	5	100	0
100	0	100	5	100	4	100	11	100	1	100	15	100	0
100	0	100	5	100	0	100	14	100	2	100	11	100	0
100	0	100	7	100	0	100	17	100	1	100	13	100	0
100	0	100	3	100	0	100	15	100	2	100	9	100	0
8	0	100	13	100	0	100	5	100	2	100	10	100	0
		100	7	100	0	100	5	100	3	100	14	100	0
		100	9	100	0	100	15	100	1	100	9	100	0
		100	7	100	0	100	10	100	0	100	10	100	0
		100	11	100	1	100	18	100	2	100	17	100	0
		100	7	100	1	100	16	100	4	100	10	100	0
		100	6	100	1	100	3	100	2	100	5	100	0
		100	14	100	2	100	12	100	0	100	14	100	0
		100	3	100	0	100	5	100	3	100	17	100	0
		100	7	100	2	100	7	100	2	100	4	100	2
		100	6	100	0	100	5	100	2	100	8	18	0
1908	0	3000	8 4	3000	0.73	3000	11.33	3000	2.16	3000	10.23	2918	0.0006

PLOT 22.		PLOT 23.		PLOT 24.		PLOT 25.		PLOT 26.		PLOT 27.		PLOT 28.	
Heads counted..	Smutted heads	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....
100	15	100	2	100	10	100	5	100	11	100	10	100	6
100	15	100	9	100	6	100	10	100	5	100	3	100	13
100	5	100	6	100	8	100	3	100	9	100	6	100	20
100	6	100	6	100	11	100	8	100	8	100	3	100	12
100	8	100	14	100	10	100	3	100	11	100	4	100	4
100	18	100	8	100	14	100	3	100	10	100	8	100	7
100	9	100	10	100	7	100	10	100	7	100	3	100	12
100	10	100	13	100	.5	100	6	100	7	100	3	100	10
100	9	100	2	100	11	100	5	100	8	100	1	100	7
100	8	100	6	100	1	100	5	100	12	100	6	100	10
100	6	100	7	100	11	100	8	100	10	100	3	100	10
100	6	100	2	100	6	100	12	100	10	100	4	100	12
100	11	100	6	100	16	100	4	100	11	100	2	100	14
100	9	100	7	100	21	100	10	100	14	100	3	100	8
100	9	100	3	100	14	100	8	100	6	100	7	100	11
100	9	100	1	100	7	100	8	100	7	100	8	100	9
100	12	100	10	100	14	100	9	100	14	100	8	100	8
100	10	100	9	100	6	100	1	100	12	100	8	100	13
100	12	100	8	100	16	100	3	100	2	100	9	100	16
100	9	100	6	100	11	100	5	100	8	100	10	100	14
100	11	100	6	100	10	100	12	100	13	100	2	100	15
100	6	100	11	100	10	100	7	100	9	100	5	100	12
100	11	100	3	100	8	100	6	100	15	100	6	100	5
100	4	100	11	100	3	100	9	100	5	100	1	100	11
100	9	100	11	100	7	100	5	100	6	100	1	100	11
100	7	100	7	100	4	100	1	100	8	100	12	100	9
100	15	100	6	100	9	100	5	100	13	100	4	100	4
100	14	100	2	100	10	100	10	100	6	100	7	100	13
100	11	100	7	100	9	100	4	100	9	100	2	100	17
100	11	100	5	100	9	100	8	100	8	100	14	100	10
3000	9.83	3000	6.8	3000	9.46	3000	6.43	3000	9.13	3000	5.43	3000	10.76

PER CENT. OF SMUT IN DIFFERENT PLOTS—CONCLUDED.

PLOT 29.		PLOT 30.		PLOT 31.		PLOT 32.		PLOT 33.		PLOT 34.	
Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....	Heads counted..	Smutted heads.....
100	3	100	0	100	5	100	9	100	17	100	14
100	2	100	0	100	9	100	6	100	27	100	12
100	7	100	0	100	12	100	6	100	4	100	14
100	6	100	0	100	11	100	7	100	18	100	12
100	0	100	0	100	5	100	7	100	29	100	15
100	1	100	0	100	8	100	12	100	23	100	7
100	0	100	0	100	10	100	6	100	17	100	11
100	0	61	0	100	7	100	5	100	25	100	16
100	0			100	3	100	15	100	22	100	18
100	0			100	5	100	10	100	33	100	13
100	2			100	13	100	10	100	16	100	12
100	0			100	9	100	16	100	19	100	26
100	3			100	8	100	11	100	20	100	16
9	0			100	8	77	5	100	22	100	20
				100	7			100	16	100	12
				100	9			100	8	100	26
				100	9			100	24	100	17
				100	10			100	7	100	25
				100	10			100	25	100	17
				100	11			100	25	100	14
				100	11			100	13	100	12
				100	8			100	18	100	9
				100	11			100	19	100	13
				100	6			100	14	100	13
				100	5			100	7	100	17
				100	15			21	2	100	10
				100	8					100	8
				100	10					100	19
				100	20					100	4
				100	9					100	10
1309	1.70	761	0	3000	9.06	1377	9.07	2521	18.64	3000	14.4

A NEW FORM OF OAT SMUT.

(*Ustilago Avenæ* var. LEVIS.)

While investigating the oat smut, a curious form was noticed in a specimen from Shelburne, N. H., collected in August, 1882. (Ellis, N. A. F., No. 1091.) The spores were entirely smooth aud quite granular, supposed to be due to imperfect ripening of the spores. No further attention was given to it until specimens from Americus, Kansas, (collected by C. W. Coman, June 23, 1889,) which germinated with unusual vigor, were found to have these same smooth spores. The Manhattan specimens were then carefully examined, and among many hundred smutted heads four or five of this form were found. They showed the same vigorous germination as the Americus specimens. The only reference to different forms of oat smut found is by Jensen, who says[1]: “I would also add that some smutted ears of oats differ very considerably in their appearance from others, but I have not had the opportunity of investigating this question minutely.” Nothing is stated regarding the nature of the different forms, and it may perhaps be that Jensen had in view smut attacked by bacteria.

[1]Jensen. Prop. and Prev. of Sm., J. R. A. S. XXIV, SS. II, p. 11.

The following is the name used:

USTILAGO AVENæ (Persoon) Jensen, variety LEVIS Kellerman and Swingle, nov. var.

Injuries to Host Plant.

This form, from what has already been said, would seem to be rather rare. It is, however, hard to separate from the normal form. The outside membrane, covering the smutted spikeIets, seems somewhat more firm, and more persistent, and often the smutted spikelets have a quite marked grayish color, arising probably from the dark spores being seen through the light membrane.

Characters of the Smut.

The spores in mass are a very dark brownish, lacking any shade of olivaceous. They seem in the specimens somewhat darker than *Ustilago Avenæ,* but not so dark as *Ustilago Hordei.* They are of about the same size as in the typical form of oat smut, being 6-12x5½–8μ, mostly 6–9x6–7μ. In shape, also, they are nearly normal, being mostly oval, sometimes elliptical, or sub-globose, and sometimes angular, or irregular. The great peculiarity of the variety is, however, that the *epispore is smooth,* or at any rate not spiny, or punctate. Sometimes thicker portions appear, but they are slight, and not like the spines of the typical form. As usual, one side of the spore is lighter colored. The contents of the spore are quite often granular or guttate.

Germination in Water.

This has not been well investigated, but seems very much as in the usual form, except perhaps the promycelia are somewhat shorter.

Germination in Nutrient Solution. [1]

The germination seems uniformly to proceed with greater vigor than in the normal form. One striking feature which called our attention to the first culture made was the growth in the air. Already by 24 hours the surface of the liquid seemed mouldy, and later the whole surface became snowy white. This growth in the air was composed of long, slender branches or germ threads proceeding from the promycelium. Examination showed that the germination of this form varied from that of the species principally in the following points: (1) More of the spores germinated—often nearly all. (2) The promycelia remain attached; they never are detached in such large numbers, and those that do fall off do so mostly in old cultures. (3) The promycelia are shorter—17-45x2½-4μ, mostly 24–36x2½-3½μ, and also less angled at the knee-joints. (4) Conidia rather fewer. (5) Germ threads very abundant, and *often very narrow,* (1–¾μ.) These very narrow germ threads had apparently a very watery and vacuolate protoplasm, yet they grew to enormous length; larger germ tubes, as they progressed often became narrower.

[1] Modified Cohn solution. (See page 231.)

The exact importance of this variety is as yet little known. It is important that investigators be certain which they are observing or experimenting with. It maybe a distinct species, but some specimens seemed intermediate between the typical form and the variety.

THE LOOSE SMUT OF WHEAT, Ustilago Tritici (Persoon) Jensen.

HISTORICAL.

Until within a few years, the loose smut of wheat has been supposed to be the same as that of oats, or, at most, simply a variety of that species. In fact, all the loose smuts have long been known under the name *Ustilago segetum*. It was first included under the name *Ustilago,* by Tragus,[1] in 1552; Lobel soon after used the same name, and figured it[2]; and in 1570 again mentioned[3] it under the name Ustilago. In 1595, C. Bauhin described it under the name, *Ustilago secalina.* These authors, however did not recognize it as a fungus. This was first done by Linnæus and Bulliard, and the first distinctive name was applied to it by Persoon,[5] who called it *Uredo Tritici,* and considered it as a variety *b* of *Uredo segetum* (Bull.) Pers. DeCandolle[6] also named it as a variety of *Uredo carbo.* Philippar[7] called it *Uredo Carbo- Tritici.* Wallroth[8] named it *Erysibe vera b Tritici.* Tulasne[9] called it Ustilago Carbo *a vulgaris* a *Triticea.* None of these writers, however, noticed any difference in it from the loose smut growing on oats and barley, except that it grew on wheat. Jensen[10] in 1888 reported that wheat smut would infect only wheat plants, and gave the following results of his experiment with the spores of these smuts when applied to the bare kernels:

Spores from smutted wheat on wheat kernels gave 1 per cent. smutted heads; spores from smutted oats on wheat kernels gave no smutted heads; spores from smutted barley (covered smut) on wheat kernels gave no smutted heads. He also adds: "With regard to the variety of smut which occurs on wheat, it should be remarked that only one diseased plant was produced in the infection experiment quoted above. Now the germinative power of wheat-smut spores is much more feeble than of other varieties. I found that of last year's wheat-smut spores only one or two in a thousand germinated when examined this year, although they had been kept in a dry place all the winter. Further, wheat-smut spores produced this year (1888) germinated even more feebly, while with barley-smut and oat-smut spores the germinative faculty was more than a hundred times as great. This ac-

[1]Tragus, De stirpinm. Nomencl. prop. lib. III, p. 666, with figure, sec. F. v. Waldheim; lib. III, cap 34, sec. L. R, et Ch. Tulasne.
[2]Lobelius. Obs. plant, p.22, with figure, sec. L. R, et Ch. Tulasne and F. v. Waldheim.
[3]Lobelius et Pens stirpium adversarial nova. Londini, 1570, p. 11, sec. L. R. et Ch. Tulasne and F. v. Waldheim.
[4]C. Bauhin. Phytopinax. Basileæ, 1596, p. 52, sec. L. R. et Ch. Tulasne and F. v. Waldheim.
[5]Persoon. Synop. meth. fung. pars prima, p. 224.
[6]DeCandolle. Flora Francaise, VI, p. 76.
[7]Philippar. Traité sur la carie, etc., p. 92, pl. 4, ch. et R.
[8]Wallroth. F1. crypt. germ., p. 217, No. 1672.
[9]Tulasne. Sur les Ustilag. comp. aux les Ured., 1847, p. 80.
[10]J. L. Jensen. The Prop. and Prev. of Smut in oats and Barley, J. R. A. S., Vol. XXIV, S. S. Part II, p. 9.

cords with the well-known fact that wheat is less liable to be smutted than other kinds of corn. All this tends to show the distinctness of wheat smut from all the other varieties."

Plowright[1] notices the peculiar color of the spores, saying: "*U. segetum*, when it occurs in wheat has a distinctively golden luster, but when on *Avena elatior* it is sooty black. Physiological research will possibly show that these two forms are specifically distinct."

Brefeld considers wheat smut received from Dr. Kühn, from Halle, Germany, the same as the naked smut of barley.[2]

Fischer von Waldheim[3] notices the greater length of the promycelia of wheat smut, and says their disorganization followed earlier than in the forms on oats, barley, and Arrhenatherum avenaceum.

The following shows, as far as known, the synonomy of the species:

USTILAGO TRITICI (Persoon) Jensen.

1552 *Ustilago* Tragus, De stirp. Nomencl. pr. lib. III, p. 666. Lobelius, Obs. plant., p. 22; Stirp. adv. nov., p. 11. p.p.
1596 *Ustilago secalina* Bauhin, Phytopinax, p. 52.
1797 *Uredo segetum* Persoon, Disp, meth. fung., p. 56. p.p.
1801 *Uredo (Ustilago) segetum b Uredo Tritici* Persoon, Syn. meth. fung., p. 224.
1809 *Cœoma segetum* Link, Obs. I, p.4; Sp. pl. Willd. VI, II, p.1, No. 1. p.p.
1815 *Uredo carbo b Tritici* De Candolle, F1. fr. VI, p. 76.
1833 *Erysibe vera b Tritici* Wallroth, F1. crypt. germ. pars post., p. 217, No. 1672.
1837 *Uredo Carbo-Tritici* Philippar, Traité, p. 92, pl. IV.
1847 *Ustilago Carbo a vulgaris* a *Triticea* R. et Ch. Tulasne, Mém. sur les Ustilag. comp. aux les Ured. in Ann. sci. nat., 3 série, t. 7, p. 80.
1888 *Ustilago Hordei* Brefeld, Neue Unters. II in Nachr. aus d. Klub der Landw. zu Berl., Nr. 221, 28 Juni, 1888, S. 1593 *(Ustilago Hordei* Brefeld, l. c., Nr. 220, 8 Juni, 1888, S. 1581, foot-note). p.p.
1888 *Ustilago segetum* var. *Tritici* Jensen, Om Kornsorternes Brand. (Anden Meddelelse), S. 61.
1888 *Ustilago segetum* var. *Tritici* Jensen, Prop. and Prev. of Smut, in J. R. A. S. XXIV, s. s. Part II, p. 11.
1890 *Ustilago Tritici* Jensen, in letter dated Jan. 24, 1890.

INJURIES TO HOST PLANT.

The loose smut of wheat resembles oat smut and naked barley smut in converting the head attacked into a powdery mass of spores, which are then liberated with the greatest ease. There is almost always a considerable

[1]C. B. Plowright. British Ured. and Ust. 1889. p. 70.
[2]Brefeld, New. Unters, II, S. 1593. "Auch in diesen fand sich derselbe Pilz wie in der Gerste, die Sporen machten keine Conidien."
[3]F. v. Waldheim. Contr. to Biol. in Tr. N. Y. Ag. Soc. 1870. p.335.

amount of shreds and plates of tissue running through the spore mass. These remnants of the tissue of the flowering parts are more numerous and larger than in *Ustilago nuda* (covered barley smut). Very often these shreds preserve more or less of their natural color at the tip, and in bearded wheat sometimes the awns remain though somewhat stunted. This remaining tissue is plainly shown in Plate II, fig. 2. In more of the specimens examined was there any sign of an external membrane or covering as in the two barley smuts. In this respect, the smutted heads resemble those of oats. Almost always the whole head is smutted; but in Plate II, fig. 1 is represented a head (from Minnesota) which was smutted only at the base. The spores are completely free, and this species is perhaps the dustiest of all the loose smuts. A few spores remain clinging to or entangled among the fibers for a considerable time. The infected heads attain their normal height.

According to Bessey's observations,[1] unlike the oat smut, a stool or hill all grown from one seed may often produce both smutted and sound heads. The following table is prepared from his report; the observations were made in different years:

No. of stalks in hill.	No. smutted.	No. sound.
2	2	..
2	2	..
2	2	..
2	2	..
4	2	2
7	5	2
1	1	..
2	2	..
2	1	1
3	3	..
3	2	1
3	2	1
4	4	..
4	4	..
4	4	..
5	5	..
5	5	..
6	3	3
16	4	12
77	55	22

The amount of damage from this parasite is usually very small, and it is hence often overlooked. Mr. Erwin F. Smith, however, reports it from Michigan, and says: "Does more or less injury every year. I saw one field of five acres much injured (50 per cent.) in 1870."[2] It seems scarcely possible that the loose smut would ever be so abundant, and it may be that he had instead the stinking smut, which is sometimes even more destructive than that.

[1]Bulletin of the Iowa Ag. Coll Dept. Bot., 1884. Cedar Rapids, Iowa, pp. 123 and 124.
[2]Erwin F. Smith, in Rept. Dept. Agr. for 1886, (Myc. sect.,) p. 133.

GEOGRAPHICAL DISTRIBUTION.

The wheat smut occurs sparingly in wheat all over the world, in all probability, and hence no attempt is made to give its detailed distribution. Its small damage is probably the cause of its not being more generally recognized. It is said to attack summer wheats the most, winter wheats less, and least of all hard wheat and spelt.

CHARACTERS OF THE SMUT.

The loose wheat smut has free spores which have a dark or dusky brown color, with a distinct olivaceous tinge almost exactly like *Ustilago nuda.* This peculiar tinge of color in the spore, when seen in mass, serves to distinguish them from the black spores of *Ustilago Hordei.* The color of the spores varies only slightly in specimens from very different localities.

In shape the spores are rather regular, being less variable than in *Ustilago Avenæ.* They are, as in *Ustilago Avenæ* and *Ustilago nuda,* mostly oval, varying rather often to subglobose and less often to angular or elliptical. (See Plate VI.) Abnormal forms are very rare, though quite often the spores are slightly angular.

In size the spores are rather variable, more so than in *Ustilago nuda,* and less so than in *Ustilago Avenæ.* They are 5-8x4½-7μ, mostly 5½-7½x5-6μ. The variations in size are shown in the many figures on Plate VI. The wall is composed of two layers, the *endospore* within and the *epispore* without. The line of separation between the two without the use of reagents is hard to see; it is, however, shown in Plate VI, figs. 4, 26, and 35. In figs. 1, 13–17, 28, 29 and 33 the division between the two layers of the wall cannot be seen.

Character of the Spore Wall.

One side of the spore is always darker colored, and in most cases the difference between the two sides is considerable. This coloration is seen in all the figures of spores on Plate VI. In optical section, the combined epispore and endospore could in some cases be traced only on the dark side of the spore (Plate VI, figs. 6 and 29). In others, as in figs. 1, 13, 17, 28, and 37, the wall could be traced entirely around; it was, however, plainest, and sometimes apparently thickest, on the dark side, where the endospore and epispore could be distinguished in optical section. In such cases, the line of separation between the two layers is usually clearest on the light side, as figs. 26 and 35. Although the wall was, as has been just noted, in some cases difficult or impossible to see, by the use of reagents it was plainly shown to exist. The promycelium, as in all the other species, arises from this lighter-colored side of the spore. The epispore of this species is always clothed with spines, which are somewhat variable in size and distribution over the surface. They may in some cases be plainly seen on the edge of the spore, as is shown in Plate VI, figs. 14, 25, 26, 32, and others. In other instances they cannot be seen on the edge—only on the face of the spore which happens to be uppermost. There is, as in *Ustilago Avenæ and Ustilago* *nuda*, a space immediately surrounding the place where the promycelium will appear (of course on the light side), a small area where spines are wanting. The spore is only rarely split when it germinates, and the promycelium is at first usually constricted where it passes through the wall, though in older cultures it often expands. Spores in nutrient solution quite often swell up and crack, as is shown in fig. 19.

Action of Reagents.

In chloriodide of zinc a portion of the spore colored at once, the entire contents being stained reddish and the wall remaining unchanged, as in fig. 1. Others collapsed, but did not stain, as shown in figs. 2 and 3. At first this was supposed to furnish an indication of the per cent. of spores capable of germinating, since older specimens which would not germinate would not stain readily, while in fresh specimens many of the spores quickly became stained. To a certain extent this test may be a good one, but it was found that if the spores are left long enough in the chloriodide of zinc all would eventualy become stained. In chromic acid the spores were rapidly dissolved, and in a few minutes only the dark side of the spore remained, and this was gradually corroded.

GERMINATION IN WATER.

This species germinates somewhat slower than *Ustilago Avenæ* and *Ustilago Hordei.* By 15 hours some of the spores had sent out a promycelium to a considerable length (18–33μ) while other spores had just germinated. All these promycelia were continuous, and some of them considerably curved, even if short. From this point the growth was rapid; by 24 hours the promycelia had in many cases obtained their full size, 18–45x3–4½μ, and were nearly all 2-3 septate, and some even (faintly) 6–7 septate. These promycelia were, like those of *U. nuda,* always attached; sometimes vacant at base, and rarely in others places. Knee-joint fusions were quite often seen. There were some branches, especially from the base, which were usually short and rather thick. With this the growth of the promycelia practically ceased. The further changes were a slight growth of the branches, especially those from the base of the promycelium. The segments often became empty above and below, leaving one to several filled segments in the middle like the one shown in Plate VI, fig. 11. Then the segment in many cases swelled slightly (becoming 4-5½μ diam.) and became rounded and somewhat slightly enlarged at the septa. The knee-joint fusions also swelled somewhat, and were often bent at a considerable angle. With this, practically all growth ceased. A few fusions were seen of the slender tube branches, either with the segments of the same promycelium or of another. At no stage were any sporidia formed or free segments produced. It was noticed that in pure water the per cent. of germination was small; but in one case a small quantity of mucilage from the label was dissolved in the water and many more germinations were observed. The character of the growth was, however, practically the same as in pure water, except perhaps slightly more vigorous.

The noticeable facts regarding the germination of *Ustilago Tritici in* water are:

1. The general weakness and small amount of the growth as compared with the cultures in nutrient solution.
2. *All* the promycelia remain attached.
3. *No sporidia are formed nor segments freed.*
4. Total *absence of long growths from knee-joint fusions* (in fact in some instances a portion of the promycelium including a knee-joint fusion was vacant, the protoplasm having receded to the cell above and below); in this respect differing very markedly from *Ustilago nuda* (q. v.).

GERMINATION IN NUTRIENT SOLUTION.[1]

In the course of about 15 hours germination begins, and then progresses rapidly. At first the growth is as already described in water, but always more vigorous. Very soon in most cases branches arose from the segments near the septa, and rapidly grew forth. They remained thick, and soon became branched themselves. These branches are peculiar in being in most cases curved (in floating spores outward and downward). By 30 hours these branches are exceedingly numerous, and form a tangled mass difficult to trace. There are on the promycelia (which are by this time more elongated and 5–8 septate) a few knee-joints, and from these grow out long germ threads, 100–250μ long, empty at base (as are sometimes the knee-joints), and filled at tip. These are slender, being 2–2½μ in diam. in filled portion, and 1½–2μ in diam. in vacant basal portion. The filled tips are 80–110μ long. This is a peculiar and noticeable phenomenon of the growth, since the ordinary branches are yet crowded with contents and are commonly septate and repeatedly branched, while the germ thread grows from the same promycelium, and has a long vacant base. Not all the promycelia by 30 hours are so much branched, and some are as simple as those shown in Plate VI, fig. 14, which is from the same culture as figs. 17 and 35, but some are as much branched as the ones shown in Plate VI, figs. 17 and 35. Fig. 17 is a good figure, as it shows also somewhat of the curved growth so common. However, the branches themselves are often strongly curved. As growth progresses a difference is to be noticed between spores floating free from and those lying close to others. In two or three days, when free, the promycelium is still free to grow, and accordingly continues to produce blunt, short septate branches till the whole makes a very complicated mass often 150μ or more in diam., all crowded full of contents and much more intricate than shown in fig. 17. On the contrary, when united in a mass, the promycelia become empty or nearly so, as do also the branches at their bases. The branches now grow out into coarse germ threads 100 to perhaps 300μ or more long, with tips 75-110x2–3μ, and base 2½μ in diam.

[1] Modified Cohn solution.

These grow rapidly, and to a great length. They are just like the same threads already found growing from the knee-joint fuisions when the culture was 20 hours old, except they are coarser. As the culture becomes exhausted these germ tubes swell up somewhat, becoming 4–5µ diam. and shorter (25–50*µ* long). They may remain so or become septate, as is especially the case when by a contraction of the protoplasm the tip is almost empty. No sporidia are produced nor free segments, but by consulting fig. 17 it will be seen that by mechanical injury segments might easily be loosened.

The description above is of the germination obtained in very great vigor from specimens collected by J. M. Holzinger at Winona, Minnesota, July 15, 1889. The only other specimen of wheat smut on hand that could be induced to germinate was that issued in A Century of Illustrative Fungi, 1889, by Underwood and Cook, "No. 56, on wheat, Syracuse, N. Y., June, 1889." The germination was much less vigorous than from the Minnesota specimens, and was moreover somewhat different. The promycelia branched much less, and sent out after several days the slender branches shown in figs. 13 and 34. In a few cultures segments or sporidia were seen, and are figured in Plate VI, figs. 10, 12, 18, and 36; also a free promycelium(?), as shown in fig. 16. It may be that these conidia and segments were from such promycelia breaking to pieces, as the similarity of figs. 12 to 16 would seem to show, but more probably it was an impurity of some kind in the culture experiment, as many cultures made after the plate was sent to the engraver failed to show such growths.

Brefeld[1] considers wheat smut the same as naked barley smut, and says it produces no sporidia. It seems certain, however, that the forms investigated by us are distinct from *Ustilago nuda,* since in nearly every particular of growth they are different.

PREVENTION.

On this point little is recorded. Plowright says[2]: "There is a certain point in connection with the reproduction of smut *(U. segetum)* wherein it differs essentially from bunt *(T. Tritici);* it is this — that however carefully wheat may be dressed with cupric sulphate, arsenic, brine, lime, etc., while such dressing almost absolutely protects the crops from bunt, yet it has no appreciable effect on the smut. This fact is obvious to any one residing in an agricultural district. The wheats are dressed for bunt on every well-managed farm, but they are as much affected with smut as the barley and oat crops, which latter, never being affected with bunt, are never subjected to protective dressing."

It is, however, very probable that the form of treatment recommended for oats may be applied with similar results to wheat. It has been proved that such treatment will completely prevent the stinking smut *(Tilletia).*

[1] Brefeld. Neue Unters, II, Nachr. aus d. Kl. d. Landw. zu Berl., Nr. 221, S. 1593.
[2] C. B. Plowright. British Urediueæ and Ustilagiueæ, p. 102.

THE COVERED BARLEY SMUT, Ustilago Hordei (Persoon) Kellerman and Swingle.

HISTORICAL.

The first writer to separate the smut of barley from that of oats was Lobelius, who, in 1591,[1] referred the forms on barley to *Ustilago Polystichi* and *U. Hordei distychi.* There is no means of knowing whether he included one or both of the barley smuts under these names. Bauhin, in 1596,[2] also separated barley from oat smut, calling the former *Ustilago hordeacea;* nothing further is known of this. Other writers included this with the other loose smuts till Tessier,[3] according to Persoon,[4] notices this smut; but Persoon, in 1801,[4] was the first to give a recognizable description of it. He has it *Uredo (Ustilago) segetum a Uredo Hordei,* "pseudoperidio subelliptico, rugulosa, pulvere latente"; or, spore cases sub-elliptical, slightly wrinkled, powder *hiding.* This reference to the powder as latente (hiding) would seem to make it certain that he had the covered barley smut. After Persoon many writers copied his varietal names, without adding anything. Tulasne in 1847[5] called the smut of barley *Ustilago Carbo a vulgaris* c *Hordeacea.* Jensen in 1888[6] was the first writer to clearly separate this form from the other on barley, under the name *Ustilago segetum* var. *tecta,* and also *Ustilago segetum* var. *hordei tecta.* In Le charbon des céréales, published in 1889, he calls it *Ustilago hordei* var. *tecta* (Jensen). In a recent letter he recognizes it as a species, calling it *Ustilago tecta hordei* Jensen. The law of priority, however, compels the use of the earliest name, so the principal synonomy will be as given below. It is, however, nearly all doubtful, since almost all the writers confused *Ust. Hordei* with *Ust. nuda.*

USTILAGO HORDEI (Persoon) Kellerman & Swingle.

1552 *Ustilago* Tragus, De stirp. Noreen. pr., lib. III, p. 666.
1591 *Ustilago Polystichi* Lobelius, Icon., p. 36. p. p. ?
1591 Ustilago *Hordei distychi* Lobelius, Icon., p. 29, with figure. p. p. ?
1596 *Ustilago hordeacea* C. Bauhin Phytop. lib. I, Sec. IV, p. 52. p. p. ?
1767 *Chaos Ustilago* Linné, Syst. nat., Ed. XIII, II, p. 1472 p. p.
1791 (?) *Reticularia Ustilago* Linné, Syst. nat., Ed. XIII, II, p. 1472. p. p.
1791 *Reticularia segetum* Bulliard, Hist. des champ., I, p. 90, tab. 472, lit. E. G. H. I. K. L. M. p. p.
1801 *Uredo (Ustilago) segetum a Uredo Hordei* Persoon, Syn. meth. fung., p. 224.
1809 *Cæoma segetum* Link, Obs., I, p. 4; Sp. pl. Willd., VI, II, p. 1, No. 1. p. p.
1813 *Ustilago segetum* [Bulliard] Dittmar, in Sturm Deutschl. Fl., Bd. III, Heft 3, S. 67, T. 33, and of various authors. p. p.

[1]Lobelius. Icones stirpium, p. 36.
[2]Baubin. Phytopinax, p. 52.
[3]Tessier. Traité sur les mal., p. 306, f. 2–4, and p. 336.
[4]Persoon. Synopsis method. fungorum, p. 224.
[5]L. R. et Ch. Tulasne. Mém. 1847, p. 80.
[6]Jensen. Om. Kornsorternes Brand., S.56, *et seq.;* Prop, and Prev. of Smut, p. 10.

1815 *Uredo carbo a Hordei* DeCandolle, Fl. fr., VI, p. 76. p. p. ?
1833 *Erysibe vera a Hordei* Wallroth, Fl. crypt. Germ. pars. post., p.217, No. 1672. p. p.?
1837 *Uredo Carbo-Hordei* Philippar Traité, p. 92, pl. 3. p. p. ?
1847 *Ustilago Carbo a vulgaris c Hordeacea* L. R. et Ch. Tulasne Mém. s. 1. Ust. comp. aux Ured. in Ann. sci. nat. 3 Série t. 7, p. 80, p. p. *Ustilago Carbo* of authors in part.
1856 (?) *Ustilago segetum b Hordei* Rabenhorst, Klotzchii herb. viv. myc., Ed. nova, Cent. 3, No. 397. p. p.?
1888 *Ustilago segetum* var. *Hordii* f. *tecta.* Jensen, Om Kornsortenes Brand. S. 61.
1888 *Ustilago segetum* var. *tecta* Jensen, Prop. and Prev. of Sm. in J. R. A. S. XXIV s. s. p. 10; Plowright Br. Ured. and Ust. p. 274.
1888 *Ustilago Hordei* (Rabenhorst) Lagerheim, Revision der im Exsiccat "Kryptogamen Badens von Jack, Leiner und Stizenberger" enthaltenen Chytridiaceen, Peronosporeen, Ustilagineen und Uredineen, S. 2, Nr. 41. p. p.?
1888 *Ustilago segetum* var. *hordei tecta* Jensen, Prop. and Prev. of Sm. 1. c. p. 11.
1889 *Ustilago hordei* v. *tecta* Jensen, Le charbon des céréa1es, p. 4.
1890 *Ustilago tecta hordei* Jensen, in letter dated January 24, 1890.

NATURE OF INJURIES TO HOST PLANT.

The covered barley smut differs from all the other loose smuts in that the attacked panicle is not at once converted into a powdery mass by the escape of the smut, but the smut remains more or less completely inclosed by a membrane. This membrane consists of more or less of the outer-surface tissue of the attacked glumes, palets, etc., of the diseased flower. It is not, as in case of the stinking smut of wheat, simply the enter coat of the transformed seed, but a membrane composed of the outer layer of the many firmly united floral parts. It is usually confined to the bases of these parts, and consequently the awns are sometimes as long as in normal spikelets. Sometimes, however, they are much stunted, and often some of the smaller floral parts are smutted to the extreme tip. The membrane surrounding this smut is not nearly as fragile as in case of the open barley smut or the loose smut of wheat and oats. It keeps the smut intact for some time, and finally allows it to escape through rents and fissure; in the membrane. (See Plate II, figs. 3–6.) Figure 6 shows a specimen in which the tips of the floral parts were apparently sound, though somewhat distorted. They were however smutted at the base. The inside of the diseased spikelets is by no means a simple powdery mass of spores. In every specimen examined (from eight widely-separated localities) the interior of these diseased spikelets was occupied more or less by thin plates and shreds of unsmutted tissue. These plates and shreds are variously connected, and in some cases are so firm that a section can be easily cut through the whole spikelet without previous preparation of any kind. The spores themselves do not readily fall to powder, and seem more or less firmly glued together. This more or less rigid strengthening of the smutted spikelet and firm mass of spores prevent very effectually their rapid escape.

GEOGRAPHICAL DISTRIBUTION.

Persoon in naming *Uredo Hordei* says nothing of its distribution or hosts.

Jensen reports it as being less abundant in Denmark than the naked barley smut.[1]

Plowright says[2]: "*Tecta* [Ustilago Hordei] has been found in the island of Iona, but it doubtless occurs all over Britain."

Beyond this we know of no record of its existence.

Our European specimens are as follows:

(1) On *Hordeum vulgare,* Franconia, Bayreuth. Ex herb de Thümen, June, 1874. A few specimens mixed with more abundant *Ust. nuda.*

(2) On *Hordeum vulgare,* Halm, Sweden. Eriksson, Fungi parasitici Scandinavici, No. 2, August 2, 1881.

(3) On barley, Denmark. J. L. Jensen, 1889.

The following are from the United States and Canada:

(4) On *Hordeum vulgare,* Shelburne, New Hampshire. Dr. W. G. Farlow, in Ellis's North American Fungi, No. 1091, August, 1882.

(5) On cultivated barley, Dearborn county (near Sparta), Indiana. H. S. Bolley, June 19,1888.

(6) On barley, Eaton county, Michigan. W. J. Beal, June 6, 1889. A few specimens, with several of *Ustilago* nuda.

(7) On *Hordeum vulgare* (?), Manhattan, Kansas, June 27,1889. Kellerman & Swingle, No, 1933.

(8) On *Hordeum*, Sevey, St. Lawrence county, New York, July, 1889. Chas. Peck.

(9) On *Hordeum*, Ottawa, Canada, July 10, 1889. Jas. Fletcher.

(10) On *Hordeum*, Orono, Maine, 1889. Prof. F. L. Harvey.

In two instances (Nos. 1 and 6) it occurred as an admixture with *Ustilago* nuda. The smutted heads were, however, easily distinguished, and were all either one or the other,

Since so little was known in this country regarding the distribution of the barley smuts, requests for specimens and notes were sent to many mycologists of the United States and Canada. Most of these sent specimens and reported that they had seen only one form, and none had noticed both forms. In many States no specimen could be obtained, there being, as in Kansas, very little barley raised.

Prof. E. S. Goff, of Wisconsin, reports[3] that barley smut is sometimes very destructive — "sometimes the damage amounts to nearly one-fourth of the whole crop." Prof. W. J. Beal says[3]: "The smut was very bad in this State

[1] Jensen. Prop, and Prev. of Smut in Oats and Barley, l. c., p. 10, and letter of Jan. 24,1890.
[2] Plowright. Br. Ured. and Ustil., p. 274.
[3] In letter, 1890.

[Michigan] last year on wheat, barley, and oats, and especially on the last." Only two smutted heads of barley were found in the small plat on the College farm at Manhattan, Kansas, this year, and both were U. *Hordei.*

CHARACTERS OF THE SMUT.

This smut is readily characterized by the dark color of its spores when compared with the open smut of barley, or the loose smut of wheat and oats. The spores in mass seem *perfectly black;* rarely in some specimens, the color is a very dark brown. It never has *any* shade of olivaceous, and seems more like *U. Avenæ* than *U. nuda* or *U. Tritici* in color. It is, however always darker than oat smut.

In shape also the spores of this species are well marked. They are almost exactly spherical, and only rarely approach the oval form so common in the other three species. The spores are, however, often very slightly angular; rarely they have a small outgrowth (Plate VII, fig. 20); and still more rarely the spores are double (Plate VII, fig. 35). The usual forms may be easily seen by inspecting Plate VII. In size the spores vary less; they are 5–8x5-7μ (mostly 6–8x6–7,μ), being appreciably larger than those of *Ustilago nuda.*

Character of the Spore Wall.

The wall is as in other species composed of two layers, the epispore and endospore. They are, however, not well defined, and often the line between them cannot be seen at all. The compared thickness of the two layers is from 1μ to 2μ, or rarely somewhat more.

As in the other species, one side of the spore is darker, and often has a thicker epispore (Plate VII, figs. 47 and 48, also figs. 40, 41). The coloration is peculiar in that it is often very dark over the greater portion of the spore, and quite light in one area. In many instances there are two such light areas; in this case one is always larger and lighter than the other. The spore appears to have dark sides, and a dark band across the middle. This is faintly shown in Plate VII, figs. 19, 25, and 40. More than the usual number of spores in this species germinated twice, and in such cases the second germ tube came out of the smaller light area. (See Plate VII, fig. 25.)

Epispore Perfectly Smooth.

The epispore of this species is different from those of the other three species in being *always perfectly smooth.* This character alone is sufficient to distinguish at a glance the two barley smuts, since *Ustilago nuda* has a spiny epispore.

The spores do not seem to separate into a powder as readily as do those of the other loose smuts under consideration, and in some cases constitute a somewhat firm mass inside the diseased spikelet. This again hinders the escape of the spores.

With reagents the spores behave much as those of *Ustilago nuda, Tritiei*, and *Avenæ*. Chromic acid soon dissolves them, beginning at the lightest side. Nitric acid causes them to swell and become lighter colored. (See Plate VII, fig. 41.) In chloriodide of zinc the endochrome is readily colored and the wall somewhat decolorized. (See Plate VII, fig. 40.)

GERMINATION IN WATER.

After remaining a few hours in water the spores sent out one, or rarely two, blunt hyaline tubes from the lightest-colored portion. When two tubes were sent out they usually arose from opposite light areas of the spore. At first this tube was narrow (usually about 2–3μ) and short; it, however, rapidly elongated, and became thicker either close to the spore or gradually — in the latter case the promycelium was club-shaped. The ends often became pointed where they produced sporules. By 24 hours, if the spores were of last year's growth (the investigation was made during February and March, 1890,) nearly every spore had germinated, and the promycelia had attained a length of 15-40μF—or even as much as 50μ. when exceptionally slender or when the promycelium had itself sent out a tube, as will be described later. The most usual length was 18–26μ; in width they ranged from 2 $^1/_2$-4μ. During these 24 hours the promycelium had become septate, either once or twice in most cases. Many sporidia had been formed, both from the sides of the promycelium, usually just below a septum, and also in many cases from the tip. These sporidia were rather abundant, but fell off almost as soon as formed, so that very few were seen in situ, although in rare instances they remained attached while they themselves budded, producing secondary sporidia of about the same size. The sporidia were narrow, cylindrical to sub-oval in shape, usually about 5 $^1/_2$–7x2–3μ, very rarely as much as 12μ long, being more regular in size and shape and smaller (especially narrower) than the sporidia produced in nutrient solution. The detached sporidia often budded, producing a secondary sporidium of about equal size. In a few cases sporidia sent out short germ tubes, and in a very few instances conidia lying not far apart were united by fusion of the germ tubes. The promycelia in very many cases became detached from the spore during the first 24 hours. They seemed to break off just at the spore, and often had a short hyaline cell attached at this end, since even in attached promycelia the protoplasm often recedes, leaving a vacant space at the base. The detached promycelia were somewhat variable. In the Canada specimens they were blunt and soon fell to pieces, vacant cells rarely being attached to filled ones. In the course of two to three days they became considerably swollen (as much as 5–6 $^1/_2\mu$), and at the septa, (where the original attached promycelia were slightly constricted), now became deeply constricted, the two adjacent cells often being swollen and rounded at the ends, causing them to be of a dumb-bell shape from the gradual narrowing towards the middle. Knee-joints were common. In Denmark specimens the detached promycelia differed from these principally in not falling to pieces so readily, the promycelia usually remaining entire, hyaline cells and all; in being narrower, and in showing more buckle-joint and other fusions. The

Manhattan specimens were intermediate between those from Canada and Denmark, as were those from Maine. The detached promycelia were in all cases so abundant as to perceptibly whiten the drop of water at the bottom of the concavity in the slides used. The attached promycelia exhibited the same swelling at the joints, and greater or less degree of coherence of the segments the same as the more numerous detached promycelia. Curious fusions and abnormal growths were, however, more common. Quite often a slender tube arose from the spore just at the base of the promycelium. This tube was always more slender than the main promycelia, and was almost always continuous. It very often united with some of the upper segments of the promycelia in fusion, and in Plate VII, fig. 43, has fused with two of the cells. The intermediate joints were sometimes connected by knee-joint fusions, making a double fusion, as is described by Brefeld.[1] In fact these slender tubes were very much like those described by him as found in *Ustilago Avenœ*. They were sometimes fused with other promycelia, as is seen in the fine specimen represented in Plate VII, fig. 45, and sometimes grew straight out, not fusing at all.

In general, fusions were rather abundant, and knee-joint fusions between adjacent cells were extremely so. A curious case of attempted fusion was seen in a number of instances where two adjacent cells grew out almost as for knee-joints, but, instead of fusing, both grew to considerable length, remaining appressed to each other the whole distance. In these cases the end of the double tube was often curved, or even uncinate. In some cases the attached promycelia, or some of the cells of detached ones, send out a tube of smaller diameter ($^3/_4$-2μ). These tubes were usually short, and often curving somewhat in their course. They were sometimes pointed, and rarely bore on the end a sporidium. In some cases many of the sporidia were produced on the ends of slender tubes, which were, however, short. A curious form was one sometimes seen, in which the promycelium is very short (4 to 6μ) though of the usual diameter, and bears a thread-like, acute spicule, which, as far as seen, was sterile. Similar ones were seen in *Ustilago Avenœ* which had germinated in place in old heads.

After being three or four days in water, at a temperature of 23° or 27° C., all growth ceased, and the culture remained dormant until the water evaporated, or it was invaded with bacteria which gradually increased until they destroyed it.

GERMINATION IN NUTRIENT SOLUTION.

The first stages of germination in the nutrient solution (modified Cohn sol.*) are very similar to that in water. Promycelia are sent out from the pale side of the spore, or, rarely, from two pale areas, and are at first short

[1] Brefeld. Bot. Unters. üb. Hefenpilze. V. Hefte, S. 56.

* This is Cohn's solution (with the addition of sugar):

Water (distilled) . . . .41 7 grammes. Potassium phosphate... .125 grammes.
Sugar (granulated) . . . . 7.5 grammes. Magnesium sulphate . . . . . . .125 grammes.
Ammonium Tartarate. . . . .25 grammes. Calcium phosphate. . .125 grammes.

The solution has a sediment, which, however, settles, leaving it clear. It was sterilized by discontinuous heating in steam sterilizer.

and simple. Soon they become septate, the division wall nearest the tip appearing first, and finally one or two nearer the base. About this time sporidia begin to be produced from the end of the promycelia, and also from their sides at the septa. (See Plate VII, fig. 42.) These sporidia are much like those produced in water-cultures, but are slightly wider and larger, and much more abundant. By 24 hours nearly every spore has germinated, and the promycelia are about as long as they ever become when grown in water. They differ from those grown in water-cultures in being thicker and more vigorous. Knee-joint fusions are common in some cultures by this time, but no other kind are seen. Many of the promycelia have become detached, and sink, while on the surface some few grow into the air and produce sporidia there (from the end, at least). The size and shape of the promycelia vary according to the locality from which the specimens were obtained. Those from Canada produced short (23–26x3–3 1/2μ) promycelia, which were nearly straight. The Maine specimens produced longer (25–37x3-5μ), more vigorous promycelia, which were often bent, or angled, especially at the base, The Denmark specimens were similar to those from Maine, while the Manhattan, Kas., and New York specimens were intermediate between the Canada and Maine specimens. These differences were, however, only as to details, and in general all were much alike.

Thus far, the cultures in nutrient solution were much like those in water, the difference being that the promycelia were more vigorous, wider, and the sporules more abundant and budding more profusely.

Instead of now growing less and less, and finally ceasing growth and becoming dormant, as the water-cultures do after two to four days, the growth in nutrient solution increases in vigor till the nourishment begins to fail. By 48-72 hours the promycelia and sporidia in all cultures had changed very much. The liquid on the slides was now white with the growth of promycelia and sporidia. Examination shows that the promycelia had branched and become many-septate, or in many cases had fallen to pieces more or less from every septum, and end cells arise, which, according to circumstances, may fall off, and would then be sporidia, or remain fast and grow or bud, and be called branches. (See Plate VII, fig. 48.) The promycelia of spores from different localities now differ still more. Those from Maine were remarkably long (as much as 200-350μ), and the spores floating on the surface of the drop were united firmly by the long, entangled growth. Branches were numerous, and sporules present in myriads. When the promycelia were separate from those of other spores, they were much-branched in all directions, and many-septate in all parts. When growing in dense mats, the course of the promycelia could not be clearly seen; but those near the edge grew out from the mass, and from some of them arose germ threads, 2–2 1/2μ. in diameter and as much as 200-300μ long, which were vacant and many-septate for a considerable distance at the base, but were filled and less septate above. These threads were similar to those found in *Ustilago Avenæ*, but were wider and shorter. Rarely, sporules arose from the septa of these germ threads. The very numerous detached sporidia reproduced very freely by budding, and were mostly of an oval, or even sub-globose shape, like those shown in Plate VII, figs. 2, 7, 15, 28, etc. All of the segments were still active in most cases, and although those at the base of the promycelium were large, scarcely any were abruptly swollen.

The New York specimens differed much from those from Maine in having very much less branched and less vigorous promycelia. The promycelia were about 25–125x2–7μ, and were, when detached, very much broken up into the separate segments. Those attached broke up less, but still were at best but loosely connected. The segments of both attached and detached promycelia were in part swollen, and in part narrow and unhealthy. Both free segments and sporidia were abundant, and both budded freely.

The Manhattan (Kansas) specimens were still shorter, the promycelia being mostly 25–50x4–7μ, rarely 100μ, long. They were much disintegrated, but some were entire and much-branched. In a few of these, slender germ threads, like those in the Maine specimens, were seen, but much shorter and apparently unhealthy, since there was a small vacant space on either side of each septum, while the protoplasm was present in every cell. The swollen cells were numerous, and, conversely, the slender, dying ones still more abundant. The detached sporidia and segments budded, but the sporules were in these specimens slender, and not short and oval.

The Canada specimens were much like those from Manhattan, but produced sporules only scantily.

In general this species is characterized by producing, when the nutrient fluid approaches exhaustion, certain *swollen segments* or groups of segments *which alone live.* These can be seen in Plate VII, figs. 17, 22, 23, 29, 31, 48, &c. They are not so large in any other loose smut of cereals, and are really resting cell. As the cultures become older these swollen cells are more abundant, and they increase in size till all growth ceases. Sometimes they are single, as Plate VII, fig. 22; sometimes consist of almost the entire promycelium, Plate VII, fig. 46. More often, however, they are certain cells in the promycelium to which the other dead empty segments remain attached, as in Plate VII, figs. 29 and 31. The sporules also by growing and rounding obtain much this form, but are often smaller. If now from an exhausted culture containing such resting cells a new culture be started, these cells bud or sprout at once. Usually they produce sporidia by budding, and often these sporidia while attached produce secondary sporidia by budding themselves. Such may be seen in Plate VII, figs. 17, 31, and 53. Others send out germ tubes which usually are short. These are shown in Plate VII, figs. 24, 31, and 58.

The sporidia of this species grown in nutrient solution vary very much in shape and size. They are usually oval, occasionally sub-globose, and vary to narrow cylindrical. In size they are about 5–11½x3–4½μ, mostly 6–8½x 3-4μ. They may be seen in Plate VII, figs. 1–15, and others.

Fusions, aside from knee- join fusions between adjacent cells, are uncommon—much rarer than in water cultures. The knee-joint fusions are numerous, and appear within the first 24 hours. They open up when the cells become swollen, as in Plate VII, fig. 46, and very often send out branches, Plate VII, figs. 16 and 48. No such variation, consisting of parallel tubes, as was found in water culture was seen. Other fusions are represented in Plate VII, figs. 50 and 52. Sporidia rarely fused.

After remaining in nutrient solution some time the spores often opened widely where the promycelium was attached and the portion within the cell apparently grew out. An example of this is seen in Plate VII, fig. 30. In such cases the cell-wall appeared to be dissolved, being very thin on the edges.

In germinations either in water or in nutrient solution, the exact course of the promycelium through the wall was hard to trace; it was, however, apparently at first always a small round hole, as is seen in fig. 16, from the inside of the spore, and in figs. 47 and 48 in optical section. From these it would seem that there is a definite pore in the light portion of the space rather than a rent, or perhaps the growing promycelia dissolves the cell-wall away. This last is rendered probable by the further solution of the wall, as is shown in Plate VII, fig. 30.

MANNER OF INFECTION OF HOST PLANT.

On this point very little is known. Jensen[1] says spores of covered smut "adhering externally to the barley kernels will propagate the smut. In this respect it is different from all the other loose smuts, and resembles the stinking smut of wheat." It is, however, according to Jensen, much less infectious. It spreads only slowly to an adjacent field, because the spores, being inclosed more or less, are not blown about by the wind.

METHODS OF PREVENTION.

According to Jensen, the loose smut is readily killed, either by treating the seed with copper sulphate or in hot water. The more common *Ustilago nuda* (naked barley smut) is, however, less easily prevented, and the methods of treating will be given under the description of that species. Of course the longer soaking required to prevent that species also prevents this completely.

It is, however, necessary to notice that this species is capable of infecting grains of barley to which it adheres, and hence the treated barley must be carefully protected from all contact with the smut.

THE NAKED BARLEY SMUT. — Ustilago nuda (Jensen) Kellerman & Swingle.

Until very recently the naked barley smut has been confused with the covered barley smut, or at any rate not carefully separated from it. Its early history is therefore the same as already given for *Ustilago Hordei*.

[1] J. L. Jensen, letter of Jan. 24, 1890.

(See p. 268.) It cannot, however, be the *Uredo Hordei* of Persoon, and from the figure is probably not *Ustilago Carbo a vulgaris c Hordeacea* of Tulasne.[1] Jensen in 1888[2] clearly separated this species from the covered barley smut. He recognized then only a varietal difference. He then uses the names *Ustilago segetum* var. *nuda,* and also *Ustilago segetum* var. *hordei nuda.* In Plowright's "British Ured. and Ust." the name is given as var. *nuda.* Recently, in a letter, he considers it as a species—*Ustilago nuda hordei.* He separated it from the covered smut by its light, olivaceous color, smaller spores, and loose character of smutted head. From other smuts it is distinguished in being unable to infect other plants than barley.

Brefeld, in a lecture delivered Jan. 28,1888,[3] describes the germination of barley smut, and evidently had this species, since he found slender threads but no sporidia.

He calls it *Utilago Hordei* Bref. He states that it retains its germinative power only a single year, while that of oats retains it more than six years. He also states that the dissimilar germination of loose smut, sometimes with and again without sporidia, has long been known.

He experimented by artificially infecting oats and barley with sporidia of oat smut obtained by growing the spores in nutrient solution. In these nine experiments, made in various manners, in every case the barley plants remained *entirely sound,* while the oat plants were in some cases as much as 40–46 per cent. smutted. These experiments showed conclusively that the oat smut was incapable of infecting the barley. According to J. P. Petersen,[4] Rostrup, in commenting on a paper by Jensen, communicated that in his germinating experiments there was a very material difference between the two kinds of barley smut: the covered barley smut develops sporidia, whereas the naked barley smut, in contradistinction from all other known forms of smut, does not form sporida, and therefore grows directly into the germinating plants.

The following synonymy includes nearly all the names applied to barley smut, but since *Ust. nuda* has been constantly confused with *Ust. Hordei* it is somewhat doubtful:

USTILAGO NUDA, (Jensen) Kellerman & Swingle.

1552 *Ustilago* Tragus, De stirp. nomen. pr., lib. III, p. 666, with figure. p. p.
1591 *Ustilago Polystichi* Lobelius, Icones, p. 36. p. p. (?)
1591 *Ustilago Hordei distychi* Lobelius, Icones, p. 36, with figure. p. p. (?)
1596 *Ustilago hordeacea C.* Bauhin, Phytop. lib. I, sec. IV, p. 52. p. p. (?)
1767 *Chaos Ustilago* Linné, Syst. nat., ed. XII, II, p. 1356. p. p.

1 R. et Ch. Tulasne. Sur les Ured. comp. aux les Ustil., 1847, p. 15.
2 J. L. Jensen. Om Kornsorternes Brand., S. 56, *et seq.;* Prop. and Prev. of Smut, p. 10.
3 Brefeld. Neue Unters. II., Nachr. der K1, Nr. 221, S. 1592 und 1598.
4 J. P. Petersen. Nye Forsög over Brand i Vaarsæden, in Landmand's Blade. Ugeskrift for Agerdyrkning, Kvægavlog Mælkeridrift. Udgivet of J. P. Petersen, 22 Aargang, Nr. 35, Den 31 August, 1889, S. 589, "Docent *Rostrup* meddelte derhos, at han ved Spirings forsög havde godtgjort, at der fandtes den meget væsentlige Forskjel mellem de to Brandarter, at dækket Bygbrand af sin Forkim udvikler Sporidier, hvorimod nogen Bygbrand i Modsætning til alle andre i saa Henseende kjendte Brandarter ikke danner Sporidier, og altsaa umiddelbart spirer ind i Kimplanten."

1791 (?) *Reticularia Ustilago* Linné, Syst. nat., ed. XIII, II, p. 1472. p.p.
1791 *Reticularia segetum* Bulliard, Hist. des champ., I, p. 90, tab. 472, lit. E. G. H. I. K. L. M. p. p. (?)
1809 Cæoma segetum Link, Obs. I, p. 4; Sp. pl, Wind., VI, II, p. 1, No. 1. p. p.
1813 *Ustilago segetum* [Bulliard] Dittmar, in Sturm, Deutschl. F1., Bd. III, Heft 3, S. 67, T. 33, and of various authors. p. p.
1815 *Uredo carbo a Hordei* DeCandolle, Fl. fr., VI, p. 76. pp. (?)
1833 *Erysibe vera a Hordei* Wallroth, F1. crypt. Germ. pars. post., p. 217, No. 1672. pp. (?)
1837 *Uredo Carbo-Hordei* Philippar, Traité, p. 92, pl. 3. p. p. (?)
1847 *Ustilago Carbo a* vulgaris c *Hordeacea* L. R. et Ch. Tulasne, Mém, sur les Ust. comp. aux les Ured. in Ann. sci. nat. 3 Série, t. 7, p. 80. p. p. (?) *Ustilago Carbo* of authors in part.
1856 (?) *Ustilago segetum b Hordei* Rabenhorst, Klotzchii, Herb. viv. myc. ed. nova, Cent. III, No. 397. p. p. (?)
1888 *Ustilago Hordei* Brefeld, Neue Unters üb. d. Brandp. u. Brandkrankh. II, in Nachr. aus d. K1. d. Landw., zu Berl., Nr. 221, 28 Juni, 1888, S. 1593. p. p.
1888 *Ustilago segetum* var. *Hordii* f *nuda* Jensen, Om Kornsorternes Brand., S. 61.
1888 *Ustilago segetum* var. *nuda* Jensen, Prop. and Prev. of Sm., in J. R. A. S. XXIV s. s., P. II, p. 10; Plowright, Br. Ured. and Ust., p. 274.
1888 *Ustilago segetum* var. *hordei* nuda Jensen, Prop. and Prev. of Sm., 1. c., p. 11.
1888 *Ustilago Hordei* (Rabenhorst) Lagerheim, Revision der in Exsiccat " Kryptogamen Badens von Jack, Leiner und Stizenberger," enthalten Chytridiaceen, Peronosporeen, Ustilagineen und Uredineen. S. 2, nr. 41. p. p. (?)
1889 *Ustilago hordei* v. *nuda* Jensen, Le charbon des céréales, p. 4.
1890 *Ustilago nuda hordei* Jensen, in letter dated Jan. 24, 1890.

INJURIES TO THE HOST PLANT.

The naked barley smut resembles oat smut and loose smut of wheat in that the attacked panicles are converted into a loose, powdery mass of spores, held together only by a few shreds of tissue, and readily blown about by the wind. It differs very materially from the closed barley smut in this particular. It is, like that species, covered with a membrane, which, however, is much thinner than in *Ustilago Hordei,* and consists apparently of the outer walls of the modified epidermal cells. Usually all, or nearly all of the floral parts are converted into the smut, only rarely being like *Ustilago Hordei* in having the tips of the floral parts sound. The awns are quit often intact, but are almost always stunted. (See Plate II, figs. 7–11. The coalesced floral parts, while yet covered by their membrane, are of a dark, dull-grayish color much darker than *U. Hordei*). The envelope ruptures very easily in any direction, and allows the loose spores to fall out. Through the spore masses run some plates, or ribbons, of host tissue, which usually remain till nearly all the spores have fallen. Some of the papery outer membrane usually remains attached to these fibers until eventually both fibers and membrane are weathered away, and the formerly smutted head has more or less the appearance shown in Plate II, fig. 8. The reason, that not withstanding the presence of fibers and a thin enveloping membrane, this species sheds its spores very readily and seems wholly different from typical *Ustilago Hordei*, **is, we** think, found in the fact that the spores are completely free, and do not adhere to each other or to the shreds of the host tissue. The infected heads, unlike those of *Ust. Hordei*, grow to their normal height, and do not tend to remain inclosed by the uppermost sheath of the barley plant.

AMOUNT OF INJURIES.

Jensen[1] gives the following table showing the amount of smut in fields in various parts of Denmark:

SMUT IN BARLEY FIELDS.

No.	LOCALITY.	Per cent. of naked smut.	Per cent. of covered smut.	Per cent. of both.
1	Field at Fyen	1.1	0.2	1.3
2	" " "	3.6	1.1	4.7
3	" " "	5.3	2.7	8.0
4	" " "	0.9	0.1	1.0
5	" " "	3.1	2.4	5.5
6	" " "	0.2	0.3	0.5
7	" " "	0.4	0.0	0.4
8	Field in Aarhusegnen	0.1	17.6	17.7
9	" " "	0.5	0.0	0.5
10	" " "	1.0	1.0	2.0
11	" " "	1.7	1.7	3.4
12	" " "	2.3	0.0	2.3
13	Field in Kallundborgegn	2.0	2.5	4.5
14	" " "	2.0	0.0	2.0
15	Agricultural College at Copenhagen—continuous barley,	1.0	2.0	3.0
16	" " Fermaks Drift	2.8	1.4	4.2
	Average	1.75	2.06	3.81

[1] Jensen. Om Kornsorternes Brand., S. 60.

Jensen says later[1] : " I found in 1889 there was six times as many ears of *nuda* as of *tecta [Ust. Hordei]."*

GEOGRAPHICAL DISTRIBUTION.

On this point Jensen says little, but from the above table it will be seen that the naked as well as the covered barley smut is found in many parts of Denmark. Brefeld records *Ustilago nuda* from Germany (Minster, i. B.), and also from Japan (Yokohama).[2]

Plowright says: "Of these, *nuda* is by far the most common."[3] He gives *Hordeum vulgaris, H. distichum* and *H. hexastichum* as hosts for *Ustilago segetum,* and from a statement following it must be *Ustilago nuda* that occurs upon them.

The specimens in our herbariums, as well as those sent to us by many correspondents, have been examined carefully.

The following are European:

(1) On *Hordeum vulgare,* Franconia, Bayreuth. Ex. herb. de Thümen, June, 1874. The specimens are mostly this species, but some are *U. Hordei.*

(2) On *Hordeum vulgare,* Bavaria. Thümen, Mycol. Universalis, No. 137, August, 1874. Very much parasitized by insects in the specimens examined.

(3) On *Hordeum vulgare,* Nossen and Konigstein, Saxony. Krieger, Fung. Saxonia, No. 761. Col. 24, July, 1886 and 1887.

(4) On *Hordeum,* Denmark. J. L. Jensen,[4] 1889.

The following are from the United States:

(5) On *Hordeum,* Lancaster, Fairfield Co., Ohio. W. A. Kellerman, No. 291, May 30, 1883.

(6) On *Hordeum vulgare,* Decorah, Iowa. E. W. D. Holway, June 18, 1884.

(7) On *Hordeum vulgare,* La Crosse, Wisconsin. L. H. Pammel, July, 1884.

(8) On *Hordeum,* Syracuse, N. Y. L. M. Underwood, July 7, 1886.

(9) On Hordeum, Eaton Co., Mich. W. J. Beal, June 6, 1889, with a few specimens of *Ustilago Hordei.*

(10) On *Hordeum (?),* Winona, Minnesota. J. M. Holzinger, June 15, 1889.

Only in two cases (Nos. 2 and 9) were there both *Ustilago nuda* and *U. Hordei* in the same collection. In both cases the *Ustilago nuda* was the more abundant.

In the American Agriculturist for October, 1881, (Vol. XL., No. 10, p. 404,) B. D. Halsted[5] figures barley smut from C. M. Youmans, Lyon Co., Minnesota. From the figure and description it is certain that the specimens were *Ustilago nuda.*

1 Jensen in letter, January 24, 1890.
2 Brefeld, Neue Unters, II Nachr., Nr. 221, S. 1592,
3 Plowright, Br. Ured. and Ustilag., p. 274.
4 Jensen, in letter, Jan. 24, 1890.
5 Wheat, Oat, and Barley Smut. l.c., fig. 3.

BOTANICAL AND MICROSCOPIC CHARACTERS OF THE SMUT.

Color, shape, and size.

The spores of this species are perfectly free from each other, and form a dusty mass of a dark, dusky olivaceous color, almost exactly like *Ustilago Tritici*. In one instance, however, (No. 5, p.280, from Ohio,) the spores were very dark, without any shade of olivaceous, very much like *Ustilago Avenæ*. All the other specimens showed a more or less marked olivaceous tint.

In shape, the spores of this species differ very markedly from those of *Ustilago Hordei,* being oval, or less often elliptical or subglobose; see figures on Plate VIII. They correspond in this respect very closely with those of *Ustilago Tritici* and *Ustilago Avenæ.* The spores are regular in shape, and only rarely present abnormal forms, such as are shown in Plate VIII, figs. 18, 21, 24, 27.

In size, the spores are 4½-8x4½-6µ., mostly 5–7x5–6½μ, and probably the least variable of all the four species studied. As will be noticed by a comparison of the figures on Plates VII and VIII, and of the measurements on p. 271, with those here given, the spores of this species are somewhat smaller than those of *Ustilago Hordei,* a fact that has been noted by Jensen.

Character of the spore wall.

As in the other loose smuts, the wall is composed of two layers, the epispore and the endspore. The two are, however, hard to distinguish in this species. They are both shown in figs. 1, 4, 12, 15, 33, 34, Plate VIII; but in many other cases, as in figs. 7, 11, 14, 22, 26, the wall appeared perfectly simple until reagents were used. These two layers together form a wall 1-2μ in thickness. Outside of the wall a thin, delicate, hyaline layer, the cuticle of Fischer von Waldheim, can often be seen, especially on the dark side of the spore. It is always very faint, but is rendered somewhat more distinct by the use of potassium hydrate or nitric acid.

The spores *lighter colored on one side.*

As in the other loose smuts, one side of the spore is plainly lighter colored than the remainder. An area of perhaps one-quarter, or even one-half of the whole surface is much lighter in color, while the opposite portion of the wall is very dark; between these two extremes the wall shades gradually in color. The promycelium always arises from some part of the light-colored area. The wall, as well as its two layers, can be most clearly seen in the part of the wall between the lightest and darkest portions. Often the two layers of the wall can be plainly seen in this part, when they can be distinguished only with much difficulty on the darkest part, and not at all in the light area.

The epispore spiny or warty.

The epispore in this species is covered with minute spines or warts, which show plainly in profile, and can usually be seen in optical sections along the light part of the wall, but not at all along the very darkest portion. In figs. 3, 20, 25, 31, 35, 36, and others, the spines can be seen, both on the face and on the edge of the spore; while in figs. 6, 7, 12, 15, 18, 21, 22, 23, and others, the warts could not be seen along the edge, though in all cases they were visible on the face of the spore. On the light side of the spore there is usually a space free from spines, as is shown in Plate VIII, figs 29, 30. The spines or warts are quite numerous, but are not very thickly or regularly set, the distance between them being ½-2μ; usually about 1-1½μ.

The germ-pore large.

The promycelium is scarcely contracted where it passes through the wall, either in cultures in nutrient solution or in water. In nutrient solution especially, the opening thus made is very wide; see figs. 4, 7, 12, 15, 17. Often the wall in such cases splits down from the opening, and in some cases the wall is then dissolved away, leaving a wide crack which may extend entirely across the spore; see fig. 2. Sometimes the wall is gradually dissolved away by the nutrient medium, all around the opening for the promycelium. When long continued the result is much as has been shown for *Ustilago Hordei* on Plate VII, fig. 30. In spores germinated in water cultures, the openings through which the promycelia pass, though not so wide as in spores grown in nutrient solutions, are wide compared with other species of loose smut. In water cultures the promycelium was often 2–3μ in diameter where it passed through the spore wall, and there was often a rent in the wall extending down from the opening. Curiously on an old spike of barley from which almost all the spores had fallen (shown in Plate II, fig. 8), many of the spores, like those of *Ustilago Avenœ* found under similar conditions, had germinated. The germ-pore in these spores could be seen, as a small, definitely limited, round opening, shown in Plate VIII, figs. 29 and 30 in profile, and in fig. 28 in optical section.

The contents of the spore are usually perfectly homogeneous as far as can be seen.

The action of reagents.

The various reagents affect the spores of this species very much as they do those of *Ustilago Avenœ*. Potassium hydrate in 20 per cent, aqueous solution obscures the markings of the epispore, but causes the endospore to swell greatly. Sulphuric acid, when diluted one-half with water, renders the markings evident, and aids in distinguishing the epispore and endospore. Salicylic acid in concentrated aqueous solution (at 32° *C.)* shows the two layers of the wall, if the spores are examined, as soon as the reagent is applied. Chlor-iodide of zinc stains the contents of the spore strongly, rendering the wall (which is only slightly tinted) very evident. It does not, however, show the two layers of the wall. This can be done by adding chlor-iodide of zinc to spores which have previously been treated with salicylic acid a moment. Nitric acid decolors and swells the spores somewhat, but renders the markings of the wall and the cuticle evident.

GERMINATION IN WATER.

After remaining a number of hours in water (somewhat longer than for *Ustilago Hordei),* the spores sent out a single hyaline germ tube, which at first appeared as a minute elevation, or boss, on the surface of the spore; it at length grew to a straight or curved slender promycelium. By 20 hours, at a temperature of 18–25° C., the promycelia were 20–46μ. long and 2½-4μ wide; continuous, or one to three septate; often with one or two knee-joint fusions, and rarely branched. They appeared much like figs. 2 and 4 in Plate VIII. These promycelia, unlike those of *Ustilago Hordei,* throughout their growth *always* remained attached to the spore. Out of a hundred careful examinations, not a single one was found detached. By 30 hours the promycelia had attained their full length, and did not change further, except in one important respect: from many segments, and very often from buckle-joints, long slender germ threads grew out, which by 48 hours reached a length of 50-150μ. The promycelial segments, and the lower portion of the thread, became entirely empty. Some germ threads, 50μ or more in length, were yet entirely filled, but those 100–150μ. long had a many-septate vacant basal portion. These tubes were 1½-2μ, in diameter, and were somewhat narrower in the vacant basal portion, which had numerous septa 7-15μ apart. The tips yet filled with protoplasm were 30–120x2μ, and but faintly if at all septate, though the protoplasm was often guttate. These threads continued to grow for four or five days, till they sometimes reached the enormous length of 300–400μ (one measured 412μ long). They remain of practically the same character all the while, and never branch. By four days none of the threads were filled to the base, and all of the promycelia thus grown out were entirely emptied. In fact, the basal portion of these germ threads was so hyaline that it was in many cases a severe task to follow the long barren length to the promycelium to which they were attached. A hasty glance seemed to show hyaline, promycelia and disconnected slender tubes filled with protoplasm. However, none were found detached.

Unfortunately, none of these were figured in time to be included in the plate, so nothing of the kind is seen on Plate VIII. The appearance was very similar to the tube shown in fig. 28, Plate V, (Ustligo *Avence)* except that it arose from a segment, or knee-joint fusion, and not from a sporidium.

It is to be especially noted, that in all the changes passed through, these threads remained without further growth of any kind until the water evaporated, or the culture was destroyed by bacteria and moulds. *No sporidia whatever were produced at any stage of growth or decay. There was not the slightest tendency observable to break into segments, or in any way throw off fragments.*

Rarely the original promycelia became as many as 6-septate after the growth of the germ threads began.

Not all the promycelia sent out these germ threads, though the great majority did. Those that did not were usually simple, but, rarely, had short, blunt branches. They showed no change while the other promycelia were sending out germ threads.

Fusions, aside from buckle-joint fusions, were rare. These were common enough, and there were often two on a single spore. A single case was seen where the base was united to the top by a tube, much as in Plate VIII, fig. 5, only more slender in all parts.

Quite often the promycelia were somewhat branched, and from these branches, or buckle-joints on them, germ threads arose.

The promycelia of 20 hours' growth had a diameter of 2½-3μ at the junction with the spore, and in consequence the spore was often sprit a short distance down the side.

IN NUTRIENT SOLUTION.[1]

At first the cultures much resemble those already described for water. The promycelia are of about the same size and shape, though perhaps less often and less plainly sepatate. Very often, in fact, they were continuous like those shown in Plate VIII, figs. 1, 3, and 4. This was the appearance at the end of 24 hours; however, some became slightly swollen and septate like fig. 6. The growth of the promycelia did not cease so soon as in water cultures, but lateral branches arose in many cases. In order cultures these branches were usually short and thick, as shown in figs. 8 and 16. Rarely germ threads grew out to a length of 100μ or even more. These lengthened branches, though like those produced in water cultures in sometimes having a vacant base, differed in being thicker, septate, and usually somewhat irregular in diameter. These irregularities were usually slight, but sometimes quite marked. They may exist in any part of the promycelial growth. This irregular diameter may or may not be connected with septa. A good example of a somewhat advanced branched and irregularly swollen promycelium is shown in fig. 14.

After 48 hours little change occurred, except that the *free ends of branches and promycelia became swollen*. By four days this was quite marked, as may be seen by examining Plate VIII, figs. 9 and 15. Not all of the branches were thus swollen up, though many were. Rarely the whole promycelium was more or less swollen, as is shown in fig. 12. During the growth many of the promycelia became emptied for one or more segments at the base, as in figs. 5, 8, 9, 14, and 16. More rarely the tip was empty, as in fig. 17. In almost every instance the promycelia remained firmly attached to the spore throughout their whole growth. A detached promycelium is figured in 8; another, probably dead, is shown in fig. 13. *At no stage of the growth were any sporidia formed, and no detached segments of promycelium were seen.*

Fusion knee-joints were very common, and often originated strong-growing germ threads. In a very few cases fusions like those shown in fig. 5 were seen. Two tubes arose from the spore, or a branch grew out at the surface of the spore and the two united at the tip. The regularly swollen

[1] Modified Cohn solution was used exclusively.

tips were very noticeable; in many cases they were as large as the spores, or even larger.

MANNER OF ENTERING THE HOST PLANT.

On this point very little is yet known. Jensen say's spores of *Ustilago* adhering externally to the barley grains will not propagate the smut —"I have proved this by experiments."

In general its behavior with preventatives is more resistant than is *Ustilago avenæ* and ustilago Tritici. It acts very differently from *Ustilago Hordei,* which, according to Jensen, infects the grain to whose external surface it adheres.

According to the same author it spreads from field to field readily, while the opposite is the case with *Ustilago Hordei.*

Jensen, finding that solutions which kill the spores adhering to the outside of the grain do not prevent the smut, says:[2] "Hence we must conclude that the infective medium is internal, not external, to the covering of the seed corn." This view, however, requires confirmation.

METHODS OF PREVENTION.

All authors previous to 1887, when Jensen published his first paper, recommended the same treatment for barley smut as for oat smut. They did not, of course, notice any difference regarding the two species growing on barley, as these were not recognized as distinct till 1888.

Jensen reported that soaking in sulphuric acid or sulphate of copper had little effect on barley smut, though it largely prevented that of oats. Treatment five minutes in water at 133° F. did not sensibly diminish the number of smutted heads.[3] He cites[4] the following experiments made in Denmark under his direction:

AT RODSTENSEJE.

Undressed barley	Amongst	2,000	heads	49	were	smutted.
Treated with 1 per cent. sulphate of copper	"	2,000	"	38	"	"
" " 1 " " " " limed 12 hours after.	"	2,000	"	50	"	"
" " 2.7 " sulphuric acid	"	2,000	"	43	"	"
" " 2.7 " " " quicklimed 12 hours after.	"	2,000	"	41	"	"

AT GERSDORFSLUFD.

Undressed barley	Amongst	2,000	heads	40	were	smutted.
Treated with 1¼ per cent. sulphate of copper	"	2,000	"	58	"	"
" " 5 " " " "	"	2,000	"	23	"	"

In the first series, the seed was completely immersed in the solution for twelve hours. The sulphuric acid of this strength killed a great deal of the seed, but was of little value in preventing the smut; and the same is true of the 5-per-cent. solution of sulphate of copper, which, although it killed much of the seed, did not completely prevent the smut. Lime and salt were without effect.

Heating the seed barley five minutes in water at 127° F., after it had

[1] J. L. Jensen, in letter, Jan. 28, 1890.
[2] J. L. Jensen. Smut (Ustilago segetum) in Oats and Barley, in Gardeners' Chronicle, May 5, 1888, p. 555.
[3] J. L. Jensen. Smut in Oats and Barley, in Gard, Chron., 1. c., p. 555.
[4] J. L. Jensen. Nye Undersögelser og Forsög over Kornsorternes Brand, S. 15; Prop. and Prev. of Smut in Oats and Barley, p. 15.

previously been soaked eight hours in cold water, prevented the smut completely, as his results quoted below show. The experiment was conducted at his suggestion by Mr. C. F. Jensen, at Rodstenseje, Denmark, in 1888:

"2,000 unprotected barley plants had 45 smutted.
2,000 treated with warm water as above, none smutted."

In his fifth paper he reports an experiment as follows.[1] Three equal packages of the same barley seed were planted, but they were treated differently:

Barley not prepared	113	smutted heads.
Barley treated by Kuhn's method[2] 14 hours	104	" "
Barley treated with hotwater[3]	0	" "

In another test there reported, he prolonged the treatment according to Kühn to 24 hours. Again three equal parcels of seed were used:

Barley treated by Kühn's method 12 hours	302	smutted heads.
Barley " " " " 24 "	240	" "
Barley " with hot water	0	" "

All of these experiments show clearly the inefficacy of the copper-sulphate and lime (Kühn) treatment, and the superiority of the Jensen treatment.

In his letter of January 24, 1890, he reports the following experiment:

(Same quantity sown of the three samples.)	*First farm.*	*Second farm.*
Barley, unprepared	628 smutted heads,	459 smutted heads.
Barley, bluestoned	542 " "	388 " "
Barley, dipped in warm water	0 " "	0 " "

All of these experiments were really concerned with *Ustilago nuda*, or naked barley smut, alone, since Jensen says (in letter) that dry dipping in hot water and treatment with copper sulphate *will completely prevent covered smut*, though not *Ustilago nuda*. The covered smut would, therefore, have been destroyed in all of the above experiments, except in untreated seed.

Owing to the extreme scarcity of barley about Manhattan, Kansas, we did not conduct any experiments to prevent this smut; nor do we know of any being attempted in the United States.

From the numerous experiments of Jensen, repeated every year since 1887, it would seem that he has the most complete and most satisfactory method for destroying the smut.

He finds that if the barley is soaked eight hours, and then put in water at a temperature of 126-128° F. for five minutes, all smut is prevented; a higher temperature proved injurious.

We therefore strongly recommend his latest form of the treatment, which is as follows: Soak the barley seed *four hours* in cold water, and then let it stand *four hours longer* in a wet sack. Finally dip and drain as *directed in the treatment for oat smut* for five minutes in water of a temperature of *126–128° F.*, after which dry and plant as in case of oats.

[1] J. L. Jensen. Le charbon des céréales. Copenhagen, July, 1889.
[2] Soaked 14 hours in a ½-per-cent. solution of copper sulphate, after which it was soaked in milk of lime.
[3] Soaked 4 hours in cold water, then left stand 4 hours in a moist sack, after which it was immersed 5 minutes in water at 127° F.

The temperature must not he above 128°, since the soaked seed would then be injured, and not below 126°, for then not all the smut would be killed. Both vessels should contain water of this temperature. Instead of soaking four hours and letting the seed stand four hours longer in a wet sack, it may be simply soaked eight hours, drained, and then treated with hot water.

The covered barley smut *will be also completely prevented by these means.* But since this (covered) smut is capable of infecting grains to which it adheres externally, care must be taken to prevent any smut from reaching the treated grain. The sacks to receive it should therefore be also disinfected with hot water.

NATURAL ENEMIES OF THE SMUT.

Although the fact is not commonly known even to specialists, the smut of oats (and smut of other plants) has several important enemies. Owing to the ease with which the disease can be prevented in other ways, the work of these natural enemies in checking the increase of oat smut is not of very great consequence. They may, however, prove to be of great advantage in combatting other smuts or similar fungi whose ravages are less easy to prevent. At least five different enemies of the oat smut have been found at Manhattan—three of them fungi, and two of them insects.

(a) THE WHITE MOULD (*Fusarium Ustilaginis* Kell. & Sw.[1]).

This causes the smut to become a compact mass covered with a white or slightly pinkish coating, often being converted into a compact mass firmly bound together by the root-like threads of the fungus. The disease is a common one. The spores or *conidia* are borne on the ends of upright, much branched, colorless threads (Plate IX, figs. 1 and 2). The conidia are spindle-shaped, usually slightly curved, and vary greatly in size (20–66x 3–6 $^1/_2\mu$.). The conidia are commonly divided into cells by 2 to 9 transverse septa (Plate IX, figs. 3–13).

(b) THE BLACK MOULD (*Macrosporium utile* Kell. & Sw.[2]).

This parasite, less common than the white mould, is somewhat related to it. It causes the smutted spikelets to become a greenish brown or dark

[1] *Fusarium Ustilaginis* Kellerman & Swingle, n. sp. Effuse, forming a white or slightly pinkish coating over the smutted spikelets or sometimes extending all over the head and even to the dead tissues of the host. Hyphæ usually crowded—below simple and stout, above usually much branched, sometimes in an opuntoid manner, ultimate branches often clavate. Conidia abundant; very variable, at first oval, finally lanceolate or linear fusoid, usually crowded more or less; rather acute at both ends, 1-9 mostly 3-5 septate; 20-66x3–6 $^1/_2\mu$, mostly 30-48x3-5 $^1/_2\mu$. On *Ustilago Avenæ*, Manhattan, Kansas. This species seems very much like *F. Schiedermayeri* Thümen, F. Austr., n. 78, Sacc. Syll. IV, p. 712, No. 3376, and may be that, but that species is said to have hyaline or very lightly dusky, thick, somewhat branched hyphæ. The hyphae of this species are never even slightly dusky, and are very considerably branched. The conidia of that species are 44-48x5μ. Like *Fusarium Ustilaginis* it occurs in company with *Ustilago (U. Luzulæ* or *Luzula pilosa)*, but upon the ovaries shrunken by the parasite.

[2] *Macrosporium utile* Kellerman & Swingle. Effused, forming a dark-brownish, olivaceous, velvety coating over the surface of the smutted spikelets. Hyphae dark, erect, septate, slightly or not at all constricted at septa, simple or rarely branched, showing toward the tips the marks of attachment of the conidia, 50–125x4 $^1/_2$-6μ. Conidia very dark, elongate cylindrical, elliptical obovate or oblong, usually somewhat narrowed into a short pedicel; 3-8 septate transversely, usually constricted at septa; longitudinal septa few, often irregular, 29-67x8-12μ, mostly 30-40x9-11μ. Mycelium dusky, or rarely becoming pallid; in some cases provided with very small flattened expansions which probably are attached to the spores of the smut. Found on oat smut at Manhattan, Kansas. Spores apparently of this species have been seen on *Ustilago nuda* from Denmark, and on *Ustilago Avenæ* from Canada.

olivaceous color, instead of the normal dark dusky brown of the smut. The fungus consists of dark-colored threads penetrating the smut and giving rise to simple dark upright threads (Plate IX, figs. 16 and 17), which bear the very large (30–67x7–16μ) dark-colored conidia (Plate IX, figs. 18 and 19). These conidia are divided into many cells by partitions running in both vertical and horizontal directions. Spores apparently of this species have been seen on barley from Denmark.

(c) BLIGHT, A BACTERIAL DISEASE (*Bacterium* ? sp.)

The smutted spikelets attacked by the blight become very compact, and are of an entirely black color. The parasite is invisible except when the blackened smut is examined with the microscope. Many of the smut spores are then seen to be imperfect, and surrounded by myriads of colorless oval bacteria. The cells of this parasite are very minute (1–1 $^1/_2$x$^1/_2\mu$), oblong or rod-shaped; stain well with methyl violet. It somewhat resembles the *Bacillus sorghi,* illustrated in the First Annual Report, but unlike that, does not show so far as observed any spore formation. It is possible that the bacteria attack the gelatinous threads, thereby injuring or destroying the contained smut-spores. This imperfectly known parasite is probably a species of *Bacterium*.

(d) SMUT-EATING BEETLES.

(1) *Phalacrus* sp. (P. *politus* or P. *penicillatus).* This beetle belonging to a small family *(Phalacridæ)* is a minute, oval, shining black insect about $^1/_{12}$ of an inch long. It moves rather slowly, but is not particularly sluggish, though it falls to the ground when disturbed. (Outline figures are shown—Plate IX, fig. 21, as seen from above, and fig. 22 from the side.) It feeds on the smut, and probably there lays its eggs, which hatch into minute white larvæ. These larvæ grow rapidly and eat smut voraciously. They become longer than the beetles when full grown, and are straight, slightly hairy, and have a small, brownish head. The pupæ are short, and somewhat resemble the mature insect in shape.

Of the closely allied, if not identical, species *Phalacrus penicillatus,* Say, writing in 1824, says:[1] "In many parts of the United States this species is found in seed vessels of such plants of wheat as are destroyed by the parasitic vegetable called smut."

It is very common in all kinds of smut about Manhattan.

(2) *Brachytarsus variegatus* Say. This beetle belongs to the *Anthribidæ,* is larger than the *Phalacrus* just mentioned, and is of a silvery grayish or canescent color, variegated with brownish and bright silvery spots. It is about $^1/_8$ inch long, and is very sluggish in its movements, falling to the ground at once when disturbed (Plate IX, fig. 20). It also feeds on the smut. Its larvae are abundant in oat smut, especially where the smutted head does not entirely emerge from the sheath inclosing it. These larvæ

[1] Journ. Acad. Nat. Sci. of Philadelphia, IV, p. 91; Insects of North America, II, p. 231,

resemble minute white grubs, are about 1/8 inch long, strongly curved, and have rather large brown heads. They are slow in motion compared to the larvæ of Phalacrus. The *pupæ* are common, and somewhat resemble the beetle in shape. Of this species Say, in 1826, remarks[1]: "The species is not uncommon, and I have found it on the 'smut' of wheat. Mr. Lea took eighty individuals from six heads of wheat." In all its stages this beetle strongly resembles the *Anthribus cornutus,* illustrated in Bulletin No. 3 of this station, pp. 34, 35, figs. 4, 5; also in the First Annual Report, p. 217, fig. 4, and p. 218, fig. 5. As seen from the quotations above, these beetles have long been known to feed on smut. We can find, however, no record of the fact that the larvæ of *Phalacrus* as well as of *Brachytarsus* are found in and feed on smut.

THE STINKING SMUT OF WHEAT.

This disease affects wheat only,* and is by no means so conspicuous (Plate III, figs. 1 and 2) as the loose, or black smut (Plate II, figs. 1 and 2), while the grain is standing. In fact, it would be overlooked unless careful search were made, as the infected heads are but little if at all different from healthy ones, and the grain (which is the only part smutted) is covered in the usual manner by the chaff; nor does the grain usually break open so as to expose the dark mass within.

But after threshing, the smutted grains are readily detected by their dark color and swollen appearance (Plate IV, figs. 5 and 6). When crushed between the fingers they emit a very strong and disagreeable odor, for which reason the disease is properly designated *stinking smut.* There are two forms, distinguishable only by the character of the spores; the one with smooth spores (which seems to be the commoner) is called in botanical language *Tilletia foetens* (B. & C.) Trel.; and the other, having spores ornamented with a net-work of ridges, is called *Tilletia Tritici* (Bjerk.) Wint. The general parasitic nature of these is the same as that of the black smut described in the preceding pages. Both species occur in Kansas.

Samples of wheat affected with the stinking smut have been received this season from Pawnee, Pratt and Rooks counties. Inquiry has revealed the fact that the disease has been prevalent in considerable portions of western Kansas. No report has reached us of the stinking smut in the eastern part of the State.

It is well known that wheat containing much smut is wholly unfit for making flour, and it is of course unsalable. Some information, therefore, in regard to this preventable pest will be here briefly given—to be supplemented next season with a full report detailing experiments already undertaken, to determine the comparative value of numerous fungicides.

The very minute reproductive bodies (spores) of which the dark mass of

[1]Journ. Acad. Nat. Sci. of Philadelphia, V, p. 251; Insects of North America, II, p. 315.
*The varieties of soft wheat are especially liable to attack; the hard wheat is said to be free from the disease.

smut is composed, adhere to the surface of the grains of the seed wheat. These, after the wheat is sown, germinate, and their slender germinal threads penetrate the young wheat in the same way as does the smut of oats before described. These slender threads, or tubes, constitute the vegetative portion of the parasite. They ramify through the tissue of the growing wheat plant, appropriating the nourishment which the latter elaborated for its own use. They enter the young grain as soon as it is formed, and in it produce the spores.

The dark color and swollen appearance of the smutted grains are shown in Plate III, figs. 5 and 6. Some of the grains become nearly globular. The deep furrow in the normal grain (Plate III, fig. 3) becomes almost entirely obliterated (fig. 5 and 6). This is shown clearly in cross-sections (fig. 4) showing the normal grain, and figs. 7 and 8 showing smutted grains. Within the testa, or hull of the diseased grain, none of the original tissue or contents remain; the space is solidly packed with the brown powder, composed of the spores as above mentioned. The penetrating and disagreeable odor is a distinguishing and unmistakable character.

If seed wheat absolutely free from the spores be used, or if the affected seed be thoroughly treated with hot water, as recommended for oats, there is no reason whatever to apprehend danger from this pest.

IMPORTANT NOTICE. — *Owing to delayed publication we are enabled to make the following important statements regarding the prevention of oat smut:*

(1) *The immersion of the seed in the scalding water should be prolonged to 15 minutes (instead of 8 to 12 minutes as above recommended).*

(2) *The volume of scalding water should be very much greater (at least 6 or 8 times) than that of the seed treated at one time.*

(3) *The basket or sack containing the seed which is being treated should be only partially filled.*